

# INTERNATIONAL HARMONIZED RESEARCH ACTIVITIES (IHRA) STATUS REPORT OF THE INTELLIGENT TRANSPORTATION SYSTEMS (ITS) WORKING GROUP

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## PURPOSE OF IHRA-ITS WG

The goal of the research coordinated by the IHRA-ITS WG is to develop procedures (including methods and criteria) for the evaluation of safety of in-vehicle information, control and communication systems with respect to human performance and behaviour. These procedures are intended to address cross-cutting issues rather than to focus on specific applications.

## BACKGROUND

### IHRA

The International Harmonized Research Activities is an inter-governmental initiative which aims to facilitate greater harmony of vehicle safety policies through multinational collaboration in research. IHRA is organized under the auspices of Enhanced Safety of Vehicles\* (ESV) representing the U.S., UK, Canada, the Netherlands, Germany, Australia, Sweden, Japan, France, Italy, Hungary, and Poland. In addition, the European Commission (EC) and the European Enhanced (Safety) Vehicle Committee (EEVC) are represented. The Working Group on ITS is one of five working groups addressing high-priority research needs.

The impetus behind this WG reflects the need for governments to understand and minimize the potentially adverse impacts of ITS technologies and to incorporate safety assurance into system development. Within the domain of ITS, traditional approaches to government intervention are limited by the lack of timely field data needed to support interventions, and the lack of a priori

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\* Enhanced Safety of Vehicles is an international forum for the exchange of scientific and technological advances in vehicle safety. Until recently, the principal activity of ESV was the biannual conference which brings together motor vehicle research administrators from government and industry to explore measures to reduce the risks and consequences of motor vehicle collisions. The conference continues to be a major, though no longer the only, activity of ESV. IHRA is an initiative which has recently evolved out of the ESV conferences.

knowledge of system functionality needed to develop performance criteria.

Harmonized research in ITS is of special importance for three reasons, 1) it represents a significant opportunity to influence active safety\* through effective collision avoidance intervention, 2) it addresses a global need to more clearly define the role of government with respect to ITS safety, 3) driver-ITS interaction is an area essentially unregulated at the present time; consequently, there is a greater likelihood of achieving harmonized safety policies than might otherwise be the case.

### Safety Risks of ITS

The advent of ITS is revolutionizing motor vehicle transportation. Not only is the nature of driving changing radically, but it will likely to be in a continuing state of flux, at least in the foreseeable future, as technologies continue to evolve. It is extremely important to ensure that new systems and technologies are guided by human factors principles and data so that they do not lead to driver behaviours and responses which are not intended by systems designers. In aviation, for example, increased pilot assistance and automation has unwittingly reduced situational awareness and produced out-of-the-loop performance problems (i.e., increased errors and response latency). There are both micro-level (the direct effects on individual drivers) and macro-level (the effects on the overall traffic system) considerations\*\*+. The risks associated with increased automation (e.g., behavioural adaptation, mixing intelligent and conventional vehicles, loss of skill, negative transfer, and driver reliance on fallible technologies) are not well understood and cannot be reliably predicted at present.

It is essential to recognize that intelligent technology per se is neither inherently beneficial or detrimental to safety. The impact of technological change on safety will depend on its implementation and, in particular, on the extent to which the system supports drivers' needs and is

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\* Active safety (also known as primary safety or collision avoidance) refers to countermeasures which are designed to prevent collisions from occurring.

\*\* See Noy, Y.I., 1997, Human Factors in Modern Traffic Systems. Ergonomics 40(10), Taylor & Francis.

compatible with human capabilities and limitations. The primary human factors issues concern central human processes such as situational awareness and cognition. Secondary issues concern peripheral processes (e.g., legibility) that are affected by the physical design of the human-machine interface.

The WG on ITS was established to help governments to better understand the safety benefits and risks associated with on-board ITS and to recommend a generic framework for evaluating the safety of driver-ITS interactions.

## SCOPE

The WG is a forum for multi-national research with the aim to develop safety evaluation procedures that can form the basis of harmonized national policies on ITS\*. It is recognized that industry's role is to develop products that are effective, safe and acceptable to the public. Government's role is to ensure that products comply with appropriate safety criteria. The development of such criteria is the *raison d'être* of this WG. It should be noted that while there are numerous groups developing ITS standards and operational requirements, no other body is developing procedures for evaluating the safety of on-board ITS devices.

Certain intelligent technologies are being developed with the express purpose of assisting drivers to avoid collisions (e.g., so-called collision avoidance systems include forward obstacle collision warning system, lane departure warning systems and fatigue warning systems); whereas other systems are being developed to enhance driver convenience (e.g., navigation, adaptive cruise control). Since both types of systems can affect safety, the framework is intended to apply to all on-board information, control and communication systems, whether they be collision avoidance systems or driver convenience features.

The WG is concerned with summative evaluations; that is, final test and evaluation of systems prior to their introduction into the market. It is recognized that during

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\* Policies can take the form of government regulation or memoranda of understanding with industry. Safety requirements can take the form of content oriented or process oriented requirements. Content oriented requirements prescribe test protocols and compare measured values against a pre-established criteria. Process oriented requirements specify system design and development processes to ensure that relevant safety issues have been considered. Process oriented requirements can also address organizational safety management practice, including core competencies of safety professionals, development of product safety information, and guidelines for auditing of the safety system.

their development, systems undergo design iterations that involve the collection and analysis of relevant human performance and other data. These formative evaluations are conducted at various stages of system development to check system performance against corporate objectives and specifications. They are primarily within the control and serve the interests of industry and, as such, are beyond the scope of this WG. While formative evaluations are important and can contribute to overall system safety, safety assurance relies on evaluations of systems that are ready for implementation in the real world.

The procedures considered by this WG for the safety evaluation of ITS apply to all on-board systems that involve driver interaction (either directly or indirectly) and take into consideration the influence of human factors ranging from behavioural adaptation to driver reactions to possible system failures. It is intended that the evaluation of a system (whether it is an individual component or an integrated multi-function interface\*) be performed in the vehicle(s) for which such a system is designed.

## SAFETY ASSURANCE MODEL

This WG is not concerned with all aspects of ITS safety and is not the only body concerned with ITS safety. In order to illustrate the role of the IHRA-ITS WG in relation to that of other groups, a simplified model of ITS safety assurance is presented in Figure 1. The model posits that safety is optimized by (1) adherence to accepted safety principles, (2) conformity with existing human-machine interface (HMI) standards, (3) conformity with minimum criteria for collision avoidance systems (CAS), if applicable, and (4) implementation of a safety assessment program. These are shown in the model as four separate blocks and are briefly described in the sections which follow in order to elaborate the model. While all of these elements are important for safety, the work of the IHRA-ITS WG is focused on developing a framework for final test and evaluation of system safety. This element is indicated in the figure by the shaded block. Other organizations are involved with other blocks of the model, as described in the sections below.

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\* Various systems should be evaluated together when they can co-exist in a vehicle. For example, separate systems for adaptive cruise control and forward collision obstacle detection may produce redundant or conflicting messages. A full appreciation for the interactions of such systems can only be gained by concurrent evaluation.

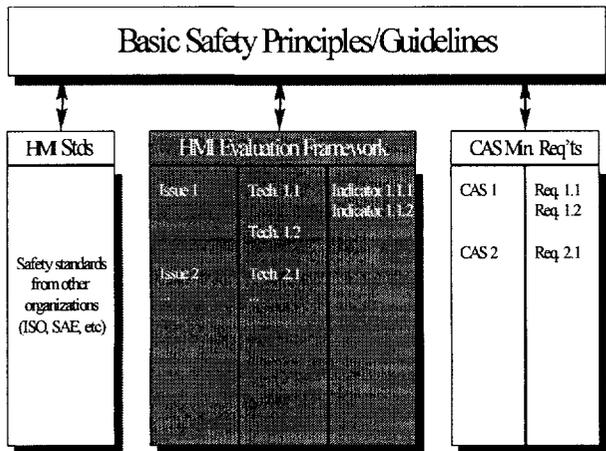


Figure 1. Principal Elements of ITS Safety Assurance.

### Basic Safety Principles/Guidelines

The basic safety principles/guidelines provide general, widely-accepted design and operational information to promote system compatibility with known driver characteristics. The European Code of Practice on Human Machine Interface for In-Vehicle Information and Communication Systems and the Draft British Standards Institute Guide to In-Vehicle Information Systems are examples of basic design guidelines. The guidelines in this category, however, are very general. For example, they may state that functions or display modes that overload the driver or intrude on the driving task should be disabled while driving, but they do not specify the functions or modes or indicate what constitutes overload or intrusion. To augment these basic guidelines, human factors engineering principles (e.g., stimulus-response compatibility) are available from standard references.

### Human-Machine Interface (HMI) standards

Another important element in the model concerns automotive human-machine interface (HMI) standards such as the design of visual and auditory displays. HMI is defined broadly and includes design aspects such as system functionality, message prioritization in addition to the physical characteristics of the interface. Several standards bodies (e.g., ISO, SAE,) are working to develop industry standards for HMI with a view towards providing an ergonomically sound interface that is compatible with driver needs, capacities and limitations. Standardization of HMI elements facilitates drivers' understanding of system function and ensure consistency of operation.

Relevant HMI standards are developed primarily by ISO/TC22/SC13/WG8. However, other groups also

develop HMI-related standards. The standards or work items currently under development within WG8 include:

- Visual Presentation of Information
- Auditory Information Presentation
- Dialogue Management
- Measurement of Driver Visual Behaviour
- Priority of TICS Suitability of TICS for Use While Driving
- Comprehensible Presentation of Visual Messages
- Audible Symbols
- ACC Systems - MMI Requirements

Standards pertaining to ITS-related visual symbols are being developed by WG5.

Relevant standards under development within ISO/TC204/WG 14 include:

- Mayday Systems
- Adaptive Cruise Control

Relevant standards under development within SAE ITS Human Factors and Safety Committee include:

- Navigation Function Accessibility
- Navigation MMI
- ACC MMI and Operating Characteristics
- Message Priority

### Collision Avoidance Systems Minimum Requirements

Collision avoidance systems are systems that detect hazardous conditions and either warn the driver or trigger an automatic avoidance manoeuvre such as braking. The distinction between collision avoidance systems and other types of ITS is often not clear. For example, an adaptive cruise control is normally described as a convenience feature, especially if deceleration is limited to that available from engine power. If the same system also warns the driver of a forward obstacle it may be referred to as a forward obstacle warning system and if that system is capable of initiative braking it is a collision avoidance system.

Collision avoidance systems present a formidable challenge to designers because of the necessity to provide the driver a clear message in a short period of time in such a way as to be non-startling and without risk of causing inappropriate response. Because collision avoidance systems intervene in situations where the risk of collision is moderate or high, it is important to establish minimum functional requirements. Several groups are working to develop minimum requirements for specific CAS. However, no standard or guideline presently exists to help designers select appropriate functional characteristics to maximize safety benefits.

Relevant standards under development within ISO/TC204/WG 14 include:

- Forward Obstacle Warning System
- Traffic Impediment Warning System
- Maneuvering Aid for Low Speed Operation
- Lane Departure Warning System

Relevant standards under development within SAE ITS Human Factors and Safety Committee include:

- Forward Obstacle Warning MMI and Operating Characteristics
- Side Obstacle Warning Backup Warning

Other collision avoidance systems not being addressed include driver condition warning, and intersection collision avoidance.

### Human-Machine Interaction Evaluation Framework

Existing guidelines, HMI standards, or minimum functional requirements for CAS, do not adequately address the safety assurance requirements of ITS for which the underlying technologies and functionality are constantly changing. Technology is advancing more rapidly than the scientific knowledge about its effects on driver performance and behaviour. For this reason, there will likely be an increasing need for prospective techniques for evaluating the safety of on-board systems in the development and certification of ITS vehicles. Questions about what issues need to be addressed in these evaluations, how to investigate them and what criteria define acceptable performance constitute the subject matter for collaborative research.

The development of the framework for evaluation of ITS systems represents the core work of the IHRA-ITS WG. An initial outline of the framework is presented in Figure 2. The details are to be developed through consolidation of scientific knowledge and further research.

The framework contains both direct measures of safety as well intervening behavioural mechanisms. Direct Safety Effects refers to measured outcomes in terms of safety, including collision or incident frequency, conflicts and safety-critical errors. Three main mechanisms are identified by which on-board information, control or communication systems can influence safety; behavioural adaptation, workload, and usability. Behavioural adaptation refers to behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change<sup>1</sup>. Workload refers to the portion of the driver's maximum mental resource capacity expended in the performance of the driving task. Usability refers to the extent to which a system or device is effective, efficient, satisfying, easy to learn and control, and is compatible with task goals in the driving environment.

Evaluations should address each of these broad areas to ensure that system design and integration is safe and compatible with the driving task. For each safety mechanism, techniques will be identified that can be used to assess the adequacy of system safety performance. Safety indicators, or measures believed to be relevant to safety will be specified for each technique indicated. Since it is unlikely that absolute safety performance criteria can be established in the foreseeable future, the techniques may

Safety Mechanism	Conditions		Technique	Indicators/Benchmarks
	Driver	Driving		
Direct Safety Effects (e.g., conflicts, incidences)				
Behavioural Adaptation				
Workload (e.g., visual demand, distraction)				
Usability (e.g., errors, time)				

Figure 2. ITS Evaluation Framework.

<sup>1</sup> OECD Scientific Expert Group, "Behavioural adaptation to changes in the road transport system". 1990, Paris: OECD.

take the form of comparative evaluations in which the subject system is compared against a benchmark. Benchmarks are reference levels of performance that are considered to be acceptable from a safety perspective. They might, for example, indicate baseline levels of performance (e.g., without the ITS). The driver and driving conditions to be represented in the evaluations are the same for all safety mechanisms.

Expert groups will be formed to identify further research needs and opportunities associated with elaborating the framework. To start the process, recognized experts in each of the four principal safety mechanisms, as identified in the table, would be asked to prepare a brief summary of the current state-of-the-art in their selected area. This would be followed by the formation of expert groups which would organize separate workshops in each area with the specific aim of summarizing current knowledge and formulating research recommendations. A fifth expert group would then consider what driving tasks and driving conditions should be incorporated in the summative evaluations.

## RECENT WG ACTIVITIES

### Workshop

An ITS Safety Test and Evaluation workshop was held in conjunction with the Third ITS World Congress in Berlin, October, 1997. There were many good presentations covering a broad range of evaluation techniques - too many, in fact, for in-depth discussion. Some of the techniques presented are summarized below. Many important aspects of evaluation were raised that are not immediately apparent. For example, the need to consider the impact on non-equipped vehicles and the influence of driving style on test results are important considerations in the evaluation of safety.

Several European projects have attempted to address this topic, with limited success due to lack of continued funding. Specifically, Drive II projects (HOPES, HARDIE, EMMIS, and GEM) attempted to prepare frameworks, guidelines, and methodologies for safety assessment of in-vehicle systems. They collected a lot of data and developed, manuals, databases, and tools such as Skill Acquisition Network (SANE) and Dialogue Design and Evaluation Method (DIADEM). However, the results of these efforts have not addressed safety specifically, they lack full scale context and employ too many measurements. Continuation of these types of studies have not been supported by European Commission (EC).

## SUMMARY OF TECHNIQUES PRESENTED

1. Usability testing using field operational tests, including de-briefings and focus groups (ref: UMTRI ACC study, J. Sayer). A feature of the data acquisition system was identification of events of interest (e.g., lane change) and capture of video data prior to and following events. The importance of collecting baseline data by individual parameters (e.g., age) was emphasized.
2. Field operational tests (ref: PSA Peugeot Citroen study of ICC, Florence Nathan). Collected engineering data in addition to human factors data, to facilitate communication with designers. Raised the issue of effects on drivers of non-equipped vehicles and other road users. Also indicated the need to include individual difference parameters such as driving style.
3. Open-road evaluation using behavioural and verbal protocol analysis to obtain insight into driver strategic behaviours (ref: INRETS/Renault study, F. Saad). Researchers analyzed general behavioural data as well as specific lane change manoeuvres. Concluded that drivers of ACC-equipped vehicles tend to exhibit fewer manoeuvres and greater left lane driving. Also showed an overall reduction of time headway with ACC. However, when performing lane change manoeuvres, time headway depended on traffic conditions (higher with ACC under lighter traffic and higher when pulling out to pass with ACC). Concluded that situational variables and driving style are important factors. Simulation for prospective evaluation of safety (ref: Lena Nilsson). A major point raised was the need to look at the individual road user as well as effects on traffic and society (as filtered through the traffic system). However, we do not have an adequate understanding of safety and therefore must rely on surrogate measures.
4. Computer-based checklist (ref; Karel Brookhuis). The development of a relatively quick prospective assessment of IVIS was described. This is still under development in the Netherlands.
5. Secondary task methodology to assess mental demand in laboratory and in the field (ref: University of Cologne, Hering).
6. Combination of techniques to address a comprehensive evaluation of the issues (ref; Tijerina) during CAS development. A framework for evaluating lane change crash avoidance systems was presented as an example. The framework consists of a series of questions to be considered during evaluation and indicates the possible methods that might be applied to address these

questions. A comprehensive evaluation should address at least the following questions:

- Does the CAS address driving conditions related to crash involvement?
- Does the CAS logic support driver's decision making tasks?
- Is the CAS display location compatible with normal driver behaviour?
- Does the CAS match the driver's sensory characteristics?
- Is the CAS display content meaningful to the driver?
- Does the CAS have any unintended negative safety consequences?
- Does the CAS reduce crash incidence or severity?

## OTHER INFORMATION

Ford and GM have established a program of collaborative research, Crash Avoidance Metrics Partnership (CAMP), to accelerate development of ITS countermeasures by pre-competitive assessment of the need, feasibility and marketability. Current area of interest is rear-end collision countermeasures, including development of relevant scenarios, functional requirements and test methodology.

NHTSA's current research is focused in three categories: projects related to specific collision types (rear-end, road departure, lane change and merge, heavy vehicle stability, intersections), driver performance (driver status monitoring, vision enhancement, human-vehicle interaction), and post-collision injury mitigation. The Intelligent Vehicle Initiative (IVI) developed to facilitate product deployment, includes development of services (autonomous and cooperative), selection of services for integration, integrated system design and development, operational tests and evaluation.

### Literature Database

The WG is in the process of developing a database of research relevant to ITS safety test and evaluation. The database will include work either on-going or completed in the last five years that may be relevant to the development of procedures that can be used to assess the safety of on-board information, control and communication systems with respect to human performance and behaviour. The techniques may include measures of performance, workload assessment, usability, situation awareness, protocol analysis, etc. A survey form was developed and distributed to WG members for completion. The database will be updated on an on-going basis.

## RELATIONS WITH OTHER GROUPS

A number of related activities have taken place recently involving other groups. For example, a proposal to amend the ECE Consolidated Resolution on the Construction of Vehicles (R.E. 3) to include new "Guidelines for the Design and Installation of Information and Communication Systems in Motor Vehicles" was submitted to WP29 by German Experts. WP 29 deferred discussion on this proposal until June 1998. The European Commission has adopted a "Code of Practice on HMI for In-Vehicle Information and Communication Systems". In addition, the EC DGX111 High Level Group on Telematics has developed a draft report, "Telematics and Intelligent Transport Applications for Road Safety". In addition, guidelines are under development in Japan and Europe addressing the safety considerations related to ITS.

The WG is in the process of establishing liaison with other groups, including;

- European Commission, Directorate-General XIII/C/6
- European Commission, Directorate-General VII
- OECD
- APEC- Special Interest Group on ITS
- INRETS: Programme de recherche et développement des industries en transport (PREDIT )
- Organisation Internationale des Constructeurs d'Automobiles (OICA)
- Comite de Liaison de la Construction d'Equipments et Pieces pour Automobiles (CLEPA)
- UNECE Working Party 29
- European Union High Level Group on Road Safety
- European Union High Level Group on Telematics
- ACEA/EUCAR Telematics Working Group 'H'
- ERTICO
- ITS America
- VERTIS Office
- JAMA
- AAMA
- US Car
- ISOTC22/WG 8
- ISO/TC204
- ISO/TC204/WG14
- Joint HLG Task Force
- CEN TC 278
- PIARC Committee C16
- PIARC Committee C13 WG6
- FCAT (Australia)
- FAIM (Australia)
- ITS Australia
- ITS Canada
- SAE ITS Safety and Human Factors Committee
- Canadian Vehicle Manufacturers' Association (CVMA)

- Association of International Automobile Manufacturers of Canada (AIAMC)
- EU-working party "Telematics and Intelligent Transport Applications for Road Safety"

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