ROADSENSE: A COMMON APPROACH TO THE EVALUATION OF HUMAN VEHICLE INTERACTION (HVI)

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SUMMARY

The current development of in-vehicle systems intended to support the driver (ACC, Navigation, GSM telephony and traffic information services) have also introduced significant challenges relating to system integration, driver workload management and the potential for driver distraction. There have been a number of responses to this challenge. The European Commission has produced a Statement of Principles on in-vehicle HMI (1) and this has been recently matched by a similar recommendation from the Alliance of Automobile Manufacturers in the USA(2). However, the human factors research community has recognised that progress in this area is currently limited by a lack of agreement on the required tools, procedures and techniques.

The RoadSense project is attempting to build a consensus view within the European Automotive sector regarding the design and development of future advanced in-vehicle systems. The aim is to ensure that future systems provide high levels of driver support, comfort and convenience without compromising the safety of road users. A common approach to design and system evaluation is at the heart of the project.

The three-year RoadSense project (started in 2001) is funded within the 5th Framework Programme by the European Commission Competitive and Sustainable Growth Programme. Project coordinator is Jaguar (UK), partners are: Blaise Pascal University (F), CNRS (F), Cranfield University (UK), Centro Ricerche Fiat (I), Porsche (D), PSA (F), Renault (F), TNO (NL), Université de Technologie de Compiègne (F).
The project web site is:http://www.eu-projects.com/roadsense/

INTRODUCTION

The level of road accident fatalities has reduced significantly in Europe over the last 20 years despite an increase in vehicle usage. However, some 40,000 citizens still die each year (with some 1.7m injured) on Europe's roads. A number of national and community level programmes have been implemented to address this problem with considerable success. However, it is widely accepted that further significant reductions in road safety will require the adoption of advanced technology (telematics and intelligent autonomous vehicle systems). The European Commission (EC) and European Council for Automotive R&D (EUCAR) have recognised the opportunities for safety improvement offered by new technology and are helping the RoadSense project to address this issue. RoadSense is a collaborative R&D project that brings together the European automotive manufacturing sector with the academic and independent research communities.

Since the 1960s the predominant strategy for reducing road accident fatalities and injuries in Western Europe and North America has involved the application of engineering countermeasures. The emphasis has been on fatality reduction and significant 'passive safety' improvements have been achieved through the introduction of seatbelts, sympathetically strengthened vehicle structures, air bags, ABS braking, enhanced highway design and improved emergency service performance in terms of the speed with which accident victims are transferred to hospital and the quality of trauma response. Whilst this strategy has been highly successful it is now commonly accepted that opportunities for further improvements using this approach may be limited. Furthermore, it has also been recognised that while the driver plays a major role in accident causation, with the notable exception of alcohol abuse, attempts to improve traffic safety by influencing driver performance have been limited.

The advent of on-board telematic systems (e.g. navigation, traffic information and mobile communications) and intelligent vehicle systems (e.g. collision warning, autonomous cruise control and driver impairment warning) in the 1990s appeared to offer the possibility of substantial safety enhancement and functional support for drivers. These technical systems have been developed with the support of major R&D funded programmes (EC DRIVE and subsequent Framework Programmes, the European Prometheus programme and the US IVHS programme). The research undertaken in these programmes has resulted in the introduction of a limited but growing number of new in-vehicle commercially available applications (ACC, head up displays and dynamic route guidance).

However, human factors experts have expressed concern about the impact of new systems on the driver's primary task of safe vehicle operation. This has resulted in the development of guidance on interface design and system development – much of which has been based on existing human factors knowledge from non-vehicle IT application areas. The most well known examples have included the 'Batelle' guidelines (3), the EC 'Statement of Principles'(1) and the IVIS 'Design Guidelines' produced by TRL(4). While these tools have provided valuable support to system developers they have not attempted to deliver a standard methodology for assessing the performance of new systems. This is the goal of the RoadSense project.

The RoadSense project is concerned with the testing of driver vehicle interfaces that are safe, effective and acceptable to drivers. In the past the focus of human factors research has often been directed towards the optimisation of individual system interfaces (MMI) but it is now clear that future vehicles will support multiple driver support systems of varying complexity and the new requirement is to consider the total human vehicle interaction (HVI). This revised orientation accommodates two critical needs: the need to consider driver-system interaction within the context of the total driving task (road geometry, traffic conditions, lighting and weather) and the inevitable conflicts that will arise when the driver is required to interact with multiple, concurrent systems. RoadSense will attempt to develop a common approach to system evaluation and also guidelines for the successful design of such systems. The technical approach adopted by RoadSense involves the integration of four critical factors (accidentology, driver performance measurement, system evaluation methodology and tool development) in order to produce a process that will be both valid and reliable.

ACCIDENTOLOGY

The starting point for the technical strategy adopted by the RoadSense project was the investigation of accident data to determine the characteristics of accidents in which driver failure is a major contributory factor. The rationale for this decision was that an understanding of the role of driver failure in accident causation is necessary in order to understand (i) the priorities for driver assistance system development; (ii) the critical behavioural issues for driver performance measurement and (iii) the most common accident scenarios where driver failure occurs.

A review of European accident databases indicated that very few contained the level of detail required to meet the project's needs. While many databases include descriptions of road type and geometry, vehicle manoeuvres, environmental conditions etc. relatively few also include descriptions of driver behaviour prior to the accident. However, it is exactly this information that is required for an informed consideration of driver failure. The French LAB database was one of the few databases that holds this data and was open to access by the project.

The project's analysis followed an approach also developed by INRETS (5) that concentrates primarily on the driver's actions immediately before the accident. This approach deliberately disregards other contributory factors such as traffic management or vehicle characteristics. The basic idea is to analyse accidents, case by case, and to group them into homogenous scenarios. A prototypical scenario can be defined as a series of accidents which are similar in terms of the chain of facts and causal relationships found throughout the various accident stages (6). The difficulty, in identifying prototypical accident scenarios, is to show the complexity of the event, the diversity of the circumstances and at the same time to achieve a certain level of generality.

Although the LAB database contains a relatively small accident sample (only 759 accidents occurring from March 1995 up to December 2000), and is clearly unrepresentative of the national situation, each accident is described using some 600 variables, which are:

- Descriptive variables that give an objective value. Example: *the age of the car occupant.*
- Variables that require investigator expertise. Example: *the use of seat belt.*
- Variables derived from occupant statements. Example: *the declared driving speed before the accident situation.*
- Analytic variables that need investigator judgement. Example: *Could an accident avoiding system have helped a user to avoid the accident*?

According to RoadSense's objectives a relatively small number of variables were selected to identify general accident clusters. The analysis focussed on driver failure (as determined by an investigator), and on accident configurations or circumstances (objective variables). The objectives of the accident analysis were to provide an understandable (and therefore simple) description of accident patterns. Usual variables such as type of road (motorway, national roads, local roads) or type of areas (urban, rural) were excluded from the analysis since these data can be found in national or international census and anyway the limited LAB sample is not representative on these criteria.

Table 1 summarises the accident sample in terms of the 7 major clusters identified. It can be seen that approximately one injury accident out of 3 occurring in the sample is an accidents at a junction and 2 out of 5 are single vehicle accidents (either loss of control or a problem of vehicle guidance).

Accident Configurations (N = 759)	
Group 1 : Accidents involving two vehicles	96 (13 %)
Group 2 : Passing Accidents	84 (11%)
Group 3 : Accidents at junctions	230 (31%)
Group 4 : Leaving a parking space	18 (2%)
Group 5 : Single vehicle accidents	289 (38%)
Group 6 : Main crash after a first impact	15 (2 %)
Group 7 : Special accidents	26 (4%)
Unknown	1 (~0%)
Total	759

Table 1: Primary accident clusters identified in the LAB sample.

A more detailed subsequent analysis identified failure of driver perception (rather than driver decision or action) as a dominant feature of driver functional failure. The failure categorisation is based on the functions that a driver must complete in order to perform the driving task: perception, comprehension (evaluation and interpretation), decision, action. These functions are typically performed in feedback loops but they are not independent and can eventually be performed simultaneously. The functions identified by LAB are very similar to those selected by INRETS although theses are more detailed and are sometimes split into sub-functions.

Table 2 shows the frequency of driver functional failures for the major accident clusters identified in the sample.

Accident Configurations (N = 634 at-fault drivers)	Unknown	Perception	Evaluation	Interpretation	Decision	Action
Group 1 : Accidents involving two vehicles	4 %	38 %	23 %	10 %	11 %	30 %
Group 2 : Passing Accidents	4 %	39 %	16 %	13 %	26 %	29 %
Group 3 : Accidents at junctions	7%	70 %	11 %	20 %	13 %	10 %
Group 4 : Leaving a parking space	0 %	54 %	8 %	8 %	0 %	31 %
Group 5 : Single vehicle accidents	16 %	33 %	16 %	7 %	11 %	40 %
Group 6 : Main crash after a first impact	0 %	23 %	23 %	15 %	15 %	31 %
Group 7 : Special accidents	0 %	65 %	15 %	8 %	4 %	4 %

(The total does not necessarily equal 100 % since the driver can present several failures).

Table 2: Driver functional failure by accident cluster

Defective perception is the most prevalent functional failure (a total of 46 % and 70 % at junctions and 65 % for special accidents). While the second most prevalent functional failure is defective action (27 % and 40 % for single vehicle accidents) this percentage has to be taken with care because it mixes up original failure and an eventual second failure, following a first one. Defective action accounts for only 13 % of first functional failures chronologically. This failure is therefore frequent but is not the origin of the accident situation: it is found more frequently as a second failure, once the accident situation is already engaged.

The analysis has led to the identification of critical scenarios that will be reflected in the evaluation trials (simulator, test track and road) - a strong test of a future vehicle system should involve contexts in which driver failure, perhaps through driver overload, has been associated. The second output from the accident analysis is the identification of case studies (technical systems and relevant contexts for usage) with a strong relevance to the accident statistics; i.e. systems that may impact on driver perception.

HUMAN FACTORS MEASURES AND METRICS

The development of a comprehensive procedure for evaluating driver vehicle interaction has required a wide ranging review of measures that might indicate an impact on safety, workload, driver performance and comfort resulting from a driver's concurrent use of an in-vehicle system. The review has considered techniques that have been used in automotive and aeronautic sectors such as lateral and longitudinal control, psycho-physiology and visual attention. The project is currently selecting a sub-set that exhibit high relevance and efficiency for incorporation within the RoadSense trials procedure.

The review has looked at measures reported in published research papers, internal technical reports, standards documents and project deliverables. While the number of potentially relevant measures was very large three well accepted super-ordinate categories were identified: Objective measures of driver performance and behaviour, subjective self assessments of performance and workload and psycho-physiological measures of driver state. After considerable internal deliberation it was decided that psycho-physiological measures would not be retained within RoadSense's plans because they lacked sufficient ease of implementation and reliability of interpretation without expert staff.

Over 80 metrics were identified in the initial review and they were grouped for convenience into the six categories, listed in Table 3. However, an initial assessment reduced this number down to just over 50 measures for which reliable evidence was available concerning their reliability, validity, sensitivity and suitability for road trials.

Lateral vehicle control
Speed Management (longitudinal control)
Driver Visual Behaviour
Interaction with other vehicles
Driver Situation Awareness
System Usability

Table 3: Primary evaluation dimensions

Although the identification and categorisation of measures required considerable effort the outcome was relatively routine, however this could not be said of the confirmation of procedures for their implementation. In very many cases – particularly in the scientific literature - inadequate or inconsistent details were provided. It is only in standards documents that these issues are defined in detail and this represents a relatively small proportion of the literature. The lack of standard definitions in this area has been recognised by a number of projects and organisations and RoadSense will contribute to progress via a process of active collaboration.

Certain measures have notional target values (e.g. the number of steering wheel corrections in a given time period) or advisory values (the minimum recommended headway for car following) whilst others (e.g. speed) are dependent on prevailing regulations or traffic conditions and the concept of a 'standard' value has little meaning. Where target values are meaningful RoadSense will attempt to identify consensus estimates or carry out original research to establish candidate values. A widely recognised target value for a measure facilitates the development of pass-fail performance tests as opposed to comparative evaluations.

In addition to identifying behavioural measures and metrics RoadSense is also attempting to develop a common set of procedures for implementing evaluation trials. This goal is particularly challenging since it incorporates objectives that are frequently antagonistic. Ideally, a single procedure would be developed that would be capable of implementation in test locations with a common level of road infrastructure. However, it is self evident that a vehicle control system and a driver information system will not be adequately evaluated using an identical procedure. Thus the project must endeavour to devise an assessment procedure that has a core of generic elements (tasks and driving environments) and guidance on their extension to accommodate the requirements of specific systems.

DEVELOPMENT OF DEMONSTRATORS

The successful development of the evaluation procedures will require their assessment and demonstration via a programme of evaluation trials. The project will therefore complete a series of system evaluations that will involve the application of the human factors based measures and procedures to a number of vehicle based systems. These systems must meet a demanding set of requirements. They must:

(i) be representative of the types of in-vehicle systems that are currently under development
(ii) require the application of a broad range of the measures and metrics being considered by the project
(iii) be relevant to the accident scenarios already identified by the project

For the purpose of testing the project aims to use a number of vehicles with different types of system (e.g. advanced communications, driver information or active safety) in order to confirm the suitability of the RoadSense approach for the very wide range of systems that are likely to be developed in the near future.

After an extended period of consultation with a range of potential new partners and also within the consortium a number of in-vehicle systems have been identified for inclusion within the validation trials. These will include forward hazard warning, enhanced navigation, lane support and 'communication manager' applications. This list, while limited, is sufficiently broad to allow vehicle control and driver workload (distraction) issues to be addressed. The project is currently preparing technical development plans that will specify the additional sensors required for the capture of the data relevant to the defined human factors measures.

A major project objective is to specify a regime for data collection that is sufficient to meet the human factors objectives but results in a minimal demand for invasive sensor introduction or expert technical support. To this end data already available within the vehicle (e.g. from the CAN bus) will be acquired. The benefit of this approach is likely to be increased ease of usage (reduced cost and time to implement) by a wider range of organizations in the automotive sector.

The proposed instrumentation will enable the measurement of a broad range of variables indicative of the driver behaviour, visual demand and driver system interaction. The following table summarises the principal proposed measures and associated data sources.

Measure	**Data source**
Lane deviation	Forward video camera
Steering performance & Yaw rate	CAN bus
Lane positioning variance	Forward video camera or dedicated sensor
Driver visual behaviour	Eye tracker
Vehicle speed	CAN bus
Headway	Radar sensor
Driver situation awareness	Peripheral detection task
Driver preparedness to brake	Footwell camera

Table 4: Principal measures and sensors

ON-BOARD TEST EQUIPMENT

In addition to producing a standard set of measures and test procedures, the project is also developing, implementing and testing a standard hardware /software system to support the implementation of the trials. The Driver Behaviour Interface Test

Equipment (D-BITE) will interact with the vehicle, prototype systems and additional vehicle sensors in order to record a rich picture of a system's usage, its impact on the driver and the driver's interaction with the vehicle. The open architecture will be based on IEEE 1394 (Firewire) and object oriented technologies. This will provide high bandwidth serial communication and the incorporation of high specification cameras and displays.

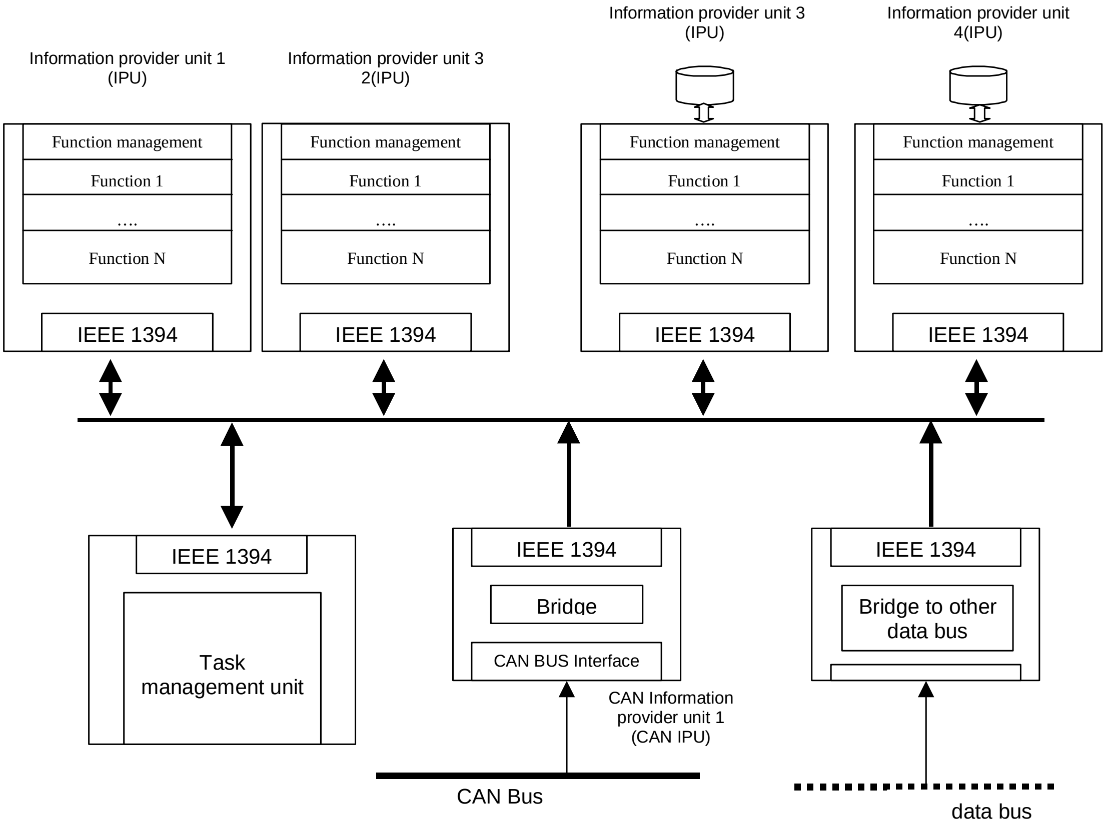

Fig. 1: System architecture

At a functional level the D-BITE system will support test configuration (the specification of sensors and data capture regimes), data acquisition (from multiple data channels and video sources with synchronisation and error detection), data storage (continuous short term or triggered long term with loss less data compression) and data retrieval (both during capture and post test on a selective basis).

At a system level D-BITE will be a Distributed Real-Time Computing system (DRTCS) in order to achieve the functionality outlined above and possess the potential for further extensions in future case studies. This requirement is necessitated by the fact that:

- Any type of centralised data recording mechanism will easily reach its physical limitation when multiple channels of information need to be recorded.
- Multi-thread processing on a centralised processor will slow down the system significantly when the number or complexity of the process increases.
- It is also difficult to expand a centralised system.

The Distributed Real-Time Computing System structure is illustrated by Figure 1, below. The main elements of the system are the information provider unit (IPU) and the task management unit (TMU). Some IPUs are connected to sensors, some to the CAN bus and some are just processing and storage units.
The D-BITE development is aimed at producing a standard system for data capture, management and analysis to guarantee the quality of data acquired in tests. The programme of evaluation trials will test the human factors procedures and the D-BITE concepts.

CONCLUSION

RoadSense's primary objective is the production of a set of procedures and recommended tools capable of delivering a standard methodology for evaluating any new vehicle system or combination of in-vehicle systems. The procedures will be grounded in accidentology and incorporate measures that are recognised as valid indicators by the human factors community.

If successful RoadSense will assist the introduction of systems that enhance driver safety, support and comfort. Safety on Europe's roads will be improved in two ways; through the accelerated introduction of new safety oriented systems and through the assurance that new systems, that do not have a safety objective, do not contribute additional risk.

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