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TNO-report

TM-02-C031

Review of European Human Factors Research on Adaptive Interface Technologies for Automobiles

Date	14 May 2002
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Copy no.	
Number of copies	15
Number of pages	60
Number of appendices	2
Contractor	US DOT/RSPA/Volpe Center, Cambridge, MA, USA
Project number	013.72103

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EXECUTIVE SUMMARY

Purpose: The US Department of Transportation (DOT) National Highway Traffic Safety Administration (NHTSA) Office of Vehicle Safety Research, working though the Research and Special Programs Administration's John A. Volpe National Transportation Systems Center (RSPA/VNTSC), needs to obtain a summary of European researchers' findings about the human factors issues related to shape the development of an adaptive interface system.
This report provides an overview of European research on managing workload, distraction due to telematics in automobiles, and ways to assist the driver through adaptive interface technologies.

Method: A literature survey on European research has been carried out that focused on four major areas:
1 How to monitor and measure activities both inside (driver's visual scanning and glance behaviours, as well as driver interactions with controls and displays) and outside (collision threats and roadway location characteristics) the vehicle.
2 How to manage driver workload/distraction based on the relative demands of the outside and inside vehicle tasks, including the impact of varying roadway/traffic scenarios and the capabilities of driver subpopulations.
3 How to create an adaptive interface, i.e. a de-cluttering system for modifying the displays and controls, strategies for adapting interfaces such as locking out information, prioritising information, slowing the rate of information presented, providing inattention warnings, changing activation thresholds for collision warnings, or saving messages for display during low driving demand conditions.
4 How to achieve the driver's acceptance of an adaptive interface and its congruence with drivers' mental model of system operation.

Results: The most relevant European projects that were discussed in detail were: GIDS, ARIADNE, GEM, IN-ARTE, and COMUNICAR. From their detailed review it became apparent that they do not follow one unified approach, and neither have they agreed yet on a common set of principles that are specific enough to conclude that there is **the** European adaptive interface. Nevertheless, progress has been made along a line of thinking that tries to be both scientifically sound and ultimately applicable in the real world.
Conclusions:
1 *Monitor and measure.* There are a multitude of measures available to monitor driver state over an extended time (minutes and longer) period. However, pinpointing a driver's momentary workload in a moving vehicle, so as to judge whether he may momentarily be overloaded, requires very specific methodology. Here the European researchers appear to have taken a pragmatic approach, as follows:
   a There is a general feeling that efforts to monitor momentary driver workload by more or less intrusive means will not succeed, or will never be suitable for practical applications, even though such methods might theoretically the best.
   b What is concluded to work is either of two approaches:
      – Estimating workload from the driver's actions on the controls, and their consequences in terms of distances/times to surrounding vehicles, etc.

– Estimating workload from a 'look-up' table that contains the factors attributing to workload and their weights, which may have been estimated in a separate investigation.

In the more recent research projects, the first of these approaches seems to have become somewhat more popular. What we will probably see is that a combination of the two categories will be developed, and that this is then the type of solution that will be implemented in European automobiles.

2 *Manage workload.* In several projects the decomposition of workload, in terms of where its constituent elements originated from, has been resolved on at least the pragmatic level. That is, quantitative indicators have been defined that represent the relevant driver characteristics or states on the one hand and the state of the outside world on the other. Examples of the indicators that are used for driver status are: use of clutch, brakes, steering wheel and blinkers turn signals. Examples of the indicators that are used for the state of the outside world are: wiper status (is it raining?), fog lights, speed level (in– or outside the maximum speed range) and time (is it dark outside?). These indicators are easy to come by, or with a little additional effort at most.
The result of the decomposition is used to determine when the driver may be ready to get support messages of a certain type or modality.

3 *Adaptive interface.* Within the major projects reviewed, fairly sophisticated but nevertheless pragmatic strategies for adapting the content, the interrelationships, and the timing of supports to the present state of the driver (and his vehicle) have been developed and—partly—evaluated. These are based on an analysis of potential bottlenecks, including risk estimates derived from the prevailing traffic situation, so that it can be determined what types of support messages are allowed in a particular situation. Although the algorithms differ somewhat, the approaches applied in the more recent projects resemble each other to a large degree.
Driver support systems can cover a full range from systems providing information, advice and warnings, through systems that assist and/or intervene in vehicle control and manoeuvring tasks, all the way to systems that support fully automatic driving. Considerable research has been devoted to finding the behavioural and safety optimum, in case of systems that permit a choice to be made on this dimension (e.g., collision warning/avoidance systems). Recently, however, issues of liability have become more prominent in the determination of the most appropriate choice. There are severe worries that when a car maker creates the impression in the driver that there is a system in the vehicle that takes over parts of the primary driving task, there is product liability in case an accident happens if the system—for whatever reason—fails.
As a result of this line of reasoning, European car makers have become hesitant in moving towards the further development of actively intervening supports, such as lane departure interventions.
It is also the case, moreover, that some car makers feel that intervening systems take away a basic quality of driving an automobile that is appreciated by the public. Driving would then tend to be seen as a boring activity, which car makers do not consider as a contribution to market attractiveness.

4 *Acceptance.* In the major projects reviewed here, relatively little attention appears to have been devoted to acceptance issues. This is somewhat surprising since there is a recognised procedure available as a tool to index acceptance. This procedure asks subject drivers/prototype users for their ratings on two sets of bipolar items. One set indexes the 'usefulness' of the device, the other set are similarly rated and averaged to obtain an overall 'satisfaction/attractiveness' judgment. Thus, the scrutinised support is ultimately positioned in a two-dimensional space which decomposes acceptance into two primary attributes. This procedure, however, appears to have been applied outside the reviewed projects only, that is, in studies that have investigated the parameter setting of isolated rather than integrated supports. From these it has appeared that some relatively new concepts, notably the application of haptic and tactile supports in vehicles, will probably gain satisfactory acceptance by 'normal' drivers.

1 INTRODUCTION

Car driving is rapidly evolving into a task that besides pushing pedals and turning wheels consists of the management of information. In-vehicle information systems are being developed to provide the driver with the necessary information. However, in the end the driver is still required to integrate the bits and pieces of information into safe traffic behavior. Therefore, whereas the driver is supported on the one hand, he or she may be overloaded and distracted by this information on the other hand.

This report presents a review of European research results on the design of so-called adaptive driver support systems. By an adaptive support we mean a system that in some way takes into account the momentary state of the driver, in particular his present level of workload, in determining the appropriate timing and the content of the supporting message or intervening activity the system will produce. This should thus prevent the driver from becoming overloaded or distracted because of the impending multitude of information.

The review has been solicited by the Volpe National Transportation Systems Center, as a step in a NHTSA phased research program to develop a test vehicle incorporating adaptive interface technology.

The review focuses on four major areas:

1 How to monitor and measure activities both inside (driver's visual scanning and glance behaviours, as well as driver interactions with controls and displays) and outside (collision threats and roadway location characteristics) the vehicle.
2 How to manage driver workload/distraction based on the relative demands of the outside and inside vehicle tasks, including the impact of varying roadway/traffic scenarios and the capabilities of driver subpopulations.
3 How to create an adaptive interface, i.e. a de-cluttering system for modifying the displays and controls, strategies for adapting interfaces such as locking out information, prioritising information, slowing the rate of information presented, providing inattention warnings, changing activation thresholds for collision warnings, or saving messages for display during low driving demand conditions.
4 How to achieve the driver's acceptance of an adaptive interface and its congruence with drivers' mental model of system operation.

The review has the following outline.
First, an inventory is provided of who are the major actors in research and development in these areas in Europe.
Second, the four major issues will be defined in somewhat more detail, so as to set the scene for the review proper.
Third, the relevant research programs—both EU-sponsored as well as 'private'—will be reviewed, and their results assessed with respect to the four major areas.
In the last part of the review the conclusions to be drawn on the basis of this material will be presented while specific attention is given to where results seem solid and where information is conflicting within the field of research.

2 THE EUROPEAN ACTORS

2.1 The European Union

The European Union has a number of Directorates, among whose duties is the initiation of relevant research programs. These programs started in the beginning of the 1990s. A project proposal within a program is eligible for funding if it meets a number of requirements, prominent among which is that it should be a co-operative effort between industry and research institutions. Usually, a project is only funded 50% so as to guarantee the offerers' own involvement.

In 1988 the research program 'Dedicated Road Infrastructure for Vehicle Safety in Europe' (DRIVE I, to be followed in 1992 by DRIVE II) was formally adopted by the Commission of the European Communities (CEC) for an initial period of three years. DRIVE envisaged a complete general European road transport environment in which individual drivers are better informed and monitored; and in which 'intelligent' vehicles communicate and cooperate with each other, the road users and the road infrastructure itself. DRIVE sought to create favorable conditions for the development in the field of information technology and telecommunications applied to road transport.

After the DRIVE I and DRIVE II Programs there followed several more waves of Projects, commonly grouped under the denominator 'Framework'. Currently, the call for proposals under the 6th Framework is being awaited.

2.1.1 Statement of principles, its 'expansion', and related activities

On December 21, 1999, the Commission of the European Communities (CEC)—which is the supranational equivalent to a national government—issued to member states and industry a recommendation 'On safe and efficient in-vehicle information and communication systems: A European statement of principles on human machine interface'. This is a landmark in the European efforts to incorporate human factors considerations into the design and evaluation of in-vehicle systems.

The statement deals with informative systems exclusively, and not with intervening types of supports.

In the preamble to the statement, the CEC provides the reasons for drawing up a recommendation of this type. Prominent among these is the following:

> ….. 'Whereas telematics devices inside vehicles will have an important impact on road transport in the near future and will provide valuable assistance to the driver under the condition that the driver is not distracted, disturbed or overloaded by the communication process and/or the information provided by the additional devices.' ……

Although the statement does not actually contain a definition of 'distraction' it is generally clear what is meant: the capture of the driver's attention by information that is irrelevant to the driving situation to a degree where insufficient attention is left for the primary task. Also, 'overload' is not precisely defined.

The principles, of which there are 35 in all, are divided into six categories. A few of the principles are relevant to the present discussion, though they identify the potential problems rather than give solutions to them:

- 'The system should be designed in such a way that the allocation of driver attention to the system displays or controls remain compatible with the attentional demand of the driving situation.'
- 'The system should be designed so as not to distract or visually entertain the driver.'
- 'Visually displayed information should be such that the driver can assimilate it with a few glances which are brief enough not to adversely affect driving.'

It should be mentioned here that European experts, working on the further specification and expansion of the principles, are considering the proposition that four glances off the road for not longer than two seconds each for any glance should be considered as a practical limit. Thus, five glances off the road would always be considered unacceptable, however brief they are.

In this context, it should be noted that the Commissions information presentation principles neither contain a specification of allowable auditory task load, nor that of the combined load on the auditory and the visual channels.

Other principles are:

- 'The system should not require long and uninterruptable sequences of operations.'
- 'The driver should be able to control the pace of interaction with the system.'
- 'The driver should have control of auditory information where there is a likelihood of distraction or irritation.'
- 'Systems providing non-safety-related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver.'
- 'Visual information not related to driving that is likely to distract the driver significantly (e.g. TV, video and automatically scrolling images and text) should be disabled or should only be presented in such a way that the driver cannot see it while the vehicle is in motion.'
- 'System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or clear warnings should be provided against the unintended use.'

The 'Statement' thus clearly presents the very fundamentals of what to demand from an in-vehicle information system. In this respect it is to be considered as a breakthrough, since for the first time human factors principles have acquired a status at that high level. A 'recommendation' is something not to be taken lightly by (national) governments and industries, and governments should demonstrate that they have done something to follow-up the recommendation within a period of two years after it was published. This is now generating legislative and research activities all over the Union.

On the other hand, the contents of the principles itself are not very much elaborated, and they contain little in telling designers how actually to accomplish what is requested. And if looked upon from the point of view of driver workload management by means of adaptive interfaces they contain next to nothing. Nevertheless, they *will* form the basis for judging—on the political level—whether a proposed system has succeeded in achieving certain HMI-standards. This will apply both to isolated support systems as to those that aim for adaptivity or integration.

2.2 Car makers

Major carmakers in Europe are located in Germany, France, Italy, and the UK. Sweden and Spain have their own car-making industry as well. Most of the remaining countries within the EU have, at most, an assemblage industry. The supplying industry is much more distributed over the continent, although there is still a concentration in the vicinity of the major carmakers.

The European carmakers were, in fact, the first to start a (fairly loosely) co-ordinated research effort into the application of advanced telematics in automobiles. This was the PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) project that started in the middle of the 1980s. It generated many ideas, beginning with the provision of estimates of what the beneficial effects of telematics on road safety could be. Much of this has emerged in the more open regular EU-Programs. However, the auto-industry still has its own network (EUCAR, within which there is a supervisory group called ADASE that sets the agenda for the combined efforts on the development of intelligent vehicles).

2.3 Research institutes

The prominent research institutes in the area of car driver human factors are in northwestern Europe (the U.K., the Netherlands, Sweden, Finland, and France). Another group is in the German-speaking countries (Germany itself and Austria). Research is relatively scarce in Southern Europe, and almost non-existent in the new Eastern-European member states that are scheduled to enter the Union sometime in the coming years.

The research institutes are of different types. Some are fully government-owned, others belong to Universities, and there are also organisations that have a special status in being neither government nor fully private. Then there are the fully private institutes, while carmakers may have their own research facilities.

In terms of the budgeting of their research, most institutes work primarily for their own governments and/or industries. A certain amount of the research that is relevant for the present review stems, in fact, from these programs. Also, most institutes have their own fundamental research that allows them to stay up-to-date as far as basic knowledge is concerned.

3 DESIGNING AN ADAPTIVE INTERFACE

Before starting the review, it is appropriate to describe the issues that are involved in general terms.

The discussion should obviously focus on driver workload, as this is what the adaptive interface should be coupled to. In particular, the *momentary* workload must be assessed, certainly so when it might reach peak levels. It is a fundamental research question how one should go about in determining what a driver’s momentary workload level is.

Next to this, ‘workload’ is to be distinguished from several related concepts that, for their measurement, rely on related variables.

Driver *distraction* is the momentary misdirection of attention to a source that is not the appropriate one from the point of view of executing the driving task in a coherent and safe way. While distraction is thus primarily a qualitative issue, it becomes a workload issue when the distracting stimulus requires a response from the driver that may diminish his remaining capacity to act on the primary task. This is, of course, exactly what could happen when separate in-vehicle supports start amassing.

Driver *drowsiness* or *sleepiness* are states that develop over longer periods of time. While it may be worthwhile to know what a driver’s drowsiness contributes to his momentary workload, the monitoring of drowsiness while it is developing is not a subject of the present review. It is true, nevertheless, that some variables are used both to measure workload and drowsiness, so that these have to be distinguished carefully where confusion could occur.

3.1 Monitoring and measuring driver state and external conditions

There are a number of approaches for determining the state a driver is in, with respect to his momentary workload.

One is to directly monitor driver state ‘in the flesh’, that is, by direct intrusion upon the driver or by asking him certain things to do while driving. This comprises physiological measures, but also secondary task performance, or subjective judgments and rating scales. These measures are either of an intrusive nature, or they require additional driver activities next to the driving task proper. It may be expected a priori, therefore, that certain practical difficulties will be associated with the implementation of these measures in a support system that has to function under real-life conditions.

Second, *performance* measures may be used, comprising driver actions on the controls and the results of those actions as they become manifest in vehicle-related parameters (e.g. speed and lane keeping). From a practical point of view this type of measure would have a priori advantages, since these measures are non-intrusive and can be obtained ‘for free’. It remains to be investigated, of course, how well they actually do in indexing momentary workload.

The third possibility is to create what is basically a *look-up table*, where the driver state is not actually monitored but is derived from a combination of known effects. These may comprise: (a) driver parameters like age, gender and experience; the categorisation of the driver as a certain type, or as having a certain driving style; and other forms of even more personalised information; and (b) relevant aspects of the traffic situation and the road geometry, for which it also has previously been determined what their effects on driver workload are. Momentary driver workload then is estimated as the sum of all these known effects originating from both workload categories (a and b). The approach is similar to the approach undertaken in the monitoring of driver fatigue. It is to resolving these fundamental issues that much European research has been devoted.

3.2 Manage driver workload/distraction

Ideally, it should be known what part of a driver's workload originates inside the vehicle, and what is to be attributed to external factors. Only then does it become possible to tune the adaptive interface to what is actually required.

Four basic aspects of driver-system interaction basically determine the in-vehicle effects:

1. the degree of freedom the driver has with respect to choosing the moment he has to pay attention to the in-vehicle application. That is: is the moment forced by the system (system-paced) or chosen by the driver (self-paced);
2. the total glance time required to extract information from a visual display;
3. the mental workload of the interaction with the system;
4. the number and precision of manual control movements required for controlling the application.

All these elements can be monitored, but at present it is highly doubtful whether their full assessment can be done real-time, on-line.

External effects can be manifold, but they can be grouped as originating from three basic categories of interaction:

1. lane-keeping per se
2. lateral encounters, i.e. with vehicles in the adjoining lane
3. car-following.

These elements can be monitored continuously on-line, and their real-time assessment presents no major technical difficulties.

Obviously, the desired decomposition into elementary workload components is the easiest to achieve in the look-up table approach. In this approach it is assumed that the required estimates of what specific elements contribute have been assessed independently, i.e. in separate investigations. The possibility must not be ruled out a priori, however, that it could also be accomplished by on-line measurements.

The review of what research has been done on this issue in Europe will focus on the way in which the decomposition has been performed, and what conclusions have followed from that.

3.3 Creating the adaptive interface

The actual design of the adaptive interface should take into account what the decomposition of the previous step has resulted in, and it should then base its supporting actions on that. This is because what the support action should be, and how it should be timed, must depend on where the momentary driver workload has been determined to originate from.

The most prominent feature of an adaptive interface is probably that it must be an *integrated* system. Not only does the system decompose driver workload, but it also attempts to fine-tune the messages to the driver that originate from each separate on-board system according to the judgment of a supervisory intelligence, or scheduling device. This intelligence takes into

account how urgent a message is, given the driver's workload, the state of affairs with respect to the surrounding traffic, etc.
Several multiyear projects have been devoted to this issue within EU and other European programs. These will be reviewed, and their progress assessed.

3.4 Driver's acceptance of an adaptive interface

Efforts to introduce adaptive-like support systems have sometimes failed because drivers did not warmly receive them. For example, the general atmosphere in Europe presently is that drivers appear little inclined to accept supports that actually intervene or take over parts of the driving task, because this is seen as an intrusion into the own responsibility and the freedom to move about as one wants.
Moreover, while it is clear that sound ergonomic design is a necessary condition for user acceptance, this need not be a sufficient condition at all. Therefore, driver acceptance has nowadays become an indispensable part of the methodology of human factors investigations into in-vehicle systems. This is not to say that the problem of a potential conflict between 'usefulness' and 'acceptability' has been solved, but that the issue is now recognised and that the methodologies are applied that monitor both these aspects.

4 RELEVANT EU PROJECTS

The first concerted research efforts in Europe devoted to the development of adaptive in-vehicle interfaces date from the beginning of the 1990s. These were the GIDS project and its follow-ups, ARIADNE and GEM. After that, there was a period of neglect for the issue, until it was taken up again at the end of the 1990s (IN-ARTE, COMUNICAR).
We will describe these projects in their chronological order, rather than juxtaposing them, because this provides the best insight in the line of reasoning and in the reasons for abandoning certain ideas and picking up new ones.

4.1 GIDS (Generic Intelligent Driver Support System)

Partners: University of Groningen (NL), Delft University of Technology (NL), INRETS-LEN (France), Philips Industries (NL), SAAB (Swe), YARD Ltd. (UK), RENAULT (France), VTI (Swe), Universität der Bundeswehr (Germany), University College Dublin (Ireland), TNO Human Factors (NL).

The project GIDS (1990–1992) aimed at producing a prototype system to help the driver cope with the avalanche of information in road traffic. The project had the objective to determine the requirements and design standards for a class of intelligent co-driver (GIDS) systems that are maximally consistent with the information requirements and performance capabilities of the human driver.

More specifically: GIDS aimed at providing the driver with the output from a number of active sensors, a navigation system and a cellular phone link. Two demonstrator systems (one a real instrumented vehicle, the other an incorporation in a driving simulator) were constructed to monitor the behaviour of the driver in response to the audio-visual output from the system, in order to determine the effect the information has on driver performance. The project is described in the book edited by Michon (1993).

4.1.1 Monitor and measure

The GIDS architecture

The heart of the GIDS concept is that it is an integrated system, that is, it is more than a collection of separate components that do not know of each other's existence.

Figures 1 and 2 illustrate the system as designed. Although the elements described in Figure 1 and Figure 2 seem very specific, the principle of GIDS is generic and as such any device can be implemented within the structure.

The central 'Analyst/Planner' consists of two modules, the Manoeuvring and Control Support Model and the Workload Estimator.

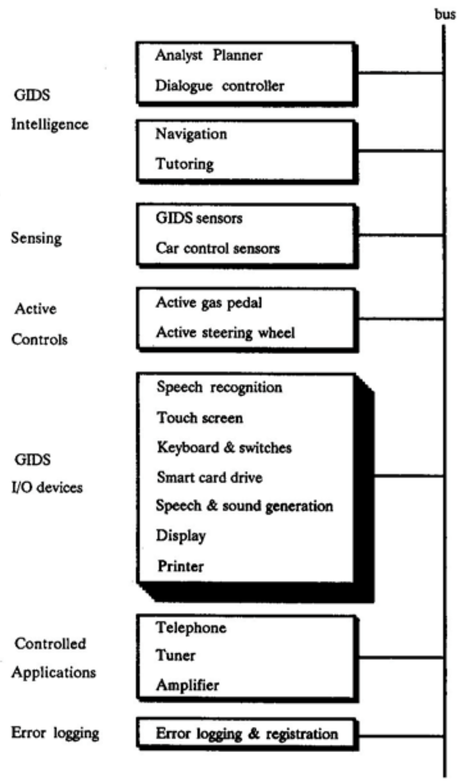

Fig. 1 The GIDS bus architecture.

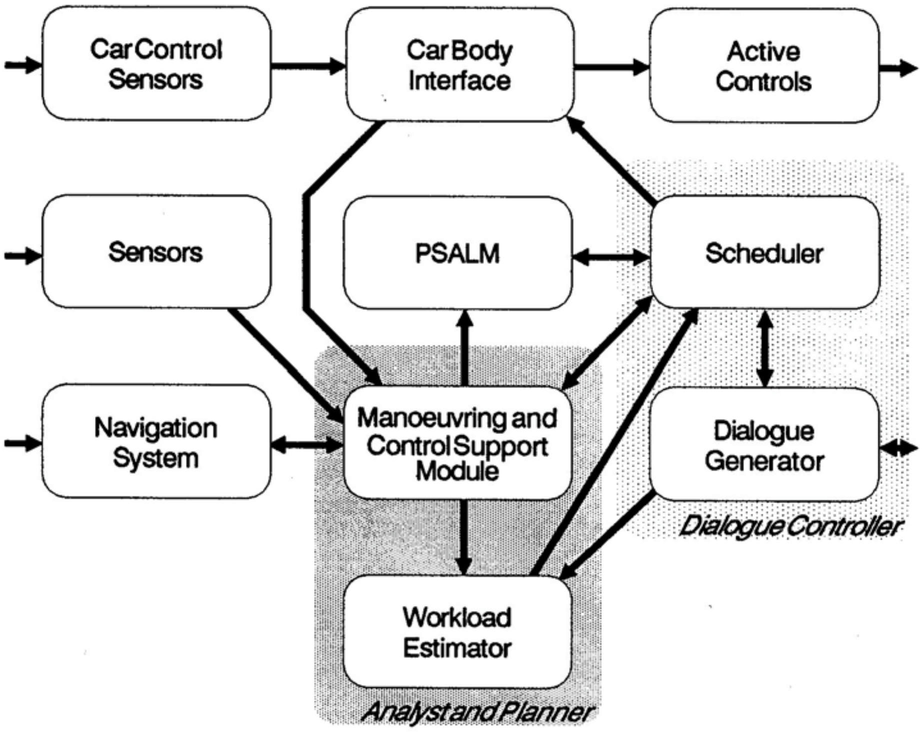

Fig. 2 The GIDS architecture. PSALM stands for Personalised Support And Learning Module.

The Workload Estimator

The Workload Estimator is the module within the Analyst/Planner that estimates the workload for the next few time-frames, based on the current traffic situation and actual and anticipated driver actions and the types of road segments to be encountered next. It informs the Scheduler accordingly.

In this project, workload was modelled in a simple, 'look-up table', way (based on the multiple resource theory, see Wickens, 1984), by treating the driver as a set of modalities or information-processing resources, each of which can be loaded separately (e.g. cognitive, visual, auditory, tactile).

The workload demands of a range of driving tasks were measured in the field (Verwey, 1991) and average estimates derived from these measurements converted into workload constraints. The following 'actions' were measured:

- Following the road,
- Turning,
- Negotiating an intersection,
- Traversing an Intersection,
- Negotiating a curve,
- Stopping,
- Slowing down,
- Moving off,
- Lane changing,
- Following a lead vehicle,
- Presence of a tailgater,
- Being overtaken,

- Overtaking,
- Waiting at traffic lights,
- Waiting for a lead vehicle to move,
- Waiting for a gap,
- Avoiding an obstacle,
- Engaging in a phone conversation.

4.1.2 Manage workload

The Manoeuvring and Control Support Model

The Manoeuvring and Control Support Model is also part of the central Analyst/Planner, and it oversees the immediate future with respect to the driving task. From the available sensory and navigational information it computes whether any rules for acceptable driving have been violated, and require a support message. Second, it times the navigation messages, that is, it determines the relevance and preferred timing to be passed on to the Scheduler (see next paragraph). Finally it anticipates driver actions for the sake of the Workload Estimator. The estimates are expressed in terms of time taken by the driver to perceive the message, to process it, and to respond to it. This is combined as a level on a three-point scale.

The sensors in the GIDS prototype are of two types. One senses the actual use of car controls by the driver. The other senses the relevant objects in the traffic environment and some of their interrelationships. In addition the navigation system computes the route to follow to the destination. On the road it keeps track of the position of the car in the road network. The road network is represented by a set of segments that represents parts of the network, such as a stretch, a curve, or an intersection. The navigation system informs the Manoeuvring and Control Support Model of the current and adjacent segments, indicating the road type and condition of each segment and of the route to follow. The sensors pick up sensory information and transmit this information to the GIDS system, once every 0.1 seconds.

The Scheduler

This is a module in the dialogue controller that accepts requests for messages and schedules the messages within the constraints imposed by the workload. Each request comes with workload estimates and importance indication attached. All messages that are, in principle, subject to advancement, postponement, or suppression are processed by the Scheduler.

4.1.3 Adaptive Interface

The integration of separate support functions into one transparent and easy-to-use system was accomplished on the basis of an analysis of potential bottlenecks, whereby multiple resource theory (e.g., Wickens, 1984, 1989) was used as the vehicle for analysis.

If at any particular moment more than one ‘action’ in traffic is to be performed, the highest workload constraint is used. Workload constraints exist for each information processing resource (cognitive, auditory, visual, voice, haptic, feet, haptic hands, output hands, output feet). The first three resources are of great importance, since they actually constrain the length and number of messages allowed, whilst the latter resources function only to prevent multiple message occurring at once. Constraints are specified for each resource by so-called constraint pairs, which define the allowable time intervals required to process particular messages from the support. A constraint pair for a particular resource at a particular instant specifies:

1 the maximum time allowed for a load on this resource by a support message starting at that instant,
2 the minimum time before the resource may be loaded with subsequent support messages if the load on the resource by a support message ends that instant.

The latter requirement avoids uninterrupted presentation of successive messages. When a message priority is very high, for instance, in an acutely hazardous situation an exception is made to the normal workload constraint rules.

This procedure determines what types of messages are allowed in each situation. The different types of messages can be in terms of modality (e.g. visual or acoustic messages) and complexity (e.g. simple and short or complex and long messages). When the demands of driving are high, the Workload Estimator informs the Dialogue Controller that under these particular conditions only a limited number of relatively simple messages may be presented. Less important messages will be postponed or even cancelled. Complex or long messages may be replaced by simpler or shorter counterparts. When driving demands are not so high these constraints may be relaxed, i.e., relatively more complex or longer messages may then be allowed.

The detailed driver interaction clusters for the functions that were incorporated into the GIDS prototype are shown below.

Table 1 shows each function within a number of so-called interaction clusters. These are more or less fixed sequences of support messages and the required driver actions. The more a cluster of interaction is consistent over time, the more it allows the driver to perform the interaction with the GIDS system without demanding attention and thus yielding little interference with the driving task. Order, timing, location, modality and format of messages and driver actions within interaction clusters should therefore be, and should remain, in proximity, i.e., they should be treated as a coherent set of elements belonging together at all times.

More detailed design criteria for the Scheduler were derived from this matrix (Table 1), resulting in a prescribed procedure for treating the request queue, i.e., to allocate priorities for handling requests to the different applications. An example of this is shown in Table 2. This table illustrates the levels of priority that can be attached to a request. The complete structure of the queue, in terms of what elements are attached to a specific interaction request, is shown in Table 3. Note that the different demands on the underlying multiple resources, i.e. the workload estimates for that resource, are coded as three-point scales, as mentioned before.

Table 1 Likely driver interaction clusters as a function of input/output modality and priority. * stands for driver-car interaction while stationary. Lower numbers indicate lower priority level: 'priority' is the degree to which a support message has potential safety implications (see Table 2). A=auditory input, V=visual input, Tw=kinesthetic/tactile input on the wheel, Tg=accelerator input and Ts=switches/buttons input. M=manual output, F=Feet output and S=speech output. Mk=keyboard, Ms=switches/buttons and Mt=touch screen.

	Interaction cluster	Highest priority allowed	System to driver	Driver to system
1	Route guidance			
	a. entering destination	*	V	Mk
	b. on-line guidance	3	A/V	
	Route information			
	c. asking for information	*		Mt
	d. information presentation	*	V	
2	Collision avoidance			
	a. warning the driver	6	Tg	
3	Control support			
	a. install lane keeping support	*	V	Mk
	b. lane keeping support	5	Tw	
	c. speed and headway support	6	Tg	
4	Performance evaluator			
	a. installing	*	V	Mt
	b. scanning driver performance			
	c. presenting feedback info	*	A/V	Mt
5	GIDS installer			
	a. setting parameters/preferences	*	V	Mk
6	Repeat last message	Depends	A/V	Ms/S
7	Telephone			
	a. dialling	1	Ts	Ms
	b. having conversation	2	A	S
8	Stereo			
	a. tuning	1	A	Ms
	b. volume control	2	A	Ms
	c. changing cassette	1	T/A	M

Table 2 Six-point message priority scale.

1	Message fully unimportant	(selecting radio-station)
2	Message may affect convenience	(adjusting stereo loudness)
3	Message may concern trip delay	(route guidance info)
4	Message may concern vehicle damage	(lane keeping support)
5	Message may concern injury	(anti-collision info)
6	Message may concern fatal accident	(anti-coll. info at high speed)

Table 3 Queue structure per interaction request.

APP	application that placed the request in the queue
PR1	message priority at time TIl on a 6-point scale
Til	absolute (system) time
PR2	message priority at time TI2 on a 6-point scale
TI2	absolute (system) time
PTP	preferred time of presentation
MES	content of message to driver coded for device
DER	device related information: which device. intensity, color, emphasis. Etc.
INP	applied system input device for driver response
CLU	number of task cluster this request belongs to
ORD	request number within task cluster
END	flag to indicate that this is the last request in the cluster
COG	cognitive processing demands of the message in relation to characteristics of the current driver (estimated processing time in one of three categories: 3-point scale)
VIS	demands on vision (required reading time on a 3-point scale: <500 ms, 500–1000 ms, >1000 ms for the whole message)
AUD	demands on audition (message duration on a 3-point scale: <500 ms, 500–1000 ms, >1000 ms)
TAH	demands on tactile hand sensor (message duration on a 3-point scale: <500, 500–1000, >1000 ms)
TAF	demands on tactile feet sensor (message duration on a 3-point scale: <500, 500–1000, >1000 ms)
HAN	required demand of hands (expected response duration on a 3-point scale: <1500 ms, 1500–2500 ms, >2500 ms)
FEE	required demand of feet (expected response duration on a 3-point scale: <1500 ms, 1500–2500 ms, >2500 ms)
VOI	required demand on voice output (expected response duration on 3-point scale: <1500 ms, 1500–2500 ms, >2500 ms)

While the car is standing still a menu structure is available on the interface screen that allows the driver to set GIDS to the driver's own preferences. The navigation, radio, accelerator pedal and steering wheel module as well as the lane keeping and speed monitoring module can be turned on or off. Tutorial functions can be added or not and the system can even be turned off completely altogether. Aside from these on/off functions a specific user profile can be fed into the system based on gender driver experience and age. The tutorial function (which was not implemented within the project's time span) would interact with this profile.

The interface itself, mounted within easy reach to the right of the steering wheel, incorporates:

- High resolution, high illumination colour screen with four soft keys to the right of the screen and two at the bottom and a fixed function rocker switch
- Spoken messages
- Voice command.

Evaluation studies of the prototype system were performed both in a driving simulator called the 'Small World' and on the road (Janssen et al., 1992; Kuiken & Miltenburg, 1993). Although the results of those are obviously tied to the particular situations and applications chosen, they were very encouraging for the concept. An important evaluation result is shown in Figure 3, where it is apparent that the integration of support and information system in the way described here does indeed make a difference in the workload experienced by drivers.

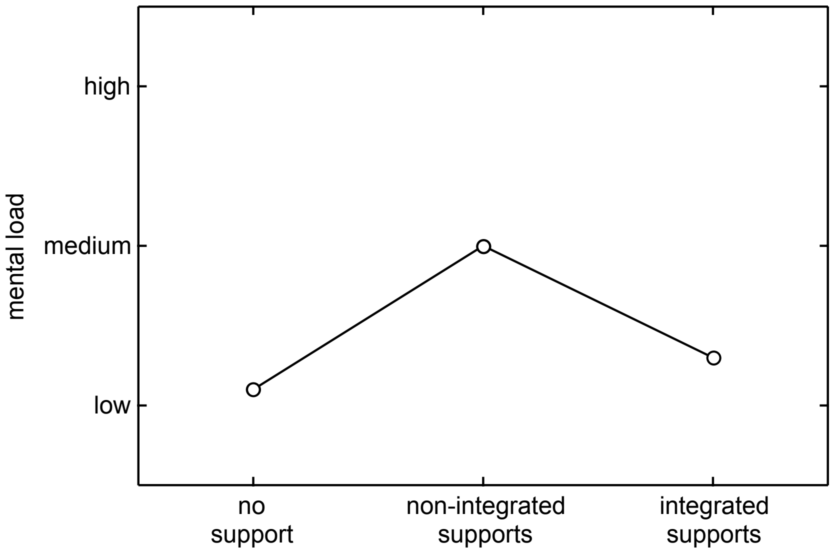

Fig. 3 Mental workload (cumulative ratings on SWAT-scale) with no support, non-integrated supports and with integrated supports.

4.1.4 Acceptance

Studies of the acceptability of GIDS have been carried out. 60–70% of those who used the system in the simulated Small World considered it useful. Almost 80% anticipated that it would enhance safety, and although almost all drivers said it would be useful for some or all drivers, only about half of the drivers said they would buy and/or use the system themselves.

GIDS adopted the standpoint that the ultimate responsibility of all actions would remain with the driver. As a result GIDS developed a non-interventionist type of driving support. Low level vehicle control—which has to do with staying on the road per se and avoiding collisions with other vehicles—is an exception due to the fact that some reactions to situations leave too little time for the driver to respond appropriately. While about 50% of the drivers questioned on the intelligent pedal and steering wheel considered these useful in general, about 75% considered them unpleasant when actually using them. This reflects that some provisions may be considered useful, but that their actual use for the individual is not very much appreciated.

4.2 ARIADNE (Application of Real-time Intelligent Aid for Driving and Navigation Enhancement)

Partners: Rover Group (UK), British Aerospace (UK), Philips Research Laboratories (UK), CARA Data Processing (IRL), TRC University of Groningen (NL), MRC Applied Psychology Unit (UK), TNO Human Factors (NL), VTI Swedish Traffic Research Institute (SWE).

In the ARIADNE project (1992–1994), in which the GIDS system was being developed further, the aim was to develop an intelligent driver support system capable of monitoring output from information sources and presenting them to the driver in a suitable manner. The project extended the work performed by the GIDS project to include more (urban) situations and road types, special driver needs, and improve the instructional capabilities of the system while also including a collision avoidance radar and making the overall system more robust. The actual GIDS prototype system MKII differs somewhat as described, but the design is not radically different from the earlier GIDS prototype. The ARIADNE project consisted, as mentioned earlier, mainly of streamlining the GIDS prototype, and extending the Traffic World and the Driver Model as well as the Instructional Module. Within the context of the current report the Instructional Module extensions are not considered.

4.2.1 Monitor and measure

The prototype built during the GIDS project was enhanced resulting in GIDS prototype system MKII (see Figure 4). by integrating the software into a single Core System which enabled it to operate on a single workstation. The Core System connects various sensors and a navigation system with the user interface, consisting of Active Controls and user interface hardware and software. The function of the Core System is to monitor the driver's actions, the road and traffic tasks, and to organise the information that needs to be processed by the vehicle operator.

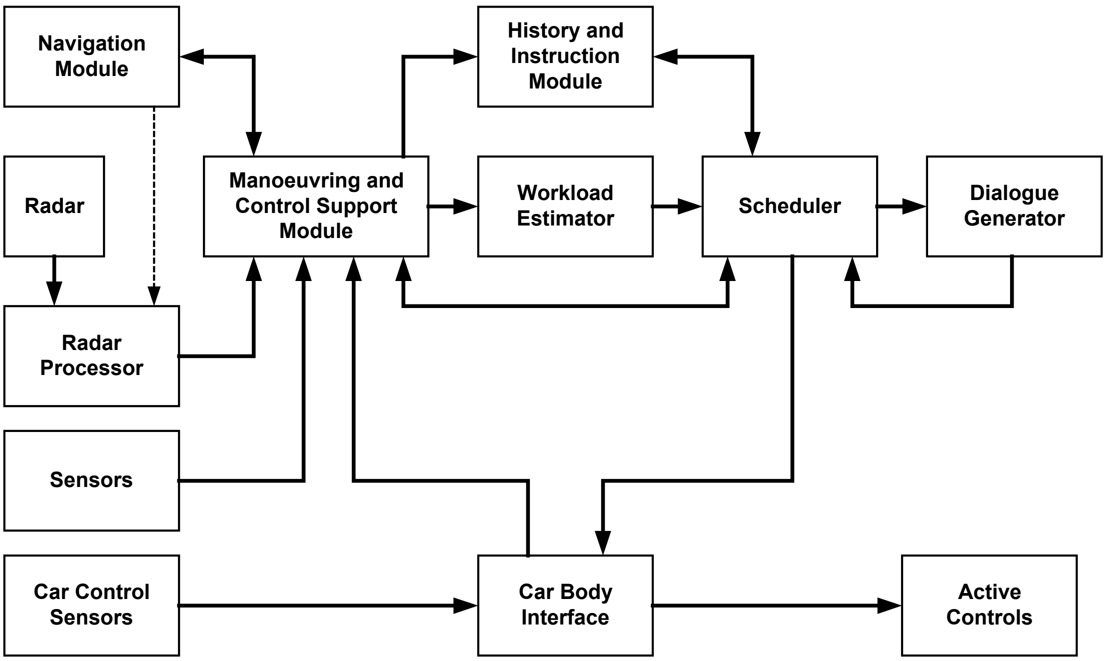

Fig. 4 The GIDS prototype system MkII.

The Core system consists of three modules: Manoeuvring and Control Support Module, Scheduler and Workload Estimator and is connected with two other modules: the Navigation System and the Car Body Interface and Sensors. A novel solid radar has been developed by Philips Research Laboratories in the UK that can detect certain types of objects reflected within a low power radar beam. Information regarding the behaviour of such objects can be passed to the ARIADNE system as another source of information to be suitably presented to the driver. The radar comprises a high-speed collision avoidance system as well as a low speed system that functions as a parking aid. The Manoeuvring and Control Support module collects all the available information and applies a set of predefined rules to determine the recommended speed and the driving lane that apply to the immediate traffic and road conditions. Via the Scheduler this information is directed to the driver when discrepancies between observed and ideal speed and driving lane are measured. The Scheduler suppresses and schedules the information for presentation to the driver based on the workload constraints by the Workload Estimator. The module also sends its information to the History and Instruction Module Information sources could now be interfaced to the core system in order to reduce the physical size of the prototype to allow it to be installed in a standard car. The most important extensions include the addition of the radar as a separate sensor and the History and Instructional Module.

The Small World simulation was extended and was now called the 'ARIADNE World'. To accommodate implementation of the required extensions for the ARIADNE World, the network representation and physical world representation were redesigned and implemented using the object oriented programming language C++. The following extensions were made:
Addition of one-lane roads without and with left and right shoulders, four and six-lane roads with and without left and right shoulders, auxiliary lanes, acceleration lanes, deceleration lanes, combined acceleration lanes and deceleration lanes, maximum speed signs, signs indicating highways and motorways, signs to prohibit overtaking, parking, stopping, turning (U-turns), left-and right turning, entering a one-way street and driving in a motorised fashion after all. Also, the possibility of the occurrence of fog was added.

The existing driver model was extended and validated and represented in a knowledge base to provide the basis for extended workload estimation. Specifically overtaking manoeuvres were explored in more detail.
In the GIDS system, the Workload Estimator was informed of the status of a number of factors in order to estimate current workload of the driver. Earlier work in the GIDS project suggested that the traffic situation is the major determinant for visual and cognitive workload and that the variation in these two forms of workload is different in some situations. In addition, the results showed that inexperienced drivers could not handle complex messages in demanding driving situations. In ARIADNE the question emerged whether there are more factors that influence workload than the one investigated in GIDS (traffic situation). A field study with the TNO Institute's instrumented car (ICACAD) assessed the effects of driver age, road situation, traffic density, and familiarity with the area of driving on visual and cognitive workload. It was found that visual and cognitive workload depended on type of situation, driver experience, and driver age. The data also strongly suggested that workload obtained in specific situations could be generalised to situations with similar characteristics. This finding results in the idea that the look-up table in the Workload Database can be relatively simple. The traffic situation basically determines which type of messages can be presented in a given situation and which cannot. Complex messages (including the ringing and use of a telephone) should not be presented in demanding driving situations when the driver is aged or inexperienced.

Another finding was that navigation messages load the driver less than other messages such as radio TMC messages and a telephone call. Exceptions were navigational messages in relation to a roundabout and approaching an intersection. The first were relatively slower and the latter relatively faster. What is still missing however is a rule indicating in what situations messages are not allowed. This is even true today.

In general, messages should be kept short and positive and each message should start with the most important information. Irrelevant information should be left out and the wording should be clear and simple. The messages used in this study showed that longer messages resulted in longer reaction times of participants. The messages were presented in Dutch however and more than resulting in an exact rule for format of messages are these studies important for their methodology in comparing various messages for their effect on workload. Another important finding was that accompanied by auditory cues visual messages should only require a limited number of glances while driving.

4.2.2 Managing workload and designing the adaptive interface

A general assertion within ARIADNE was that visual or mental workload inducing messages should be presented only scarcely in situations in which the chance of interactions with other traffic participants is high (e.g. high density traffic, pedestrians or cyclists present). In some situations complex visual messages should not be presented at all. This led to the notion that instead of trying to measure workload for all possible driving situations that is virtually impossible, a categorisation of driving situations can be obtained on the basis of a few specific characteristics. In general: Tasks at the tactical level of driving are more loading than tasks at the control level. This suggests that situations can be categorised with respect to the workload they incur on basis of the estimated number of tactical driving tasks in that specific situation.

Studies were also performed to assess the possibility of presenting auditory and haptic or tactile messages concurrently. The general question being whether messages from different in-vehicle systems should be presented sequentially (one-by-one) or in parallel (two-at the same time). According to the Multiple Resource Theory it is possible to effectively time-share two messages, if they address different sense-modalities. It was found that concurrent presentation of an auditory and a tactile message had a negative impact on driver performance in a number of safety related aspects (reaction time, headway). But it was also found that this negative impact could be strongly reduced as the driver’s experience with the messages increases. It was therefore concluded that concurrent presentation of RTI messages is possible when experience with the messages is high.

Another study performed within the context of ARIADNE by Alm (1993) aimed to identify the optimum minimal time interval between two sequentially presented rather complex auditory messages that cannot be send to different modalities. This is an important factor as too many messages may cause increased workload or distraction or ignorance of messages provided thereby reducing the increased safety that a system like GIDS has to offer. Alternatively it may lead the driver to ignore the messages. It was predicted that the longer the interval between messages the less negative effects on the drivers’ ability to drive safely would be produced. However, it was found that the optimal time interval between the two auditory, rather complex messages tested, seemed to be close to three seconds. This finding was based on minimum, average and maximum headway, speed level and lateral position. The intervals were 0, 1, 3, and 5 seconds between messages. A three-second interval between messages tended to produce a longer headway compared to the other intervals. It was found thus that the relationship between length of interval and measurements on the dependent variables as mentioned earlier was not a

linear one but resulted in an optimum. Aside from the effect for traffic safety (longer headways), the three seconds interval was also favoured from a user preference point of view as shown by the results on three questions in relation to the time- intervals asked to the participants in this study. Future research is needed to investigate the optimal interval between other types of messages.
Finally, an extended evaluation of the integrated support system (cf. 4.1.3) was performed (Janssen, 1995), to assess what the effects on driver behaviour would be when drivers would start building up experience with the system. This is worth mentioning because most evaluation studies limit themselves to 'one-shot' experiments. The study traced the development of subjects gaining experience with the support over a total period of about 10 hrs of driving on several types of road. The results provided no evidence for the existence of 'early indicators' of later adaptation to the support system. That is, an effect on a given parameter of driving behaviour existed right from the beginning or it did not occur at all.

4.2.3 Acceptance

No specific attention was devoted to the acceptance issue within this project.

4.3 GEM (Generic Evaluation Methodology for integrated driver support applications)

Partners: Rover (UK), British Aerospace (UK); Philips (UK); TNO Human Factors (NL); Cara (UK); Acit (Germany); TRC Groningen (NL); University of Leeds (UK); VTI (Sweden).

The primary goal of the GEM project (1994–1995; funded under the DRIVE II initiative) was to develop a methodology for assessing how the provision of integrated driver support systems affects the performance of the driver. This Generic Evaluation Methodology would have to be employed as, and when, new driver support systems become available. The methodology addresses all of the factors that must be considered when incorporating a new application into a vehicle, i.e. driver characteristics, driver tasks, vehicle capabilities and the requirements of the application itself, from both a behavioural analysis and systems integration viewpoint.

In short the project identified:

- A generic method for evaluation of the effects of combining multiple applications,
- Criteria for determining what types of applications can be combined to the benefit of the driver, and which combinations seem likely to be detrimental,
- Whether new Man Machine Interfacing technologies (e.g. Head-Up Displays) are likely to enhance the potential of existing support systems.

A series of experiments was performed to increase the confidence in the validity of the methods that are included in the GEM database. Studies were performed with respect to the following topics: impact of (integrated) applications on workload and driving behaviour, assessment of the effects of practice and experience with (integrated) applications, impact of (integrated) applications on workload and observation skills, and finally validation of aspects of the testbeds.

4.3.1 Monitor and measure

A comparative study on workload assessment techniques used 9 different parameters in an effort to establish what would be the most sensitive index for peaks in (visual and mental) workload (Kuiken et al., 1995). The study used loading tasks (e.g. a Continuous Memory Task) during motorway driving in order to induce (different) peak levels against which the potential to detect workload peaks was assessed for the different measures.
The sensitivity of the workload measures was found to be as in Table 4.

Table 4 Sensitivity to peak loads (high, reasonable, poor or no sensitivity for peaks in visual or mental load).

Parameter	Visual load	Mental load
Steering reversal rate	Reasonable	Poor
Secondary task	High	High
SWAT	High	Reasonable
RSME	High	High
Skin conductance	None	Reasonable
Heart rate var.	Poor	Poor
Heart rate (IBI)	None	None
Driving speed	None	None
Eye blinks	–	None

Thus, secondary task performance overall was the best indicator of peak workloads. Several forms of subjective ratings were reasonably sensitive to peak loads. Steering reversal rate (the number of times per minute that the direction of steering wheel movement is reversed) was reasonably sensitive to visual load only, and skin conductance to peak mental loads. Heart rate and eye blink parameters performed poorly for both types of workload.
In terms of practical applicability, the results of this study appear to indicate that the steering reversal rate is a likely candidate to be included in the list of variables to monitor on-line.

4.3.2 Manage workload

As one part of the project a matrix was produced matching HMI devices against applications for use within an integrated context. In other words, the matrix was to provide guidance on how to combine applications from the point of view of the driver's input and output requirements. The matrix would define the most appropriate combinations of HMIs and applications to implement on the various test beds available to the GEM consortium, so as to form the basis for validation studies.
As a precursor to the integrated matrix a matrix for the individual applications was produced.

The *applications* were divided into three categories:
Category 1 – Applications supporting the primary driving task:

Collision Avoidance System (CAS)
Autonomous Intelligent Cruise Control (AICC)
Blind spot warner warning
Lane support
Vision enhancement

Category 2 – Applications supporting important secondary functions:

Navigation
Route guidance
Travel and traffic information
Reverse parking aid
Emergency call
Driver performance/state information feedback
Vehicle status

Category 3 – Applications supporting less important secondary functions:

Trip information
Radio/Entertainment
Telephone
Driver comfort (Air conditioning + seat position)

The HMIs were divide into two broad categories: input and output devices. This latter category was further sub-divided according to the sensory channel which the MMI (Man Machine Interface) utilised.

HMI Input Devices:

- Direct Voice Input (DVI)
- Keyboard/keypad (KEY)
- Touchscreen (TCH)
- Softkeys (S/K)
- Conventional controls (CON)

HMI Output Devices:

- Visual: Dedicated Head-Down Display (HDD)
  Multifunction HDD
  Head-Up Display (HUD)
  Other (e.g. Dedicated indicator)
- Auditory: Voice messages (DVO, Direct Voice Output)
  Tones/attensons
- Haptic/tactile: Active gas pedal – torque
  Active gas pedal – vibration
  Active steering wheel – torque
  Active steering wheel – vibration

In order to produce the matrix (this applies both for the individual as well as the integrated matrix) a small number of human factors guidelines were applied, where the applicability rested on the subjective judgement of the Project members. They were:

1 Sensory and perceptual channels should not be overloaded. Applications which could potentially make use of the same channels/modalities, thereby giving rise to conflict, should be prioritised according to the criticality of the information they convey and the degree of difficulty of presenting that information using a different channel.

2 In a system with many integrated applications, it may not be possible to avoid presenting information from different applications using the same modality and possibly the same HMI output device. In such cases, simultaneous presentation of information should be avoided. This can be achieved by assigning priorities and scheduling messages appropriately, to allow the driver sufficient time to process a message and, if necessary, to act on it before the next message is presented.
3 Information should not be presented in such a way that it forces the driver to attend to it immediately, unless it is safety-critical.
4 Collision warnings are safety-critical and should always be given high priority.
5 Information which is presented continuously (like some kinds of car status information) should be presented on a HDD. Car status information should only be presented on a HUD if the driver requests it, or if it is intended as a status warning. Only when car status information is intended as a warning should the auditory channel be used.
6 DVO (Direct Voice Output) should only be used for urgent messages or for route guidance instructions (since the safety of a route guidance system substantially decreases if information is only presented visually).
7 Applications which are time- or safety-critical should not be controlled by DVI alone, since speech input may at times be temporarily impossible (for example, because of external noise levels) or uncomfortable.
8 Only important or requested information should be presented on a HUD and it should also be available elsewhere.
9 Keyboards, keypads and touchscreens should only be used when the vehicle is stationary.
10 If vision enhancement is selected by the driver (on a HUD), route guidance instructions (if available) should be presented on a HDD.
11 Map displays should only be presented when the vehicle is stationary.

4.3.3 Adaptive Interface (de-cluttering)

The development of the adaptive interface as such was not the purpose of the project, as the methodology for *evaluating* this type of interface was of prime importance. To this purpose, a very extensive database of available evaluation methods was put up, the idea being that the selection of the most appropriate method would then follow from a definition of the integrated HMI, what it requires from the driver, and also in what phase of prototype development the evaluation takes place.

The main part of the database is shown in Tables 5, 6, 7, and 8.

Table 5 The GEM Method Matrix Version 2.0 (part1). Each available method is described in terms of the aspect of HMI to which it specifically pertains, the type of measurement method that it requires, the actual source of the data, and in what environment the evaluation is done.

	To access detailed information about a method select the method in this column and open the info window !	Procedure for generating data																	
		Aspect of MMI which is measured				Measurement method				Data source						Location of measurement			
Cluster	Method	Device	Load	Stress	Other than MMI aspect measured	Objective	Subjective	Analytical	Empirical	Observational	Analysis / Simulation	Rating by users or subjects	Expert rating or checklist	Controlled Experiment	Other (e.g. interview)	Field	Simulator	Laboratory	Other (e.g. location not relevant)
Analytical evaluation methods	SANe	x	x			x		x			x								x
	DIADEM	x	x			x		x			x								x
	ORACLE	x	x			x		x			x								x
	PASSPORT	x				x		x			x								x
	Screen Analyser	x				x		x			x								x
Task analysis methods	TAFEI				x	x		x			x					x			
	Conflict-Checker				x		x	x			x								x
Checklists for MMI quality	Software Checker	x					x	x				x				x			
	Ergonomie-Prüfer	x	x				x		x				x			x			
	MMI criteria list 3.0	x					x		x				x						x
Evaluation of subjective factors / questionnaires and Cognitive Workload	Heuristic Evaluation	x	x				x	x					x						x
	SUMI			x		x			x			x				x			
	QUIS			x		x			x			x				x			
	SMEQ			x		x			x			x				x	x	x	
	MCH			x		x			x			x				x	x	x	
	SART			x		x			x			x				x	x	x	
	SWAT			x		x			x			x				x	x	x	
	NASA TLX			x		x			x			x				x	x	x	
	NASA RTLX			x		x			x			x				x	x	x	
	CI			x			x		x						x	x			
Standardised driver performance tests	Wiener Fahrprobe			x			x		x	x						x			
	TTC			x		x			x					x		x	x		
	DSE			x			x		x	x						x			
	SPR			x			x		x					x		x	x	x	
Performance test	DRUM			x		x			x	x								x	
Physiological measures of workload and stress	Cardiac Activity			x		x			x					x		x	x		
	EDA			x		x			x					x		x	x		
	EMG			x		x			x					x		x	x		
	EOG			x		x			x					x		x	x		
Generally applicable methods and techniques	ASPA-CAS			x		x			x					x		x	x		
	ASPA-RGS			x		x			x					x		x	x		
	ASPA-AICC			x		x			x					x		x	x		
	Secondary task performance			x		x			x					x		x	x	x	
	Learning Time Measurement			x		x			x					x		x	x		
	Questionnaires	x		x			x		x					x		x	x	x	
	Thinking aloud	x		x			x		x	x						x	x	x	
	Driving Simulator (e.g. VTI)			x		x			x					x			x		
	Driver behaviour (prototype)			x		x			x					x		x			
	Driver behaviour (product car)			x		x			x	x				x		x			
	Critical incidents technique				x		x		x	x				x		x			
	Accident Statistics				x	x			x	x				x		x			

Table 6 The GEM Method Matrix Version 2.0 (part2). This part focuses on the stage of HMI development in which the method is particularly applicable. Also, it is indicated how complete the method is, in terms of the availability of tools and services.

Cluster	Method (To access detailed information about a method select the method in this column and open the info window !)	Phases in the development process where the method can be considered					Development status of MMI where method is applicable			Method Support	
		Requirements Analysis	Dialogue Specification	Detailed Design	Implementation	Product in Use	Specification	Prototype	Product	Tools available	Services available
Analytical evaluation methods	SANe	x	x	x	x	x	xxx	xxx	xxx	x	x
	DIADEM		x	x	x	x	xxx	xxx	xxx	x	x
	ORACLE		x	x	x	x	xxx	xxx	xxx	x	x
	PASSPORT		x	x	x	x	xxx	xxx	xxx		x
	Screen Analyser		x	x	x	x	x	xx	xxx	x	
Task analysis methods	TAFEI	x	x	x	x	x	xxx	xx	x		x
	Conflict-Checker	x	x	x	x	x	xxx	xx	x	x	
Checklists for MMI quality	Software Checker					x			xxx	x	
	Ergonomie-Prüfer					x			xxx		
	MMI criteria list 3.0		x	x	x	x		xx	xxx	x	
Evaluation of subjective factors / questionnaires and Cognitive Workload	Heuristic Evaluation	x	x	x	x	x	xx	xxx	x		
	SUMI					x		x	xxx	x	x
	QUIS					x		x	xxx	x	
	SMEQ				x	x		x	xxx		
	MCH				x	x		x	xxx		
	SART				x	x		x	xxx	x	
	SWAT				x	x		x	xxx	x	
	NASA TLX				x	x		x	xxx	x	
	NASA RTLX				x	x		x	xxx		
	CI			x	x	x		x	xxx	x	x
Standardised driver performance tests	Wiener Fahrprobe				x	x		x	xxx	x	x
	TTC				x	x		x	xxx		x
	DSE				x	x		x	xxx		x
	SPR				x	x		x	xxx		x
Performance test	DRUM			x	x	x		xx	xxx	x	x
Physiological measures of workload and stress	Cardiac Activity				x	x		x	xxx	x	x
	EDA				x	x		x	xxx	x	x
	EMG				x	x		x	xxx	x	x
	EOG				x	x		x	xxx	x	x
Generally applicable methods and techniques	ASPA-CAS				x	x		xx	xxx		x
	ASPA-RGS				x	x		xx	xxx		x
	ASPA-AICC				x	x		xx	xxx		x
	Secondary task performance				x	x		xx	xxx		
	Learning Time Measurement				x	x		xx	xxx		
	Questionnaires	x	x	x	x	x	xxx	xxx	xxx		
	Thinking aloud	x	x	x	x	x		xxx	xxx		
	Driving Simulator (e.g. VTI)			x	x	x		xxx	xxx		x
	Driver behaviour (prototype)			x	x			xxx		x	x
	Driver behaviour (product car)				x	x		xx	xxx	x	x
	Critical incidents technique					x			xxx		
	Accident Statistics					x			xxx	x	

Table 7 The GEM Method Matrix Version 2.0 (part3). This part contains the information of the costs of applying a particular method, and of the reliability of the measurements obtained by it.

	To access detailed information about a method select the method in this column and open the info window !	Cost estimation										
		Cost of evaluation (mandays) for projectsize			Additional cost					Reliability of measurements		
Cluster	Method	Small (= Detecting deficiencies in a single design)	Medium (= Comparing 3 designs)	Extensive (= Repeated evaluation at different stages of the design process)	Subjects required	High material cost	Low material cost	No material cost	Training (in man-days)	High reliability	Medium reliability	Low reliability
Analytical evaluation methods	SANe	5	10	10			x		5	x		
	DIADEM	5	10	10			x		5	x		
	ORACLE	5	10	15			x		5	x		
	PASSPORT	10	20	30				x	2	x		
	Screen Analyser	2	4	6			x		1	x		
Task analysis methods	TAFEI	10	20	30				x	1			x
	Conflict-Checker	2	4	6				x	1	x		
Checklists for MMI quality	Software Checker	1	2	3				x	1		x	
	Ergonomie-Prüfer	1	2	3	x			x	1		x	
	MMI criteria list 3.0	1	2	3				x	1		x	
Evaluation of subjective factors / questionnaires and Cognitive Workload	Heuristic Evaluation	2	4	4				x	1		x	
	SUMI	1	3	3	x			x	2	x		
	QUIS	1	3	3	x		x		1		x	
	SMEQ	2	6	6	x			x	1		x	
	MCH	1	2	3	x			x	1		x	
	SART	2	4	6	x			x	5		x	
	SWAT	1	2	3	x		x		1		x	
	NASA TLX	1	2	3	x			x	1		x	
	NASA RTLX	1	2	3	x			x	1		x	
	CI	15	30	45	x			x	5		x	
Standardised driver performance tests	Wiener Fahrprobe	30	50	50	x		x		5		x	
	TTC	5	7	9	x	x			2	x		
	DSE	30	50	50	x		x		30			
	SPR	30	50	50	x			x	5		x	
Performance test	DRUM	20	60	50	x		x		5	x		
Physiological measures of workload and stress	Cardiac Activity	30	60	90	x		x		3		x	
	EDA	30	60	90	x		x		30		x	
	EMG	30	60	90	x		x		20		x	
	EOG	30	60	90	x		x		10		x	
Generally applicable methods and techniques	ASPA-CAS	100	150	200	x	x			200		x	
	ASPA-RGS	80	120	160	x	x			200		x	
	ASPA-AICC	80	120	160	x	x			200		x	
	Secondary task performance	30	40	50	x	x			20		x	
	Learning Time Measurement	50	70	90	x	x			20		x	
	Questionnaires	5	8	10	x			x	5		x	
	Thinking aloud	15	30	60	x			x	1		x	
	Driving Simulator (e.g. VTI)	100	150	200	x	x			0	x		
	Driver behaviour (prototype)	100	150	200	x	x			200		x	
	Driver behaviour (product car)	50	75	100	x	x			30		x	
	Critical incidents technique	35	70	100				x	10			x
	Accident Statistics	35	70	100	x		x		50			x

Table 8 The GEM Method Matrix Version 2.0 (part4). This part contains estimates of several quality factors of available methods.

	To access detailed information about a method select the method in this column and open the info window !	Quality Factors										
Cluster	**Method**	Efficiency of task performance	Learning cost	Workload	Adaptedness for the task domain	Robustness	Error probability	Subjective ratings of users	User problems / design deficiencies	Conformance with standards	Display deficiencies	Interference with the driving task
Analytical evaluation methods	SANe	xxx	xxx	xxx	xxx	xxx	x			xx	xxx	xxx
	DIADEM	xxx	xxx	xxx								xxx
	ORACLE	xxx					xx				xxx	
	PASSPORT					xxx	xxx					
	Screen Analyser						xx				xxx	
Task analysis methods	TAFEI	x			x		xxx					
	Conflict-Checker						xxx				xxx	xxx
Checklists for MMI quality	Software Checker	xx	xx		xx						xxx	
	Ergonomie-Prüfer	xx			xx					xxx	xxx	
	MMI criteria list 3.0								xxx	xxx	xxx	
Evaluation of subjective factors / questionnaires and Cognitive Workload	Heuristic Evaluation	x			xx				xx	xx	xx	
	SUMI							xxx	xx			
	QUIS							xxx				
	SMEQ			xxx				xx				
	MCH			xxx			xx	xxx	xx			xxx
	SART			xxx			xx	xxx				xx
	SWAT		x	xxx			xx	xxx	xx		x	
	NASA TLX		x	xxx			xxx	xxx	xxx		x	xxx
	NASA RTLX		x	xxx			xxx	xxx	xxx		x	xxx
	CI											
Standardised driver performance tests	Wiener Fahrprobe	xxx	x				x		x			xxx
	TTC	xxx		xxx	xx						xxx	xxx
	DSE	xxx					xxx					xxx
	SPR	xxx										
Performance test	DRUM	xxx					xx		xxx			
Physiological measures of workload and stress	Cardiac Activity			xxx								
	EDA	xx		xxx							xx	xxx
	EMG	xx		xxx								
	EOG	xx		xxx							xx	xxx
Generally applicable methods and techniques	ASPA-CAS	xx					xxx		xx		xx	xx
	ASPA-RGS	xxx					xx		xx		xx	xx
	ASPA-AICC	xxx										
	Secondary task performance	xxx	xxx	xx					x		x	xxx
	Learning Time Measurement	xx	xxx	x								xxx
	Questionnaires	xx	x	x				xxx			xx	xx
	Thinking aloud			x					xxx			
	Driving Simulator (e.g. VTI)	xxx	xx	xx				xx			x	xx
	Driver behaviour (prototype)	xx	xx	xx	xx	x	x		x		x	xxx
	Driver behaviour (product car)	xxx	xx				x		x			xxx
	Critical incidents technique						x	xx	xx			xx
	Accident Statistics			x			xx					x

In the later stages of the project it appeared that the database still did not sufficiently capture the possibilities to capture possible interference between devices that can be used together and which can interact with the same user. In order to resolve this, a pragmatic 'conflict checker' was added to the evaluation procedures. This considers the use of a device by the driver as a function of the driving situation (context), the device (see the list of applications as given in the previous section) and the input and output modalities which it uses (see the list given earlier).

The system takes account of two components in estimating usage, based on the amount of time for which they are used (the ‘Loading’ model) and on the peak amounts of loading which they incorporate (the ‘Timing’ part). Discrete, five-point scales were used to indicate these ‘usage’ aspects. These were based on the ‘human factors’ guidelines, as presented before.
The levels for ‘Loading’ were as follows:

1 None
2 Low
3 Medium
4 High
5 Overload.

The levels of time usage were:

1 Never
2 Occasional
3 Intermittent
4 Continuous
5 Overload.

The system shows where either the peak loading or the amount of time required by the combination of devices might overload the driver. It tends to indicate ‘worst case’ situations, and can be used to check where conflicts may be found and to indicate the combinations of devices and situations which may cause overload for some modalities.

The GEM Project did not quite succeed in producing recommendations for a generic methodology to be applied when evaluating integrated support systems. The information it gathered about the available methodologies is, however, useful by itself. Apart from this, what effort that was spent in the development of HMI principles themselves, continuing along the lines laid out by the GIDS and ARIADNE projects, did not yield very much in terms of concept development.

4.3.4 Acceptance

The acceptance aspect was not considered explicitly in this project.

4.4 IN-ARTE (Integration of Navigation and Anticollision for Rural Traffic Environment)

Partners: FIAT (It.), RENAULT (France), Siemens (France), Fraunhofer IAO (Germany), TÜV Rheinland (Germany), TRD International (Greece), VTI (Swe), VOLVO (Swe), NAVTECH (NL), TNO Human Factors (NL).

The aim of the IN-ARTE project (1998–2000) was to improve traffic safety in rural environments by means of an integrated driver support system. In rural environments (limited number of lanes, simple intersections, various types of curves, non optimum infrastructure, limited numbers of vulnerable road users) 28% of injury accidents take place, accounting for 58% of deaths. Most of them have been related to problems in driven vision and vehicle conspicuity, poor judgment of drivers' speed, driver merging difficulties in junctions and lane change errors (even in only two-lane streets).

Hence, the aim of IN-ARTE was to develop an integrated autonomous on-board system to be able to build an extended view of the environment in front of the vehicle, integrating signals from anti-collision radar, road recognition CCD sensors and navigation map, in order to guide and warn the driver through an optimum HMI in a series of rural areas related traffic tasks, such as intersection handling, speed selection while negotiations, curves, obstacle detection, etc.

It is generally expected that the system can simultaneously improve driving performance and simplify the task of driving for the human driver. The combination of improvements of system performance and simplification of the driving task is expected to improve driver acceptance, driver behaviour and traffic safety. Thereby the IN-ARTE system is designed both for increased safety and for increased driver comfort. The IN-ARTE system is designed for extra urban areas such as motorways, rural roads and urban arterials.

The IN-ARTE system is a driver support system, in the sense that the main goal is to improve traffic safety and driver comfort by supporting the driver, and not by taking over the driving task per se. The system supports the driver by providing extra information during driving (the presence of railway crossings, navigational support etc.). The most important function with respect to traffic safety is probably the combination of information from different subsystems, offering the possibility to support the driver in case of dangerous situations. There are several reasons related to human factors that explain why dangerous situations while driving can occur, to mention a few:

- a driver may be occupied with another task than driving (for instance changing the channel on the radio) and may therefore not pay enough attention to the driving scene, failing to notice the presence of a curve or a braking car.
- the driver may have misinterpreted the situation, experiencing the situation as safe, whereas it is not.
- a sudden and unexpected event may occur that the driver did not expect, like a car in front of the subject is braking rather abruptly.

With the IN-ARTE system different kinds of support will be available to the driver under all these circumstances.(even if they occur on non-rural roads). Support can be given by a warning to the driver, or the driver can be supported by a system intervention in case driver response would take too long to guarantee a safe situation. Related to this, the criteria that decide when a warning or an intervention should be activated are of importance. Warnings or interventions can be activated in an early stage, guaranteeing a level of relative high traffic safety, but risking many false alarms or in a later stage, running the risk of being too late to avoid a dangerous situation.

4.4.1 Monitor and measure

The IN-ARTE system supports a wide range of driver tasks: navigation, keeping distance to preceding cars (by means of adaptive cruise control), lane keeping and collision avoidance. The system combines information from an extended road database (developed by Navtech) with information from different sensors into a single driver support system.

An outline of the IN-ARTE architecture is presented in Figure 5.

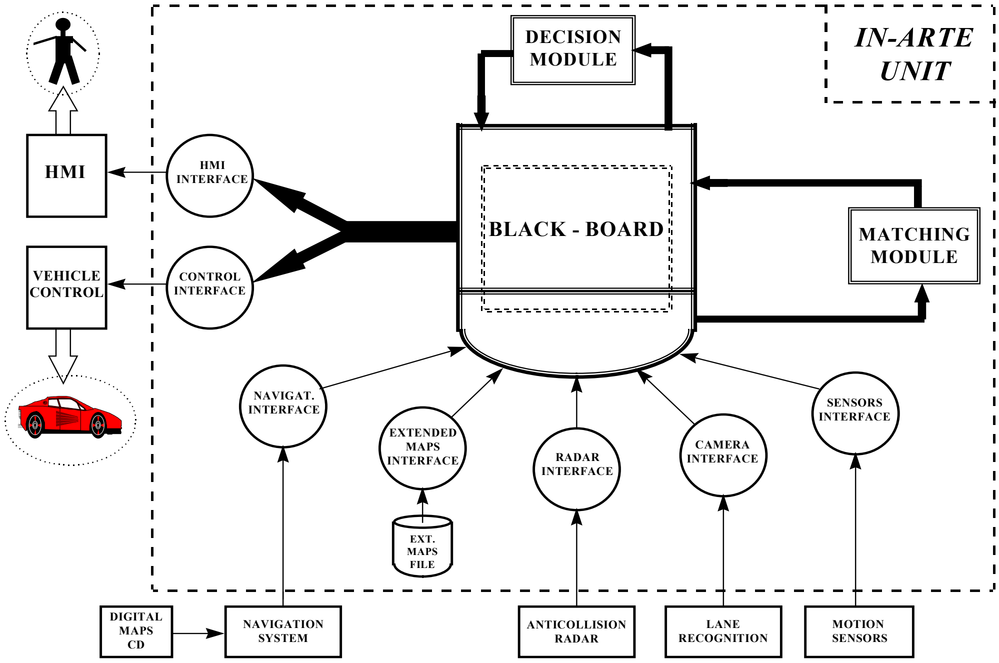

Fig. 5 An outline of the IN-ARTE architecture.

The IN-ARTE system has basically three modes of operation:
1 transmission of information to the user interface,
2 warning messages, and
3 system intervention.

System interventions include activation of the steering wheel in order to stay in the lane and automatic brake interventions.

The sensors providing information to the IN-ARTE architecture are vehicle motion sensors, lane recognition camera, radar and an extended road database. The safety improvements obtained by the IN-ARTE architecture are mainly due to the extended road database in combination with the blackboard architecture, which is able to process information from different sources to match the information and to “decide” about actions to be taken in accordance with the predefined system algorithms.

Extended information improves traffic safety by being both more comprehensive and also more precise than the information from each individual sensor. Moreover by being able to schedule and prioritise information the relevance of information presented to the human driver is enhanced.

4.4.2 Manage workload

The advantages of the IN-ARTE system over other driver support systems is the integration of information from different data sources, which results in a multi-functional system with a single user interface. In line with the above-mentioned findings the integration of information is expected to improve precision and comprehension of messages. The integration also gives opportunity to prioritise and schedule driver information. The system should be able to discriminate between different scenarios and their criticality and decide either to give an intervention or a message (information or warning) to the human driver. Compared with multiple single-function systems, each with their own user interface; this is a more advanced application. It is related both to the multi-functionality of the system and to the simplification of the user interface. The driver will be required to attend to a single stream of information, referring to most salient aspects of the current driving task.

Figure 6 shows the IN-ARTE UNIT which can be divided into three main modules: Matching Module, Scenario Definition Module and Decision Module.

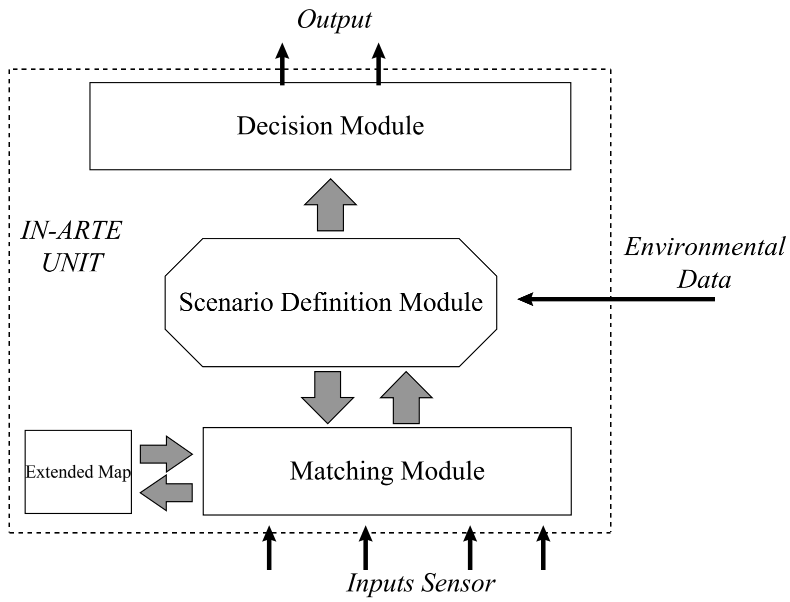

Fig. 6 IN-ARTE modules.

The aim of the Matching Module is to filter and match all the data from the information units and Extended Map data, then collect them into the Scenario Definition. The match function allows the integration of all the data for a correct reconstruction of the scene in front of the vehicle. The Scenario Definition is a data store where processed data from the on-board sensors represent the current vision of the scene in front of the vehicle.

The IN-ARTE's core is the Decision Module, it analyses the Scenario Definition data and decides an adequate support to the driver or an automatic active control of the vehicle.

Principally, IN-ARTE unit executes a loop (loop frequency around 10 Hz). During the loop, the data from the on-board components are sampled by Interface Modules and combined by the Matching Module in a common "view" of the traffic situation around the vehicle, called Scenario Definition. After this, the Decision Module executes the data analysis in order to produce the proper output towards the driver and the vehicle.

Each Interface Module gets the data from the corresponding on-board component, then puts it in the suitable form into the Scenario Definition Module. In the same way, the HMI and the Vehicle Control modules get the IN-ARTE unit outputs by two different interface modules.

4.4.3 Adaptive Interface

Prioritisation

After active actions have been identified, the problem is to understand which one has to be performed if more are present at the same time. The required deceleration value is a natural parameter to prioritise actions. In fact, the stronger deceleration value that is required, the more dangerous the situation is in front of the vehicle.

Emphasis is given on how to resolve cases of multiple dangers, namely prioritisation of warnings, avoidance of driver's overload and/or subsequent interventions ("stop and go"-like car behaviour), still allowing the user to remain in control of the vehicle for as long as possible.

For this reason, critical time margins have been defined. If the activation for a following risk is within these time margins, the warnings for the two dangers are integrated in one, that is consistent to both. The intervention, once initiated, may need to be further retained, so that the next danger coming soon is also faced and does not re-emerge soon. In other words, the algorithm does not reduce car speed to negotiate safely the curve, only to start braking after the curve because of a slow moving obstacle but handles both dangers simultaneously.

The prioritisation of control actions and warning messages will be performed by the BRAKE and WARNING modules, respectively.

The BRAKE module chooses the biggest (in absolute terms) value of each of the control accelerations, if such exists, and brakes with this maximum value. However, if the resulting deceleration is less than -2 m/s^2, then the system brakes with $-2 m/s^2$. This has been implemented, to speed up the braking process and to avoid braking with very low values for long.

The WARNING module is more complicated. Multiple icons can be switched on at the same time, so this case is simple. The following speech warnings are possible:

1 "CHANGE LANE. APPROACHING CAR"
2 "OVERTAKE WITH VMIN"
3 "DO NOT OVERTAKE"
4 "STAY IN ROAD"
5 "SLOW DOWN. CURVE"
6 "SLOW DOWN. OBSTACLE"
7 "SLOW DOWN OR CHANGE LANE. OBSTACLE"

Warnings 1 to 4 are of higher priority than the rest. Warning 1 corresponds to the situations, when the IN-ARTE vehicle has already initiated the overtaking manoeuvre and has already entered the cautionary distance for the approaching vehicle. The relevant warning is of highest priority. In such a case, only this warning is being given to the driver.

Warnings 2 and 3 derive from overtaking situations (when the indicators are on) and are given in different situations according to the environmental and vehicle data. There is no possibility of contradiction between these two, and again, if such a warning emerges, only this is being given to the driver, as again they are of highest priority.

Warning 4 refers to road departure cases, which again may be dangerous. Therefore, such a warning is being given first to the driver.

Warnings 5 to 7 refer to obstacle handling and curve approaching. Warnings 6 and 7 are exclusive each, namely in each case of an obstacle either Warning 6 is being given or Warning 7. If the system decides in the beginning that lane change is not allowed for this case, then warning 6 is being given during the whole manoeuvre. Namely, this decision (whether lane change is allowed) is being taken only once, in the beginning of the obstacle handling. Also, this decision depends on whether the vehicle is approaching a curve. If yes, then lane change is not allowed. In this notion, the system can not give warning 5 together with warning 7.

After prioritisation and selection are done on the basis of required deceleration and comparison between safety critical and non-safety critical actions, then the proper action is performed by the system through Human Machine Interface or vehicle intervention. Three options exist:

1 In warning mode, only warning messages are generated and no intervention is performed automatically from the system.
2 In warning + intervention mode, warnings are generated as before but also automatic system intervention is allowed.
3 In ACC mode, longitudinal control is delegated to the system and the driver releases the foot from the gas pedal. The vehicle will then automatically slow down or accelerate in front of the given scenario in a comfortable way.

For non safety critical functions, which include speed limitations, traffic signs and lane departure, it was decided to provide only level 1 support through an icon warning, so that the system is less protruding and the driver is free to adjust speed adequately.

For safety critical functions however, which include front obstacles handling and curves approaching, two levels of support are provided, namely warning through speech messages or tactile warnings through a gas pedal jerk, and control (braking of the vehicle).

It was decided to provide only an icon warning, when the speed limit is exceeded by 20% for longer than 2 s, so as to allow also for overtaking manoeuvres handling without warnings. If the current vehicle velocity becomes less than 95% of the speed limit, then the relevant warning will be de-activated and the icon will be switched-off.

The warnings about speed and lateral position were presented either as speech messages or as tactile feedback on the accelerator pedal (for speed-related warnings) or the steering wheel (for lateral position-related warnings). In addition, pictograms were presented on a display in the car for a duration of 10 s (only in the speech and tactile conditions). These were meant to give further information to the driver that could be attended to if desired. Support messages could be of either two levels: cautionary warnings and imminent warnings. Cautionary warnings were issued to the driver when the situation was mildly dangerous. In this case the pictograms on the visual display were given a blue background, see Figure 7 for an example. An imminent warning was given in case of greater danger. Pictograms of imminent warnings carried a red background.

Fig. 7 Example of a pictogram for a cautionary warning (translated: “Lower your speed. Maximum speed 50”).

4.4.4 Acceptance

In a series of driving simulator experiments the IN-ARTE system was tested.
The aim of the three driving simulator studies was to investigate the effect of warning strategies and activation criteria on driving behaviour, workload and driver acceptance. The first study concentrated on the effect of tactile versus speech warnings on driving behaviour, workload and driver acceptance. The second study concentrated on the acceptance of different activation criteria and the third study investigated the effect of strong or weak brake interventions on driving behaviour, workload and acceptance.

Both speech and tactile messages (accelerator or steering wheel) turned out to reduce mean driving speed and frequency of speed violations, but the frequency of severe speed violations was only reduced in case of speech messages. The results suggest that speech warnings are better suited for purposes of law-enforcement, while tactile warnings are better suited for situations that are more directly related to driver safety. In case of lane keeping support, any difference between speech and tactile warnings is not present. The Peripheral Detection Task showed to be very sensitive to momentary variations in workload. Speech warnings resulted in relatively large momentary increases in workload whereas tactile warnings did not result in an increase in workload. It is therefore advised to use tactile messages when possible, especially in situations that require an immediate response of the driver. If speech messages are to be used, the length of the message should be very short. In terms of acceptance, no difference was found between tactile or speech warnings. The frequency of provided warnings was very high. Especially in situations like warnings for stopsigns or in case one decreases headway in order to overtake the lead vehicle, warnings are not accepted by drivers. A reformulation for warnings under those circumstances is highly recommended.

The acceptance of warnings depends highly on the amount of support that drivers’ experience when the warnings are provided and the timing of the warning with respect to a dangerous situation. When warnings are provided either too late or too early, warnings will not be all too acceptable. In order for a driver support system to be successful, the acceptance of drivers should be sufficiently large.

For curve warnings, subjects indicated to experience that the timing of the warning was better in case of curves with the lower design speeds. In practice this indicates that the warning was provided earlier, since a lower design speed resulted in a warning further away from the curve. The timing of a criterion with a deceleration level of 2 m/s^2 was rated best, with criteria with higher deceleration levels being experienced as too late, less supportive and less acceptable. For warnings indicating one exceeds the speed limit, acceptability was not high, independent of applied criterion. The experienced support from these messages was rather low, and timing was considered too early. Based on these results it can be concluded that warnings for speed limit violations are not acceptable to drivers. Maybe only in extreme cases, this warning would be accepted. The evaluation of obstacle warnings is independent of approach speed. The timing, experienced support and acceptability for a deceleration criterion of 2 m/s^2 and 4 m/s^2 and the timing for a criterion with a TTC of 6s score equally well. Messages warning for a braking lead vehicle are also evaluated independently of speed, with the deceleration criteria of 2 m/s^2 and 4m/s^2 scoring best on timing, support and acceptability.

In case of brake interventions, contrary to the already discussed warnings, the system actually intervenes in case of a dangerous situation. The subjective ratings of the system were generally positive. The general tendency was more positive about the IN-ARTE system on motorway sessions than in rural sessions, but comparisons between those conditions are questionable since the judgements are due to both different driver groups and different test scenarios. The system had a speed reducing effect with a high number of brake interventions when the drivers exceeded the speed limit. Analysis of time margins, headway and TTC values were affected by the presence of IN-ARTE system support. Generally longer time margins were observed in supported driving sessions. It may be questioned whether longer time headways in overtaking situations is a positive or a negative effect. Longer headways in supported driving could be an instance of behavioural adaptation to system support—in order to avoid a brake interventions the drivers could prefer to change lane earlier, and thus in the left lane with possibility of meeting traffic. Apparently system support did not result in passivity since the drivers still braked actively in supported sessions. And they also prevented critical scenarios from developing into dangerous situations. The overlap—the degree to which the drivers' reactions matched what the system would have done—between drivers and system ranged from 27% in rural road sessions and 36% in motorway sessions, suggesting drivers use different brake criteria for different types of road. The results also show that drivers who were exposed to automatic brake interventions and experienced a few emergency brakings judged automatic interventions reasonably positive. Only minor effects of intervention strategy and driver age were found. The difference in brake force between intervention criteria was actually very small since many scenarios were critical and the system simulated a technically reliable anti-collision system.

4.5 COMUNICAR (Communication Multimedia UNit Inside CAR)

Partners: FIAT (It.), VOLVO (Sweden), Daimler Chrysler (Germany), Metravib (Fr.), Frauenhofer IAO (Germany), BORG Instruments (Germany), BAST (Germany), University of Genoa (It.), University of Siena (It.), Technical University of Athens (Greece), TNO Human Factors (NL.).

COMUNICAR is a project in the 5th Framework's IST (Information Society Technology) programme of the EU. It started in 2000 and will finish by the end of 2002.
COMUNICAR's main goal is to design, develop and test an easy-to-use on-vehicle multimedia Human-Machine Interface (HMI). Such an HMI will manage the communicative exchange with the driver taking into account his/her workload, the different environment conditions and traffic scenarios. The HMI is an on-board information system that defines how, when, where and in which format to give the messages to the driver. When more than one information message arrives to the driver at the same time, a multimedia device able to manage an increasing amount of information chooses the best way (e.g. visual, acoustical, haptical, etc.) and time to give each message to the driver without decreasing his/her workload and driving performance. The multimedia HMI will be integrated in two vehicles: a FIAT city car and an upper class VOLVO car.

4.5.1 Monitor and measure

The system responsible for managing information priorities is the Information Manager. The Information Manager monitors and measures data coming from four kinds of sources:

1. The environment, with input about the:
   - visibility from the wiper, headlamp and fog light status
   - humidity on the windshield from the air condition
   - road condition with a danger value of ice and snow from the external temperature sensor
2. The driving scenario with input from data concerning traffic status around the car
3. The driver workload by means of the DWE (Driver Workload Estimator), an electronic control unit able to detect the level of activity of the driver primary task
4. The input devices, such as mouse, keyboard, etc.

All these data will be used by the Information Manager to define the best way to provide information to the driver in terms of information layout, output devices activated and input tasks allowed.

Driver workload
The DWE (Driver Workload Estimator) is a neural network developed by Metravib Inc., which elaborates 5 parameters coming from the car: clutch, brake, steering wheel, and blinkers). The neural network processes these primary driving tasks inputs and comes up with a three-level warning output. Green for low workload, amber for average workload and red for high workload.
A prototype of the DWE was already developed and validated before the start of the COMUNICAR project. An evaluation has been carried out in real driving conditions. Data have

been analysed in order to produce a diagnosis of several driving situations centred on a comparison between experts' diagnosis and the automatic diagnosis produced by the DWE.
The experts classified the driving situations in 3 levels of complexity. These three levels have been converted into a code of colours (see also Figures 8 and 9):

- Red for very complex situations that potentially require all drivers' cognitive resources.
- Amber for complex situations that potentially require an important part of the driver's cognitive resources.
- Green for the driving situations that do not present a significant complexity.

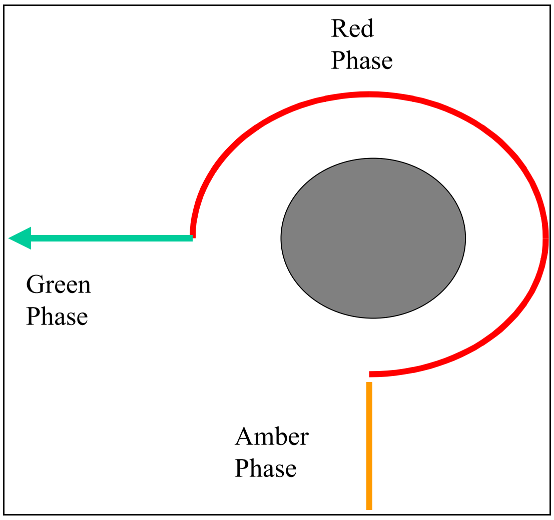

Fig. 8 Example of roundabout coding. Approaching is coded amber, entry and on-the-roundabout is coded red, and post-roundabout is coded green.

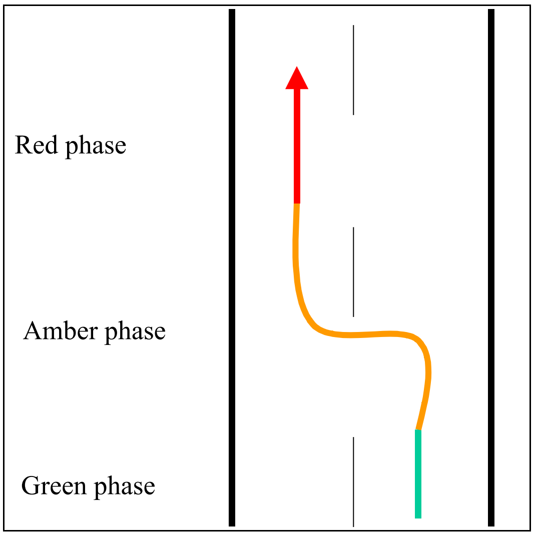

Fig. 9 Example of overtaking coding on the highway. The approaching phase is coded amber, overtaking is coded red, and after-overtaking phase is coded green.

The evaluation of the DWE shows that with a small set of sensors it is possible to evaluate effectively the workload of the driver.

4.5.2 Manage workload

The functions that are managed by the Information Manager are shown in Figure 10. These functions are divided into four categories:

1 Traditional on-vehicle information
2 Entertainments
3 Telematic funcions
4 Advanced Driver Assistant Systems (ADAS).

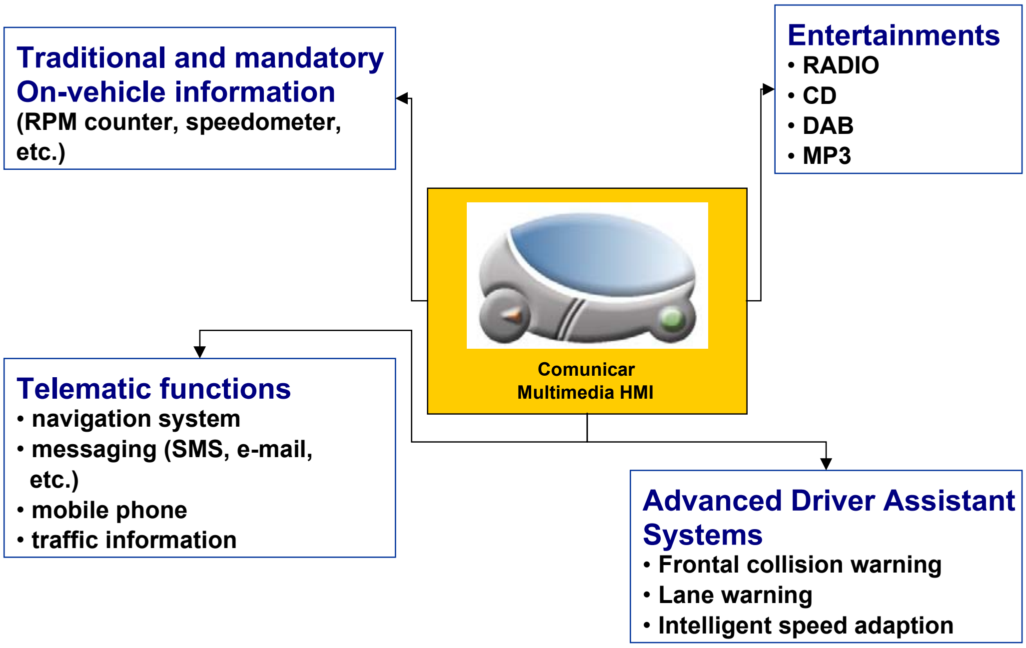

Fig. 10 Functions managed by COMUNICARs information manager.

In order to manage all these functions, the Information Manager (IM) implements sets of rules that define the modalities of filtering the information provided to the driver. The main objective is to give consistent information to the driver, exploiting the various human sensory channels, without overloading or distracting the driver from the driving task. The IM selects the set of rules active at a given moment in time according to the estimated status of the car. Figure 11 sketches the role of the IM as the filtering interface between the automotive and external-world information and the driver.

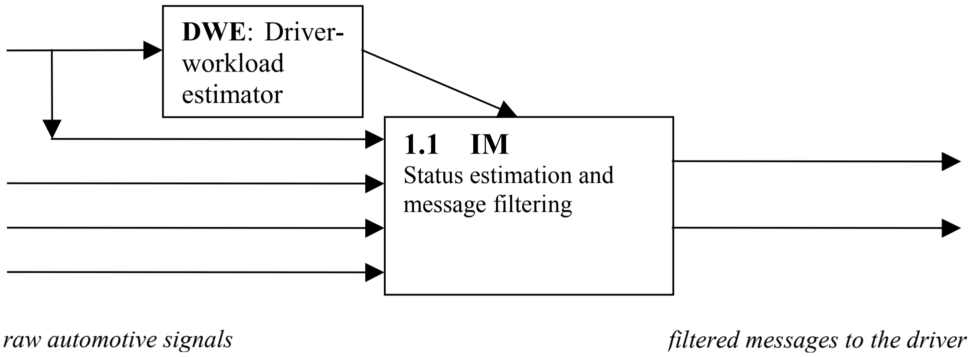

Fig. 11 The information manager as the filter of the information to be provided to the driver.

In the IM algorithm design, the various kinds of information messages (e.g. lane warning, brake failure, e-mail, incoming phone call etc.) have been formalised and mapped to the most suitable sensor channel and output modality. Then, each message has been assigned a priority level (ranging from 1 to 4) and priority-based rules have been defined. A different set of rules is active at a given time, according to a parameter, namely: the *index of risk* (ranging from 1 to 4), which synthesises the status of the car and the driving situation. For instance, when the index of risk is high only the rules concerning high priorities incoming messages are considered by the IM. The final high-level schema of the IM is sketched in Figure 12. The IM does not deal directly with the raw automotive data. Rather, a first module filters these data, selecting messages (i.e. information that changes the status of the car and/or is to be signalled to the driver) from raw data. For instance, it is important to signal that speed has overcome the limits, while it is not necessary that the IM is triggered again (as far as only speed is concerned) until the speed becomes lower than the limits. Thanks to this optimisation, the IM algorithm computation is triggered only when really needed, significantly reducing the impact on processor computation, thus improving the performance. The right side of the picture shows that the output of the IM controls the AutoGraL objects. AutoGraL objects are multimedia software components onto which the dashboard user interface is built.

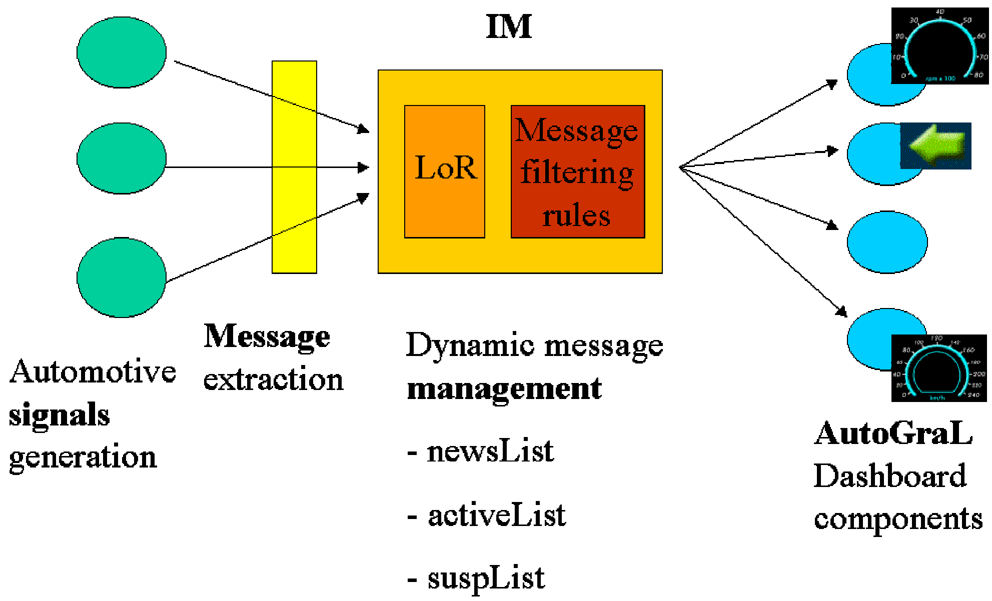

Fig. 12 The information manager and the AutoGraL objects.

In order to effectively manage the flow of information between the driver and the HMI it is necessary to recognize not only the driver workload but also the Index of Risk, which is an integer value $0 \leq x \leq 2$, derived from the merging between the values of the Risk Level and the Time Factor. The Risk Level measures the severity of the damage which can derive from certain driving situations (see Table 9).

Table 9 Indices for the Risk Level.

Risk Level	Index
Injury/death and material damage	2
Inconvenience or legal demand	1
No increased risk	0

Table 10 shows the different levels of Time Factor of a potential accident.

Table 10 Different levels of the Time Factor.

State	Reaction Time	Index
Imminent	< 2 sec	3
Cautionary	< 15 sec	1
Long range	> 15 sec	0
Indifferent		0

Table 11 Presentation of different scenarios.

Data	Relevant sensor	Levels	Risk level	Time factor	IoR
Speed level	Navigation system (defining categories of road) + speed	IN	0	0	0
		OUT of the range > 10%	1	0	1
		OUT > 30%	2	0	3
Presence of potential obstacle	Front radar	Nothing	0	0	0
		Time for collision avoidance <10 sec?	2	1	3
		T c a <5 sec ?	2	3	3
Distance to unintentionally cross the lane	Lane recognition camera	In the threshold of distance	0	0	0
		Out With indicator	0	0	0
		Out Without indicator	2	3	3
Status of fog lights	Vehicle electronics	OFF	0	0	0
		ON and speed < 50	1	0	1
		ON and s > 50	2	0	3
Status of wipers and duration of their activation	Vehicle electronics	OFF	0	0	0
		ON s of the wiper low	1	0	1
		ON Sw high	2	0	3
Time	Vehicle clock / Dark sensor	Night	1		1
		Day	0		0
Outside temperature	Thermometer	Ice	1	0	1
		No ice	0	0	0
Output of traction control	ASR	Danger	1	0	1
		No danger	0	0	0

As we can see from Table 11 the value of the Index of Risk (IoR) is the maximum between the Risk Level and the Time Factor Value. When the Level of Risk has value 2 the Index of Risk has always the value 3, because the level 2 of the level of risk means a really dangerous scenario which needs to be considered of the highest priority. Table 11 presents different scenarios related to potentially unsafe driving conditions: in the first column there are the data coming from the vehicle and its sensors, in the second the list of sensors able to detect information about driving scenarios. The third column shows the possible levels of collected data. The Risk Level and the Time Factor related to each scenario (data + level) are provided in columns 4 and 5. The 6th column shows the Index of Risk, which is the higher level between the Risk Level and the Time Factor. Possible values for the Index of Risk are 0, 1, 2, and 3, because of the matching between values of the Risk Level (0, 1, and 2) and the values of the Time Factor (0, 1, and 3).
The next step consists in the functional merging of the value coming from the Driver Workload Estimator (DWE) and the value obtained through Environment Evaluation (Index of Risk). In this way the full range of priority levels is used and a better separation between the different priority levels is achieved. The final result has four levels.

If one of the two parameters shows that the driver is in a difficult condition (high workload or high risk) then only high priority messages should be given to the driver. The merging between the DWE states and the Index of Risk is considered to address the correct information through the HMI. So messages are delivered to drivers according to the environment evaluation (Index of Risk) and to the primary task evaluation (DWE Value).

4.5.3 Adaptive Interface

The COMUNICAR multimedia HMI is based on two different areas located along the dashboard.

The first one is in front of the driver and it provides the traditional information of the panel cluster (e.g. speed, rpm etc.), the warning functions (e.g. frontal and lateral collision warnings) and all the messages that can be considered safety critical (i.e. priority 1). To permit that so many and different kinds of information can be grouped together, the output device located in this area should be totally reconfigurable (LCD).

The second area is located in the centre of the dashboard given that an overall information flow, shareable between the driver and the passenger, has to be assured. This area is mainly devoted to the telematic and the entertainment functions.

Two types of multimedia HMI lay-outs for the central display were developed: a haptic display (see Figure 13) and a visual display (see Figure 14) Both prototypes are designed to operate integrated functions such as navigation, lane warning, traffic information, mobile communication and entertainment functions.

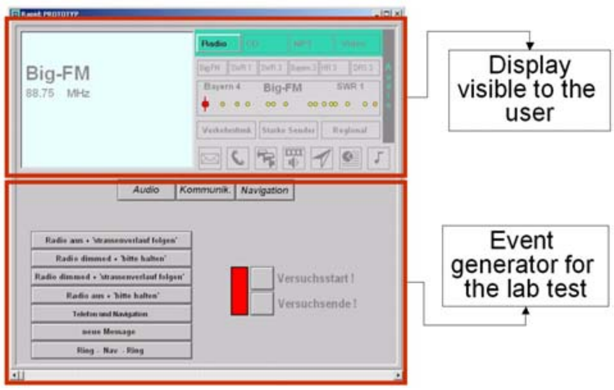

Fig. 13 Haptic prototype display.

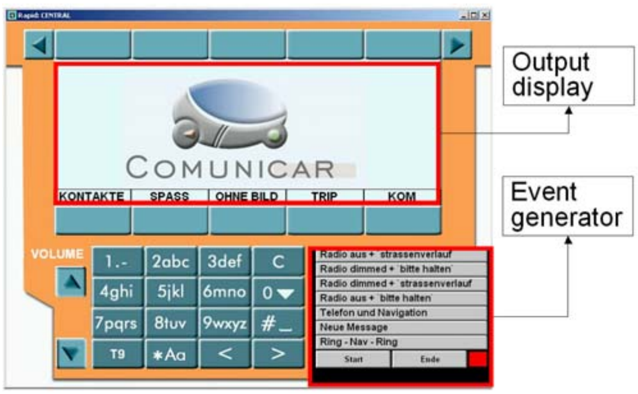

Fig. 14 Visual prototype display.

4.5.4 Acceptance

In the test and validation methodology of COMUNICAR the laboratory tests represent the first set of tests in the validation phase. They are followed by driving simulator tests of more elaborated prototypes and on-road tests of prototypes in demonstrator cars.

The laboratory tests can be considered as a part of the iterative design process of the multimedia HMI in COMUNICAR. The pre-tests conducted gave feedback to the design and prototyping work. The result of the main tests are an input for the further HMI development in and the development of the Information Manager software.

In comparison to the further validation in simulators and on the road, testing in the laboratory will only allow for a rudimentary representation of the driving task. For this reason, the impact on workload and safety in the real traffic environment cannot be assessed. Conclusions on workload and safety can only made in an indirect way, when HMI variants are compared.

The virtual prototypes of the multimedia HMI have been tested in two rounds of laboratory experiments, the pre-tests and the main lab tests. The pre-tests were carried out as desktop experiments using the virtual prototypes together with commodity hardware and also with special interaction devices with haptical feedback. The main tests were performed in a simulator environment.

From the main tests of the Virtual and Haptic prototypes, it can be concluded that both are principally suitable for further development. A tendency was found for the Haptic Prototype to be better accepted. Concerning the required operation times the Visual Prototype performed better unless extensive text input is required. A task-by task analysis makes evident that the workload is rather influenced by the type of task to be performed than by the interface design used to perform this task.

5 RELEVANT NON-EU PROJECTS

5.1 The PROMETHEUS Program

Most results of the PROMETHEUS Program are still not open literature. In the area of adaptive and integrated supports there appears to be one exception, which is the ‘DAISY’ (Driver Assisting System) Project, of which there is some limited material available (Onken & Feraric, 1997).

DAISY aims at providing driver-adapted warning messages on the basis of the behavioural model of the actual person driving. It contains the following components:

The Situation Analysis Module (SA). This performs an analysis of the traffic situation by classifying it by looking at situational features which are relevant with regard to the actual driving task. Examples of situation models are car following and lane keeping/overtaking. These models are vectors that include sensor measurements of the vehicle itself, road parameters, and

information about other vehicles. It is not described in the available sources how this is actually accomplished.
The Model of the Actual Driver (MOAD). This is based on an approach that uses artificial neural nets, including a (real-time) learning module. This uses very simple parameters to base its learning on: for the lateral control it is the steering wheel rate and for longitudinal control it is the brake and gas pedal position.
The Warning System (WS). This mainly uses haptic and vibration actions on the steering wheel (including a torque signal in the correct direction), as well as on the accelerator.

It is difficult to judge from the available information how much of DAISY has actually been implemented. Neural networks have since been applied in related settings, notably the detection of driver hypovigilance on the basis of the 'normal' driving pattern of individual drivers (e.g., Dillies-Peltier, 1997). And some of the ideas in the project have shown up in other initiatives, notably COMUNICAR.

5.2 CO-DRIVE (COoperative DRiving in an Intelligent Vehicle Environment)

Partners: TNO Human Factors, TNO Automotive, TNO Inro, TNO TPD, TNO FEL.

The CO-DRIVE project, which started in 2001, centres around the issues of providing the driver with useful information by means of new car-related services, while at the same time helping him in anticipating his behaviour and activities. The project's aim is to develop a state-of-the-art open ICT (Information and Communication Technology) platform on which intelligent ITS services can be implemented safely because an "intelligent co-driver" will assist the driver in prioritising the messages according to the traffic conditions and the driver workload.

5.2.1 Open state-of-the-art platform

The ICT platform in the CO-DRIVE car will comprise a system of interlinked computers, together with sensors, mobile communication facilities and driver interfaces. The platform provides for transparent communication between the software components of the different information services, enabling new services to be efficiently integrated (plug & play).
An open ICT platform makes it possible without driver intervention to gather details about the car (speed, journey time) at the lowest level and to disseminate this to receivers outside the car (other cars, traffic management centres).

5.2.2 Manage workload

BIBI—the acronym stands for Supremely Intelligent Co-driver Interface—is the intelligent right-hand of the driver that provides him with access to the various intelligent systems he has in his car. In doing so, BIBI acts as a filter, balancing the use of information services with the attention the driver needs to pay to driving in order to do so safely.

BIBI is the priority algorithm that ensures that the driver can get and process information safely. BIBI determines when a service can give information to the driver and, in certain cases, in which form (for example, visual, auditory or haptic) it has to be conveyed. This enables the information that has to be processed by the driver to be appropriate to the situation in which he finds himself and prevents him from getting several messages at the same time. BIBI is being designed as an open concept, with the possibility to upgrade certain services or supplement new services in the prioritising algorithm.

BIBI has three subfunctions:
1 To estimate the traffic risk
2 To estimate the workload
3 To set priorities.

1 Subfunction 'to estimate the traffic risk'
This function estimates the momentary risk (R) at a value between $0 \leq x \geq 2$. This can be seen in the example shown in Table 12.
0 = normal situation
1 = cautionary case
2 = imminent case.

Table 12 Example of the various risk estimates.

	Level	R
Speed & GPS	Within limit	0
	Outside limit > 10%	1
	Outside limit > 30%	2
Obstacle present?	None	0
(time to collision)	TTC < 10 s	1
	TTC < 5 s	2

2 Subfunction 'to estimate the workload'
How the driver's momentary workload (W) can be estimated is still unclear. Probably the DWE (Driver Workload Estimator) from the EU project COMUNICAR will be used (see also section 4.5.2). In this system an estimation of the momentary workload is given, based on fuzzy logic and inputs like speed, acceleration, breaking, steering and clutch, at a value between $0 \leq x \geq 2$:
0 = low workload
1 = middle workload
2 = high workload.

3 Subfunction 'to set priorities'
For each type of message that can be issued by the various services, BIBI assigns a priority value (P). This function has a table that can be extended and looks like the one presented in Table 13.

Table 13 Example of various information priorities.

	Level	P
Navigation message	Acting within 50 m	2
	Acting above 100 m	3
Travel tips from travel guidance	All	3
Email	Sender with personal preference	2
	Sender without personal preference	3
Telephone	Sender with personal preference	1 (highest)
	Sender without personal preference	2

The proposed algorithm that this subfunction continuously calculates is simple:

If max(R,W) = 2 **Then**

only information with the highest priority is allowed through (P1).

If max(R,W) = 1 **Then**

only information with priority 1 (P1) of 2 (P2) is allowed through

If max(R,W) = 0 **Then**

all information is allowed through

If information to be allowed through > 1 **Then**

first P1, then P2, then P3

NB: References to ‘allowing information through’ also include information that the driver wishes to enter.

On the basis of this changing priority, a service can be postponed by BIBI.

5.2.3 Adaptive interface

Each service takes care, in principle, of their own interface with the drivers. So each needs permission from BIBI that is able to delay or postpone the services by making them temporarily inaccessible on the basis of the calculated priorities. As soon as the primary workload of the driver allows it, BIBI will reconnect the service again. BIBI has its own graphic interface for the driver so that the driver can modify his preferences.

Each service can independently exchange information with the driver. All the possible messages that come from a service have a certain priority level. Depending on the current situation on the road (e.g. heavy traffic, close following, icy roads), it is decided which priority level messages are presented to the driver. This means that an incoming email is postponed when a high priority warning comes in. BIBI is the service that prioritises the messages according to internal algorithms.

BIBI prioritises the various services and tailors the information that the driver is given to his workload at that point in time. In this way, BIBI determines whether a service is given access to the driver at a certain moment, but is not responsible for the message content. Figure 15 gives an indication of the global design of the interface.

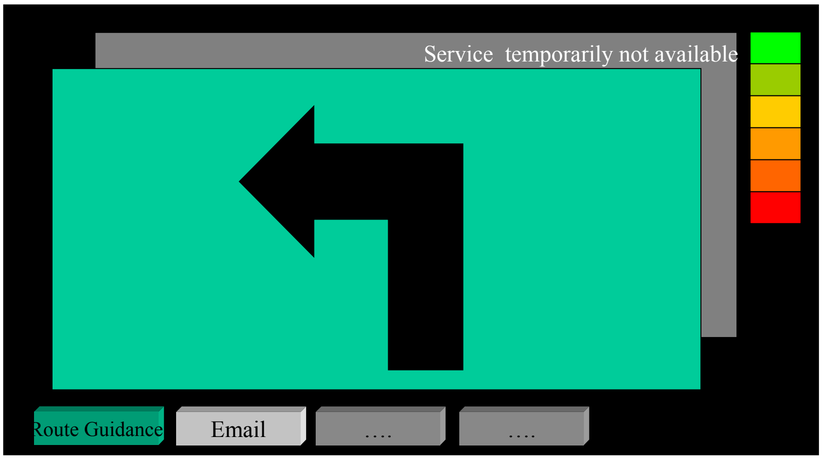

Fig. 15 Global design of the adaptive interface of the CO-DRIVE display.

Every service can use the green window with their own interface. When this window is on top, BIBI has approved of using this service. The lower buttons are for the driver to indicate that he wants to use one of the available services. A green button indicates that this is the active service. A white button indicates that this service is not active but still available to be activated by the driver (because BIBI sees no problem in terms of workload and priorities). A grey button indicates that this service is currently not available, because it is overruled by BIBI. The message “service temporarily not available” is sent to the display by BIBI whenever this service is disrupted and put to the background.

5.3 Vibro-Tactile Information Presentation in Automobiles

Since most information in driving is presented via the visual channel, employing other sensory modalities may be a major step to accomplish safety improvements. One of those channels is the tactile channel. Technological developments in the field of driver support systems and tactile displays, combined with the ever increasing need to enlarge the capacity of the driver’s information channel, lead to promising applications.

Vibro-tactile displays in general consist of arrays of vibrating elements coupled to the skin. Appropriate stimulation of specific receptors in the skin by means of applying localised vibration typically leads to a ‘tickling’ sensation at that specific location. Human vibro-tactile perception is sensitive to location, duration, frequency, amplitude and several other (derived) aspects of vibro-tactile stimulation.

Advantages of the tactile channel are, amongst others, that it is always ready to receive information, that it draws attention, that it is private, and that it can be used in a natural and intuitive way. The latter is of course dependent on the kind of information that is presented. Examples include displaying object properties such as roughness, and variants of a ’tap–on–the–shoulder’ to present navigation information. Another good reason to incorporate the vibro-tactile channel in MMIs is that adding the tactile modality may enlarge the total effective information processing capacity of the user. It may thus free the overloaded auditory and /or visual modalities, and may thus constitute a welcome addition to the feasibility of designing integrated supports.

In several of the projects described in the main section of this report simple tactile supports have already been used, notably in the form of vibrations and/or torque signals on the steering wheel. What is the issue now, however, is to start using the tactile channels for informative or warning signals that have real content and complexity. Preliminary studies (Van Erp, 2001) indicate the usefulness of tactile devices in more complex forms. A further expected development will then be the in-vehicle application of multimodal supports, which not only cover the ‘classical’ modalities but the ‘new’ modalities as well.

6 CONCLUSIONS

It may have become apparent from the reviewed projects—which were the major ones that have been performed in this area in Europe during the last decade—that they do not follow one unified approach, and neither have they agreed yet on a common set of principles that are specific enough to conclude that there is **the** European adaptive interface. Nevertheless, progress has been made along a line of thinking that tries to be both scientifically sound and ultimately applicable in the real world. The EU-Programs in the relevant areas are to be credited for bringing industry and research institutes together at an early stage.

6.1 Monitoring and measuring

There are a multitude of measures available to monitor driver state over an extended time (minutes and longer) period. However, pinpointing a driver’s momentary workload in a moving vehicle requires very specific methodology. Here the European researchers appear to have taken a pragmatic approach, as follows:

1. There is a general feeling that efforts to monitor momentary driver workload by more or less intrusive means will not succeed, or will never be suitable for practical applications.
2. What is concluded to work is either of two approaches:
   - Estimating workload from the driver’s actions on the controls, and their consequences.
   - Estimating workload from a ‘look-up’ table that contains the factors attributing to work-load and their weights.

In the more recent research projects, the first of these approaches seems to have become somewhat more popular. What we will probably see is that a combination of the two categories will be developed, and that this is then the type of solution that will be implemented in European automobiles.

6.2 Management (term not clear)

In several projects the decomposition of workload, in terms of where its constituent elements originated from, has been resolved on at least the pragmatic level. That is, quantitative indicators have been defined that represent the relevant driver characteristics or states on the one hand and the state of the outside world on the other. Examples of the indicators that are used for driver status are: use of clutch, brakes, steering wheel and blinkers turn signals. Examples of the indicators that are used for the state of the outside world are: wiper status (is it raining?), fog lights, speed level (in– or outside the maximum speed range) and time (is it dark outside?). These indicators are easy to come by, or with a little additional effort at most.

6.3 Adaptive interface and de-cluttering

Within the major projects reviewed, fairly sophisticated but nevertheless pragmatic strategies for adapting the content and the timing of supports to the present state of the driver (and his vehicle) have been developed and—partly—evaluated.
It may be appropriate at this time to summarise what are the conclusions within Europe on what is the bandwidth that supports—systems that relieve a driver from executing parts of the driving task—should act in.
Driver support systems can cover a full range from systems providing information, advice and warnings, through systems that assist and/or intervene in vehicle control and manoeuvring tasks, all the way to systems that support fully automatic driving. Considerable research has been devoted to finding the behavioural and safety optimum, in case of systems that permit a choice to be made on this dimension (e.g., collision warning/avoidance systems). For example, one particular empirical study within the GIDS Project (Janssen & Nilsson, 1990) found that a CAS that uses a TTC (time-to-collision) criterion and is followed by an activation of the gas pedal has the most beneficial effects on behaviour: it produces the desired effects in critical situations, and it does not suffer from side effects like counterproductive adaptation (which some other forms of support did).
Recently, however, issues of liability have become more prominent in the determination of the most appropriate choice. In the RESPONSE-I project in particular, in which car makers, law firms, and human factors specialists co-operated, much emphasis was put on car maker's product liability. Here it was concluded that when a car maker creates the impression in the driver that there is a system in the vehicle that takes over parts of the primary driving task, there is product liability in case an accident happens if the system—for whatever reason—fails.
As a result of this line of reasoning, European car makers have become hesitant in moving towards the further development of actively intervening supports, such as lane departure interventions.
It is also the case, moreover, that some car makers feel that intervening systems take away a basic quality of driving an automobile that is appreciated by the public. Driving would then tend to be seen as a boring activity, which car makers do not consider as a contribution to market attractiveness.

6.4 Acceptance

In the major projects reviewed here, relatively little attention appears to have been devoted to acceptance issues. This is somewhat surprising since, at the same time, the procedure proposed by Van der Laan et al. (1997) has gained widespread recognition within Europe as a tool to index acceptance. This procedure asks subject drivers/prototype users for their ratings on two sets of bipolar items. One set (useful–useless, good–bad, effective–superfluous, helpful–worthless, raising alertness–sleep-inducing) indexes the 'usefulness' of the device. The ratings on these items, to be made on a scale from –2 to +2, are averaged to determine the scale value on this dimension. The other set (pleasant-unpleasant, nice-annoying, likeable-irritating, and desirable-undesirable) are similarly rated and averaged to obtain an overall satisfaction/attractiveness judgment. Thus, the scrutinised support is ultimately positioned in a two-dimensional space which decomposes acceptance into two primary attributes. This procedure, however, appears to have been applied outside the reviewed projects only, that is, in studies that have investigated the parameter setting of isolated rather than integrated supports.

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APPENDIX A

In this appendix the European projects are briefly described that, though not directly related to research questions on adaptive interfaces, touch on some of the elements that are involved.

A.1 HOPES (Horizontal Project for the Evaluation of Safety)

Partners: Swedish National Road Administration (Sweden), University of Lund (Swe), ITS Leeds (UK), University of Munich (DL), Traffic Research Centre, Groningen (NL), Chalmers University of Technology (Swe), University of Cork (UK), Technical Research Centre of Finland, SWOV (NL), TUV Rheinland (DL), INRETS (Fr).

The objective of the project, which ran from 1992 to 1994, was to provide a framework for safety evaluations of Advanced Transport Telematics implementation within DRIVE II and to integrate safety evaluation results that came out of the different pilot projects. The project covers both Man-Machine Interaction (i.e. usability) and Traffic Safety (i.e. the overall safety effect of the system in actual operation). A specific investigation is carried out in relation to safety aspects of improving roads of low standards by implementing ATT systems. In relation to the scope of the current project specific attention is given to the Man-Machine Interaction Safety Analysis portion of the project HOPES since this aspect of the project has the most relevance for issues around adaptive interfaces in the light of driver workload. However the outcome of HOPES is more relevant in relation to the different European projects within DRIVE II that HOPES evaluated. Therefore outcomes of HOPES are discussed in relation to the specific project. What follows here is a short description of the methods used by HOPES while evaluating safety factors of MMI.
After a screening process projects that were relevant for further investigation were selected. A selection was made such that all the major areas of interest, as defined in the DRIVE II work plan, were covered. The consecutive screenings were done in two stages with specific help of the investigators in the pilot projects themselves. In the first stage a short review was done based on the specific aims of the projects, the area of interest, level of traffic system, tasks or subtasks addressed, applications to be implemented, and information available about MMI function regarding system performance, system effects, usability, user characteristics and behavioural effects. As a result of this stage a more extensive review of selected projects was done in the second review stage. The second review list contained an extensive set of detailed questions concerning:

- Activation and timing of the application
- User action and system output relations
- Dependence of MMI aspects on functioning of other system elements
- System malfunction
- Task matching
- Sensory and response modalities proposed
- Compliance with ergonomic standards
- User error resistance
- Adaptability to user characteristics
- Workload
- User acceptance and ease of learning
- Behavioural interference, adaptation and compensation
- Behavioural transfer, diffusion and isolation effects.

A.2 HARDIE (Harmonisation of ATT Roadside and Driver Information in Europe)

Partners: TRL (UK), INRETS (Fr.), HUSAT (UK), SRC (UK), TUV-Rheinland (Germany), TØI (Norway).

The aim of this project (1992 – 1994) was to produce a handbook of Human Factors guidelines for Advanced Telematics Transport (ATT). This handbook provides a reference source for designers and summarises best human practice. It proposes recommendations for the presentation of information to drivers based on:
- Understandability, usability and safety
- The role of audible and visual information
- Harmonisation of text and symbols
- Harmonisation with externally presented information.

From the resulting HARDIE design guidelines handbook (see the deliverable 20 for all the detailed guidelines) the most important guidelines are stated here:

Visual
- Whenever it is possible, pictograms from the transport environment and roadside signs should be used rather than text messages.
- When a symbol has a key role in the meaning of a road and traffic message, its understandability among a sample of future users should be tested.
- Whenever the space available is sufficient, abbreviations should be avoided.
- If road and traffic information is to be displayed on a colourful map, the location of the event should be easily identifiable as information added to the road network.

Auditory
- A tonal message should be used for attracting attention, and for delivering a preparatory message. It may also be selected to deliver a general information such as “attention” or “danger”.
- The number of tonal signals used in a car should be limited to 3.
- Speech coding should be chosen instead of tonal code when it is necessary to provide precise information.
- The delay between the message and the expected action must be considered to define the length of a message.
- Audible cues should lie in the range of 500 to 3000 Hz.
- The driver should be able to request a repeat of an auditory message.

Both
- Whenever possible, both auditory and visual modes of R&TI presentation should be provided.
- It is recommended that the auditory mode can be switched off or on by the driver.
- Use visual information when the delay between the message and the expected action is long.
- Use auditory information for the messages which ask for immediate or nearly immediate action.

General
- Whilst driving, the driver should not be required to manually zoom in and out to different scale levels. Instead the system should automatically present the optimum of usable information.
- The structure of the menus should be logically organised and oriented to the driver’s demands (e.g. the most frequent function should be easiest to select).

- It should be possible to select according to different levels of system experience (novice vs. expert).

A.3 HINT (Human Implications of New Technologies)

Partners: University of Leeds (UK), VTT (Finland), ARISE (Swe), British Aerospace (UK), University of Lund (Sweden), TNO Human Factors (NL), OCTAV (Hungary), University of Coimbra (Portugal).

The purpose of the project (1997–1999) was to develop a European strategy for managing the human and organisational impacts of the new support technologies in transportation likely to be implemented over the next 10–20 years. The objects were:
1 To identify the relevant technologies;
2 To investigate the human factors, organisational and safety implications of these technologies and;
3 To develop a strategy for managing those impacts.
All the transport modes were addressed as well as inter-modal travel by passengers. For the current project however (Review of European Human Factors Research on Adaptive Interface Technologies for Automobiles), only that part of the HINT project discussing the automobile transportation mode is reviewed.
The project HINT has approached the human and organisational issues facing transport with the introduction of new technologies in two ways:
1 By looking at how tasks in the traffic system are being affected and changed by new technologies.
2 By looking at how transport and travel services are being affected by those technologies.

The work structure was to identify technologies to be evaluated as well as to develop an analytical framework. With this framework some technologies would be evaluated at a broad level and some more detailed. The detailed studies were related to four areas of interest: 1. Traffic Info and Control Centres; 2. Information and the Operator; 3. Automatic and Semi-Automatic Control; 4. Transport Services and Modality.

A.4 STAMMI (Definition of Standards for the In-Vehicle MMI)

Partners: INRETS (France), MERIT (Spain), Yard Ltd. (UK), Lougborough University of Technology (UK), TÜV (Germany).

The STAMMI project (1988–1991) aimed to provide knowledge towards the development of European standards for in-vehicle man-machine interaction.
A review of existing European and International standards revealed that most standards deal with the hardware aspects of the system. Very few consider the software issues of HCI and information presentation and the majority of those that do consider those aspects are not directly applicable to the in-vehicle environment (see for details Deliverable 2.1). Important areas of system design for which standards do not exist are the dialogue interface, the tool interface (manipulation of the system) and the universals of information presentation, such as human perception and information overload. Activity in Office Ergonomics is reviewed with the idea that work in this area on usability statements of, for example, displays etc., could have potential for adaptation in the vehicle environment. Specifically ISO 9241 might have that potential.
Supporting information for standards was gathered by means of a review of driver's functional abilities and a typology of French Drivers. Measurement of ambient conditions such as noise

and lighting conditions within the vehicle environment were taken to explore the adaptation of the ISO 9241 standards from the office to the vehicle environment.
The vehicle lighting environment differed from that in an office in two ways: range and adaptability. A wider range of illumination levels is found in the vehicle environment than in the office. Displays to be used in vehicles must be designed according to the harsher lighting environment in which they will be used. The greater variability and unpredictability of light directions and intensity in the vehicle provides a challenge to the designers of display technology for use with RTI systems. Conditions can suddenly change from direct sunlight to sudden darkness (tunnels). The information presented on such displays will need to be clearly visible at all times if the systems are to be acceptable for drivers. Additionally, auditory information might in some conditions be needed to support the visual information specifically in adverse lighting conditions.

One of the essential objectives of this project was the development of a Criteria List for the man-machine interface of information systems in vehicle in order to: support the design of safe and useful systems, and contribute to a basis for discussion and consensus concerning evaluation and standardisation of MMI for such systems. The list has two parts: the first part gives criteria for a particular system in order to check whether the intended use of the system is conveyed and usable in its design. The second part contains the detailed MMI criteria that have to be taken into consideration during the design and evaluation of an in-vehicle information system. The list is structured into four parts:

a. Physical Interface
b. Human Computer Interaction
c. Information Presentation
d. Installation.

Overall it is however important to consider that the Criteria List only serves as an evaluation for the particular system of interest and not for the whole cockpit. As such the list should be considered as a starting point and should be developed and discussed further, specifically in relation to criteria necessary to check the different combinations of systems in a cockpit.

A.5 HASTE (Human Machine Interface And the Safety of Traffic in Europe)

Partners: University of Leeds (UK), TNO Human Factors (NL), University of Delft (NL), MIRA (UK), Volvo (Swe), VTI (Swe), VTT (Finland), University of Minho (Portugal), Transport Canada (CDN).

The recently (January 2002) initiated HASTE Project is the major EU follow up of the ‘Statement of Principles’. It is focussed on addressing the influence of task load on driver behaviour. Its aim is to develop a procedure to quantify safety problems with in-vehicle information systems with a view that this procedure can eventually become the basis for an objective performance standard. It explicitly rejects checklist approaches as a basis for the judgment of HMI design, because they are in the main subjective and cannot provide a certainty that a minimum level of safe performance in driving has been met.
Co-operation with the Northern-American CAMP initiative is envisaged.

There is little in the HASTE Workplan that will be specifically applicable to the design of adaptive interfaces. Instead, the project deals with the limitations to be put on driver workload in general, and on the development of procedures for assessing whether any (prototype) in-vehicle system does actually stay within these limitations. It is, indeed, primarily to be seen as a step towards the further concretisation of the ‘European Statement etc.’ What it will eventually have to say on the measurement of momentary workload itself will, of course, be relevant to the present issues.

A.6 ROADSENSE

Partners: Jaguar (UK), Fiat (It.), Porsche (Germany), PSA (France), Renault (France); CNRS (France), Cranfield Institute of Technology (UK), TNO Automotive and TNO Human Factors (NL).

This project is HASTE's direct competitor, originating as an initiative from the automobile industry rather than the EU itself. It will develop guidelines for the methods of HMI tests that measure the effects on driver behaviour that any technology, or combination of technologies, will have. It wants to produce a 'Code of Practice' that the European motor vehicle manufacturers will adopt. The project started in February 2001, and it has not yet yielded results that are public.

APPENDIX B

By way of summary, the reviewed projects and initiatives are positioned along the relevant timeline (starting in the 1980s).

	EU Projects on adaptive interfaces	Other EU HMI projects	Non-EU Projects
1980–1989			• PROMETHEUS
1990	**DRIVE-I:** • GIDS	• STAMMI	
1991	**DRIVE-I:** • GIDS	• STAMMI	
1992	**DRIVE-I/DRIVE-II:** • GIDS • ARIADNE	• HOPES • HARDIE	
1993	**DRIVE-II:** • ARIADNE	• HOPES • HARDIE	
1994	**DRIVE-II:** • ARIADNE • GEM	• HOPES • HARDIE	
1995	**DRIVE-II:** • GEM		
1996			
1997		• HINT	
1998	**4TH Framework:** • IN-ARTE	• HINT	
1999	**4TH Framework:** • IN-ARTE	• HINT • Statement of Principles	
2000	**4TH / 5TH Framework:** • IN-ARTE • COMUNICAR	• Expansion of Statement of Principles	
2001	**5TH Framework:** • COMUNICAR	• Expansion of Statement of Principles • ROADSENSE	• CO-DRIVE
2002	**5TH Framework:** • COMUNICAR	• Expansion of Statement of Principles • HASTE • ROADSENSE	• CO-DRIVE
2003	**(6TH Framework:)**	• HASTE • ROADSENSE	• CO-DRIVE
2004		• HASTE	