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Abbreviations

ADAS: Advanced Driver Assistant Systems
BAST: FEDERAL HIGHWAY RESEARCH INSTITUTE
BORI: BORG INSTRUMENTS
CAN: Car Area Network
CRF: CENTRO RICERCHE FIAT
DC: DAIMLERCHRYSLER
DIBE: UNIVERSITÀ DEGLI STUDI DI GENOVA
DSRU: Driver Status Recognition Unit
DWE: Driver Workload Evaluator
ESoP: EC Recommendation on safe and efficient in-vehicle information and communication systems: a European statement of principles on human machine interface
FHG: FRAUNHOFER Institute
ICCS: INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS OF THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS
IM: Information Manager
LCD: Liquid Crystal Display
HMI: Human Machine Interface
MITO: Multimedia Innovative Telematic Observatory
MVIB: METRAVIB RDS
MMMPlayer: MICROMULTIMEDIA Player
OEM: Original Equipment Manufacturer
RPM: Revolutions per Minute
SW: Software
TIP: Technological Implementation Plan
TNO: NETHERLANDS ORGANISATION FOR APPLIED SCIENTIFIC RESEARCH
UCD: User Centred Design
UNISI: UNIVERSITÀ DEGLI STUDI DI SIENA
VOLVO: VOLVO CARS CORPORATION
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Project overview

Statistics show how in Europe the road accidents cause around 45,000 deaths and 1.5 millions injured people - involving social costs for around 45 billion Euro - every year. On the other hand, the market demand and the technological trend of these years are offering new functions and devices for the next vehicles’ generation. As a consequence, the number of information that can be provided to the driver is going to grow rapidly.

Without a strategy for the information management which permit to not overload the drivers (as recommended by the “EC Recommendation of 21 December 1999 on safe and efficient in-vehicle information and communication systems: A European statement of principles on human machine interface” [ESoP]) and without an integrated in-vehicle user interface where the input and output devices as well as the system functionality are highly usable, all these pieces of information given to the driver could represent a source of distraction endangering driving safety.

Both these issues (information management and high usable integrated in-vehicle HMI) are becoming relevant into the automotive field; furthermore, because of their expected positive impact on improvement of driving safety, they also support the achievement of the main goal of European Union policies in this domain.

Moving from this scenario, the COMUNICAR project (COmmunication Multimedia UNit Inside CAR) has designed, developed and tested an integrated multimedia Human-Machine Interface (HMI) able to handle the following functions: (1) mandatory and traditional vehicle information (speedometer, RPM counter, vehicle warnings, etc.); (2) advanced driver assistance systems (ADAS) (i.e. lateral and longitudinal collision warning); (3) telematic services (i.e. navigation, traffic information, phone, messages, etc.) and (4) infotainment (RADIO, CD, MP3, etc.).

All these pieces of information are provided to the driver according to the driving conditions and his/her workload thanks to a rules-based system named Information Manager (IM). It chooses in real time if, when and in which format each incoming message has to be delivered to the driver and how the possible overlapping among contemporary information can be solved.
In the meanwhile, the integrated multimedia HMI permits to control a relevant amount of functions with a reduced number of devices because of the integration of innovative input and output devices (e.g. LCDs, haptic switch, etc.) and the development of highly usable visual and acoustical HMI layouts. The entire system usability depends on the general design approach adopted since the beginning of the project. This is called “User Centred Design” methodology and is aimed to involve the users (reaching their wishes and needs) into the entire HMI design process. Therefore, a wide test campaign in different environments has been conducted, namely: (1) a multi-techniques user needs analysis; (2) several laboratory tests to verify the HMI usability; (3) a driving simulator test, to check the impact on the driving safety; (3) two road tests (in Italy and Sweden) for the final system assessment.
1. Project objectives and approach

1.1 Summary of the main achievement

COMUNICAR project was aimed to design, develop and test an on-vehicle integrated multimedia HMI (Human Machine Interface) able to handle different drivers’ information. The pieces of information have been grouped in 4 sets: the mandatory and traditional vehicle information (speedometer, RPM counter, warnings, etc.), the innovative functions for the driving support (the so-called Advanced Driver Assistance Systems (ADAS) such as the lateral and longitudinal collision warning), the telematic services (e.g. navigation, traffic information, phone, messaging etc.) and the entertainment (RADIO, CD, MP3, etc.)¹.

![Functions classification of the COMUNICAR multimedia HMI](image)

The simultaneous information coming from all these systems can be an benefit for the driver and the entire mobility domain - in terms of safety, comfort and

¹ This classification has been adopted since the beginning of the project and it has represented a useful way to handle the entire design process. Further project proposals (including the 6FP
improvement of the alertness - if the HMI is able to choose in real time if, when and how one or more messages, warnings, information can be provided to the user according to the driving conditions and the driver workload. Therefore, the COMUNICAR HMI is not only an integrated HMI but also a system to filter the information delivering. This role is played by a specific SW unit named Information Manager (IM) which is able to select if an in-vehicle information can be provided, which is the best format to improve its effectiveness and how the possible overlapping among contemporary messages can be solved. For instance, if the driver is approaching a difficult manoeuvre (e.g. a roundabout) and in the meanwhile a phone call is arriving, the system postpones the incoming call till the manoeuvre has been completed (i.e. few seconds later).

The HMI - including the Information Manager - has been designed and tested with an iterative user-centered design (UCD) process where laboratory, driving simulator and on-road tests have been carried on. To achieve these goals, different system prototypes (from the first sketches to the final vehicles) have been developed.

![Figure 2 – Volvo S60 and Alfa Romeo 147 prototypes with corresponding dashboard](image)

In more details, the main scientific and technological aims of the project are listed below:

Integrated approach “AIDE”) is continuing with the same approach and in literature, this model has been frequently adopted (see for instance the results of the ADASE HMI workshop [ADASE 2002].
• to study and assess the driver needs in terms of driving and mobility related information;
• to identify the best format per each traditional and innovative information that can be handled by a in-vehicle HMI within four main sets: vehicle messages, Advanced Driver Assistance Systems (ADAS), telematic services and entertainment;
• to find a set of rules and algorithms to handle the information delivering and to solve possible overlappings among messages according to the different driving conditions and driver's activity;
• to design and develop:
  o an integrated multimedia HMI based on a set of innovative input and output devices;
  o a rules-based SW unit named Information Manager to select if, when and how each information can be given to the driver on the basis of the rules identified and previously mentioned;
• to integrate this HMI and the Information Manager in two vehicle prototypes: a Volvo and FIAT car;
• to test the entire system in different environments, namely: in laboratory; in the driving simulator and on the road for the final assessment;
• to investigate possible initiatives on how the standardisation bodies and the European commission activity in this area (e.g. ESoP) can be improved;
• to investigate all the measures to encourage the exploitation of the multimedia I-HMI.

1.2 Description of work

The COMUNICAR project followed an articulated research process (see figure below) mainly structured in two phases: the design of the integrated multimedia HMI and the system tests. The first one is aimed to define the specifications of the multimedia HMI and the main rules according to which the Information Manager works. The second one evaluates the usability, the acceptance, the workload and the safety impact of the HMI during laboratory, driving simulator and real drive tests.
As shown in figure below, the project started with a *state of the art analysis* and a *user needs survey*. Both studies permitted to identify the main directions of the HMI design. This phase has been structured in three main phases: the identification of the *functions* to be handled by the HMI (on the basis of the user needs analysis), the selection of the *best format in terms of input and output devices* per each function (taking the ergonomic literature it close consideration) and the identification of the rules according to which the Comunicar HMI selects if and when an information can be given to the driver.

After the specification phase, several HMI prototypes have been developed and tested in a laboratory environment. The results of these tests (mainly focused on usability issues) permitted the final selection of the HMI structure, the solution of the main relevant usability troubles and the further evaluation steps. In particular, a test in the driving simulator (to investigate the safety impact of the Information manager and the HMI in a controllable environment) and the final on-road test to verify the system impact in real driving conditions (two test tracks have been set up both in Italy and Sweden). Both in the driving simulator and in the real driving environment, the test permitted to verify the impact of the Comunicar HMI context and driver
awareness (mainly due to the Information Manager) to the workload and the driving performances.

Finally, the development phase included also technical challenging tasks such as the set up of an innovative dashboard (including innovative display place instead of the traditional instrument panel, haptic switch, etc.) and the integration of advanced driver functions as the radar and the camera for the frontal and lateral collision warning.

1.3 Approach followed to achieve project objectives

As already introduced, the design and test of the integrated multimedia HMI have been done following the “User Centred Design” approach (UCD). The main aim of the UCD is the development of usable artefacts through the involvement of the final users during the different design phases, from the requirements analysis to the redesign of the final prototypes.

According to the UCD approach, different test phases on the prototypes at different design stages (as reported in the figure below) have been performed, i.e.

(1) three user needs analysis at the early stage to define users’ expectations for the driving and mobility related information;
(2) six different laboratory tests to identify the best input and output devices, their integration, the HMI layouts and their functionalities into 4 different virtual prototypes;
(3) a driving simulator test to check how the integrated HMI and the Information Manager improve the driving safety reducing the driver’s overload;
(4) two on-road tests (in Italy and Sweden) to finally assess the HMI into real driving conditions.

In parallel with the test process, different techniques for the rapid prototyping of the multimedia HMI have been adopted, i.e.: the first concept sketches, the desktop prototypes, the virtual prototypes and the final mock-ups integrated on the vehicle demonstrators.
Through the UCD approach, it has been possible to improve the prototypes of the Integrated Multimedia HMI avoiding the discrepancy between the development of the concepts and the users expectations. Furthermore, all the rules defined for the Information Manager have been validated so to estimate their expected benefits on the driving safety.
1.4 Consortium composition and roles

The consortium is composed of 11 partners coming from 6 different countries: 3 car manufactures (Centro Ricerche FIAT, Volvo Car and DaimlerChrysler), 2 vehicle and component suppliers (BORG Instrument and Metravib), 2 technical universities (University of Genova and Institute of Communication and Computer Systems of the National Technical University of Athens), 1 academic user interface design laboratory (University of Siena), 3 research institutes (BASt, TNO and Fraunhofer Institute).

The following list reports the partners’ role in the project:

1. CENTRO RICERCHE FIAT (CRF):
   - Management and coordination;
   - Contribution to the design of the communication plan (i.e. the guidelines for the development of the multimedia integrated HMI) and the channel harmonisation plan (where the functional rules of the Information Manager have been defined);
   - On-vehicle integration of the COMUNICAR system (Alfa Romeo 147);
   - Contribution to the multimedia integrated HMI design;
   - Contribution to the on-road tests carried out;
   - Exploitation plan (i.e. Technological Implementation plan)
   - Project video and DVD;

2. UNIVERSITÀ DEGLI STUDI DI SIENA (UNISI):
   - User needs analysis;
   - Communication plan design and development, i.e. the guidelines for the development of the multimedia integrated HMI;
   - Contribution to the design of the entire system;
   - Dissemination strategies, i.e. COMUNICAR official website (www.comunicar-eu.org), project CD ROM, newsletter, etc.
3. VOLVO CARS CORPORATION (VOLVO CAR)
   • On-vehicle integration of the COMUNICAR system (VOLVO S60)
   • Design of the test plan and evaluation methods;
   • Contribution to the on-road tests carried out;

4. DAIMLERCHRYSLER (DC)
   • Contribution to the design of the channel harmonisation plan where the functional rules of the Information Manager have been defined;
   • Driving simulator tests;

5. BORG INSTRUMENTS (BORG)
   • Multimedia HMI HW component delivering;
   • Definition of the multimedia integrated HMI specifications;
   • Contribution to the exploitation plan (i.e. Technological Implementation plan)

6. METRAVIB RDS (MVIB)
   • Contribution to the design of the channel harmonisation plan where the functional rules of the Information Manager have been defined;
   • Improvement of the DSRU (Driver Status Recognition Unit) into the DWE (Driver Workload Evaluator)\(^2\) and its integration with the Information Manager;

7. INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS OF THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS (ICCS)
   • Quality control;
   • Contribution to the design of the channel harmonisation plan where the functional rules of the Information Manager have been defined;
   • Contribution to the dissemination;
   • Cost-Benefits Analysis;
   • Project assessment methodology;

\(^2\) The DSRU has been firstly develop within “CEM VOCAS” project and significantly updated into COMUNICAR where it has been re-named DWE. Functional system rules have been improved and
8. UNIVERSITÀ DEGLI STUDI DI GENOVA (DIBE)

- State of the Art analysis;
- Multimedia HMI design and SW development for the entire multimedia HMI into both vehicle prototypes;
- Contribution to the design of the channel harmonisation plan where the functional rules of the Information Manager have been defined;
- Information Manager SW development;
- Development of additional modules for the simulation of the navigation system output and the ADAS systems of the Volvo car;
- Contribution to on-vehicle integration of the Comunicar systems in both the Alfa and Volvo cars;
- Dissemination through the part of the web site, named MITO (Multimedia Information Telematic Observatory, where the quarterly update of the State of the Art on then project topics has been provided;
- Contribution to the Cost-Benefits Analysis;

9. FRAUNHOFER Institute (FHG)

- Multimedia integrated HMI design and virtual prototyping
- Laboratory test
- Dissemination providing web site version of the project virtual prototypes

10. BUNDESANSTALT FUER STRASSENWESEN / FEDERAL HIGHWAY RESEARCH INSTITUTE (BASf)

- Contribution to the design of the test plan and evaluation methods;
- Pilot-plan design for CRF and VOLVO on-road tests;
- On-road tests: experimental set up and data analysis; contribution to test results evaluation;
- Contribution to standardization guidelines and standardization plan.

the unit is now able to work not using a direct sensors as it was in CEMVOCAS but working into a vehicle standard network (i.e. CAN).
11. NETHERLANDS ORGANISATION FOR APPLIED SCIENTIFIC RESEARCH (TNO)

- Statistical data analysis for the driving simulator and on-road test;
- On vehicle test: experimental set up and statistical data analysis;
- Overall test plan evaluation and assessment.
2. Project results and achievements

2.1 Scientific and technological achievements

According to the research structure, the project has provided the deliverables listed below:
1. a deep analysis to identify the final users wishes and needs in terms of driving and mobility related information;
2. a set of criteria to identify the best format per each traditional and innovative information that can be handled by an in-vehicle HMI within four main sets such as: vehicle messages, Advanced Driver Assistance Systems (ADAS), telematic services and entertainment;
3. a set of rules and algorithm to handle the information delivering and to solve possible overlappings among several messages in case of different driving conditions and driver’s activity (this rules serve as a baseline for the information manager);
4. the design and development of:
   a. an integrated set of input and output devices to handle all the HMI functions;
   b. different visual and acoustical layouts to display these functions;
   c. the development of the Information Manager to select if, when and how each information can be given to the driver on the basis of the driving conditions and driver status;
5. the integration of these devices, layouts and Information Manager into an integrated multimedia HMI;
6. the HMI tests in different environments, namely:
   a. in laboratory to check the usability;
   b. in the driving simulator to verify impact on the driving safety;
   c. on the road for the final assessment (two prototypes have been developed);
7. the possible initiatives to improve the standardisation bodies because of the introduction of integrated on-vehicle context and driver aware multimedia HMI;
8. a cost benefit analysis that proves the COMUNICAR benefits in an economical and societal perspective.

2.1.1 User needs analysis

A multi-techniques “user needs analysis” to investigate the wishes and needs of the users in terms of driving and mobility related information has been firstly conducted. The analysis has been structured in three studies as reported below:

a. In the first one, three focus groups (two of them taking place in Italy, at CRF and FIAT Auto, and the third in Sweden, at Volvo) have been performed. The main goal was to elicit knowledge from experts in what the innovative systems COMUNICAR is concerned with. Discussions resulted in the specification of the clusters of instruments in terms of: information provided, activities supported, positive and negative user’s impact, constraints on implementation;

b. In the second study, ten user tests were performed. Three different cars were used, each one equipped with representative prototypes of the technologies to be developed (navigator, collision warning system, entertainment, adaptive display, telephone, trip computer, etc.). Questionnaires were administered to subjects before and after the tests so to have quantitative data on different dimensions (e.g. experienced usability, usefulness, etc.). User experiences with prototypes were video taped and analysed to get a set of requirements for the HMI design;

c. The third and last study consisted of a survey on drivers' information needs and preferences. The survey has been made by means of a questionnaire administered to about 60 drivers in Italy and 60 more in Sweden. The survey made it possible to identify the information/services in which drivers are more interested.

Final conclusion on this study has been a clear set of recommendations for the designers to develop an integrated on-vehicle HMI avoiding any preliminary usability trouble. The method (where qualitative and quantitative techniques have been fruitfully combined) revealed significant benefits as a guide for the further
design steps, for instance in the idea to assign the highest relevance to the driving and safety related functions. Most of the benefits depended on the usage of the previous design experiences, mainly focused on non integrated systems.

2.1.2 COMMUNICATION Plan

The second step of the design process has been a study named “Communication plan” to identify the best modality (i.e. visual, auditory, haptic and multimodal) to control and display the function and information identified after the User needs analysis. The background for this research has been taken from the Human Factors literature. Therefore, the “Communication Plan” got a preliminary specification of input and output devices for the COMUNICAR HMI as a further support for the whole design process.

The criteria identified to choose among the modalities already mentioned depends on the information complexity, the period in which the information has to be referred and if it has to attract driver's attention (e.g. alerts, warnings). According to the previous criteria, three rules to select the best modalities both in input and output have been identified.

2.1.3 Information Manager specifications

A rules-based system to handle if an in-vehicle information can be given to the driver, which is the best format to improve its effectiveness (on the basis of the “Communication Plan”), how to harmonise its relationships with other current messages solving possible overlappings has been designed. The basis of this work is a study named “Channel Harmonisation Plan” completed in the second project year.

These rules have been embedded into a SW unit named “Information Manager” (IM). The IM SW architecture works on the basis of three set of rules:

- the first one identifies if a message can be provided on the basis of the information priority and the so-called Total Level of Risk (the TLoR); the
TLoR estimates the risk due to driver activity in the primary and secondary tasks, the driving scenario and the environmental conditions (for instance, if a low priority information such as a traffic info arrives while the driver is approaching a dangerous manoeuvre, the IM postpones the message until the manoeuvre has been completed);

- the second set handles all the overlapping in case that more than one information are provided contemporary (i.e. a phone call and a navigation message); these rules solve also possible overlapping between the message output and the driver initiative on the on-board information system (i.e. an incoming phone call while the driver is selecting something on the menu of the central display);
- the third set of rules addresses the best message format to effectively catch the driver’s attention according to the “Communication Plan”.

On the basis of the “Communication plan” results, the entire structure of the integrated multimedia HMI (where the input and output devices have been chosen) and a the audio and visual layouts to handle the HMI functions have been conceived. These specifications are reported into tables (i.e. the “Interaction matrix”) that represents another relevant step to guide and support the design and development of the HMI concept to be implemented into the vehicle.

### 2.1.4 Multimedia HMI

According to the requirements and guidelines identified in the previous analysis, (i.e. user needs surveys, communication and channel harmonisation plans), it has been possible to define the HMI structure (called “Communication Model”). Into the communication model, the proper input/output devices have been identified and structured as follow:

- a first area (i.e. the instrument panel) is located in front of the driver and provides the traditional information of the panel cluster (e.g. speed, RPM values, etc.), the ADAS output (i.e. frontal and lateral collision warnings) and all the messages that can be considered safety critical (namely, with priority 1 according to the classification proposed in the “Channel Harmonisation”). To permit that so many and different kinds of information
(from the speed to the collision warning) can be grouped together, it has been established during this project phase that the output device located in this area have to be totally reconfigurable (namely, an LCD):

- a second area (named central display) is located in the centre of the dashboard, it has to be shared between the driver and the frontal passenger and it handles the telematic and the entertainment functions; to fulfil these requirements, it has been established to implement a reconfigurable output display (another LCD) and an ad-hoc input system such as the haptic switch.

![Diagram with the vehicle cockpit](image)

**Figure 4** - Diagram with the vehicle cockpit

In terms of communication strategies, this solution has permitted to address the information according to their relevance for the driver and in relation to the driving task (as recommended after the user needs survey results). In details, the input/output devices located in the first area have to get the driver’s attention, to inform the driver on the driving condition or to suggest the right manoeuvre in case of critical situations (therefore, all the information included here have been thought to be immediate, unambiguous and impressive); the other area is conceived to handle the driver’s interaction containing the time to complete a task, reducing the driver’s distraction and the eyes off the road.
2.1.5 HMI virtual prototype and laboratory test

According to the structure of the multimedia HMI and the guidelines emerged both from the communication and channel harmonisation plans, a wide set of audio and visual user interface layouts have been designed and firstly implemented as virtual prototypes. In particular two virtual prototypes for the instrument panel (named respectively abstract and perspective\(^3\)) and two for the central display (first named visual and second haptic\(^4\)) have been developed (as shown in the figures below). The entire functional logic and specifications of all these prototypes has been defined and developed.

Six different laboratory tests to assess the usability of all the prototypes and the structure of the multimedia HMI (as reported in the project outcome no. 5) have been conducted, i.e.:

1. control concept study;
2. text input variants study;
3. instrument cluster desktop study;
4. instrument cluster simulator study;
5. haptic prototype;
6. visual prototype study.

It is essential to specify that these tests have been performed on the very first “version” of the system layout and that test results did allow the further development of the concept and of the design. The results from the pre-tests show that the main reasons for the user errors were incompatibilities of required control motion and a confusion of pushbuttons and jog-dial. The situation has been improved by optimisation of the layouts of display and control for better compatibility. It was also

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\(^3\) Main differences of the two instrument display layout depends on the way to show the ADAS warning, i.e. the frontal and lateral collision avoidance systems. The “abstract warnings” layout shaped these warnings along the up, left and right borders of the instrument panel. The “perspective warnings” shows a representation of the real driving context placing an icon of the car in the centre and the warnings around.

\(^4\) Main differences of the two central display layout depends on the input devices. In the visual one includes hardware push-buttons and a display. Display and related controls are spatially grouped together and therefore allow for visual monitoring of control action. In the haptic one, a know to control remotely the display has been place. The controls of this prototype are designed to be operated without looking at the control actuators.
found that the menu-based prototype leads to worst results and the string-based one to the best results. Handwriting on a handheld prototype seems to have most potential for improvement with experienced users whereas the string-based prototype is best for inexperienced users. Comparing the menu-based and the string-based prototype it seems that using the menu-based prototype is more time-consuming for an inexperienced user whereas the ranking changes for experienced persons. Since the difference for experienced users is however small, it is concluded to use the string-based variant for the further development of the Haptic Prototype.

It was found that warning symbols at the periphery of the instrument cluster display can easily be overseen. A “compact” design such as the “perspective” one can improve the detection rate together with a good anthropometrical quality of the compartment. Additional audible warnings might further improve the detection rates and reaction times. From the main tests it can be concluded that both tested prototypes for the information and entertainment functions (Haptic and Visual Prototype) are principally suitable for further development. There is an observed tendency for the Haptic Prototype to be preferable in terms of acceptability.

The performance findings are supported by the analysis of the subjective workload data. A task-by-task analysis makes clear that workload is rather influenced by the type of task to be fulfilled than by the interface layout used to perform this task.

The usability tests revealed some weak points of both prototypes. The crucial ones and vast majority of them have been eliminated by design adjustments in further development and prototyping work. Specific weak points and recommendations for the optimisation of the first design of the Haptic and of the visual prototypes have been listed. As general finding for the haptic prototype the recommendation was related to the fact that during the test only a limited number of functions were used, it is therefore recommended to give the possibility to personalise the components of the system according to the user needs. As general finding for the visual prototype the recommendation was related to the fact that during the test only a limited number of functions will be needed by users. It is recommended to give the possibility to personalise the components of the system according to the user needs.
It has therefore decided to adopt the Haptic prototype for the further development including all advantages found in both prototypes.

2.1.6 Driving simulator tests

The adjusted integrated HMI (according to the virtual prototype design phase and the laboratory tests) has been tested in a driving simulator experiment. The objective of this experiment was to assess the impact of the Information Manager on driving performance (hence safety) and the impact on subjectively experienced workload. Comparative evaluation was used to determine the enhancement of driving safety with the COMUNICAR concept as compared to driving without any system manipulation. The first prototype of the Information Manager has been here developed according to the specifications identified in the channel harmonisation plan.

A total of 36 subjects (18 male, 18 female, average age 32) drove the DaimlerChrysler fixed base driving simulator with and without the information manager activated. On both routes they encountered the same events, like passing a stationary object or overtaking a slow vehicle. During these events a message from one of the information systems was presented, like an incoming phone call or a traffic information. The combination of an event and a message resulted in a total of 12 different scenarios that the subjects encountered during the route.

Without the Information Manager, the message was presented exactly during the event, while with the IM the message was postponed to right after the event. Under a third baseline condition the subjects just drove the route with the events, but no information messages were presented. The order of these three conditions was balanced over subjects to prevent memory and order effects.

Testing the effects of information management with a driving simulator turned out to be an extremely intricate subject. The subjective data (ratings on workload) provided no evidence in favour of information management. At first sight this result is different than the expectation since it was expected that driving with the IM would decrease experienced mental workload compared to driving without the IM when messages
are presented during difficult events on the road. There are two possible explanations for this result:

- The first one is that the effect of the IM is overruled by the interaction effect with what condition participants start out. This condition is rated as the one with the highest workload, whether without or with IM. So there could be a kind of learning effect.
- The second explanation is that the participants rated the condition with IM as being more effortful because they used their (implicit) memory on the number of separate events to give the rating. The number of separate events, as experienced by the participants, is larger for the condition with IM, as without the filtering effect of the IM some events occur together. Consequently, participants who employ such a frequency-based “availability heuristic” when asked to give a rating on mental effort might tend to rate the condition with information management as being more effortful (Hoedemaeker et al., 2003).

The objective data (driving performance) showed overall advantages for the condition with the IM. The different scenarios that the participants encountered during their drive were sometimes more critical than others. Looking at the critical scenarios, e.g. “overtake slow vehicle”, “vehicle in front brakes”, the IM has positive effects on driving performance. But looking at the non-critical scenarios, e.g. “rain”, “two messages presented at the same time”, the IM has no clear effect on driving performance. Overall, there are more positive results for driving with IM.

2.1.7 Vehicle demonstrators

After the definition of the integrated HMI in laboratory tests and the IM rules in the driving simulator (and when the main re-design actions have been performed), a final version of the integrated multimedia HMI has been embedded in two vehicles demonstrators (a Alfa Romeo 147 and an Volvo S60).
In particular, the following components have been integrated into each vehicle:

- two LCDs, one put in place of the standard instrument panel and the other located in the centre of the cockpit (i.e. the central display);
- an haptic switch to handle the central display and a few buttons to select general HMI functionalities;
- the corresponding visual and acoustic layouts to display the functions handled by the instrument panel (speedometer, RPM counter, vehicle advises, frontal collision and lateral warnings, etc.) and the central display (i.e. the navigation system, the mobile phone, the Radio, the CD, the MP3, etc.);
- the Information Manager;
- proper on-board PCs to handle the HMI for the instrument panel and for the central display;
- sensors to provide the frontal collision and lateral warning.
The integrated multimedia HMI in each car handles the following functions:

- Frontal collision warning;
- Lane warning;
- Vehicle functions (e.g. speedometer, RPM counters, vehicle warnings, trip computer, etc.);
- Telematic and communication functions (e.g. navigation, telephone, messaging, integrated address book, etc.);
- Entertainment (radio, CD, MP3).

According to the project objectives and to the experimental set up requirements, some of the functions have been simulated and only those which it was not possible to simulate have been implemented. The basic reason behind this choice is that the human factor tests have been centred on the HMI and therefore ideally they should not have been affected in any way by the system performances (e.g. false alarms, problems in GPS / GSM coverage, etc.).

### 2.1.8 SW development environments

An ad-hoc software development environment to programme the digital instrument panel and the central display have been created to implement the integrated HMI. The development environment is called MADE\(^5\) (Mobile Applications Development Environment). MADE includes M3P (MicroMultiMedia Player), a network-enabled multimedia player easily programmable through the MicroMultiMedia Services Language (MSL). MSL provides high-level components encapsulating advanced services (e.g. positioning, database query, phone interface, path search, etc.), that can be easily integrated in multimedia presentations.

The MicroMultiMedia Services Language (MSL) is a simple Object Oriented (OO) scripting language, that supports development of interactive multimedia programs able to integrate added-value services for mobile users. A typical MSL presentation consists of a set of pages (cards, in MSL terminology) containing multimedia and service objects. The MSL script specifies pages’ layout and objects’ appearance,
synchronization and user-interaction modalities. MSL scripts are interpreted at runtime by an OO multimedia player, MicroMultiMedia Player (M3P), that manages presentation of contents and user interaction according to the instructions specified in the input MSL script.

Such a high-level, integrated approach to building multimedia and service-rich mobile applications provides significant advantages to end-users and developers. Users benefit from interacting with a single HMI framework and from exploiting synergies between the integrated services.

On the other hand, developers can leverage a single and simple script language to implement highly usable applications. Using such a high-level tool allows designers to concentrate on the analysis of HCI methodologies, exploring several solutions, without caring for the low-level aspects of writing code for event handling and multimedia/service management.

For the development of the central display components, the environment has been ported to the target Win32 platform and to integrate additional services specific for the car environment (e.g. the drivers for the database and for the haptic knob, specific high-level components for interaction with email, SMS, cellular phone, navigation, traffic information, etc.)

Finally, MADE includes the Autogral libraries aimed to implement the components of the instrument panel. This library (re-written in C++ to improve system performance) has been enlarged with a wide set of ADAS outputs and new vehicle warnings, as well as the linkage with the Information Manager. A general architecture of the MDE platform is reported below.

2.1.9 Road test

Both the vehicle prototypes have been tested in a road scenario to verify empirically that the use of the COMUNICAR multimedia HMI and the Information Manager (IM) leads to a reduction of driver workload, which in turn is expected to support the safe performance of the primary driving task. Also aspects related to performance, acceptance and usability were addressed by the on-road-tests. As there is clear evidence that the level of driver workload depends on the demands of the traffic

\footnote{MADE has been firstly developed by DIBE for palmtop computers in the context of the E-Tour IST project and widely expanded in COMUNICAR for automotive information systems.}
situation, test drives with and without the IM were performed under conditions of real traffic. Therefore, each participant had to do the test drive twice, one with the IM on, the other with IM off. The order of the test drives (IM on/off) was counterbalanced.

The on-road-test were performed in parallel in Italy (Alfa Romeo 147) and Sweden (Volvo S60) and have been characterised by the following common elements:

1. The status of the IM (on/off) and the level of driver workload imposed by the demands of the traffic situation (low, medium, high) were manipulated as independent variables in a complete within-subjects design experiment;
2. The test routes were segmented in scenarios which differed with respect to the level of load imposed upon the driver by the primary task of driving.

Participants were asked for ratings of their workload by using:

- an interview on issues of acceptance, usability and debriefing at the end of the test;
- the Rating Scale of Mental Effort (RSME; Zijlstra & van Doorn, 1985) after each test drive.

The analysis of the acceptance questionnaire (van der Laan et al., 1997) provided evidence that the participants held generally positive attitudes towards the COMUNICAR system. Italian participants rated the system significantly higher on both scales “usefulness” and “satisfying”. The notion of an high acceptance was also supported by participants’ responses in the post-test interview. Most of the more specific comments given by the participants were referred to elements of the Integrated HMI, especially the haptic switch. These can be considered as an useful input for future developments.

As far as it concerns the RSME the predicted effect of driving with/without IM was not found. But at least the patterns of results in the Swedish and Italian data, i.e. the interaction effect with the order with which participants drove, replicate each other fairly nice. Moreover, the Driving Quality Scale (DQS) data from both the Swedish and the Italian study showed also an interaction with the order of the drives.

To measure the workload, the Peripheral Detection Task (PDT) method has been adopted (van Winsum et al., 1999). PDT enabled us to study the interactions of the
IM status with the criticality of the scenarios. The most general expectation was that driving with the IM should decrease the workload of the driver. This was measured by PDT response times and number of missed signals. The PDT results showed differences between the Italian and the Swedish study. The PDT results of the Italian study didn’t show a strong evidence of the IM effects on drivers’ workload in either positive nor negative way. However the information management system did measure high risk levels in a number of scenarios (5 out of 17), 4 of which were directly confirmed by the performance on the PDT.

A difference between IM on/off for PDT became visible with the Swedish drivers. Confirming our expectation, the road tests in Sweden showed us that driving with the IM system decreases driver workload. Larger reaction times and a higher number of missed signals here indicate that when driving without IM, drivers have less spare capacity to react in time to the LED lights. The scenarios that were identified as critical showed the biggest difference. On the other hand the effects in the data of Italian study can most likely be explained by generally lower level of difficulty or criticality of the scenarios defined for the test drives.

2.2 Cost benefit Analysis

A study evaluating the financial viability of COMUNICAR system was conducted within COMUNICAR project research activities. It is considered necessary for every research project to try to evaluate not only technical aspects of the innovative product developed but also it’s potential to be successfully forwarded to the market. Therefore this study will try to assess the product from the financial point of view and to provide draft information to possible investing companies in producing COMUNICAR system, given the data available at the present point when COMUNICAR system is still in a pre-industrialization phase.

At this purpose a Value Engineering Methodology was implemented. Value Engineering aims to functionally analyse COMUNICAR system. The Value Engineering approach is function oriented, and not component oriented, as the cost of a component is not the object of the study, but the focus is on the cost that is paid for the function supplied by the component. Cost data were collected based on expert’s estimation since COMUNICAR system is still at a pre-market stage and
system's cost will significantly vary compared to the prototype cost. Despite this, Value Engineering provides valuable data and direction for further research or exploitation activities.

By Value Engineering Methodology, specific functions of COMUNICAR system on which further research activities should focus were tried to be identified. The degree of each function's participation to the overall cost of the system was calculated and functions with high proportion are flagged for further review. For COMUNICAR system function analysis indicated that the functions related to linking different ADAS with each other, reading and directing input, elaborating priority rules, select output, warn driver and providing information to the instrument panel are the ones that represent more than 5% of the cost of the product but still their portion is not critically over the threshold. If further research was directed to components directly linked to these functions and ways of decreasing their cost were found, then we could benefit with the highest rate of return for the resources consumed. Limits and constraints are identified of course for each modification to COMUNICAR system.

Next, a FAST (Functional Analysis System Technique) diagram representing all functions in a graphical way was formed and function's costing was introduced.

For the complete evaluation of the system developed within COMUNICAR project, subjective evaluation of volunteers that have tested the system was also included. Multi Criteria Analysis was implemented in order to find out if COMUNICAR system is subjectively accepted. For this pilot subjects were questioned and each of the selected qualitative criteria for COMUNICAR system was rated. The evaluation criteria for COMUNICAR system were chosen by an experts' group. These criteria were comfort, safety, reliability, clarity of indications, easiness of learning how to use it, easiness to use, usefulness and pleasantness. Overall, COMUNICAR system was found to be well accepted by people that have tested it. With no exception all evaluation criteria were successfully above the acceptance threshold.

Finally, a pre-study of COMUNICAR system's financial viability is performed. Cost Benefit Analysis methodology was implemented so as to get a first draft idea of the possible financial benefit that companies are going to have if they decide to invest on COMUNICAR system. These are the companies that are going to produce COMUNICAR system i.e. the COMUNICAR suppliers and the car manufacturing companies that are going to buy the system from the COMUNICAR suppliers and install it to their vehicles. Four different scenarios were formed for four different
ranges of sales forecast both for COMUNICAR suppliers and car manufacturers. With no exception, all cases concluded that COMUNICAR system has the potential to be financially profitable for all companies even at the worst-case scenario. Overall, Cost Benefit Analysis for COMUNICAR system indicated a financially viable product, that worth further market analysis by interesting companies.

### 2.3 Implications on standardisation initiatives

Part of the work within the project has been dedicated to identify how the project results (especially the development of an information management system and the prioritisation strategies) can be considered as guidelines and/or recommendations to improve existing automotive HMI standardisation and EU policies.

The main contributions are expected to be given in the **EC eSafety initiative**. In fact, among the 28 recommendations that have been recently identified (November 2003), two are related to the HMI domain and they could receive a significant contribution from the COMUNICAR project results, i.e.:

1. to assess the reports by the Member States on the Commission Recommendation in the already mentioned European Statement of Principles on HMI (EsoP) and decide on further actions as necessary taking into account the rapid development in this area;
2. to develop workload assessment, testing and certification methodology and procedures for complex in-vehicle working environments involving interfacing in-vehicle devices for vehicle control, driver assistance, intelligent integrated road safety, including Multi-Media systems.

The specific results of the COMUNICAR project which are of relevance for further use under the framework of the eSafety initiative can be clustered around the following topics:

1. The ways to identify the best channel for providing a specific in-vehicle function (from indicators to route guidance outputs);
2. The strategies to assign an information priority according to its usefulness within a time horizon range (e.g. the navigation output “turn right” now is supposed to have higher priority than the output “turn right in 500 meter”);

3. The information handling and scheduling when more than one message arrives contemporaneous to the driver;

4. The strategies to handle the driver initiatives into the secondary task;

5. The way to identify a proper strategy for delivering messages according to an index which estimates the level of risk either related to the driver activities in the primary task and the driving conditions;

6. An innovative methodology to design the integrated multimedia HMI where an information management system is included;

7. Empirical data from laboratory tests, simulator tests and field tests on effects of information management on usability, acceptance, workload and safety.

The results listed here can be subsumed under the categories “principles of information management” (1 – 5) which have been developed by the COMUNICAR project and “Testing and validation” (6 and 7). From a scientific point of view both are, of course, closely linked to each other but can also be related to different HMI tasks under the framework of the EC eSafety initiative as follow:

- First, based on the “principles of information management” explained before, suggestions for the revision and extension of the ESoP can be derived;

- Second, from the results on “Testing and validation” contributions to the development of workload assessment, testing and certification methodology can be expected.
2.3.1 Implications on EsoP

COMUNICAR project results have been compared to the EsoP articles so to emphasize where and how this project could contribute to improve this set of principles and eventually suggest further extensions:

<table>
<thead>
<tr>
<th>COMUNICAR results</th>
<th>EsoP extensions</th>
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<tbody>
<tr>
<td>1. identification of the best channel to provide drivers’ information</td>
<td>In EsoP art. 4 (“Overall design principle”) it is said that a driver interface should be compatible with the “attentional demand of the driving situation”. Attentional capacity required by the driving situation is not a constant; therefore, as well as it should be avoided to overload the driver when the driving conditions are critical (for instance giving irrelevant information while driving through a cloverleaf), some more information could be given if the conditions are normal or tend to be calm. Therefore, the way to give a message should not be constant but aware of the context and dependent on the level of driver workload, as shown in the final results of the COMUNICAR on road test.</td>
</tr>
<tr>
<td>COMUNICAR results</td>
<td>EsoP extensions</td>
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<tr>
<td>2. Strategies to assign an information priority according to its usefulness within a time horizon range</td>
<td>In the ESoP art. 6 (“Information presentation principles”) it is formulated that “information relevant for the driving task should be timely and accurate”: therefore, criteria to identify the relevance of information with respect to the driving task is a way to implement this principles; the same principle should be improved by adding the requirement that the accuracy might not only be related to the information content but also to the conditions in which the information is presented to the driver (as developed via the Information Manager of the COMUNICAR HMI).</td>
</tr>
<tr>
<td>3. Strategies to handle the driver initiatives into the secondary task:</td>
<td>Even though in ESoP art. 7 (“Principles on interaction with displays and controls”) and 8 (“System behaviour principles”) some relevant principles on interaction with displays and controls are reported, the overlapping between input and output (e.g. an incoming call while the driver is changing a cassette) is not included. According to the COMUNICAR findings, the proposal to handle the input initiative within an “information management approach” looks like an innovative and fruitful proposal to extend these principles and the related standards.</td>
</tr>
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</table>
4. Identification of a proper strategy for delivering messages according to an index which estimates the level of risk either related to the driver activities in the primary task and the driving conditions.

Either for proposals no. 4 (“Overall design principles”) and 5 (“Installation principles”), the idea could be to propose new criteria in the ESoP according to which the information management should be also context aware.

Table 1 – Relations between COMUNICAR results and extension proposal on EsoP

Finally, in the ESoP art. 2 (“Scope”) it is said that in case of an integrated driver interface, the entire system should follow the principles. But when an integrated multifunctional interface is implemented, a management to avoid message overlapping according to the driving condition and driver status can not be omitted as this project has shown.

Therefore, as the aspect of information management is not explicitly covered by the present version of the ESoP, these recommendations can serve as a starting point for the definition of future items extending and elaborating the scope of this document by the eSafety HMI Working Group.

2.3.2 Implications on eSafety HMI task

COMUNICAR is among those EC funded industry projects which are expected to provide main inputs to perform this task. Results from the COMUNICAR project which can be exploited for this purpose come from the area of Human Factors methodology. These are:

- Evaluation of the “User-centred-design-approach” (see COMUNICAR Deliverable 6.1 [Peterson et. al. 2000] and COMUNICAR Deliverable 6.5 [Schindhelm et al. 2003]);
- Results from workload measurements (subjective measure) and driver behaviour from simulator tests (see COMUNICAR Deliverable 6.3 [Weiland et al. 2002]).
Results from workload measurements (secondary task, subjective measures) and driver behaviour from two on-road-tests (see COMUNICAR Deliverable 6.4 [Schindhelm et al. 2003]).

The task of developing a “workload assessment, testing and certification methodology” requires the continuous accumulation of knowledge. The COMUNICAR project contributes to this task by extending the set of available data and practical experiences with methods recently suggested for HMI assessment and testing. In particular, there is evidence that the Peripheral Detection Task is a promising method for the assessment of workload induced by drivers’ interaction with in-vehicle information and communication systems.

Subjective measures of driver workload as e.g. the “Rating Scale of Mental Effort” (RSME) is another method of widespread use in the area driver workload assessment, which was also used in the COMUNICAR simulator tests and on-road tests. Results obtained by the simulator test show that the application of this well established instrument in the domain of information management is highly sophisticated from a methodological point of view since possibly biasing memory effects have to be considered (see Hoedemaeker et al. 2003).
3. Lesson learned and future developments

3.1 Lesson learned

Because of the wide amount of topics and knowledge mobilised within the project, COMUNICAR offered to all the member a significant amount of expertise and results to be exploited. A close cooperation among different expertises (coming from industrial, research centres and academics) has been concretely performed during the project. In particular: user interface design institutes (e.g. University of Siena and Fraunhofer) developed a set of HMI concepts that has been implemented thanks to the collaboration among software engineering universities (University of Genova) and suppliers (BORG and Metravib); meanwhile, relevant work to integrated these HMI prototypes into the vehicle has been performed by automotive suppliers (e.g. CRF and Volvo) with a significant collaboration oncoming either from the supplier (e.g. BORG) and the technical universities (e.g. university of Genova, ICCS); moreover, a significant collaborative work among all the partners has been spent to conceive the algorithms of the “Information Manager”; finally, partners focused to develop the HMI and to provide its vehicle integration have been working closely with Human Factor experts (BASt and TNO) so to provide a vehicle targeted to the experimental aims.

Thanks to the Technological Implementation Plan, the main project results to be further exploited have been identified. These results can be exploited entirely (as an integrated multimedia context and driver aware HMI) or separately according to the vehicle models pre-existent requirements. For instance, the Information Manager can be implemented into an already designed on-board information system improving significantly its usability and acceptance, especially during the driving conditions.

In more details, the TIP includes the following results as candidate to be exploited (partners responsible for these results are within brackets):

1. User-centered audio and visual layouts of the integrated multimedia HMI (FHG);
2. Integrated Multimedia HMI input / output devices (BORG);
3. Information manager (CRF);
4. Software libraries and applications to activate the audiovisual layouts for the integrated HMI (DIBE).

Each partner intends to use and exploit these results differently as reported below (all these information are reported with all details into the TIP deliverable):

1. CRF:
   • Implementation of the entire COMUNICAR integrated multimedia HMI (including multimodal layouts, input and output devices and information manager) into FIAT, Alfa Romeo, Lancia vehicles and support to start the production phase;
   • Implementation of the audiovisual layouts, input output devices and on-board PC into FIAT, Alfa Romeo and Lancia on-board information systems (e.g. the telematic infotainment system already on the market named “CONNECT” or expected in the further vehicle models);
   • Implementation of the IM into FIAT Auto on-board information systems (e.g. the telematic infotainment system already on the market or expected in the further vehicle models);
   • Improvement of the IM functionalities via innovative RTD initiative (for instance, the already approved AIDE 6th FP integrated project represent the major way to improve and develop the context aware and driver workload sensitive user interfaces);
   • Introduction of a completed innovative test-design cycle for the on-vehicle user interface harmonised in accordance with the driving context and driver activity

2. UNISI:
   • Further extension of the user interface layouts to other in-vehicle functions not yet implemented into the COMUNICAR integrated multimedia HMI (e.g.

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6 Before COMUNICAR project, the rules and the methodologies to design and test the user interface for on-board information system have been limited to static applications where their behavior is not affected by the driving task and the driver workload. The dynamic user interfaces (as the COMUNICAR one) requires a completely new approach based on innovative test procedures (as the one identified into this project) and a design team composed of user interface designers, expert in
innovative ADAS functions which work linked with the telematic infrastructure; more complex telematic services where, among the others, navigation information are merged with traffic and weather news, etc.);

- Further integration of the techniques to study and evaluate the on-board information system usability, the driver behaviour and the workload with quantitative methods which give to the designer useful information of the redesign procedures;

3. VOLVO:
- Implementation of the COMUNICAR integrated multimedia HMI into Volvo models and support to start the production phase;
- Improvement of the IM functionalities via other innovative RTD initiative as the already mentioned AIDE proposal.

4. DC:
- Implementation of the COMUNICAR integrated multimedia HMI into DaimlerChrysler models and support to start the production phase;
- Implementation of the IM into the driving simulator for further test of the on-board information systems based on a real time workload control system (e.g. the telematic infotainment system expected in the further vehicle’s models);

5. BORG:
- Implementation of the COMUNICAR integrated multimedia HMI into vehicle models of the consortium’s car manufactures.

6. MVIB:
- Adaptation of the IM as an open product for different on-board information systems.

7. ICCS:
- Improvement of the IM functionalities via innovative RTD as the already mentioned AIDE project; for instance integrating the IM with new software

driver workload and technicians able to merge the driving task and user modelling algorithms with the user interface controlling systems.
architecture as the agent based technologies, merging these rules with the risk assessment strategies.

8. DIBE:
   - Improvement of the IM functionalities via innovative RTD initiative as the already mentioned AIDE project; for instance upgrading the IM rules using more sophisticated algorithms (based on dynamic reconfiguration of the information priorities, tailored around user profiles, etc.);
   - development of MADE, a comprehensive tool kit for the integrated in-vehicle user interface design (in parallel, the SW libraries to control the driver information in a digital instrument cluster will be extended to other functions);

9. FHG:
   - Further extension of the user interface layouts to other in-vehicle functions not yet implemented into the COMUNICAR integrated multimedia HMI;

BASst and TNO are not expected to exploit the afore mentioned results because of their background and the corresponding company roles. Anyhow, they improved an high expertise and the methodology to test the integrated multimedia HMI where more than one input/output devices are included and an information management system is embedded.

Finally, as explained before, they will drive further activities to integrate, into the standardisation body, issues related to the on vehicle user interfaces managed by a workload and driving context monitoring systems.

COMUNICAR project also contributed to identify and encourage new skills and expertise, improving concretely EU policies for job creation. In particular:

1. *in-vehicle user interface designers* aimed to identify and to prototype how a specific function can be controlled by and/or given to drivers (this skill has been significantly improved in University of Siena and Fraunhofer Institute);
2. *user interface software and hardware engineers* aimed to develop respectively the software applications where the functions and layouts of a multimedia HMI work and the input and output devices using which a driver can control these functions (this skill has been significantly improved in the
three car manufacturers, the automotive supplier BORG and the University of Genova and Athens; in both this academic partners, specific laboratories and working group has been created during the project);  

3. “information management systems” designers for vehicle applications able to identify how, when and in which way a function can be given to the driver and how the driver’s activity, the external scenario and the driving conditions can be monitored and evaluated (this skill has been established into the project merging pre-existent experiences and a working methodology completely built during the work in common: all the partners found benefits from the development of this knowledge);  

4. human factor experts focused to test context and driver aware user interfaces (based on the functionality of the “Information Manager”) and to propose proper re-design recommendations (this skills has been particularly developed in BASl, TNO and DaimlerChrysler).

3.2 Future developments  

In the last three years, the human machine interface for automotive application gained a relevant role both in the research domain and in the industrial production area. It is well known, even before COMUNICAR project, that the success of an on-board information system or, more generally, every automotive function directed to the drivers depends on the usability of the corresponding user interface. A first way to improve the usability has been the user centered methodology adoption, based on the analysis of the user task, the identification of a solution involving the users themselves in the design phase, and an iterative design-test process until the solution developed will not reveal its full compliance with the identified usability requirements. 

Things started to be more difficult when the number of functions (related to telematic, entertainment and ADAS) increased and the distraction issues gained a relevance in the automotive domain. Both these topics represented the horizon from which COMUNICAR project moved.

The solutions here identified within the project present two promising answers to the items mentioned, i.e.: how to integrate heterogeneous drivers information and how to avoid a driver workload improvement.
From one side COMUNICAR developed a prototype mature for the production phase since that all the car manufacturers involved (FIAT, Volvo in principle) plan to have on-board systems based on the information manager in their vehicle quite soon. From another, a completed methodology to design and test context and workload aware on-vehicle user interface, based on the user-centered design methodology, has been developed and applied. This methodology has significantly updated the classical UCD approach.

Anyhow, a new scenario has been opened and future works should point in several directions:

1. improving the algorithms and systems to detect the driver workload, to evaluate the driving environment and to assess the correlated risk, to monitor the driver behaviour and to build up a user profile; all these elements represents the part of a so-called holistic system from which a new IP of the 6th FP named AIDE will move;

2. introducing innovative rules that could dynamically adapt the information priorities to the driving context, driver profile and mission (for instance, a phone call could have an highest priority in respect to the default because of the relevance of the caller number for a specific user and/or the relevance in respect to the driver mission);

3. comparing alternative software technologies to handle the information-management-based on-board multifunctional user interface; e.g. rules based system, agent technologies architecture, statistical network decision systems, etc.

4. adapting the multimodal input device behaviour to the driving conditions; in case an haptical switch is available on the car (COMUNICAR tests demonstrated how this input device has been positively evaluated by the users), the system behaviour can not only be related to the visual card displayed but also to the condition of use; for instance, the system could suggest to not proceed in a demanding input task in case the driver initiates this task during a difficult manoeuvre; in this case, the haptic communication channel could give an immediate impression without any significant workload improvement;
5. integrating the on-board information with user nomadic devices to avoid that any unexpected information which arrive to the portable system located into the car could create driver distraction;

6. extending the context awareness evaluation systems not only to the vehicle but to different contexts of use from which the users could need an access to information and communication technologies; this future perspective could update the so called A3 paradigm (information anywhere, anytime and any device) with the features of a sort of extended information manager;

7. improving the management and the usability of the ADAS which are arriving to the market with the promising integration between the preventive safety functions and the road infrastructure; this is exactly the further development which occurred to the COMUNICAR prototype, now updated as a safety car for an Italian national project aimed at reducing the risk in case of fog;

As mentioned, some of this future perspective are becoming new RTD projects where the COMUNICAR know how will be fruitfully utilised; this is the case of AIDE and of the afore mentioned Italian national project to support the drive in poor vision conditions; but this is also the case of new projects in the area of mobile applications and services for mobile users where the seamless access to the information from various environments, with different devices, according to the user profile, workload and context represent one the major challenging issue.
4. Conclusions

In the preamble of the ESoP, it is mentioned that the telematic services for the mobility as well as the corresponding in-vehicle user interfaces will provide a valuable assistance if they will not distract, disturb or overload the drivers. Meanwhile, market opportunities for industries and service providers should not be inhibited unnecessarily (i.e. if the system and services design will not affect the driving safety).

COMUNICAR has been an innovative way to encourage a positive link among driving safety requirements, and in-vehicle HMI and the user acceptance. In fact, the design and development of an integrated HMI - able to provide the drivers’ information and to handle the user initiatives - according to the driving conditions and the driver workload, overtook the current position that seems limited to only to separate information available when car is standing and/or in motion.

In this report, the COMUNICAR project rational, the objectives, the approach adopted has been summarised. Wide part of the report has been dedicated to the project results and their links among a process cycle where different kind of output and deliverables have been provided: background studies, user needs researches, virtual prototyping development, laboratory and real tests, economical analysis and evaluation of the project outcome impact into the automotive human factor standardisation body.

Because of this heterogenous and cross-related array of results, conclusions can not cover the project as a whole but each of the following sub-class of findings:

- **Design of integrated HMI**: as mentioned in deliverable 6.5 on test results evaluation (Hoedemaeker et al. 2003), the UCD approach works very well in the design of the user interface since the first conception of the HMI main components (e.g. the communication model, the distribution of the drivers’ information per each area of the cockpit, etc.); on of the main benefits has been found in the capability to drive a wide and heterogeneous group of HMI designer performing a sort of fine tuning among their creativity, the
requirements coming from the human factors guidelines (as pointed out after the communication plan) and the user needs gathered in several ad-hoc analysis; the laboratory tests permitted to make several and useful iterations between the design stage and the early validation of the identified solutions; thanks to this approach, most of the higher usability troubles in the central on-board information system has been solved as the input and output devices identified and the best layout of the instrument panel (where new ADAS functions have been included) selected;

- **Design and development of the information manager:** this part of the project represent one of the main technical and scientific innovation since it has been realised, as pointed out from the EU in the second annual project review, a complex and articulated set of rules aimed to monitor the driving task, driver workload and to provide an harmonised information delivering; the integration between the IM and the rest of the HMI has been quite challenging and it represented one of the main project success; in fact, an innovative relationship between user interface designers, expert in workload and driving task monitoring algorithm, software developers and human factors expert have been established;

- **the Integrated HMI and information Manager:** from the technical point of view a really complex vehicle architecture and the development of a challenging and innovative dashboard have been realised; even they only prototypes, their technical features are close to the production and they work in standard vehicle network; of course, the main gap to be overtake for a fully integrated COMUNICAR HMI (as pointed out in the TIP) is the availability in production of a first set of ADAS functions; according to the other project main focused on ADAS development, the scenario seems promising: once the ADAS will be on the market, a set of proper user interface can be implemented; in the meanwhile, their integration with other driver information and workload monitoring system has bee already explored and developed; anyway, the project results can be scalable in different solution, some of them almost ready to the market as FIAT and VOLVO are working to implement the information manager into their on-board information systems;
• **Impact on standardisation:** Results of the COMUNICAR project provide evidence for limitations of available workload assessment methods for application in complex in-vehicle environments. Moreover, the results show that the relationships between IM and level of driver workload are not simply linear but interact in a complex manner with vehicle-controlling behaviours and the road environment. This should clearly be considered by the work of the eSafety Working Group HMI but defines also some needs for future research on workload assessment methodologies and by making suggestions for possible extensions of the ESoP.

Finally, in respect to the technical annex, almost all the expected results have been achieved. The integrated multimedia HMI developed and integrated in the two vehicle prototypes as well as the Information Manager met both the usability and the expected users’ acceptance requirements, and a reduction in the drivers’ workload (with a consequence road safety benefit).
Annex 1 : deliverable and other outputs

<table>
<thead>
<tr>
<th>Id</th>
<th>Deliverable code and title</th>
<th>Nature*</th>
<th>Submission date</th>
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<tr>
<td>1</td>
<td>D1.1 – Project Management Plan</td>
<td>R</td>
<td>31-03-2000</td>
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<td>2</td>
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<td>31-03-2000</td>
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<td>3</td>
<td>D2.1 – State of the art of driving support systems and on-vehicle multimedia HMI</td>
<td>R</td>
<td>27-06-2000</td>
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<td>D2.2 – User needs expectation and acceptance</td>
<td>R</td>
<td>27-06-2000</td>
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<tr>
<td>5</td>
<td>D3.1 – Content Plan: functions to be merged into multimedia HMI</td>
<td>R</td>
<td>27-06-2000</td>
</tr>
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<td>6</td>
<td>D3.2 – Communication Plan: definition of the best way to give information to the driver</td>
<td>R</td>
<td>30-11-2000</td>
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<td>7</td>
<td>D3.3 - Channel Harmonisation Strategy Plan</td>
<td>R</td>
<td>15-05-2001</td>
</tr>
<tr>
<td>8</td>
<td>D3.4 - Specification of Multimedia Network</td>
<td>R</td>
<td>03-07-2001</td>
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<td>9</td>
<td>D4.1 – Layout of multimedia HMI</td>
<td>O</td>
<td>16-07-2001</td>
</tr>
<tr>
<td>10</td>
<td>D4.2 – Multimedia HMI virtual prototype</td>
<td>P</td>
<td>21-09-2001</td>
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<td>11</td>
<td>D5.1.1 – Multimedia HMI real prototype</td>
<td>P</td>
<td>31-04-2002</td>
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<td>12</td>
<td>D5.1.2 – Specification of the multimedia HMI</td>
<td>R</td>
<td>31-04-2002</td>
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<td>13</td>
<td>D5.2 – Information Manager and Driver Situation Recognising Unit (DSRU) integration</td>
<td>P</td>
<td>05-04-2002</td>
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<td>14</td>
<td>D5.3 – Two car demonstrators</td>
<td>D</td>
<td>31-05-2003</td>
</tr>
<tr>
<td>15</td>
<td>D5.4 – Multimedia on-vehicle verification</td>
<td>R</td>
<td>31-05-2003</td>
</tr>
<tr>
<td>16</td>
<td>D6.1 – Validation Plan</td>
<td>R</td>
<td>04-08-2000</td>
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<tr>
<td>17</td>
<td>D6.2 – Laboratory evaluation of the multimedia HMI virtual prototype</td>
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<td>18</td>
<td>D6.3 – Driving simulator test results</td>
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<td>31-05-2003</td>
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<td>D6.4 – Human factor tests on car demonstrator</td>
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<td>D6.5 – Test results evaluation</td>
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<td>22</td>
<td>D7.2 – Dissemination and use plan</td>
<td>R</td>
<td>04-08-2000</td>
</tr>
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</table>

*R = Report; P = Prototype; D = Demonstrator; O = Others.*
A description of the main relevant project deliverables reports is reported below:

1. The “State of the art of driving support systems and on-vehicle multimedia HMI” (D2.1) covers all the items related to the project (from the driving functions to the software that can be used to design the Hmi virtual prototyping). After the first deliverable provided at the beginning of the project, the state of the art has been continuously updated in a specific area of the web site named MITO;

2. The “User needs expectation and acceptance” (D2.2) reports the methodology and results of the multi-techniques analysis conducted to find the wishes and needs of the users in terms of driving and mobility related information;

3. The “Content plan” (D3.1) lists the content to be handled by the integrated multimedia HMI and it represent the background for the “Communication Plan” (D3.2) where the best modality to control and display each information handled by the HMI is reported;

4. The “Channel Harmonisation Strategy Plan” (D3.3) reports the rational and the specifications of the Information Manager while the “Specification of Multimedia Network” (D3.4) explains the requirements of the electronic vehicle architecture to handle an integrated multimedia HMI;

5. The “Validation plan” (D6.1) describes the expected test process, the items to be evaluated (safety, workload, usability, etc.) and the variables measures; on the other side, the “Test results evaluation” provides a final assessment of the experiments conducted;

6. The deliverables “Laboratory evaluation of the multimedia HMI virtual prototype” (D6.2), “Driving simulator test results” (D6.3), “Human factor tests on car demonstrator” (D6.4) reports methodology and results of respectively the laboratory, driving simulator and on-road tests results;

Table 2 - Project deliverables
7. The deliverable “Guidelines for standardisation” (D741) reports general recommendations based on the project results that could support the standardisation activities especially in the filed of on-vehicle ergonomics; the “Standardisation Plan” (D742) describes how the COMUNICAR outcomes are expected to contribute the EC eSafety initiative and in particular the improvement of the so-called EsoP;

8. The “Project assessment plan” (D81) measure how the entire project have concretely achieved the results indicated in the technical annex (a quantifiable methodology ahs been developed within the project);

9. The “Cost Benefit Analysis” (D71) identified the economical value of the integrated multimedia HMI developed into the project; the “Technological implementation plan” (D73) defines the exploitation strategies and activities per each partner after the end of the project.

A description of the main relevant project deliverables prototypes is reported below:

1. the “Layout of multimedia HMI” (D4.1) is a multimedia deliverable where all the audio and visual layouts of the COMUNICAR multimedia HMI are reported while the “Multimedia HMI virtual prototype” (D42) includes all the virtual prototypes developed;

2. The deliverable “Multimedia HMI real prototype” (D511) is the final integrated multimedia HMI to be embedded into the vehicles, the “Specification of the multimedia HMI” (D512) reports the Hmi specifications;

3. The “Two car demonstrators” (D53) is referred to the task aimed to integrate the final version of the integrated multimedia HMI into the vehicle prototypes while the “Multimedia on-vehicle verification” (D54) include the final check of the system functionality;

4. the “Information Manager and Driver Situation Recognising Unit (DSRU) integration” is referred to the task where the two units have been integrated and implemented into the two vehicle prototypes.
A comprehensive table of the articles and conference presentations is included in the following table.

<table>
<thead>
<tr>
<th>ID</th>
<th>Date</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27/09/2000</td>
<td>Presentation to ISATA2000 Conference (Dublin) of a scientific paper titled “Towards an optimum ADAS HMI configuration within the Automotive Interior”</td>
<td>Angelos Amditis (ICCS/NTUA); Evangelos Bekiaris (ICCS/NTUA); Francesco Bellotti (DIBE)</td>
</tr>
<tr>
<td>2</td>
<td>08/11/2000</td>
<td>Presentation to ITS World Congress (Turin) of a paper article titled “Comunicar: multimedia communication inside car”</td>
<td>Roberto Montanari (CRF); S. Damiani (CRF)</td>
</tr>
<tr>
<td>3</td>
<td>15/05/2001</td>
<td>Presentation to the “Detroit Auto Interiors Show” of a scientific paper titled: “COMUNICAR: ADAS and Telematics Services Integration under a Multimedia HMI for the Automotive Interior”</td>
<td>Roberto Montanari (CRF), Angelos Amditis (ICCS/NTUA); Gunther Rettich (FHG/IAO); Francesco Bellotti (DIBE)</td>
</tr>
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<td>4</td>
<td>26/9/2001</td>
<td>Presentation to the SIE (Italian Ergonomical Society) national congress (Florence) of a scientific paper titled: “Fasi iniziali della progettazione centrata sull’utente per sistemi multimediali d’auto”</td>
<td>Michele Mariani (UNISI), Roberto Montanari (CRF), Sebastiano Bagnara (UNISI)</td>
</tr>
<tr>
<td>5</td>
<td>1/11/2001</td>
<td>Presentation to ITS 2001 World Conference (Sydney) of a paper titled “Comunicar: multimedia communication inside car”</td>
<td>Angelos Amditis (ICCS/NTUA), Roberto Montanari (CRF), Bernard Baligand (Metravib RDS), Friedemann Kuhn (DaimlerChrysler)</td>
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<td>7</td>
<td>09/2002</td>
<td>Paper presented to the E-Safety Conference 2002 (Lion) titled: “Definition of a management structure for the information flow through a HMI unit inside car”</td>
<td>Angilos Amditis (ICCS), Roberto Montanari (CRF), Aristomenis Polychronopoulos (ICCS), Francesco Bellotti (DIBE), Domenico Morreale (UNISI)</td>
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<td>8</td>
<td>10/2002</td>
<td>Presentation to the ITS World Conference 2002 (Chicago) of a scientific paper titled: “COMUNICAR: integrated on-vehicle human machine interface designed to avoid driver information overload”</td>
<td>R. Montanari (CRF), G. Wenzel (FHG), S. Mattes (DC), F. Kuhn (DC), F. Bellotti (DIBE)</td>
</tr>
<tr>
<td>9</td>
<td>06/2002</td>
<td>Paper published in a Italian technical magazine (ATA) titled: “Il progetto COMUNICAR: disegno e sviluppo di un’interfaccia multimediale di bordo per ridurre la distrazione in guida”</td>
<td>Roberto Montanari (CRF), Francesco Bellotti (DIBE), Michele Mariani (UNISI)</td>
</tr>
</tbody>
</table>
Table 3 - Project articles and participation in scientific conferences

A first multimedia presentation in a public exhibition has been done at ITS World Conference in Torino at the EC stand. Later on, the “Alfa Romeo 147” prototype has been presented in an industrial exhibitions in Italy named “AUTOMOTOR 2003” (march 26-30 2003) at Lingotto Fiere (Turin). “AUTOMOTOR” is the yearly most important appointment in Italy dedicated to the OEM, Aftermarket, and quality accessory sectors.

Figure 7 – AUTOMOTOR 2003 Comunicar presentation

Figure 8 - AUTOMOTOR 2003 Comunicar presentation

A final public workshop on the project results took place in Torino at Centro Ricerche FIAT on 27 of May 2003.
Annex 2: Project management and co-ordination

The COMUNICAR project management structure has worked efficiently since the beginning thanks to the cooperative work of the three boards below reported:

1. PROJECT MANAGEMENT BOARD (PMB) which is led by the project manager and composed by one representative person per each partner contractor and assistant contractor; the PMB is responsible for project planning, project financial status, progress status of the tasks, communication strategy definition and upgrade, management of the non technical issues and securing of the intellectual property rights;

2. TECHNICAL MANAGEMENT BOARD (TMB) that is composed of workpackage (WP) leaders, task leaders, task participants and the project coordinator (with the role of technical leader); the TMB is responsible for definition of the technical work items to be started; revision of the WP/Task in course or just finished, check of the project milestones and deliverables status, management of the technical issues;

3. PROJECT QUALITY CONTROL BOARD (PQCB) that is composed by quality experts (one per each principal and assistant contractor); the responsible is the quality assurance manager (in the consortium has been ICCS/NTUA); the PQCB reports every three months to the PMB and it is responsible for: the output consistence with project objectives in terms of quality of project progress report, the peer review report compiled per each deliverable by correspondent reviewers and the project requirements and outcomes assessment.

TMB, PMB and PQCB met quarterly since the beginning of the project and representative of all the partners have always participated. In total 13 meetings (including kick off) have been done. After each meeting, the following document have always been provided:

- a detailed meeting minute document with all the expected actions and deadlines (including contingent plan if necessary);
- a quality report on the project status and current deliverable analysis results;
• an assessment report with the declared project results level of achievement (a quantifiable methodology has been defined for COMUNICAR);
• a dissemination report on the most recent activity in the dissemination of the project results.

Moreover, other 12 project technical meetings (including an internal workshop) took place with the participation of the mainly involved partners in the corresponding specific topics. The results of these meeting have always been relevant and fruitful. In general, all the partners have concretely worked to achieve the project objectives and they not only maintained their roles and what promised into the technical annex, but also provided further contributions once that unexpected problems or needs occurred. For instance, DIBE worked more than planned to cope with the different SW needs emerged during the project. TNO supported the statistical data analysis of all the test phases. Fraunhofer conducted 6 different experiments instead of 1 as mentioned in the technical annex. During the project work and especially in the meetings, a really positive and enthusiastic attitude has been showed by all the partners and none serious problem has been encountered.

The main deviations occurred in respect to the technical annex are reported below:

• During 2001, Metravib concluded (after a detailed inquiry) that regarding the "intelligent acoustical framework" design and development (planned within the task 5.1), it was very difficult to prove the feasibility of this solution. Therefore, due to the high level of risk that could be coped, they decided to focus its efforts in the DSRU upgrade skipping this part of the project. To technologically upgrade the DSRU (re-named DWE), the following actions has been taken by Metravib: reduction of the instability of the system during changing status, improvement of the robustness to avoid false alarms, development of an auto correction process using an automatic recording of signals, adaptation to Swedish and Italian, implementation on MITSUBISHI micro controller and integration of a CAN card to permit the functionality with the vehicle electronic architecture;
• the CRF vehicle prototypes do not have a vocal recognition system installed on board even if they are in the condition to include it; the reasons is mainly
related to the integration work of the multimedia HMI and Information Manager which required more time than planned;

- In deliverable 7.4.1 (“Requirements for standardisation”) has been proposed to focus the COMUNCAR expected initiatives for standardisation and EU policies into the human factor domain and in-vehicle user-interface based on information management and prioritisation system. However, because the developments promoted by the COMUNICAR project clearly have the status of a prototype and the test have given a first significant picture on this domain, providing concrete proposals for the process of standardisation was considered as precipitate and to immature to find consensus. Thus, it was decided to focus on possible contributions from the COMUNICAR project to the activities around the ESoP under the umbrella of the EC eSafety initiative addressing in particular the following topics:
  - how the integrated HMI based on the information management and real-time workload assessment systems should be designed and developed;
  - how these systems can become a valuable contribution to the entire market sector.

Finally, in the same deliverable, specific actions has been identified to address most of the COMUNICAR results into the eSafety workgroup on HMI. Via this group and further contribution of the project’s partners, standardisation initiatives can be further encouraged.
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