EU Statement of Principles for HMI: Final report

Prepared for Transport, Technology and Telematics Division, Department for Transport, Local Government and the Regions

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Executive Summary

In December 1999 the European Commission adopted the European ‘Statement of Principles’ (SoP) in acknowledgement of the importance of the HMI for in-vehicle telematics. In recommending adherence to the Statement of Principles, the EC urges the European motor manufacturing and supply industries to comply with a number of basic safety requirements concerning the design of, and driver interaction with, in-vehicle information, communication and entertainment systems.

Member states were invited by the EC to take steps to encourage industry to comply with the Principles and report back on the impact of the SoP by December 2001. TRL have been commissioned by the DTi to assess the knowledge about and impact of the SoP, within the UK IVIS industry.

The first stage involved assessing the UK industry’s knowledge of the Statement of Principles and where appropriate, providing information about the SoP. A large number (>200) of organisations were contacted, and 35 UK producers were identified. More in-depth interviews were held with those individuals identified as involved in the design or manufacture of IVIS in the UK.

The feedback received suggests that only a relatively small number of in-vehicle information, communication and entertainment systems are designed and manufactured in the UK. Rather, that the well known branded ‘key players’ conduct the design and development of these systems elsewhere in the world, with the UK operations focusing on distribution, sales and service provision.

Types of system designed or produced in the UK include; navigation, congestion warning, mobile data terminals, mobile phones, reversing aids, taximeters, and portable hand-held data terminals.

Knowledge about the Statement of Principles among those who do design and manufacture these systems in the UK varied considerably.

The motor manufacturing companies appeared well informed and stated that they apply the SoP recommendations during the design process. Others had little or no knowledge of the SoP, relying instead on input from academic institutions, ergonomic literature and consultant ergonomists or simply trial and error for their design information.

The second stage of this project involved conducting ergonomic evaluations of a variety of IVIS, to assess the extent of their compliance with the EU Statement of Principles. The TRL/DETR HMI Safety Checklist was utilised to provide an initial assessment of whether or not an IVIS complies with the SoP.

Twenty-three systems have been evaluated including a congestion warning system, mobile data terminals, handheld data terminals, navigation systems, driver information systems, a reversing aid, a taximeter, a radar speed camera detector and a mobile phone.

The evaluations demonstrated that it is perfectly possible to design systems that comply with the SoP. For a number of Checklist items the level of system compliance with the Statement of Principles was reasonably high (greater than 50%). For example in the area of system installation and integration, no concerns were noted for the majority of systems, whether after-market or OEM.

However, in terms of the specific systems evaluated they also identified a number of HMI areas currently affected by frequent ‘non-compliance’: the documentation provided with the system, the driver input controls, the menu facilities and the extent of interaction required with the system.

Almost half of the systems evaluated failed to comply with the recommendations for documentation. The quality and depth of advice given within the user manuals was frequently inadequate, or not clearly stated and was often not presented in a prominent location.

Almost a third of the driver input controls were placed in locations beyond the drivers’ easy reach, while a large number of systems utilised input controls that were considered unsuitable for use when driving. This was usually because the controls could not be easily distinguished, provided inadequate control activation feedback, and required sustained visual-manual interaction, touch screens being a typical example.

Over 60% of systems required numerous sequential keystrokes during interaction and this was often exacerbated by complex menu systems. Additionally, almost half of the systems were assessed as presenting excessively distracting information.

In addition to the HMI evaluations, a small number of ‘user trials’ were piloted to evaluate areas of the SoP not covered by the Checklist. These included measurement of visual demands using video-recording equipment, aspects of workload associated with system operation using the NASA TLX, understanding of the system manual using a task based approach and a post-drive questionnaire about the system usability.

The UK approach of Checklist assessment has proved extremely valuable as a method of providing a consistent and swift account of compliance with the SoP. It has produced a comprehensive and in-depth view of issues surrounding the SoP and the impact the SoP has had in the UK both for the large car manufacturers and smaller independent companies.

The assessments suggest that currently no strong relationship exists between either knowledge about the SoP, or the formal input by qualified ergonomists, and the extent of SoP compliance. The areas of most frequent non-compliance were not restricted to the smaller less-well informed companies, but applied across the full range of system producers, and to both OEM and after-market devices.

Our HMI evaluations also identified a number of areas where the SoP could be strengthened. These include: the use of mobile data terminals by fleets of vehicles; the responsibilities of individuals involved with after-market devices and multiple component systems, crashworthiness of after-market installations; the assessment criteria for context specific applications.
Our evaluations also demonstrated that even where knowledge about the SoP exists, this does not imply compliance with the principles. However, it would appear that undertaking evaluations and providing feedback to system manufacturers is useful, and can make an impact on design issues.

The results of our survey and evaluations suggest that the future of the Statement of Principles should be an important issue both within Europe and internationally.
1 Background

Within the EC Community Strategy document of 1997, one of the five areas for initial action was concerning the Human-Machine-Interface. The challenge was presented to develop new in-vehicle technology that is usable and safe, so that human machine interaction does not present a barrier to innovation. In response to this strategy, a small task force that included participants from government, industry and research proceeded to develop a ‘Statement of Principles for HMI’.

The Principles apply to all information and communication systems intended for use by the driver when driving, whether directly related to the driving task or not, and include both portable and permanently installed systems, whether after market or OEM (European Commission, 1998).

They are primarily concerned with:

- The design and location of information and communication systems to ensure compatibility with the driving task.
- The presentation of information to the driver so as not to impair the drivers visual allocation of resources to the road scene.
- The design of system interaction such that the driver maintains safe control of the vehicle, is confident with the system and ready to respond to unexpected events.

In December 1999 the European Commission adopted these European ‘Statement of Principles’ (SoP) (European Commission, 1998) in acknowledgement of the importance of the HMI for in-vehicle telematics. In recommending adherence to the Statement of Principles, the EC urged the European motor manufacturing and supply industries to comply with a number of basic safety requirements concerning the design of and driver interaction with in-vehicle information and communication systems.

Member states were invited by the EC to take steps to encourage their national industry to comply with the Statement of Principles. Specifically, Member States were asked to inform the Commission, within 12 months of the ‘Principles’ publication, of the steps taken by them and their industries to encourage this compliance. Further, since the SoP aimed to provide sufficient detail of safety requirements to enable the assessment of specific systems against the criteria, they were also asked to evaluate and report on the extent of adherence to the Principles by industry within 24 months.

DTLR has already taken a number of steps to promote the safe design and use of in-vehicle systems through the development of both design guidelines and a checklist for evaluating safety related aspects of in-vehicle system use.

In 1996 the Department supported the production of a BSI DD235 Draft for Development (British Standards Institution, 1996) which provided design guidelines for in-vehicle systems and since last year have supported the production of an updated set of design guidelines (Stevens et al., 2001). These have now been published and widely disseminated.

Additionally, under commission by the Department, TRL have produced and published, (December 2000, Project UG 115), an HMI Safety Checklist (Stevens et al., 2000), which provides a standard tool for the assessment of IVIS with regard to human machine interaction and road safety. TRL has also reported on the correspondence between the HMI Safety Checklist and the EC Statement of Principles (Stevens and Board, 2000) under the DTLR project UG 61.

2 Introduction

TRL has been commissioned by the DTLR to assess the knowledge about, and compliance with, the SoP by UK industry.

Project UG362 commenced in October 2000, as a 1-year study to investigate the awareness of and compliance with the EU Statement of Principles within the UK industry.

The work has been carried out in two stages. The first stage, the assessment of knowledge, involved a widespread consultation exercise with individuals identified as working in the field of in-vehicle information, and communication systems in the UK.

The second stage of the project involved conducting ergonomic evaluations of a variety of IVIS, to assess the extent of their compliance with the EU Statement of Principles.

User trials were also undertaken to assess areas within the Statement of Principles that are not currently covered by the HMI Checklist. These trials included measurement of visual demands using video-recording equipment, aspects of workload associated with system operation using the NASA TLX, understanding of the system manual and working in the field of in-vehicle information, and communication systems in the UK.

This report provides a summary of the two stages of work undertaken, including a description of the evaluative tools used for the assessment of in-vehicle systems against the Statement of Principles.

2.1 UG362 main aims and objectives

The main objectives of the project were to:

- Identify UK industries that should be aware of the SoP and additional groups who are influential in issues of system design and use.
- Assess knowledge of / inform those identified about, the SoP and its implications.
- Identify any steps taken in response to the SoP by those identified.
- Assess the extent to which OEM and after-market systems comply with the SoP.

3 Stage 1: Assessment of knowledge

A full description of this stage of the project and its results can be found in the TRL unpublished report ‘Assessment of knowledge of the EC Statement of Principles for HMI (Final Report) (Board and Mitchell, 2001).
In brief, over 200 companies were contacted, of which around 30 were identified as involved in the design or production of IVIS and interrogated more thoroughly through structured telephone interviews.

The feedback received suggests that only a relatively small number of IVIS are designed and manufactured in the UK. Rather, the well known branded ‘key players’ conduct the design and development of these systems elsewhere in the world with UK operations focusing on distribution, sales and service provision.

Organisations that are actively involved in the design and development process include motor manufacturers, independent companies, consultants and organisations that represent the motoring public. It was observed that partnerships frequently exist between the different organisations that provide the various hardware, software and information components.

The types of system produced in the UK include navigation, in-car entertainment, multi-media (including DVD and video based systems) traffic information, taximeters and reversing aids.

While the car manufacturers often benefited from the services of professional ergonomists and industrial designers within their design departments, others had no in-house HMI resources and relied on human factors input through their collaboration with Universities, or through consultation with industrial design houses, OEM styling departments and consultant ergonomists. A large number (around 42%) received no ergonomic input at any stage.

The degree of knowledge about and impact of the Statement of Principles varied considerably between those interviewed. Of those UK producers questioned fully, 56% were aware of the SoP, of which 43% referred to the SoP either regularly (14%) or occasionally (29%) during the design process. Others had little or no knowledge about the SoP prior to receiving a copy from TRL.

4 Stage 2: Assessment of compliance

The second stage of this project involved conducting ergonomic evaluations of a variety of IVIS, to assess the extent of their compliance with the EU Statement of Principles. The TRL/DETR HMI Safety Checklist was utilised to provide an initial assessment of whether or not an IVIS complied with the Statement of Principles.

A total of 23 systems were evaluated. These included: 7 navigation systems, 5 mobile data terminals, 3 handheld devices, 2 traffic information systems, 2 mobile phones, 1 congestion warning system, 1 reversing aid, 1 taxi-meter and a radar (speed camera) detector.

The evaluations were carried out by a team of experts during both daylight and darkness. Consensus meetings were held to discuss and agree on the results, prior to each report being produced.

4.1 HMI Safety Checklist

The ergonomic assessments were carried out using the TRL/DETR HMI Safety Checklist (Stevens et al., 2000). This checklist allows experts to make a rapid and structured assessment of the key safety related features of an IVIS and provides an initial assessment of whether an IVIS complies with the Statement of Principles.

The current version of the HMI Checklist has been available since December 2000 and has been used regularly by TRL for ergonomic assessments. During Stage 1 of this project, it became apparent that a small number of other organisations (2 OEM, 1 major mobile phone producer, 1 after-market information system producer and the producer of in-vehicle system components) have also used the Checklist to inform their design process and evaluate their systems (Board and Mitchell, 2001).

A previous report outlining the correspondence between the HMI Safety Checklist and the EU Statement of Principles (Stevens and Board, 2000) revealed that there are a small number of areas where the Checklist does not cover all elements of the principles.

For example the Checklist does not:
- Assess users comprehension of the manual, nor of system operation.
- Fully assess visual distraction and drivers’ visual workload.
- Investigate system performance during failure.

While for the purpose of this project we used the Checklist to provide an initial assessment of whether a specific IVIS complied with the SoP, the overall purpose of the Checklist is:
- To identify obviously unsafe products.
- To provide a common language and focus during safety assessments.
- To highlight which sub-functions may be inappropriate for use while driving.

In order to decide whether safety concerns exist, an assessment is made of risk to the driver and other road users of use of the HMI components of the IVIS. Acceptable risks are defined as those that exist when the IVIS is absent, while unacceptable risks are defined as those which the presence and/or use of the IVIS constitutes a greater risk to the user than its absence or non-use.

Each Checklist item provides three boxes in which to record the degree of assessed safety concern for that aspect of system HMI, and an additional ‘not applicable’ box to note when the IVIS does not have the particular attribute the question is addressing.

The ‘Serious Safety Concerns’ box was ticked when the use or presence of the IVIS was judged to present a strong (unacceptable) risk to the driver or other road users. The ‘Minor Safety Concerns’ box was ticked when the presence or use of the IVIS or its components was judged to present a minor risk, or the usability was compromised in some way. The ‘No Safety Concerns’ box was ticked when the presence or use of the IVIS did not present an unacceptable risk to the driver or other road users, or, when the user manual stated that the particular attribute the question is assessing should not be used while the vehicle is in motion.
Systems / vehicles were loaned for a minimum of 3 days and supplied with the user manual when available. During this time three pairs of assessors undertook 2 daytime and one night-time evaluation.

Prior to undertaking the assessment, the assessors familiarised themselves with the user manual, the system and the vehicle and a number of decisions were made about which functions of the system would be assessed and which functions would not be assessed. These decisions were based on the absence of any documented restrictions for their intended use, the likelihood of their use when driving (whether intended by the designers or not), and the individual circumstances of the loan.

Following the assessments a consensus meeting was held to discuss the results, and resolve any differences between the expert assessors.

4.2 Compliance with the Statement of Principles
The evaluations have illustrated that for a number of Checklist items the level of system compliance with the Statement of Principles is reasonably high (greater than 50%).

For example in the area of system installation and integration, no concerns were noted for the majority of systems, whether after-market or OEM (see Figures 1a and 1b).

Aspects of systems visual display properties also complied largely with the SoP with the exception of legibility, which in both after-market and OEM systems tended to be compromised by small text, making reading difficult on occasion (see Figures 2a and 2b).

Other areas where compliance with the SoP was evident were the ease with which information presented by the system could be comprehended by the user, as illustrated in Figures 3a and 3b, and temporal aspects of information presentation (see Figures 4a and 4b).

The evaluations also highlighted a number of particular areas where a considerable number of systems failed to comply with the Statement of Principles. Areas of frequent non-compliance were similar for both OEM and after-market devices.

Specifically, areas most affected by frequent non-compliance included:
- Documentation.
- Driver input controls.
- Safety aspects of information (e.g. number of keystrokes required during interaction.
- Menu facilities.

Documentation is one area where approaching half (46%) of all the systems evaluated failed to comply with the recommendations concerning non-use. In particular, the after-market systems failed to highlight the drivers responsibilities for safe vehicle control, while the OEM systems neglected to provide advice about non-use of system functions when driving (see Figures 5a and 5b). The quality and depth of advice given within the user manuals was frequently inadequate, or not clearly stated and was often not presented in a prominent location.

This is an area where rapid immediate improvement should be possible with little effort, and one that is important both in terms of driver safety, and for issues of liability that are likely to arise in the event of an accident associated with system use. Where systems are not physically disabled when the vehicle is in motion, it is strongly recommended that clear, strong warnings and advice be provided in a prominent location within the documentation.

![Figure 1a and 1b Compliance with installation recommendations](image-url)
Figures 2a and 2b Compliance with visual display property recommendations

Figures 3a and 3b Compliance with recommendations for information comprehension
Figures 4a and 4b Compliance with recommendations for temporal information

Figure 5a and 5b Non-compliance with recommendations for documentation
It is also recommended that, where appropriate, systems should present a further advisory note on system start-up, and require that the driver acknowledge the advice before system operation is enabled.

The second area of frequent non-compliance related to the driver-input controls (see Figures 6a and 6b), where a variety of problems were observed.

Approaching a third (32%) of all the controls were placed in locations beyond the driver’s easy reach, requiring the driver to stretch, lean or adopt an awkward arm or body position during interaction. While it is appreciated that competition often exists between systems (climate controls, in-car entertainment) for the ideal dashboard location particularly for integrated in-vehicle systems, priorities in terms of type and frequency of interaction need to be considered. Any interaction with the system that involves a change from the normal driving position will have a negative impact on the drivers view of the road scene, and consequently the ability to maintain full and safe control of the vehicle.

A large number of systems also utilised input controls that were considered unsuitable for use when driving. This was usually because the controls could not be easily distinguished, either visually or non-Visually, provided inadequate control activation feedback, and required sustained visual-manual interaction. Touch screens were a particular example with additional concerns when combined with the use of a handheld stylus.

The evaluations highlighted many of the problems associated with the use of touch screens and their overall unsuitability for use when driving. While touch screens can provide a simple, accurate and effective method of data entry and menu navigation if used when stationary, they are judged unsuitable for use in a moving vehicle.

Over 60% of all systems (14 out of 23) demanded numerous sequential keystrokes during interaction (see Figures 7a and 7b). For half (7) of these 14 systems (30% of all systems), this was exacerbated by a complex menu system containing an inappropriate number of menus and sub-menus (see Figures 8a and 8b). Additionally, almost half of the systems presented information that was assessed as excessively distracting.

Allowing drivers to perform tasks that involve sustained visual-manual interaction with the system while driving is clearly highly inadvisable, and likely to have a detrimental impact on their ability to maintain safe and full control of their vehicle. Such tasks included entering destination details, or sequentially navigating through a series of menu options (see Figures 8a and 8b). Guidelines have been produced (Stevens et al., 2001) that recommend the use of both visual and auditory modalities for information presentation in order to share the workload and reduce distraction.

Key issues in this area for designers are:
- deciding which functions are accessible when mobile;
- how to minimise driver interaction with them; and
- how to minimise driver distraction by them.

4.3 Closure questionnaire
Following the completion of the HMI evaluations a questionnaire was sent to the producers of all those systems evaluated (see Appendix C), encouraging their comments and feedback on the SoP and results of the evaluation process. To date we have received comments in relation to 12 of the 23 systems evaluated. These comments will be included within the final evaluation reports (these reports are confidential to TRL and DTLR and thus not appended within this report).

**Figures 6a and 6b** Non-compliance with recommendations for driver input controls
Safety related aspects (after-market)

Safety related aspects (OEM)

Figure 7a and 7b Non-compliance with recommendations for safety related aspects

Menu facilities (after-market)

Menu facilities (OEM)

Figures 8a and 8b Non-compliance with recommendations for menu facilities
5 User trial

In addition to the Checklist it was felt necessary to pilot a complementary method that would address some of the additional issues within the SoP that are not covered by the Checklist assessment, and to this end a user trial was conducted.

A full description of the study method and results is given in Appendix B.

In brief, 10 participants took part in a small-scale trial comparing the use of an integrated navigation system, with a traditional map, for a route finding task.

The user trials included measurement of visual demands using video recording equipment, aspects of workload associated with system operation using the NASA TLX, understanding of the system manual using a task based approach and a post-drive questionnaire about the system and its usability.

The manual assessment revealed that in order to be more easily used and understood, a number of improvements could be made, for example to the overall structure and format of the manual, as well as the presentation of the information within it. The assessment illustrated how important this aspect of information provision can be for consequent human machine interaction, by demonstrating the types of problems that may be experienced by novice users.

It was appreciated that the manual assessment was not without its limitations, including the limited period of time that users had to familiarise themselves with the user manual and the time pressure they may have felt to complete each task.

The NASA TLX task workload questionnaire provided a useful illustration of the extent to which various components of workload are associated with in-vehicle system use, and how these affect subjective performance rating. During these trials the NASA TLX revealed that participants experienced lower mental workload when using the navigation system in comparison with the map.

The video recordings of eye glance behaviour were less helpful than anticipated. As might be expected, the participants tended to glance briefly at the navigation system every time a junction was approached when an auditory instruction was provided. On the other hand participants using the map produced much more varied results, some barely looking at the map and presumably relying solely on memory, while others were less confident and stopped the vehicle to confirm their location and the direction of travel. Consequently, while for the navigation task the total number of eye glances was fairly constant across participants, and the glance times quite brief, overall, the video recordings revealed similar total glance durations for both task types.

The usability questionnaire was a useful tool for obtaining information about the system from the user’s point of view. It appeared to cover most of the salient aspects of system use, and provided an opportunity for users to give an overall opinion about the system.

6 Discussion

The UK approach of identifying and evaluating specific IVIS has proved extremely valuable as a method of providing a consistent and swift account of compliance with the SoP by the UK IVIS industry. The pro-active approach adopted by the DTLR, while demanding considerable time and effort, has produced a comprehensive and in-depth view of issues surrounding the SoP and the impact it has had in the UK both for the large car manufacturers and smaller independent companies. Consequently, and as a direct result of our evaluations, the DTLR should feel confident that the results of the assessments undertaken reflect an accurate, unbiased account of the real compliance situation within the UK, that has gone beyond the interrogation of IVIS manufacturers and designers.

While stage 1 of this project illustrated in many cases the system manufacturers’ awareness of the SoP, the experience we have gained from our evaluations suggests that this knowledge of the SoP has not always been reflected in system design. In particular, the three main areas of non-compliance were found to be:

- Documentation.
- Driver-input controls.
- Excessive demands for interaction with the system during operation often exacerbated by a large and complex menu facility.

Documentation was also highlighted as a problem during the user trials. This suggests that there is a need for more extensive advice concerning effective provision and presentation of information in user manuals and associated documentation.

The results have not demonstrated any strong relationship between either knowledge about the SoP, or any formal input from qualified ergonomists, and the extent of SoP compliance. The areas of most frequent non-compliance were not restricted to the smaller less-well informed companies, but applied across the full range of system producers, and to both OEM and after-market devices. This suggests that, at present, availability of the SoP is having limited impact on the design of IVIS in the UK.

HMI design guidelines have existed in the UK for at least 5 years (British Standards Institution, 1996) but its impact on system design has been rather slow. Since the SoP has been in existence for even a shorter period (just over 2 years), it is likely that it may not have had time yet to filter through to impact on system design.

It is not possible to have absolute knowledge about the SoP’s impact, since we do not possess consistent data for systems produced prior to its availability, and it is possible that the situation will improve as designers become more aware of the issues. Publicity and direct contact with manufacturers (for example through the assessment and feedback work undertaken by DTLR and TRL) are possible dissemination routes. Unfortunately, however, the current situation is that we have several examples of organisations (large and small, both OEM and after-market) that claim to be aware of the SoP, and yet have still produced products that do not comply with the principles.

Our HMI evaluations have also raised a number of other issues.
Experimental vehicles:
Included within the evaluations were a small number of prototype experimental vehicles and systems, not currently covered by the scope of the SoP, which in addition to the TRL evaluations, were being trialed using participants from the general public. The use of user trials for the evaluation of experimental vehicles raises questions about safety, insurance and liability, and whether such vehicles should be expected to conform to the SoP.

Crashworthiness:
Over half of the systems evaluated were after-market devices. The ready availability and increasing use of these devices, including Mobile Data Terminals (MDTs) designed for use by fleets of employees during the course of their work, raises questions concerning their installation and use. One particular concern was the type of installation / mounting brackets utilised by some after-market systems. Several of the MDTs possessed large display screens that were mounted using rigid metal brackets. The crashworthiness of this type of installation was questioned, and it was felt that there is a need to address the additional safety concerns relating to the likelihood of injuries being caused by installations of this type, in the same way as Type Approval testing does for new vehicles.

Installers and employers:
The after-market devices in particular raised a number of issues concerning the responsibilities of associated personnel. For example, we evaluated a number of mobile data terminals designed to be used by employees within the emergency services and utility industries during the course of their working day. In the current working climate, where pay and bonuses are often performance related, the introduction of this type of system raises concerns about the likelihood of inappropriate use while driving and the responsibilities of both employers and employees. Additionally, where systems are being bought ‘off the shelf’ and installed, questions arise about the responsibility of the installer, to comply with the Principles, and how best to inform installers about the SoP. The Radio Frequency Agency Code of Practice on the installation of radio equipment may also be relevant.

Context specific evaluation:
The MDTs also illustrated some of the issues associated with the evaluation of context specific applications. The majority of MDTs were evaluated in demonstration rather than live operating mode, limiting the extent of the assessment. Additionally the assessors did not possess the specific expertise and knowledge of the intended user population, nor had they experienced the training that would ordinarily be given prior to system use. Consideration needs to be given to the most effective method of evaluating systems of this type, and whether, in fact, it is possible to evaluate all elements of system use out of the intended context for use, and without using the intended user population during their normal working day.

Design responsibility:
Many of the systems we evaluated consisted of multiple components, including system hardware, software, communications links, and information providers. A small number were computer-based applications running in a windows type environment. Consequently, in addition to the system application, drivers were also able to access other functionality associated with the underlying operating system. The concept of a mobile in-vehicle P.C. has started to become a reality in recent years, and issues surrounding the availability of and interaction with additional non-driving related functionality need to be addressed. At present there is a lack of definition of responsibility for multiple integrated in-vehicle systems. With the advent of such complex systems there is a need to identify the roles and responsibilities of all those involved in creating the interface with which the driver interacts, to ensure that integration and information provision are as seamless and consistent as possible.

Impact of assessment feedback:
As noted above, our evaluations demonstrated that even where knowledge about the SoP exists, this does not imply compliance with the Principles. However, it would appear that undertaking evaluations and providing feedback to the system manufacturers is a useful exercise, and can make an impact on future design issues. Only a small number of manufacturers chose to comment on the results of our evaluations. However, their feedback suggests that not only was the information useful and thought provoking, but additionally, in some cases the information was being discussed with the system designers. For others, their newly found understanding of the implications of the SoP was being incorporated within their quality control procedures (implying that the situation might improve in the future).

7 Conclusions
The HMI studies undertaken have been an extremely effective means of gathering accurate and useful information about UK manufacturer’s perspective on and compliance with the EU Statement of Principles. The evaluations have provided valuable information about areas of compliance as well as non-compliance, and the distribution of safety concerns among both OEM and after-market manufacturers. The evaluation of a broad range of individual systems has enabled compliance to be assessed directly and thoroughly, and has clearly demonstrated discrepancies between manufacturer’s awareness of the SoP and their actual compliance with the Principles.

Although we did not receive information from every producer of the systems we evaluated, there does not appear to be a strong relationship between either knowledge about the SoP, or the formal input by qualified ergonomists, and the extent of SoP compliance. The ergonomic concerns noted were not restricted to products from smaller companies, but applied across the full range of system producers, and to both OEM and after-market devices. So, although awareness of human factors issues
may be growing generally, we can conclude that the impact of the EU Principles to date has not been sufficient to eliminate the many non-compliance issues highlighted by our studies.

We cannot be sure exactly why the Principles have not been adhered to. For the smaller companies it may simply be that they were less well informed about the SoP, and consequently lacking in awareness of the recommendations provided within them. For others, the short length of time between the publication of the SoP and our HMI evaluations may have prevented the recommendations from having their full impact. Additionally the early publication of the SoP expansion might have proved more useful by providing greater depth of information than the original abridged version.

The results of our survey and evaluations have raised a number of issues related to the status, scope and contents of the SoP and suggest that its future is an important issue both within Europe and internationally.

8 References


Details of specific evaluations are not provided within reports made available outside of the Department for Transport, Local Government and the Regions (DTLR) to respect the confidentiality of individual system providers as agreed.
Appendix B: User trial

Introduction
Although the HMI Safety Checklist covers many aspects relating to the safety, ergonomics and usability of in-vehicle systems, several areas identified in the Statement of Principles, such as workload, glance duration and assessment of the user manual, are not considered. This small-scale user trial was carried out on a navigation system to investigate these additional areas and to consider the system from the users point of view rather than from that of a human factors expert.

Method
Ten participants recruited from the TRL driving simulator database were involved in this small-scale user trial of an integrated navigation system. Participants were aged between 25 and 50 (eliminating inexperienced and elderly drivers). All participants had experience with computers and technology and would not describe themselves as 'techno-phobic'. However no participants owned their own navigation systems.

Prior to commencing the trial, participants were given instructions about what would be required of them, and were informed that they had the right to withdraw from the study at any point. They were then required to sign a consent form to this effect.

Manual assessment
Before familiarisation with the vehicle and navigation system, participants were asked to carry out several tasks on the navigation system using the user manual (see page 21). After attempting to carry out each task, participants were asked to rate the ease with which they found the information, how clear and easy the information was to follow and whether the system had responded in the manner they had expected. After attempting a number of tasks, participants were asked more general questions about how easy to use they found the user manual and were asked to suggest ideas for improvements to it.

System and vehicle familiarisation
Following the manual assessment, participants were given further instructions to firstly familiarise them with the navigation system while they were stationary and then to familiarise them with the vehicle through a ten-minute familiarisation drive when the navigation system was switched off.

Navigation system and map drives
Following familiarisation, participants were asked to carry out two drives, one using the navigation system and one using a paper map. The sequence of these navigation or map drives was varied to prevent an order effect. The routes were chosen due to their similarity; they both used a variety of main and small roads and were calculated as taking around 20 minutes to complete.

In the navigation drive, participants were asked to enter the destination whilst stationary and then follow the instructions given by the system, driving the vehicle to the destination as they would their own vehicle. It was emphasised that primary importance should be given to vehicle control. Similarly, during the map drive, participants were asked to travel to the given destination using the map and were given time before the drive to study the map and write ‘post-it’ notes of the journey, if required. Again, participants were instructed to give primary importance to vehicle control and to pull over to look at the map when necessary.

During both drives, participants’ eye movements were recorded using a video camera installed within the vehicle. At the end of each drive, participants were asked to fill in a workload questionnaire (NASA-TLX, see page 24).

Usability questionnaire
After using the navigation system, participants were administered an additional questionnaire designed to assess the usability of the navigation system (see page 26).

Results of user manual assessment
General manual issues
Several users expressed a dislike for using manuals, stating that they would not normally use them and would prefer to receive verbal instructions on how to use the system.

Users did not agree on whether the manual provided enough information. Some felt that the information provided was adequate while others felt that important information was omitted. Similarly, some users thought the information provided by the manual was clear and helpful and others disagreed entirely.

Navigating manual and locating information
A common problem expressed by many users was that information was often difficult to locate. Several users commented that the manual provided enough information, but that it was difficult to find and that an index should be provided in order to locate required information more easily.

Diagrams
The majority of users found the diagrams helpful by illustrating what the system screen should look like and aiding use of system controls. However, some of the users found the diagrams and illustrations overcomplicated and confusing. The main complaint was that they were not easy to find; for example, that the switch operation diagram would have been far more useful had it been located at the front of the manual.

Operations and controls
A few of the system operations were found slightly confusing, and full explanations of control functions were
not provided in the manual. For example, the menu and enter buttons were easily confused as they are poorly labelled. Further, the manual did not provide advice about how to navigate through the menus using the rotary knob, and users often became frustrated as they tried to use the arrow keys to move around the menu system.

**Volume**
The rotary knob looked like the volume control of an in-car stereo. Consequently, a number of users to mistook it for the volume control and did not realise that they had to select the volume option from within the system menu hierarchy. Additionally, a couple of users found that the machine pacing on the volume function did not allow them time to change the volume if they were doing so slowly whilst following the instructions within the manual.

**Entering destination**
The majority of users found that once they understood the functionality of the rotary knob they were able to use the system far more easily. Most users reported that the instructions for entering the destination were easy to find, and were clear to follow.

**Route preferences**
Users did not agree on how easy information on route preferences was to find. However, once the information was located, users found it clear, easy to follow and the system responded as they expected.

One user did comment that additional feedback from the system informing that route type has been set would be helpful.

**Points of interest**
A couple of users had problems locating points of interest (POI) information simply because the abbreviation was not written in full anywhere in the manual.

Once the information was located it was found clear, easy to follow, and the system did what was expected.

**Changing route or deviating from route**
Problems were experienced in locating information on what happens if you deviate from the prescribed route and on how to change route or request a detour.

**Warnings**
While participants did notice warnings within the manual, they commented that they could have been displayed more prominently.

**User suggested improvements**
Users suggested a number of possible improvements that could be made to the manual including:

- Cross referencing of some items would be helpful, e.g. how to operate switches could be cross referenced in the inputting destination and volume control sections.
- Illustrations should be accompanied by more detailed written instructions.

**Results of workload assessment**
The overall subjective workload experienced by participants was higher when navigating with the paper map ($x = 31.42$) in comparison to using the navigation system ($x = 18.35$), see Figure B1. However, it should be noted that both sets of workload scores were on the lower end of the scale, which ranged from 0-100.

![Figure B1 Mean overall workload scores driving with a paper-based map or navigation system](image)

When looking at the specific sub-categories of workload, participants experienced greater mental demand, physical demand, temporal demand and frustration and felt they were required to make greater effort when using the paper-based map in comparison with the navigation system. Further, participants reported their performance to be lower when using the paper-based map.

**Results of eye movement assessment**
Video tapes of the participants eye movements were analysed looking at the number of times participants looked at the map or navigation system, the duration time of these glances and how often participants stopped the vehicle to look at the system or map.

The total number of times participants looked at the map whilst driving was more variable in comparison to the navigation system, as illustrated in Figure B2. On average, participants looked 36 times at the map during the twenty minutes drive while they looked 63.5 times at the navigation system. However, participants using the map to navigate stopped the vehicle more often to be able to take time to verify their route on the map.

Glance duration for the navigation system and the map were very similar. Figure B3 illustrates the average eye glance duration per participant and shows the differences between looking at the map whilst driving and looking at the navigation system. The average eye glance duration of participants looking at the map was 1.09s, whilst the average eye glance duration of participants looking at the navigation system was 1.01s.
Results of system usability assessment
The majority of participants did not find the spoken announcements or display to be distracting (see Figures B4 and B5).

Figure B2 Number of times participants looked at the navigation system or map

Figure B3 Average eye glance duration per participant

Figure B4 The spoken announcements distracted me from driving

Figure B5 The display distracted me from driving
All participants found the information on the display easy to read (see Figure B6).

Participants had mixed views regarding the control layout. Some were unsure whether they liked it, some liked it and one did not like it (see Figure B7).

Most users felt they knew what the symbols and graphics meant (see Figure B9).

Most users found it easy to remember which buttons to press to operate the system (see Figure B10).

Participants did not agree on how easy it was to retrieve information by selecting the menu options (see Figure B11).

The majority of users liked the tone of voice used by the system (see Figure B8).
Over half of the users reported that they did not find the navigation system frustrating to use, while the rest were undecided (see Figure B12).

![Figure B12: I found the system frustrating to use](image1)

Most participants felt that the design of the buttons, headings and text made the system difficult to use (see Figure B13).

![Figure B13: The design of the buttons, headings and text made using the system easy](image2)

Although half the participants found it easy to find the information they needed when using the system, several participants did report experiencing difficulties (see Figure B14).

![Figure B14: I found it easy to find information I needed](image3)

Most participants found it easy to undo accidental actions (see Figure B15).

![Figure B15: I found it easy to undo accidental actions](image4)

The majority of participants found it easy to access the functions which they had intended to access (see Figure B16).

![Figure B16: I found it easy to access the functions which I intended to access](image5)

The majority of participants found it easy to learn how to use the navigation system and did not find it difficult to remember what the symbols and labelling on the system meant (see Figures B17 and B18).

![Figure B17: I found it easy to learn how to use the system](image6)

![Figure B18: I found it easy to remember what the symbols and labelling on the system meant](image7)
The majority of participants did not find the system to be complex (see Figure B19).

Most participants reported that they felt it was clear how to achieve their goals and that they knew in advance the effect their actions would have on the system (see Figures B20 and B21).

A couple of participants did not like the physical appearance of the navigation system. However most participants found the system pleasant to look at (see Figure B22).

Most participants reported that if the navigation system was in their car they would use it frequently and the remaining participants reported that they would use the system occasionally. None of the participants reported that they would not use the navigation system (see Figure B23).

Figure B18 I found it difficult to remember what the labelling on the system meant

Figure B19 I found the system to be very complex

Figure B20 It was clear how to achieve my goals when using the system

Figure B21 I knew what the effect of my actions would be when using the system

Figure B22 The system looked pleasant

Figure B23 If this system was available in my car I would use it
Discussion

The manual assessment provided additional information to that derived from the Checklist assessment. The assessment revealed that the manual could be improved by:

- adding an alphabetical index to the back;
- putting information into smaller chunks and bolding important words;
- cross referencing related information;
- providing clearer information about how to use various input controls and making graphical illustrations less complex.

The NASA-TLX questionnaire provided workload data that was not available from the Checklist assessment. The data revealed that participants experienced lower mental workload when using the navigation system in comparison with the paper based map. This was also the case for mental demand, physical demand, temporal demand, frustration and effort. Participants also felt that they performed better when using the navigation system. These results indicate that the navigation system is a superior alternative to the paper-based map.

The video analysis of eye movements revealed that the total amount of times participants looked at the map whilst driving was more variable in comparison to the navigation system. In addition, participants using the map to navigate stopped the vehicle more often to be able to take time to verify their route on the map. Eye glance duration for the navigation system and the map was found similar.

The system usability questionnaire gave information from the users’ point of view, rather than from that of human factors experts. Overall, the questionnaire revealed users to have a positive opinion regarding the usability of the navigation system. The majority of users did not find the system distracting, frustrating or complex. Users reported that they liked the tone of voice of the system, knew what the symbols and graphics meant, found it easy to operate the controls, easy to find the information they needed and easy to undo accidental actions. Further, most participants thought the system looked pleasant and all participants reported that they would use the system occasionally or frequently if it was in their own car.

The TRL HMI Safety checklist is a useful tool to effectively assess a system and identify areas of potential concern. However, the checklist does not address some aspects covered in the Statement of Principles and additional measures, such as those used in this small-scale trial, may also be required. These areas may need to be included when carrying out a full assessment of an in-vehicle system.
MANUAL ASSESSMENT TASKS AND QUESTIONNAIRE

USER EVALUATION OF IN-VEHICLE SYSTEM MANUAL

Before we ask you to drive the car we would like you to carry out a few tasks on the navigation system using the manual provided.

The aim of this part of the trial is to evaluate the usefulness of the manual, therefore we would like you to use only the written instructions given in the manual rather than any previous experience you may have with in-car systems.

1. **Using the manual, please turn the system on.**
   - Did you find it easy to find the information?  Y  N
   - Did you find the instructions clear?  Y  N
   - Did you find the instructions easy to follow  Y  N
   - When you followed the instructions did the system operate as expected?  Y  N

   Comments

2. **Using the manual, please adjust the volume**
   - Did you find it easy to find the information?  Y  N
   - Did you find the instructions clear?  Y  N
   - Did you find the instructions easy to follow  Y  N
   - When you followed the instructions did the system operate as expected?  Y  N

   Comments

3. **Using the manual, please input a destination of your choice**
   - Did you find it easy to find the information?  Y  N
   - Did you find the instructions clear?  Y  N
   - Did you find the instructions easy to follow  Y  N
   - When you followed the instructions did the system operate as expected?  Y  N

   Comments
4. **Using the manual, please select your route preferences**
   - Did you find it easy to find the information?  
     Y  N
   - Did you find the instructions clear?  
     Y  N
   - Did you find the instructions easy to follow  
     Y  N
   - When you followed the instructions did the system operate as expected?  
     Y  N

Comments

5. **Using the manual, please select a point of interest of your choice**
   - Did you find it easy to find the information?  
     Y  N
   - Did you find the instructions clear?  
     Y  N
   - Did you find the instructions easy to follow  
     Y  N
   - When you followed the instructions did the system operate as expected?  
     Y  N

Comments

6. **Using the manual, please find out how to change your route and request a detour.**
   - Did you find it easy to find the information?  
     Y  N
   - Did you find the instructions clear?  
     Y  N
   - Did you find the instructions easy to follow  
     Y  N
   - When you followed the instructions did the system operate as expected?  
     Y  N

Comments

7. **Using the manual please find out what happens if you deviate from the prescribed route.**
   - Did you find it easy to find the information?  
     Y  N
   - Did you find the instructions clear?  
     Y  N
   - Did you find the instructions easy to follow  
     Y  N
   - When you followed the instructions did the system operate as expected?  
     Y  N
8. Using the manual, please find out the maintenance requirements of the system
   - Did you find it easy to find the information?  Y  N
   - Did you find the instructions clear?          Y  N
   - Did you find the instructions easy to follow Y  N
   - When you followed the instructions did the system operate as expected? Y  N

Comments

9. In general were you provided with enough information?  Y  N

Comments

10. In general was the information clear and helpful?  Y  N

11. Did you find any diagrams / illustrations helpful?  Y  N

12. Do you think the manual could be improved? How?  Y  N

13. Did you notice any warnings within the manual about use of the navigation system when driving?  Y  N

Any other comments?
NASA-TLX WORKLOAD QUESTIONNAIRE

*Please place a mark through each line to show the amount that each factor applied to YOU.*

**For example,** if you felt that your response was high, you would place a line as shown below.

- **Mental Demand**
- **Physical Demand**
- **Temporal Demand**
- **Performance**
- **Effort**
- **Frustration**
<table>
<thead>
<tr>
<th>TITLE</th>
<th>ENDPOINTS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENTAL DEMAND</td>
<td>LOW/HIGH</td>
<td>How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?</td>
</tr>
<tr>
<td>PHYSICAL DEMAND</td>
<td>LOW/HIGH</td>
<td>How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?</td>
</tr>
<tr>
<td>TEMPORAL DEMAND</td>
<td>LOW/HIGH</td>
<td>How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td>GOOD/POOR</td>
<td>How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?</td>
</tr>
<tr>
<td>EFFORT</td>
<td>LOW/HIGH</td>
<td>How hard did you have to work (mentally and physically) to accomplish your level of performance?</td>
</tr>
<tr>
<td>FRUSTRATION LEVEL</td>
<td>LOW/HIGH</td>
<td>How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?</td>
</tr>
</tbody>
</table>
USABILITY QUESTIONNAIRE

This questionnaire is designed to assess how easy you found the in-vehicle system to use. Please circle a response to indicate your opinion as soon as you have read and understood each statement.

1. The spoken announcements distracted me from driving

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

2. The display distracted me from driving

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

3. I could easily read the information displayed on the screen

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

4. I liked the control layout

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

5. I liked the tone of voice used by the system

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

6. I knew what all the symbols and graphics meant

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

7. I found it easy to remember which buttons to press to operate the system

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>
8. I found it easy to retrieve information by selecting the menu options

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

9. I found the system frustrating to use

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

10. The design of the buttons, headings and text made using the system easy

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

11. I found it easy to find the information I needed

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

12. I found it easy to undo accidental actions

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

13. I found it easy to access the functions which I intended to access

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

14. I found it easy to learn how to use the system

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>
15. I found it difficult to remember what the symbols and labelling on the system meant

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

16. I found the system to be very complex

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

17. It was clear how to achieve my goals when using the system

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

18. I knew in advance what the effect of my actions would be when using the system

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

19. The system looked pleasant

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
</table>

20. If this system was available in my car I would use it:

<table>
<thead>
<tr>
<th>Frequently</th>
<th>Occasionally</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
</table>
Appendix C: Closure questionnaire

Thank-you very much for lending your in-vehicle system to us for an HMI evaluation.

Our project is now in its final stages and in order to provide an accurate account of the UK perspective on the European Statement of Principles, we would be very grateful if you could provide some final feedback by answering the following questions.

1. What useful or interesting information (if any) was provided by TRL’s evaluation?

2. Would you like to comment on the feedback provided by the evaluation? (If you have not already done so).
   For example: -
   • Did the system perform as well as you expected?
   • In your opinion were the comments provided fair?
   • Were you surprised by any of the comments?
3. To what extent were you aware of the Statement of Principles for HMI of in-vehicle systems prior to your involvement with this project?

4. How useful do you think the SoP are?
   For example:
   - Do the principles cover all the design and usability issues that you are concerned with?
   - Are there additional areas you would like to be included?
   - Is enough detail provided within the SoP to inform the design process?

5. Did you feel that the HMI Checklist was a suitable / fair evaluation tool?
6. Will you be making any changes to your working practices / design process as a result of:
   - Your awareness of the Statement of Principles
   - The feedback you received from our HMI evaluation?

7. How do you think the European SoP should be used in the future?
   For example should they:
   - Remain as guidelines
   - Be expanded
   - Provide the basis for a voluntary memorandum of understanding between the government and system producers
   - Provide the basis for a European standard
   - Provide the basis for new Type Approval requirements?
Abstract

This report describes work carried out under project UG362, investigating the extent of knowledge about and compliance with the EU Statement of Principles for HMI, within the UK. The results of the two stages of work undertaken are presented followed by a discussion and conclusions.

Related publications

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<th>Year</th>
<th>Price</th>
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<td>D Watts, J Rattle and A Stevens</td>
<td>1998</td>
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<td>Measures for assessing on-board units for electronic toll collection - Parts 1 and 2</td>
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<td>PR41</td>
<td>Urban traffic control, system review</td>
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<td>£35</td>
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<td>PA3536/99</td>
<td>A safety checklist for the assessment of in-vehicle information systems: a user's manual</td>
<td>A Stevens, A Board, P Allen, A Quimby</td>
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<tr>
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<td>Design guidelines for in-vehicle information systems</td>
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