TRANSPORT RESEARCH LABORATORY

A preliminary study of in-vehicle interfaces for electronic toll collection

Prepared for Tolling and Private Finance Division, Department of the Environment, Transport and the Regions

D Watts, J Rattle and A Stevens

TRL REPORT 359

First Published 1998
ISSN 0968-4107

This report has been produced by the Transport Research Laboratory, under/as part of a Contract placed by the Department of the Environment, Transport and the Regions. Any views expressed are not necessarily those of the Department.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.

Transport Research Foundation Group of Companies
Transport Research Foundation (a company limited by guarantee) trading as Transport Research Laboratory. Registered in England, Number 3011746.

TRL Limited. Registered in England, Number 3142272.
Registered Offices: Old Wokingham Road, Crowthorne, Berkshire, RG45 6AU.

CONTENTS

Executive Summary

This report is based on an initial survey of the proposals received by the DOT (now DETR) for Electronic Toll Collection (ETC) systems on motorways. The focus of the survey is the Human-Machine Interface (HMI) of the In-vehicle Units (IVUs) although the amount of detail available varies considerably between proposals. Where possible, comments are made about each unit from a human factors perspective and recommendations made for improvements in the proposed designs.

Since only outline system requirements were established when proposals were invited, different assumptions have been made by consortia about what the IVU is actually required to do. Therefore, a formal evaluation against a design specification cannot be undertaken at this time, and comments on proposed designs are necessarily either very general or very specific.

As a result of this, the study was extended and proposed for discussion purposes, one way in which a smart-card based IVU could operate. This has allowed some of the system requirement and design issues to be addressed. Based on some assumptions about required functionality, TRL has begun the process of constructing design guidelines specifically applicable to IVUs for motorway tolling.

The UK Code of Practice for In-Vehicle systems has been examined and no major conflicts have been found between the requirements of the Code and ETC IVUs. It is recommended that the final ETC specification should include detailed requirements for IVUs which, together with the general principles embodied in the existing Code of Practice, will ensure that acceptable operation is attainable.

The next phase of work is proposed which will involve an examination of drivers' interaction with IVUs during field trials. This, along with the evolving system requirements, will lead to a consolidation of design guidelines for future IVUs.

1 Introduction

The DOT (now DETR) have received a number of proposals for systems to demonstrate motorway tolling during field trials beginning in 1995 and TRL has been commissioned to investigate the human-factors issues surrounding the in-vehicle part of the systems.

This preliminary study is based on an examination of the proposals submitted by Consortia to DOT (DETR).

2 Initial assessment of proposed IVUs

2.1 Method

Each proposal document was examined by ergonomists from TRL and information about operation and design aspects of the IVUs studied. The amount of detail available varied considerably, ranging from little or no textual information to proposals with diagrams and pictures of units in operation.

Tolling systems can be classified in a number of ways (e.g. by the technology they use). For this study, it was found useful to classify the proposed IVUs by the complexity of their construction according to the following scheme:

Class	Description
0	No device suggested in proposal.
1	Vague alternatives suggested in proposal.
2	***Simple IVU*** This has no display, keypad, or any external features. It is simply fitted to the inside of the windscreen.
3	***IVU with display*** This has the same characteristics as the 'simple IVU' above, but also has a display on the unit (for example, to show the remaining credit).
4	***IVU with display and button*** This has a display and a single button (used e.g. as an on/off switch or to scroll around displayed information).
5	***IVU with display and keypad*** This has a display and number of buttons or controls (to implement several functions including indicating a trailer).
6	***Demonstration IVU sub-system*** These were often based on a portable PC and have high functionality but are clearly not saleable as production units.

Where possible, comments were made concerning the units from a human factors perspective, and recommendations made for improvements in particular designs. More general design guidelines are presented in a later section based on both general principles and the experienced gained from this initial survey.

2.2 Classification of proposed IVUs and specific notes

In this section, each IVU is designated with an identifier used by DOT (DETR). The code number in brackets is a classification of the IVUs according to the construction scheme described above. There then follows a brief description of the IVU and specific comments from a human factors perspective.

A(3) This proposal suggests a screen mounted transponder. However, the mounting position is poor and there seems to be little consideration of the effects of placing such an item on the windscreen in the driver's field of view.

B(4) This system envisages a portable transponder which, it seems, would be left to rest on the dashboard. This is extremely undesirable, especially if the unit has controls (as it is very much more difficult to operate a button which is not held firmly). Guidelines for in-vehicle devices (see below) propose that any IVU must be securely fixed to the vehicle and that crash worthiness of the transponder and mounting must be considered.

C(3) This IVU is affixed to the inside of the windscreen and contains a simple smart card holder. The unit is shown fixed to the left hand side of the windscreen which implies that the view of the road is not obscured but that viewing of the tolling LCD display would be difficult and dangerous if attempted while driving.

D(3) The device features a card slot and display and has been specified in several proposals. It is designed to be fixed behind the rear view mirror, which it is unlikely to block the driver's view. This device is in operation in other trials, according to the documentation (so it may be possible to conduct studies to see if users have experienced any problems).

E(2) This proposal specifies a box mounted on the top of the dashboard. No details are provided except that the system uses smart cards as a data storage medium. The size of the box is unknown but if it is too big it will cause problems with the driver's view of the road.

F(3) (see D proposal above).

G(6) The suppliers wish to use a microwave transponder, with a smart card reader, although these have not yet been integrated into an IVU. The proposal suggests additional extra value services could be provided because there is spare capacity on the communication link.

H(6) The interface of this system is based on a PC terminal, which is activated by the insertion of a smart card. A keyboard and display are mentioned in the text but no indication of size or design is given. Emergency call is possible with this system.

I(5) This IVU has a display, four buttons and a slot for a smart card. The LCD display appears to have

two rows of perhaps 10 to 15 characters. The four buttons are labelled ‘ON’, ‘INFO’, ‘DOWN’ and ‘RIGHT’. The latter two are used for scrolling through a transaction log. No mention is made as to whether this is possible all the time or only while the vehicle is stationary. There is also a switch for use when a trailer is being towed. The IVU’s dimensions are 120x74x82mm. It is proposed that a smaller unit would be designed for mass production.

J(3) This system’s HMI consists of 3 coloured LEDs and a 2-tone buzzer. There is an option for an LCD screen. The system also appears to use a smart card. There is no other information relevant to the IVU.

K(0) No information is provided about this design which proposes a combined Transponder and tax disc.

L(0) No relevance. Not a full tolling proposal.

M(2,3) This proposal offers two different IVUs. The first is a plain transponder with no interface and no display which simply fits behind the rear view mirror. Little information is given about the charging method or other operational matters.

The second option is an IVU with a display and smart card reader. The power for the unit comes from a cigarette lighter socket. Both IVUs are small and compact, but the suitability of the power source is questionable. A motorcycle unit is also available, which has no buttons and is sealed in a plastic case. The unit is mounted on a stalk attached to the handlebars. Such a mounting appears insufficiently robust and may have safety implications.

N(0) The amateur nature of this proposal precludes serious consideration.

O(5) This IVU requires the driver to select the correct charging band and then turn ‘on’ the system when it enters a charging area. Apart from the suggested position of the unit, which would make such an operation difficult or dangerous whilst driving, the need for manual intervention has implications for both safety and violation rates. The system as proposed, therefore seems unsuitable from both a human factors and system operation perspective. The economics of the system which has high violation rates will also be adversely affected.

P(2) This proposal accords with the Code of Practice and suggests an IVU which required no interaction whilst driving. The unit is placed at the top left hand side of the windscreen (where it should not obscure the driver’s vision). It is proposed that the unit be incorporated with the tax disc such that the external facing side displays the expiry date and vehicle registration number plus other relevant details. The internal facing side has an audio output device (although it is unclear how this would be used), and an LCD which displays account balance, account debit, invalid operations and IVU malfunction. It is suspected that the latter two features would involve an audible presentation. The IVU appears very compact and approximately 1cm thick (but no measurements are given).

Q(1) This proposal appears to have given little consideration to the IVU beyond the declaration that it would be ‘a device with a smart card’.

R(4-5) This proposal suggests an IVU with some form of display showing the system data and time, and the current zone and service. The possibility of adding a small keypad for accepting or confirming an action is also mentioned (an example given being the confirmation of a right of way in a restricted area). Little thought seems to have been given to the implications of such an IVU and no information is given on its size or position in the vehicle.

S(3) The proposed IVU is a ‘small rectangle box’ approximately 20mm square located in the top left hand corner of the windscreen. There would be either an LCD screen or a print out facility. No details are provided of the function of the screen or print-out but presumably they could display transactions. Access to such functions while driving are not considered in the proposal.

T(0) Only retail aspects are considered in this proposal.

U(0) This proposal is concerned only with pricing issues.

V(5) In this system the antenna is attached to the windscreen and the IVU placed wherever convenient by the driver. The IVU appears to consist of a smart card interface and a keypad which can be used for entering pin numbers.

An LCD is used for displaying the credit and debit (which can presumably be seen whilst driving). Pre-payment via smart card is advised but the proposal contains the idea of electronic duplicate information so that debt could be settled when a new card was inserted. It is suggested that accounts could be checked annually when road tax is renewed. Whilst presumably more expensive, the concept of separating the antenna and IVU has several advantages: the antenna can be placed in an optimal position (e.g. behind the rear view mirror), and the IVU interface can be placed near to the driver. Professional fitting is likely to lead to more appropriate positioning.

W(3) As an alternative to a smart card, this system proposes an account based method of payment. The IVU, which uses a battery operated microprocessor and antenna is 85mm x 55mm and very slim. It is located on the windscreen inside a plastic sleeve for easy removal (but could it get lost or forgotten?). With such an arrangement, as with smart card systems, there is also a danger of a driver trying to insert the IVU (or smart card) while driving and it is therefore suggested that the device is permanently fixed in the vehicle. The interface provides information either by a set of LEDs, to show the device status (e.g. green = correct functioning,

yellow = low token level, red = low battery level), or an LCD to show device status. The use of coloured LEDs has an appealing simplicity and enables use in light or dark conditions.

X(4) The proposed IVU comprises a Trailer switch, LCD and LEDs for showing highway tariffs and amount left on the card. No information is available on location of the IVU. Its size is HxWxD = 65x127x96 mm, which seems unnecessarily large for this type of application and may be difficult to mount. The display of information, such as highway tariffs, is discussed in a later section. Trailer switches are considered to be open to abuse and therefore not recommended. The violation system should be able to detect the presence of a trailer and adjust the charging rate accordingly.

Y(1) This proposal suggests the use of a smart card/tag on the outside of the vehicle, with an audio or visual IVU. No further details are provided.

Z(3) This IVU has LEDs to show battery levels, an LCD to indicate level of card credit and a buzzer. It is to be located inside the windscreen of cars (at an unspecified position) or on the handlebars of motorcycles. The buzzer may produce an unacceptable distraction. On a motorcycle the suggested positioning may be inappropriate due to poor crashworthiness and possible injury problems. Smart cards are specified but it is unclear whether they would implement a post or pre-payment facility.

ZA(1) This IVU can be located as desired, but the proposal recommends inside the windscreen behind rear view mirror using a hook and loop (Velcro) method of attachment. The wisdom of Velcro attachment is challenged for a permanent fitting .'Something' would advise of battery levels. Insufficient information is provided for further comment.

ZB(1) This consortium recommend three alternatives:

1 A Tag 115x48x1.5 mm positioned to 'not cause obstruction' e.g. behind the rear view mirror. This system would use account billing.

2 A Tag and smart card. The IVU would be positioned within the driver's reach. It could also have a spoken output to inform of a low level on the card and could show a record of transactions. The ability for spoken information needs further investigation.

3 A Tag and mobile car phone. The driver is required to dial a number before driving and 'swipe' their credit card through the reader on the phone. From a safety perspective, such a system could encourage the use of mobile phones while driving (for tolling and voice purposes) which is undesirable. There is also an issue concerning the point at which the system stops charging the swiped card.

ZC(1) This proposal does not present a clear IVU concept, but suggestions include:

LED/LCD displays

Push buttons

Aural devices

Smart card interfaces

Computers or 'devices' on board

Console with displays, aural devices, entry keypad etc on board

Other on board devices

3 Interaction with the UK Code of Practice

3.1 The UK Code

The ease of use and safety of in-vehicle equipment (particularly of new information systems) has been an area of interest for DOT (DETR) for several years and their Code of Practice for the design, installation and use of in-vehicle displays will shortly become a BSI 'Draft for Development'. The Code identifies those factors - from the design stage of a system through to its actual use - that need to be considered in order to achieve safety and effectiveness of any particular system.

The Code of Practice comprises a set of Principles (concerned with *what* needs to be achieved) and a set of design guidelines (which provide advice on *how* this might be accomplished). The set of principles are reproduced at Appendix 1. These are necessarily of a rather general nature and, whilst conveying useful concepts, are not written in a formal and unambiguous way that can be used as a basis for rigorous assessment (Stevens, Watts, Crompton, 1994).

3.2 The Principles

Each Principle was examined in the context of this study and, whilst the majority are equally applicable to tolling IVUs, three have been identified as being in possible conflict with the requirements of an ETC IVU. The reasons are discussed below:

4.3 The system should be easy to use and be able to be switched off without adversely affecting the control of the vehicle.

NOTE: Depending on the performance specifications of the IVU, it may be desirable for the IVU to be permanently 'on' and not have external controls (since an off button will increase the number of violations through the system being inadvertently switched off).

4.4 The driver should be able to control the volume of sounds generated by the system.

NOTE: It may be more advantageous for the IVU not to emit sounds or for any 'beeps' to be of pre-set volume to minimise external controls.

8.3 ... the system should be easily usable from the driver's preferred seating position while wearing a seat belt.

NOTE: 'Usable' in this context may refer to (a) reading, (b) inserting smartcards and (c) pressing buttons. One problem may be the conflict between a usable position from a driver's point of view and functionality from a communications point of view (assuming the transponder and smartcard/display are within the same unit). This point is further discussed below and will be a subject for examination during field trials.

3.3 The Design Guidelines

The Design Guidelines part of the Code of Practice contains much general information about displays and controls and the design of dialogue. Nothing within it is directly in conflict with tolling IVU requirements since advice is given that the guidelines must be intelligently applied to each application and with adequate knowledge of the user requirements.

3.4 Discussion of future requirements

The degree of conflict between the Principles of the Code of Practice and future IVU designs is dependent on the system requirements but is, in any case, minimal. The Design Guidelines part of the Code of Practice contain general information which is not intended to be exhaustive or application specific.

It is anticipated that as field trials progress, system specifications will evolve and design requirements and specifications of IVUs can be developed which are in general agreement with the Code of Practice but which can be more specific in terms of design parameters such as modes of operation and external controls required. The Design Guidelines part of the Code of Practice will be a useful source of information to which a future design specification may refer.

The Code of Practice as a 'Draft for Development' is intended as a 'living document' and comments can be made at any time to BSI within the next three years. Experience gained with the tolling trials may provide information with which to improve the Code.

4 Interaction with standardisation work

The objective of standardisation in the field of Transport Telematics is to create the technical basis for 'compatibility and interoperability' of systems and services (provided by different operators and across different countries) and to facilitate the creation of markets extending beyond national boundaries.

The main focus of standardisation work in Telematics in Europe has, until recently, been CEN TC278, which first developed its programme of work in 1992. More recently, the global committees, ISO TC22 and ISO TC204 have been reactivated or initiated to tackle the same area. In addition, there are several other committees which have some relevance to work in the tolling area, such as CEN TC 224 on Machine Readable Cards.

Standards are relevant to consideration of HMI design issues since, once a standard is accepted, all national members must implement (adopt) the standard as a national standard within 6 months and withdraw any conflicting national standards. In addition, standards are increasingly required to be used in procurement activities.

Some relevant standards activities are noted below:

TC224 Smart-cards:
Among its 14 Working Groups which define many aspects of design and operation, is one WG on Transport applications. The main influence on IVU design, however, will be physical parameters of the cards.

ISO TC22 SC13 WG8 (previously CEN TC278 WG10):
This group is developing general principles for interface design and dialogue including the presentation of audible and visual information. There may also be some guidelines concerning evaluation of in-vehicle distraction. General recommendations arising from this standard will have to be considered in interface designs for tolling equipment.

ISO TC204 WG13:
This group is concentrating on developing guidelines for the HMI of specific applications. At present, the applications are:

- collision warning systems
- navigation and route guidance
- driver information system integration.

Currently, therefore, there are no plans for tolling application design guidelines.

Other ISO/TC 22 SC 13 Working Groups:
Three other groups have recently been re-activated, although their impact on tolling is likely to be minimal:

- WG 3 Controls and Tell-tales
- WG 5 Symbols
- WG 7 Hand and Reach determination

Overall, this brief survey of standardisation work relevant to in-vehicle equipment for tolling has revealed no specific information that needs to be considered. Although some general design principles are expected to emerge, these are not likely to be controversial or impose major constraints on tolling IVU design.

The corollary of this is that the UK is effectively unconstrained, from a standardisation point of view, in its design requirements of the in-vehicle interface for motorway tolling applications.

5 Discussion of usability issues

In order to consider properly the safety and usability of IVUs it is necessary to consider system requirements, user requirements and dialogue design as well as design, construction and installation issues.

This section explores some of the issues that have been

raised by examining IVU designs and proposes some initial guidelines. Of necessity, many of these points are considered at a general level and often relate to overall system design requirements which are still evolving.

Overall design:

All IVUs should be identical, or at least sufficiently similar that motorists will have no reasonable grounds for claiming ignorance or confusion. As it is anticipated that IVUs will initially be an 'after-market' fitment, they need to be carefully designed for fixing into existing vehicles and should, for example, have no sharp edges liable to cause injury in an accident.

Reliability:

The IVU should be *extremely* reliable, with a reliability similar to that of other in- car electronic devices such as car radios.

Fixing in vehicle:

IVUs should be securely (perhaps permanently) fixed in the vehicle but consideration needs to be given to replacement if, for example, they are attached to a broken windscreen. Velcro, or similar, fastening would need to be tested for durability before being considered as acceptable. Professional fitting of IVUs has much to recommend it from a safety perspective since fitting guidelines would be more likely to be observed.

Positioning of the IVU:

Positioning an IVU which contains both a transponder and smart card (possibly with a display and buttons) poses a dilemma: in principle, fitting the IVU to the windscreen is acceptable as long as it does not significantly reduce the driver's visibility. However, if a driver has to interact with the IVU or view the display, this also places constraints on its position (see figure 1). B1 and A1 are unacceptable as they will block the view of the road. B2 and A2 are better but then the unit cannot have a display (which is visible to the driver). At A the display is likely to be invisible and any controls will be out of reach. At B controls may be within reach but the device could block the view of the road. It may be sensible to invoke the MOT test requirements which specifies areas on the screen which must be free from cracks and stone chips.

Experience shows that drivers will adopt quite risky strategies and postures to interact with in-vehicle equipment if it is physically possible to do so. Thus, if a unit requires a smart-card to be inserted before joining a motorway, there is little point advising drivers to ensure that their card is inserted while the vehicle is stationary - drivers will continue to drive whilst retrieving their cards from glove-boxes, handbags etc and placing it in the IVU. Overall, therefore, if any interaction is required with an IVU it should either be physically impossible to accomplish it in a moving vehicle (e.g. by motion sensors) or the IVU must be placed where the interaction can be easily and safely accomplished.

An ideal solution, perhaps for later generation IVUs would be for transponders, smart-card slots and displays to be separately integrated into a vehicle.

Number of controls:

A full keyboard should be avoided! Clearly, the number of controls should be minimised and, from a purely human factors perspective, none should be required to be operated routinely whilst driving.

Degree of interaction:

The design specification has to be derived from functional requirements of the IVU. A good principle here is 'KISS' (Keep it Simple Stupid) i.e. What is the minimum functionality required? This may, for example, be:

- status OK (which can be provided by credit balance)
- credit balance
- credit zero or negative
- system or IVU failure (which could be implied by a blank screen).

There are a large number of additional items of information that *could* be presented to the driver: e.g.:

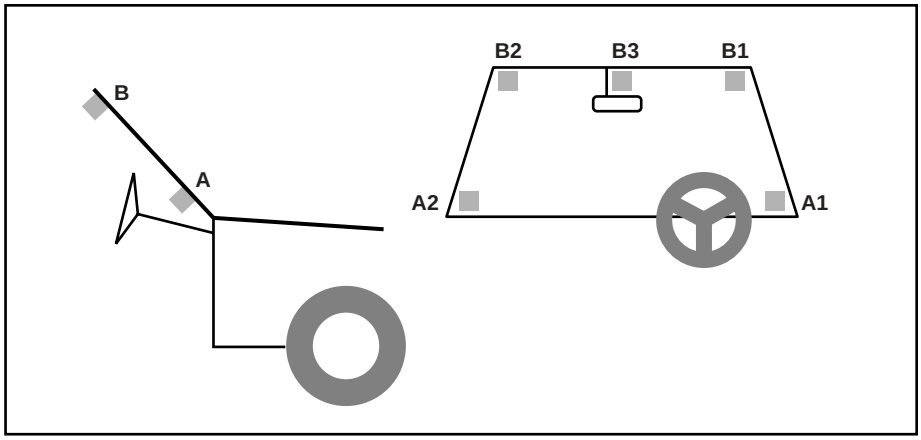

Figure 1 Possible position of IVU on a vehicle windscreen

- ‘you have been debited’

- change of zone

- change of charging band (if appropriate)

- additional information (Extra Value Services).

However, the provision of additional information requires a balance between drivers’ needs (or manufacturers’ perceptions of these needs!) and the requirement of safe driving. Ideally, it should not be necessary (and, therefore be made physically impossible) to operate any tolling IVU controls whilst driving.

Battery:

Battery changing and any required maintenance should either be unnecessary or infrequent and very simple. There should not be a need to consult a manual for the mundane task of changing a battery (e.g. the battery type should be clearly marked on the casing). Ideally the system could be wired into the car electrical system, although it will add to the cost.

Indicating zero credit:

How does the unit tell the driver that the smart card has run out? An attractive option could be for the IVU to display (discreetly) a warning that the card is empty. When the next card is inserted the ‘debt’ amount is taken from the new card.

Motorcycles:

Most proposals consider that a weather and dirt proof IVU would be too expensive to develop. However, this is a policy question and motorcycle IVUs are operating in Singapore.

6 Sample of operating requirements

This section is provided to illustrate the interaction between IVU functional requirements and design, and describes one way in which the IVU could operate.

IVU Design and installation:

- Driver should be able to insert the smartcard easily whilst driving.
- IVU should have no external controls.
- The display should consist only of digits but with the possibility of a minus sign ie: [negative sign or blank], [3 digits], [decimal point], [2 digits]
- The digits should be capable of flashing with a period of less than 1 second.
- The digits should be easily readable from the driving position (a great deal of human factors information is available on readability issues).

Operation:

- When a smartcard is absent, the display should be blank.
- When a smartcard is inserted, the display should show the credit balance in pounds and pence.
- Faulty, poorly inserted, or an illegal smart card should cause the display to flash
- When the IVU passes a charging point, the display balance is reduced (silently).
- When the balance reaches zero, subsequent transactions should cause an audible bleep and the display should show a negative balance. The negative sign should continue to flash and further transactions should cause an audible bleep.
- Subsequent insertion of a charged card should cause the negative amount to be taken from the old card, and the new balance should show the resulting overall credit.

7 Requirements for human factors work during the field trial phase

Examining the design of tolling IVUs based on initial descriptions provided by potential consortia is clearly limited and it is expected that much more information can be obtained when access to working units is possible.

It is therefore recommended that advantage be taken of the main trial phase to undertake evaluation work with the prototypes available, to monitor drivers’ interaction with them and to conduct surveys to appreciate better drivers’ needs in terms of IVU design.

As the trial progresses, and the system specification develops, it will be important to track the requirements and limitations that the overall specification places on IVU design.

7.1 Static evaluations

TRL plan the use of a number of checklists to test ergonomic performance. These will include the evaluation checklist derived from the ‘Statement of Principles’ which has been applied to other in-vehicle devices such as Trafficmaster and Columbus. An additional, more detailed, ergonomic checklist, under development for DITM Division of DOT (DETR), and another from the DRIVE2 project HARDIE, will also be used to assess the safety and usability of the IVUs. Additional points noted above will be incorporated into the checklists as necessary.

Checklist results and additional commentary will document TRL’s opinions of the features found on the interfaces undergoing field trials.

7.2 Driver Interaction Evaluation

It is understood that a fleet of drivers will be involved in the trials (on both the test-track and the road). These people will be a valuable resource for ergonomic investigations and it is recommended that the trial design includes human factors elements. One topic which would be particularly valuable is close monitoring of their interaction with the tolling equipment - particularly any system start-up procedures (such as inserting the smart-card) and when requiring the IVU to perform special functions (such as recalling transactions).

It is recommended that monitoring be essentially qualitative in nature and performed by observers, rather

than involving quantitative measures of vehicle control and visual performance. (Such measures are more expensive, time-consuming and 'invasive'. They would probably require a special vehicle and produce results which still require qualitative interpretation. It is anticipated that the effort involved in obtaining quantitative measurements is unwarranted for the complexity of the displays and controls involved.)

The close observation task will require the development of a simple checklist for the observers to use while watching the users. This will allow later interpretation and data analysis.

7.3 Driver surveys

In the closing stages of the trials, it will be possible to survey a group of 'experienced' drivers. A series of questionnaires will be developed asking both specific questions pertinent to each IVU and more general questions about IVU features. Note that such questionnaires are 'internal' to the trial participants (and consequently the results will have to the viewed in this context). A completely separate exercise would be required in order to obtain user requirements from the general population and this is not proposed within the scope of this work.

7.4 Specifications

The overall system specifications will impact on IVU design and it will be important to be fully informed of the monetary and ergonomic 'cost' of proposed requirements. Interaction with any wider work on user requirements will also be important. It is anticipated that experience gained with the ergonomic evaluations during the trial phase will be a useful contribution to the overall system specification development process.

When requirements for the IVU have been established, it is recommended that further detailed work on the IVU design be undertaken. The intention would be to ensure that IVUs procured from multiple sources are designed to a high standard and that they are sufficiently similar that driver confusion is unlikely to result.

8 Conclusions and recommendations

1 The initial survey of the proposals received by the DOT (DETR) for Electronic Toll Collection has been a useful pre-cursor to future considerations of IVU design requirements.

2 Since only outline system requirements were established when proposals were invited, different assumptions have been made by consortia about what the IVU is actually required to do. Therefore, a formal evaluation against a design specification cannot be undertaken at this time.

3 The UK Code of Practice for In-Vehicle systems has been examined and no major conflicts have been found between the requirements of the Code and ETC IVUs.

4 Standardisation activity in the HMI area is unlikely to impose significant constraints on tolling IVU design. The UK is therefore able to develop its own requirements for in-vehicle interface design.

5 The implications of IVU design (particularly for safety) are considered a vital contribution to decisions about system, and particularly IVU, functionality. It is recommended that system requirements and IVU design requirements be developed in parallel.

6 Based on some assumptions about required functionality, the process of developing design guidelines specifically applicable to motorway tolling IVUs has begun. It is recommended that the final ETC specification should include detailed requirements for IVU design.

7 It is recommended that the next phase of work should involve an examination of drivers' interaction with IVUs during field trials. This, along with the evolving system requirements, will lead to a consolidation of design guidelines for future IVUs.

9 References

Stevens A, Watts D and Crompton M J (1994). *Towards a quantitative approach to in-vehicle information system safety*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems (Paris), Ed. ERTICO, Vol 6 pp 1860-1867. ISBN 0-89006-825-9. November 1994

CONFÉRENCE EUROPÉENNE DES MINISTRES DES TRANSPORTS
EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

RESTRICTED

Paris, drafted : 29-Apr-1994
OLIS : 29-Apr-1994
dist. : 02-May-1994

CEMT/CM(94)20

Or. Eng.

COUNCIL OF MINISTERS

ERGONOMICS AND SAFETY OF IN-VEHICLE INFORMATION SYSTEMS

COVER NOTE AND STATEMENT OF PRINCIPLES OF GOOD PRACTICE

This document, included under Item 7 on the Agenda, is submitted to the Annecy Session of the Council of Ministers for information and the Statement of Principles for adoption.

013763

Cover Note

1. Technologies already exist, and new ones are being developed, that can provide drivers with route guidance, personal messages, and up-to-the-minute information on traffic and road conditions. Many of these products will use an in-vehicle display to supply the information or guidance to the driver.

2. A number of systems are already on the market and the growth in their use is expected to be considerable. They can help drivers with pre-journey planning and while travelling which will bring benefits for highway authorities in terms of better use of the highway network. By calming drivers and giving information and guidance they have potential for contributing to safety and traffic management. Such uses of In-Vehicle Information Systems are, in principle, not constrained by national frontiers and the benefits should be available for all.

3. But poorly designed IVIS could adversely affect driver behaviour and thus safety by distracting attention from the driving task. Also, if they supplied inaccurate, untimely or misleading information they could prompt a driver to take inappropriate action thus endangering himself and other road users. They could also interfere with the vehicle's electrical or electronic systems particularly when not designed in collaboration with the original vehicle manufacturers. So it is essential that IVISs are well designed with safety in mind. Clearly, their emergence in the market needs some oversight at minimum and perhaps regulation.

4. A number of member states are looking at the issue of safety and ergonomics with a view to establishing at minimum a regime for oversight and possibly regulation. Any kind of intervention in this context presents a dilemma. Too much action could stifle development and result in the full benefits of IVISs not being realised. Too little action could allow disbenefits and unacceptable consequences of the kind noted above. Regulation in the case of IVISs would presently be difficult because:

(i) the technology is changing very rapidly;
(ii) the impact of their applications is not necessarily obvious;
(iii) there could be some risk of creating unnecessary barriers to trade.

5. The need is to develop suitable design and performance-based standards for the introduction and use of IVISs. Meeting this need will require:

A. Objective research information about IVISs and their ergonomic and safety implications;

B. the development of measurement and evaluation techniques; the CEN seems to be the most appropriate body for the development of such techniques;

C. the development of a prior consensus on what such a standard or standards should cover. A pre-standard [ENV] in the CEN framework might be helpful. The European Commission is sponsoring research on design and methodologies under the 3rd Framework Programme, DRIVE II, which is due to be completed in December 1994. Topic Group 4 within DRIVE II, is charged with liaising with CEN TC278 WG10. Also, the Prometheus programme which is sponsored by the motor manufacturers, is working in this area and additional advisers such as the PROGEN Safety Group could also be consulted.

6. The TCT Group (Group on Transport, Computers and Telecommunications) believes that the appropriate body to undertake the rest of the work to meet the need is CEN Technical Committee 278, which is working on telematics and traffic control systems and in particular Working Group 10 (Man-Machine Interfaces). The TCT Group **recommends** ECMT Ministers press for Working Group 10 to be charged with meeting this need; to give it the highest priority; and to be resourced accordingly.

7. It will take some considerable time for all this work to be commissioned, carried out and completed and for a standard or standards for safe IVIS systems to be drawn up and formally accepted. The estimate of the TCT Group is not before 1998.

8. The TCT Group **recommends** that ECMT Ministers should urge Member States to avoid taking unilateral legal action and seek to regulate the introduction and use of IVIS only in the event that a particular system or systems are shown to have unacceptable safety implications.

9. The TCT Group also **recommends** as an interim solution that ECMT promulgates the best advice it can. Existing Material and expert knowledge can contribute to descriptions of what makes for safer systems. The accompanying Statement of Principles of Good Practice highlights the key issues that must be considered if a product is to achieve the highest level of effectiveness and safety when it is used. It seeks to give the best possible advice consistent with the state of the art. Ministers are requested to approve this Statement which is then to be officially transmitted to the appropriate standardization bodies. Work to assist those concerned with applying the Principles, eg. by developing suitable assessment methods, has already begun.

Statement of Principles of Good Practice concerning the Ergonomics and Safety of In-Vehicle Information Systems

Introduction

Over the part 2-3 years there has been a rapid growth in the number of Driver Information Systems on the market or at the prototype stage. Many products use an in-vehicle display and Departments of Transport in ECMT countries have become increasingly concerned about the potential impact of these systems on driver behaviour, and thus road safety, and traffic management. In addition, many items of business equipment are now available as portable units which can be adapted for in-car use.

This document provides a series of statements on the key issues that should be considered if products, especially products incorporating displays, are to achieve the highest levels of efficiency, effectiveness and safety when they are used.

It is emphasised that this is an interim Document because in a number of areas there is insufficient underpinning research to be able to specify clearly and unambiguously what constitutes a safe in-vehicle system. Many research establishments are studying this issue and several EC research projects are aiming to produce objective results needed for performance-based Standards. The Comité Européen de Normalisation (CEN) has begun work to develop such performance standards for the Man-Machine Interface (MMI) aspects of road transport telematics which is expected to take until 1998 to complete. This document is being made available now as a contribution to the general effort.

In summary the Statement:

- is issued as a contribution to general awareness about In-vehicle information systems, safety and usability.
- only applies to systems that will be used by the driver while driving.
- is not intended to replace existing National, European or International standards directives or regulations.
- is for guidance.

The Scope of the Statement

1.1 This Statement details important safety related issues that should be addressed by the designers, manufacturers, suppliers and installers of in-vehicle information systems that could conceivably be used by drivers while driving. For the purposes of this document driving is defined as, when the vehicle is moving. Use of in-vehicle equipment while stationary presents less of a safety concern, although some attention has still to be reserved to monitor external events whilst stopped in traffic.

1.2 It applies to all information systems except those solely giving information about the state of the vehicle or its equipment(e.g. speedometer, fuel gauges, etc).

1.3 Such systems include communications systems (such as telephones and radios), entertainment systems, traffic information systems, navigation systems mobile data terminals, portable personal computers and fax machines. With the rapid growth in new technologies at this time it is not feasible to list all the equipment which is covered by the Statement and so this list should not be viewed as exhaustive.

1.4 The Statement applies to equipment which may be used by the driver whilst the vehicle is being driven. It applies whether one or more IVIS are fitted. And it applies to equipment capable of multiple applications and multifunction displays.

Who is Responsible for Safety?

2.1 Designers, manufacturers, suppliers and installers all have some responsibility for safety in relation to the construction and installation of in-vehicle information systems. Companies promoting any system, employers, hire companies and drivers all have some responsibility for the way in which the equipment is used.

Responsibilities of the Designer and Manufacturer

General Issues

3.1 System controls should be designed to be securely fixed to vehicles interior where they can be safely used.

3.2 The system should be designed so that it does not unduly distract the driver, nor give rise to potentially dangerous driving behaviour by the driver or other road users.

3.3 Information systems should be compatible and consistent with existing vehicle equipment.

3.4 System functions not intended for use while the vehicle is being driven should be designed so that they cannot be activated when driving.

3.5 Use of the system should not result in the vehicle becoming unsafe to drive during normal use or during total or partial failure of the system.

3.6 Use of the system should not present an additional hazard to other road users.

3.7 The system should not present an electrical, chemical or mechanical hazard to vehicle occupants, during normal use and reasonably foreseeable misuse and should not increase risk of injury in the event of an accident.

3.8 This system should not present an electromagnetic hazard or any type of irradiation risk to the vehicle's control systems, its occupants or other road users.

3.9 The system should not present a hazard to the vehicle occupants or other road users as a result of unintended or naive use by inexperienced operators, or by children.

3.10 The system should comply with relevant National, European, or International Standards, Directives or Regulations.

Driver/System Interaction

4.1 Any display should not aim to visually entertain the driver. It should not interfere with the driver's central or peripheral view.

4.2 The system should not produce patterns or sounds liable to unintentionally startle the driver.

4.3 The system should be easy to use and able to be switched off without adversely affecting the control of the vehicle.

4.4 Drivers should be able to control the volume of sounds generated by the system.

4.5 Audible information should not prevent reception of external warning sounds.

4.6 The system should not require the driver to make time-critical responses when providing inputs to the system. The driver should be able to dictate the pace of interaction with the system and still derive the benefits.

4.7 Information provided should, as far as reasonably practicable, be sufficiently timely and accurate to assist the driver. Route information should be given sufficiently in advance of the manoeuvre for it to be accomplished safely.

4.8 Nationally and/or internationally agreed standards for icons, symbols, words, acronyms or abbreviations should be used wherever possible.

4.9 The driver should be able to assimilate visually displayed information at a glance that must be brief enough not to affect driving safety. For example, a glance lasting no more than two seconds has been proposed as a reference in less visually demanding driving conditions (eg a straight motorway with little traffic and good visibility).

4.10 Text messages should be relevant to the driving situation, easily read, and limited in length. As a guide, a suggested maximum of seven words has been proposed for variable message signs.

4.11 Text input by keyboard should be minimised while driving. Long and repetitive sequences of actions should be avoided.

System Instructions and System Literature

5.1 The system should have written instructions for use. These should cover all aspects of installation, use and maintenance.

5.2 Instructions should be correct, simple and clear and in the native language.

5.3 The system literature and instructions should clearly state the intended user groups and the intended use of the system.

5.4 The system literature and instructions should clearly state if specific skills or capabilities are required to use the system.

5.5 Instructions should be durable so that future owners will be able to learn about the system. Ideally they should also be integrated into the system; for example as a programmed tutorial.

System Assessment[1]

6.1 The system should be assessed, preferably independently, against all aspects of this Statement of Principles or other rules which could be drawn up in its place. By agreement with appropriate authorities, self-assessment by established manufacturers may be carried out using widely accepted methods as soon as such methods have been defined by appropriate bodies.

6.2 The assessor should provide the manufacturer or designer with a written report describing the assessment method, an explanation as to why that method was considered appropriate and the results of the assessment. This report should also state the limitations of the methods selected and, accordingly, of the results obtained.

6.3 The designer or manufacturer should keep all information related to the assessment of the system.

6.4 Details of the assessment of the commercially available system should be made available to the appropriate authorities if requested.

---

1. The German Delegation has expressed a reservation on points 6.1 to 6.4 inclusive.

Responsibilities of the Supplier

7.1 Suppliers should ensure that any promotion (eg advertising) does not encourage unsafe use.

7.2 Suppliers should request advice or assessments from appropriate authorities or experts in order to avoid the promotion of systems which might result in unsafe use.

7.3 Suppliers should be sufficiently familiar with equipment offered in order to assist buyers at the time of purchase and to provide after-sales support.

Responsibilities of the Installer

8.1 The system should not obstruct or interfere with existing vehicle controls or instrumentation, especially those required for safe control of the vehicle.

8.2 The system should not obscure the driver's view out of the vehicle.

8.3 The system should be located and fitted in accordance with the relevant standards for installing equipment in vehicles. The system should be easily usable from the driver's preferred seating position while wearing a seat belt.

8.4 If the system is intended for use by a front seat passenger as well as the driver, it should be located such that reasonable use by the passenger does not interfere with the driver in any way.

8.5 The installation should be performed in accordance with the manufacturer's instructions.

8.6 Where more than one information system is installed within a vehicle the complete installation should be assessed for safety and usability in realistic situations. Expert help should be sought where necessary.

Responsibilities of an Employer

9.1 As employers may make use of more than one system or require specific procedures of their staff while driving, the person responsible for having one or a number of information systems within a vehicle should assess the complete installation for safety and usability in realistic situations. Expert help should be sought where necessary.

9.2 Employers should be satisfied that anyone required to use the in-vehicle system whilst driving is capable of safely doing so.

9.3 Adequate training should be provided on all installed systems that drivers are required to use. A record of training should be retained and methods of assessing the effectiveness of the training should be considered.

9.4 A copy of the manufacturer's user instructions should be provided in every equipped vehicle. These should be retained and passed to subsequent owners of the system.

9.5 The Employer should ensure that the system is maintained in accordance with the manufacturer's instructions.

Responsibilities of Vehicle Hire Companies

10.1 Drivers should be informed of the purpose of all information systems installed in the vehicle and should be offered instruction in their safe use.

10.2 A copy of the manufacturer's user instructions should be provided in every equipped vehicle. These should be retained and passed to subsequent owners of the system.

10.3 The company should ensure that the system is maintained according to the manufacturer's instructions.

Responsibilities of the Driver

11.1 Ultimate responsibility for safe control of the vehicle rests with the driver. Drivers should only use in-vehicle information systems when it is safe to do so.

11.2 Drivers should ensure that they have access to the manufacturer's user instructions and should not use a system until they are content that they can do so safely. This may mean a period of training or familiarisation is required.

11.3 Information systems the controls to which are hand-held or placed on a seat should not be used while driving.

11.4 Communications equipment, even with hands-free operation should be used with care. Drivers should warn conversants that they are driving and may break off conversation to attend to driving tasks.

11.5 Drivers should ensure that the use of an information systems by a passenger does not interfere with safe operation of the vehicle.

11.6 All instructions associated with the in-vehicle equipment should be retained and passed to subsequent vehicle owners.

Abstract

This report is based on an initial survey of the proposals received by the DOT (now DETR) for Electronic Toll Collection (ETC) systems on motorways. The focus of the survey is the Human-Machine Interface (HMI) of the In-vehicle Units (IVUs). Where possible, comments are made about each unit from a human factors perspective and recommendations made for improvements in the proposed designs.

A formal evaluation against a design specification cannot be undertaken at this time. As a result, comments on proposed designs are either very general or specific.

The UK Code of Practice for In-Vehicle systems has been examined and no major conflicts have been found between the requirements of the Code and ETC IVUs. It is recommended that the final ETC specification should include detailed requirements for IVUs which, together with the general principles embodied in the existing Code of Practice, will ensure that acceptable operation is attainable.

The next phase of work is proposed which will involve an examination of drivers' interaction with IVUs during field trials. This, along with the evolving system requirements, will lead to a consolidation of design guidelines for future IVUs.