### Use cases, functional specifications and safety margin applications for the SAFESPOT Project

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<tr>
<th>Deliverable No. (use the number indicated on technical annex)</th>
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<tr>
<td>SubProject No.</td>
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<td>SubProject Title</td>
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<td>Workpackage No.</td>
<td>WP8.4</td>
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<td>Workpackage Title</td>
<td>Internal and external integration activities</td>
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<td>Task No.</td>
<td>8.4.1</td>
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<td>Task Title</td>
<td>Sub-project integration activities</td>
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| Authors (per company, if more than one company provide it together) | R. Brignolo, G. Vivo, F. Visintainer (CRF)  
F. Belarbi (Cofiroute),  
M. Dozza (Volvo). |
| Status (F: final; D: draft; RD: revised draft):                | F      |
| Version No:                                                   | V1.9   |
| File Name:                                                    | SF_D8.4.4_SAFESPOT_Applications_V1.9.doc |
| Planned Date of submission according to TA:                   | 15/03/2008 |
| Issue Date:                                                   | 15/04/2008 |
| Project start date and duration                               | 01 February 2006, 48 Months |
# Revision Log

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Reason</th>
<th>Name and Company</th>
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<tr>
<td>1.0</td>
<td>17/12/2007</td>
<td>First release</td>
<td>R. Brignolo (CRF)</td>
</tr>
<tr>
<td>1.1</td>
<td>12/01/2008</td>
<td>Included SP4 contributions</td>
<td>G. Vivo (CRF)</td>
</tr>
<tr>
<td>1.2</td>
<td>20/02/2008</td>
<td>Review of SP4 Contribution</td>
<td>M. Dozza(Volvo)</td>
</tr>
<tr>
<td>1.3</td>
<td>25/02/2008</td>
<td>Revision and modification of SP5 applications description (based on COFIROUTE contribution)</td>
<td>F. Visintainer (CRF)</td>
</tr>
<tr>
<td>1.4</td>
<td>20/03/2008</td>
<td>Included Executive Summary, System Objectives and Conclusions. Content harmonization.</td>
<td>R. Brignolo (CRF)</td>
</tr>
<tr>
<td>1.5</td>
<td>25/03/2008</td>
<td>Editorial revision, figures numbering, references, final internal review of methodology, adding SP5 related aspects</td>
<td>G. Vivo, F. Visintainer, R. Brignolo (CRF)</td>
</tr>
<tr>
<td>1.6</td>
<td>26/03/2008</td>
<td>Further detail on the SP4 applications</td>
<td>G. Vivo (CRF)</td>
</tr>
<tr>
<td>1.7</td>
<td>31/03/2008</td>
<td>Revisions, Added Executive summary and conclusions</td>
<td>R. Brignolo (CRF)</td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td>Unpublished version containing peer reviewer comments</td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>15/04/2008</td>
<td>Submitted version improved according to Peer reviewers suggestions</td>
<td>R. Brignolo (CRF)</td>
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## Abbreviation List

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<th>Description</th>
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<tbody>
<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
</tr>
<tr>
<td>AIDE</td>
<td>Adaptive Integrated Driver-vehicle Interface – EC Integrated Project</td>
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<tr>
<td>AM</td>
<td>Application Manager</td>
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<td>CSA</td>
<td>Cooperative Support Application</td>
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<td>DAA</td>
<td>Driver Assistant Application</td>
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<td>HMI</td>
<td>Human Machine Interface</td>
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<td>MM</td>
<td>Message Manager</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>OV</td>
<td>Other Vehicle</td>
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<tr>
<td>PReVENT</td>
<td>Preventive and Active Safety Applications - EC Integrated Project</td>
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<tr>
<td>PTW</td>
<td>Powered two wheels vehicle (Motorcycle)</td>
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<tr>
<td>SMA</td>
<td>Safety Margin Assistant</td>
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<tr>
<td>SPX</td>
<td>Subproject x (X = 1 to 8)</td>
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<tr>
<td>SUD</td>
<td>System Under Definition</td>
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<tr>
<td>UC</td>
<td>Use Case</td>
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<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
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<td>VANET</td>
<td>Vehicle Ad-Hoc Network</td>
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1. EXECUTIVE SUMMARY

This document describes the SAFESPOT applications.

An introductory Chapter reports the SAFESPOT System objectives and architecture. Both items are key starting points to understand the applications and how these applications were conceived and designed. Moreover the concept of vehicle based and infrastructure based application is introduced.

A chapter follows describing the methodological approach used for the definition of the applications. A structured approach in line with the FRAME guidelines has been adopted. UML diagrams were extensively used in the architecture and functional specifications.

The next chapter is devoted to the description of the main blocks of the applications, explaining in detail the concept of primary and secondary actor. In SAFESPOT each application acts as a primary and a secondary actor. The primary actor activity is related to the generation of a warning to the driver of the ego-vehicle (i.e. the vehicle in which the application is running); the secondary actor is a vehicle or infrastructure node responsible for generating information to be communicated to other vehicles or to the infrastructure. According to this logic an infrastructure node is always a secondary actor providing the right information (raw data or driver oriented messages) to the vehicles.

A transversal “external message application” is then described. The main objective of this application is to provide a remote HMI in the vehicle for the application running in the road side units. Road side units may transmit text messages or coded information to be presented as icons or hearcons.

In chapter 5 a detailed description of the Vehicle based and the Infrastructure based applications is reported. As part of the description some of the identified use cases are also reported. The content shows the large number of applications and use cases considered in order to demonstrate the functionality and the potentiality of the SAFESPOT system. Moreover the defined architecture is open to add further applications if available in the future.

In the last section of the chapter a description of the HMI is presented with particular emphasis of the three level of risk associated to the SAFESPOT messages: Comfort, Safety and Critical.
2. The SAFESPOT system objectives and architecture.

The SAFESPOT system is aimed at improving road safety using Cooperative Applications based on data exchange among vehicles and among vehicles and infrastructure through an ad-hoc network.

The main objectives of SAFESPOT are the following:

- **To develop or improve and assess the key enabling technologies:**
  - *Communication* through *ad-hoc dynamic network* whose nodes are vehicles and road side units.
  - *An accurate relative positioning*
  - *Local dynamic maps.*
  - SAFESPOT will also evaluate how a wireless sensor networks may improve the sensing ability at infrastructure level.
  
  All the relevant technological aspects are dealt in D8.4.2 [11]

- **To develop the Safety Margin Assistant.** This is an integrated application framework using the *safety-related information* provided by the network properly fused with the on board sensors and able to advise the driver in order to keep the vehicle as far as possible from emergency situations or to provide a proper warning when they occur.

  The SAFESPOT applications operates in order to:
  - detect in advance potentially dangerous situations,
  - extend “in space and time” drivers’ awareness of the surrounding environment.
  - provide recommendations in order to keep the vehicle as far as possible from emergency situations or providing a proper warning when they occur.

  The content of this deliverable is aimed to provide a brief description of the application.

- **To define in common with other EC projects an open, flexible and modular architecture.**

The SAFESPOT architecture has been defined and reported in the deliverable D7.3.1 [10] and also explained briefly in D8.4.2 [11]. However in order to understand the role and structure of applications it is important to briefly recall the SAFESPOT architecture here.

The system is composed of a set of “nodes” (in other words SAFESPOT equipped vehicles or Road Side Units), which are able to exchange information with the other nodes through short range wireless communication (IEEE802.11p*) called the VANET (Vehicle Ad-hoc NETwork) and to use this information in order to generate messages for the drivers.

A node runs applications using the data provided by the other nodes and/or by its own sensors. All the available data, after a fusion process, are collected in a multilayered Data Base named Local Dynamic Map (LDM –
see Fig. 2-1).

LDM consists of four different layers:
- Static Maps
- Landmarks (fixed objects in the road, e.g. trees, buildings, road signs)
- Temporary Objects (e.g. fog area, road works)
- Dynamic Objects

![The LDM structure](image)

The internal architecture of a node is depicted in Fig 2-2 where the main data flows are reported.

Applications have a double task:

- **Message Generation** → To define which data should be provided to the other nodes through the VANET. This is a mandatory feature of any SAFESPOT node.
- **Elaboration of data for the ego node.** This function is not mandatory for all the nodes – e.g. for RSU providing speed warnings.

Both these tasks will be described in detail in the next sections.
The applications rely on the data available in the LDM where all safety relevant information is continuously updated. From a technical viewpoint both the Application Coordination (Application Manager) and the Application part of the Message Generation (Message Manager) may be considered as a framework integrating several applications. Applications should be able to operate in any road scenario. In the SAFESPOT project timeframe a number of applications and use cases have been selected and analyzed and they will be demonstrated in the experimental phase of the project. SAFESPOT identified two classes of implementation steps depending on the level of intelligence required on board the vehicle. The first is based on V2I-I2V communication with applications mainly running on the infrastructure side. These applications may represent a first step of the future exploitation and aim to cover Static and Dynamic Black Spots (i.e. specific locations where the probability of accidents is higher) in which a RSU is located. The second involves V2V based applications which involve dynamic black spots potentially occurring in any location and require a higher level of intelligence on board. Fig. 2-3 represents the scenario with the highest level of integration, where V2V and V2I operate concurrently.
The structure of the Integrated Project SAFESPOT reflects this classification and includes two different Subprojects: each one dedicated to a specific class of application:

- SP4 – SAFESPOT COoperative Vehicle Applications (SCOVA)
- SP5 – Cooperative Safety Systems Infrastructure Based (COSSIB)

In the subsequent Chapters the methodology and the applications for each Application class are described.
3. The SAFESPOT applications: methodological approach

Concerning the vehicular applications, the original definition of the overall set of the SAFESPOT application was established starting from a list reported in the Definition of the Work for the project itself. This set of applications was then slightly modified, during the very initial activities of SP4-SCOVA, in order to meet with the technical possibilities of the participants. In this phase, the major role was played by the OEMs and Suppliers, due to their experience in the field of ADAS (Advanced Driver Assistance Systems) and participation in previous significant projects, such as PReVENT [20] and AIDE [19].

A similar procedure happened for the SP5-COSSIB applications which take into account the accident data analysis for different European countries [17]. The aim of this study was to investigate the combination of factors leading to safety risk, and to classify in terms of priority the considered scenarios. In SP5 the major role was played by the Road Managers and Infrastructure System Suppliers.

In order to collect a proper set of User Needs and Requirements - and also as a general foundation for the overall analysis a Structured Analysis tool (Enterprise Architect, from Sparx System) was used to describe the SUD (System Under Design) by means of the adoption of Use Cases.

Use cases are goals (the terms ‘use case’ and ‘goal’ are used here interchangeably) that are made up of scenarios. Scenarios consist of a sequence of steps to achieve the goal. Each step in a scenario is a sub- (or mini-) goal of the use case. As such, each sub-goal represents either another use case (subordinate use case) or an autonomous action that is at the lowest level desired by our use case decomposition.

This hierarchical relationship is needed to properly model the requirements of the system being developed, consisting of the SP4 applications. A complete use case analysis requires several levels. In addition, the level at which the use case is operating at is important for understanding the scope which it addresses. The level and scope are important to assure that the language and granularity of scenario steps remain consistent within the use case.

The main reason for producing the SP4 and SP5 UCs has been the feature of the UC of representing natural “boundaries” for the definition of the system requirements for the SUD – i.e. the vehicle and infrastructure based applications to develop inside SP4 and SP5, respectively. The process is based on an incremental approach that starts from the collection of the basic user needs, and adopts the UC as samples of behaviours expected by the SUD. In this way, the system requirements are established by putting into evidence, in the collected UC, the functional characteristics and the contextual requirement enabling the deployment of the proper behaviours in each application.
user needs → use cases → system requirements

![Diagram](image)

**Fig. 3-1 Method for producing system requirements starting from user needs and use cases**

Of course UCs do not specify system requirements in terms of performance: these are under the domain of the system specifications. Other relevant tasks, which are **not directly covered** through the production of the UCs, are:

- Specifications of the user interface design - in fact, use cases specify the intent not the action detail.
- Specifications of the system and implementation details - since for the actor it is important that the goal is properly met not to know how it is met.

The System Requirements are addressed by the different SAFESPOT sub projects, which are responsible for implementing different parts of the SAFESPOT system and are intended as the major basis for the specification phase of the project - in line with the general European ITS Framework Architecture (FRAME) methodology.

For both SP4 and SP5 three different types of system requirements have been identified:

- **Functional requirements**: specifying the service(s) expected from the system, and/or the functions needed to provide a working system;
- **Non-functional requirements**: specifying the performance and/or quality attributes of a workable system;
- **Context requirements**: specifying the context within which the system is intended to operate. They include the constraints imposed by the environment and the effects that the system introduction might have on the operating environment. These include assumptions made on the environment, or statements as to what is needed for the system to work effectively under the agreed conditions.

All requirements are a reflection of the user needs; through the system requirements it is ensured that the needs expressed by the system users are addressed during the specification phase through a specific system feature. The SP4 and SP5 user needs and requirements reflect the information and functionality needed for the vehicular applications to be implemented in the SAFESPOT system.

For each of the SP4 applications the user needs and requirements were presented [13].

Concerning the infrastructure based applications, the user needs and use cases were first reported in [15], along with preliminary requirements. Then, useful and appropriate applications were then identified supporting the safety margin concept. During this process the outcome of D5.2.2 Common
Architecture and Communication [16] was taken into account, in order to design applications that are coherent with the possible system architectures. In particular, the following aspects are specific of SP5 design phase and pose the main constraints for the system implementation:

- the availability of basic resources such as energy and communication means;
- the availability of components (sensors, VMS, etc.) which could allow the installation of SAFESPOT roadside unit at low impact and costs.

This motivates the choice of referring to the driving environment, classified according three main categories: rural roads, urban roads, highways/tunnels. These different parts of the road network have indeed specific characteristics that strongly influence the applicability of the SAFESPOT-COSSIB system.

In parallel to the definition of the applications, the requirements were consolidated. This parallel and iterative process required a close co-operation of all the partners involved in the different applications. The requirements were listed in D5.2.3 [14]. The following picture shows the logical steps of SP5 methodology.

![CoSSIB Methodology Diagram](image)

The strong connection between the System Requirements and User Needs is explicitly recommended by the FRAME methodology guidelines. This connection is ensured, in the general FRAME methodology, by a set of built-in relations called “Trace Tables”. There is not a one-to-one relationship between the User Needs and the functionality in the Functional Viewpoint. In other words, the same User Needs (or System Requirement) may be served by several Functions or several System Requirements may be served by one function.
Taking into account the large quantity of new User Needs/System Requirements an ad-hoc procedure was created in order to ensure this connection, allowing performing the fundamental design step leading from the User Needs to the definition of the main system functionalities. The Fig. 3-3 shows the parallel between the general FRAME approach and the SAFESPOT-SP4 and SP5 case.

Fig. 3-3 General FRAME approach and the SAFESPOT case.
4. The Main Blocks and associated technologies

4.1. Reference model for the SAFESPOT applications

In the SAFESPOT approach, several applications are normally running within each vehicle system. According to the general architecture of the SAFESPOT system, the vehicle platform has access to the sensors by means of a dedicated Gateway. A dynamic representation of the environment surrounding the vehicle or RSU is stored inside the LDM. Applications access the information inside the LDM and perform the appropriate operations on this information to achieve their goals. The applications also decide what information should be exchanged among the different nodes of the VANET which is in charge of establishing and maintaining the network connectivity for the V2V and V2I communications.

4.1.1. VANET communication constraints

The SAFESPOT architecture is meant to match with the reference scenarios proposed by the Car to Car Communication Consortium (C2C-CC).

![Classical reference scenario for the C2C-CC.](image)

Within the C2C-CC Scenario (Fig. 4-1), the SAFESPOT VANET domain is marked with blue ellipses. The SAFESPOT VANET deals with vehicle-to-vehicle communications and vehicle-to-roadside communications. The VANET architecture is using the European version of IEEE 802.11p* as physical layer. The protocol is currently under standardization in ISO TC204/WG16 and ETSI. The same communication media will be used in other relevant European initiatives, e.g. the IP CVIS (where the media is described as CALM native media CALM M5) [21].

As reported in deliverable D3.2.3 - Consolidation Report of User Needs and Requirements for Positioning, Local Dynamic Maps and Vehicular Ad Hoc Networks - severe technological constraints exist on the data rate and communication channel usage that can be exploited by the SAFESPOT applications:
Fig. 4-2: Control channel usage limits (US WAVE 802.11.p).

Clearly, such restrictions are given for normal usage and this does not affect high priority (emergency) messages that are emitted on an event basis. The figure above allows the calculation of the maximum transmitted data rate per node for the control channel of the US WAVE system (it will be most probably the same for SAFESPOT):

$$r_{OBU} = 3 \text{ Mbit/s} \times 580 \mu\text{s} / 750 \text{ ms} = 2320 \text{ bit/s}$$

$$r_{RSU} = 3 \text{ Mbit/s} \times 750 \mu\text{s} / 100 \text{ ms} = 22500 \text{ bit/s}$$

Although these figures might look different for the European version, they reveal that the communication channel should be retained as a severe (physical) bottleneck for the whole SAFESPOT system, but especially for vehicles. Thus, a significant effort has been performed in order to build up a reference model for the SP4 (and in general for the SAFESPOT) applications in order to make an efficient usage of the very limited communication resources.

### 4.1.2. Vehicle based applications model

As a consequence of the arguments presented in the section above, it turns out that all simple application models where “vehicle A ask vehicle B for…” should be discarded for reasons of efficiency. In fact, it is an evident waste of resources to send communication packets whose information content is just a query.

Of course, for the purposes of elementary peer to peer feasibility studies or for some very small scale demonstrations, involving few actors in the VANET, the adoption of intrinsically inefficient models (wasting the 50% of the channel usage for queries) can be easily accepted.

Based on these considerations, the adoption of policies absorbing the minimal bandwidth occupancy by the co-operative applications is fundamental in order to make the whole approach sustainable in real life scenarios, where hundreds of communicating vehicles can easily be active in the same timeframe for some realistic, congested scenarios (populated intersections, queues in the traffic, etc.).

To clarify this concept, the “Speed Limitation and Safety Distance” application can be considered. An evident distinction exists between 1) the data, available to the node, that need to be used locally (not transmitted to the VANET) in order to warn the driver of the ego-vehicle (primary actor), and 2) the data that need to be transmitted to the VANET (by a secondary actor) in
order to enable the operation of an application running on a different node. Only the second type of data has an impact on the use of the communication channel, since these parameters are the only ones involved in the co-operative approach.

Fig. 4-3: Pictogram for the Speed Limitation and Safety Distance application.

In order to obtain speed and distance recommendations, the application running on vehicle 2 (the *ego-vehicle*, in Fig. 4-3 above) needs to know the brake pedal actuation of vehicle 1. This information is easily available on the CAN bus of vehicle 1, but this actor, normally does not broadcast such parameters. Vehicle 1 knows (and needs) to transmit this information only when it is aware of being part of an applicative scenario (it plays a passive role), while warnings are presented only to the driver of Vehicle 2.

In the LDM of vehicle 2, that is the primary actor of the described Use Case of the “Speed Limitation and Safety Distance application“, the parameter “BRAKE_PEDAL_STATUS” of vehicle 1 needs to be present in order to perform the applicative task of actor 2, e.g. to properly warn the driver.

Vehicle 1, which is an obstacle in the perspective of vehicle 2 (i.e. it is a secondary actor of the proposed Use Case), needs to send to the VANET the “BRAKE_PEDAL_STATUS” parameter in order to allow vehicle 1 to perform its applicative task.
Applicative task running on the ego vehicle (in charge of analysing the Speed Limitation and Safety Distance UC) has the purpose of properly driving the on board HMI. It is assumed that the related specific information (for instance the BRAKE_PEDAL_SIGNAL of vehicle 1) is available in the LDM. It seems this assumption, especially near to the state switching conditions, can not be guaranteed, in a formal manner and in all situations.

This vehicle (secondary actor) is always aware of being part of a Speed Limitation and Safety Distance UC; a dedicated applicative task - the client of the given application - is running on this vehicle with the purpose of analysing the surrounding scenario, in order to send the parameters and the application-specific information (e.g. the BRAKE_PEDAL_SIGNAL) onto the VANET. Sophisticated strategies can be implemented, in order, for instance, to cast these parameters and information with a frequency progressively higher as the primary actor (2) approaches.

Fig. 4-4 Key elements of the reference model for the SCOVA applications.

Since it is assumed that the communication channel should not be used to explicitly request information by any of the actors involved in the UCs. All of the secondary actors need to perform a specific analysis of the scenario in order to know when and how (or better, with which repetition rates) to deliver their parameters and data to the primary actor.

In order to implement this model of minimal transmission channel occupancy, some high level strategies should be implemented for enabling the secondary actors to place data on the VANET only when such data are explicitly needed by some primary actor. In the adopted approach the analysis of a given scenario must be executed both in the ego-vehicles, with the purpose of driving the driver’s HMI, and in the secondary actors (and other “active nodes”), with the purpose of deciding when and how to deliver on the VANET the specific applicative parameters and information needed by the primary actors. Decision of adopting unicast, multicast or broadcast transmission scheme for the communication should be taken by the specific application case by case, since it is depending on the particular UC.
So, in total, four applicative tasks are needed to support the SAFESPOT co-operative applications:

- **driver assistance application (DAA)**, running in the *ego-vehicles*, carrying out the specific functions of the driving support applications, with the purpose of providing a warning to the driver of an *ego-vehicle*;

- **application manager (AM)**, running in each SAFESPOT vehicle on which driver assistance applications are installed, with the purpose of performing the analysis of the surrounding scenario, and to provide unified applicative support for all of the driver assistance applications running in the *ego-vehicle*;

- **message manager (MM)**, running in all of the other SAFESPOT vehicles (different than the ego vehicle), with the purpose of performing the analysis of the surrounding scenario, and providing an unified applicative support for all of the co-operative support applications running in the co-operative (non ego) vehicles;

- **co-operative support application (CSA)**, running in the co-operative vehicles, implementing the “parameter transmission rules”, and carrying out the functions of the co-operative support applications, with the specific purpose of sending to the VANET all of the parameters at the proper time and with the proper repetition rate, to support efficiently the tasks of the driver assistance applications running on the *ego-vehicles*.

In order to fully understand the above, it should be underlined that:

- The same vehicle may be at the same time *ego-vehicle* and *co-operative vehicle* for different UCs.

- Each SAFESPOT vehicle must run the message manager and the co-operative support application in order to serve all the possible applications, while only a reduced set of the driver assistance applications may be present in a single vehicle.

The UML diagram in Fig. 4-5 provides a high level view of the Primary and Secondary actors blocks namely of AM/DAA and MM/CSA.

It has to be underlined that a scenario analysis is performed in both parts of the application.

**AM main task**: activate/deactivate (in functional terms) the different co-operative applications - driver's assistance side - with the aim of providing the assistance for the primary actors (*ego-vehicle*) in the different Use Cases for all the running applications. Composing modules are:

- Coordination of HMI requests
- Coordination of DAAs
- Scenario Analysis
  - Monitoring
    - Acquisition of ego-vehicle parameters
    - Acquisition of the parameters of the Secondary Actors
    - Acquisition of Road Information
  - Data assessment
    - Query to LDM (*) Note: all the acquisitions use the Query LDM module)
- Activation/deactivation of DAAs

**DAA tasks:**
- Refined Scenario Analysis
  - Monitoring
    - Acquisition of parameters of Primary Actor
    - Acquisition of parameters of Secondary Actors
    - Acquisition of Road Information
  - Assessment of the SMA zones (Comfort / Safety / Critical)
  - Defining priorities for HMI
  - Generation of HMI requests

**MM tasks:** to activate/deactivate (in functional terms) the different co-operative applications - co-operative assistance side, running on the secondary actors of each Use Case for all of the running applications – with the aim of proving the communication of the specific parameters (messages) on the VANET, at the needed time, with the needed repetition rate. Composing modules are:
- Management of Applications Information to send on the VANET
- Coordination of CSAs
- Scenario Analysis
  - Monitoring
    - Acquisition of parameters of Primary Actor (*)
    - Acquisition of parameters of Secondary Actors (*)
    - Acquisition of Road Information (*)
  - Data assessment
    - Query to LDM (*) Note: all the acquisitions use the Query LDM module).
- Activation/deactivation of CSAs

CSA tasks:
- Refined Scenario Analysis
  - Monitoring
    - Acquisition of parameters of Primary Actor
    - Acquisition of parameters of Secondary Actors
    - Acquisition of Road Information
- Assessment of the SMA zones (Comfort Safety Critical)
- Defining frequency and repetition rates for parameters to send
- Generation of requests of sending parameters on the VANET

It is important to remind that the scenario analysis recognizes the use cases of the related application evaluating of the situation surrounding the ego-vehicle using the data provided by the LDM which are maintained updated by the Data Fusion process running in the SAFESPOT platform.

Finally another important concept in SAFESPOT, described in section 5.3 is the risk classification. Three levels of risk (Comfort, Safety, and Critical) are considered in SAFESPOT.
**Fig. 4-5 Description of the roles for primary actor and secondary actor.**
4.2. Interface to external applications

During the job of building up the SAFESPOT specifications, carried out by the different SPs, a significant set of deliverables and working documents was produced. The interface to applications external to the SAFESPOT domain has been analyzed and defined in deliverables D4.3.2 [2] and in D4.3.4 [4].

One of the issues to be solved was the presentation in the vehicle dashboard of messages generated by applications running on RSUs as alternative or complement to Variable Message Signs existing along the roads.

An application has been defined for displaying general text messages, in order to support some more general warnings, such as a predefined set of screenshots (icons) and earcons (sounds). These may be also presented to the driver independently from the occurrence of a specific SAFESPOT Use Case.

Such “External Message Application” is characterized by some specific features that are shortly described in the following. Normally the SAFESPOT DAA is driven by the detection of specific scenarios and UCs, analyzed by the AM. In other words, all of the SAFESPOT applications rely on the presence of objects and parameters, in the LDM, characterized by precise physical and/or spatial attributes, representing the vehicle itself and its surroundings. These objects and parameters, whenever received by means of the SAFESPOT VANET, should be checked and integrated, by means of dedicated data fusion blocks, under the domain of the vehicular platform.

On the contrary the external messages maybe considered as mailbox containing information, stored in LDM, but decoded only by the application.

A graphical representation is reported on the following figure.

![Diagram of Interface to external applications](image)

The Messaging Application operates at this level of the HMI architecture.

Fig. 4-6 Interaction of the “External Message Application” with the HMI of the vehicular node.
Basically SP5 (or other compliant sources capable of interacting with the SAFESPOT vehicular Application Manager), should generate a specific “Message”, addressing the vehicle. This Message is stored in the LDM almost directly (data processing and fusion consists in a simple read and store operation).

The message is stored in a dedicated queue, associated to the ego vehicle object. The “External Message Application” is in charge of managing this queue and to serve the HMI requests defined in the Messages.

The concept is based on the identification (and sharing) of a common set of predefined icons and earcons, and on general textual messages, to be activated by the SP4 application manager without concerning on the specific (and potentially unknown, or newly introduced) applications requesting to access the HMI resources available on the given demonstrator vehicle.

Specifically, these “Messages” can be assimilated to descriptors of “Playback Events”. A given application external respect to SP4 may request to show a specific icon or a general text message (or to play an earcon) on the on board HMI of a SAFESPOT vehicle. In order to guarantee the generality of the approach, the requesting application should provide a precise time and/or spatial (geo referenced) delimitation to the intended “playback” event, other than the message string to visualize and/or the reference to the icon and/or the earcon to play.

An example of usage of the External Message Application is proposed in D4.3.4 [4]. A further basic example could be the following: let’s assume an Infrastructure based application is dedicated to the monitoring of an intersection and it is able to acquire the traffic lights status. This information can be delivered to the LDMs of the vehicles traveling in the intersection in order to implement some specific I2V functions. Even without any knowledge about such application, the specific requested functions can be decomposed into playback events to present to the drivers depending on the specific content of the provided assistance.

This is illustrated in the following figure, where it is assumed there is no specific support (application “clients”) running on the vehicles; nevertheless it is still possible to deliver, by means of the “External Message Application”, specific playback events (screenshots) and messages in order assist the drivers about the presence of a vehicle crossing with the “red”: 
Fig. 4-7 Assistance to a vehicle about the presence of vehicle crossing with the “red” provided by means of the “Messaging Application”.

In this very simplified representation, three different messages are used to implement the sequence of playback events in the three areas located before the crossing zone:

- Message for Area 1: - Crossing area 200 meters ahead. Keep your speed but be careful;
- Message for Area 2: - Crossing area 100 meters ahead. Pay attention to a vehicle oncoming from the left;
- Message for Area 3: - Crossing area 50 meters ahead. Slow down: a vehicle is in your collision path coming from the left.

The same messages may be substituted or complemented by icons or earcons which may provide a most direct signal to the driver as illustrated in [4].
5. The intelligence partitioning (Vehicle and infrastructure based applications)

5.1. The Vehicle based applications

Vehicular applications are implementing the Safety Margin Assistance concept, and are grouped into four clusters, as showed below:

<table>
<thead>
<tr>
<th>Application</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Intersection Safety</td>
<td>Lateral Collision - LATC</td>
</tr>
<tr>
<td>Lane Change Manoeuvre</td>
<td></td>
</tr>
<tr>
<td>Safe Overtaking</td>
<td></td>
</tr>
<tr>
<td>Head On Collision Warning</td>
<td>Longitudinal Collision - LONC</td>
</tr>
<tr>
<td>Rear End Collision</td>
<td></td>
</tr>
<tr>
<td>Speed Limitation and Safety Distance</td>
<td></td>
</tr>
<tr>
<td>Frontal Collision Warning</td>
<td></td>
</tr>
<tr>
<td>Road Condition Status – Slippery Road</td>
<td>Road Departure - RODP</td>
</tr>
<tr>
<td>Curve Warning</td>
<td></td>
</tr>
<tr>
<td>Vulnerable Road User Detection and Accident Avoidance</td>
<td>Vulnerable Road Users - VURU</td>
</tr>
</tbody>
</table>

Table 1 – Clusters and Applications developed in SP4 – SCOVA.

Lateral safety applications (LATC) are addressing the avoidance of the risk of lateral collision through an early warning to the driver. Specific scenarios for the three component applications are:

- road intersection safety: two types of urban intersections are analysed; in the first type it is assumed both infrastructure sensors and V2I communication are available; in the second type – longer term - the scenario is more complex, assuming all of the involved vehicles having V2V capabilities implemented (with or without the support of the infrastructure);
- lane change manoeuvre: prevention, during the road merging situations and approaching to the intersections, of the risk of lateral collisions; safe lane change manoeuvre with blind spot for trucks;
- safe overtaking: prevention of collision among vehicles in an overtake situation (integration of blind spot and early notification to the preceding driver of the intention to overtake of the vehicle behind).

Focus of the longitudinal collision cluster (LONC) is the possibility to inform the driver at an early stage about potential risk of frontal or rear-end collisions due for instance to the reduced speed of the preceding vehicles or, in case of two ways roads, due to overtaking maneuvers that the vehicles in the opposite traffic direction have started. The cooperative vehicles communicate directly to the other vehicles or to the SAFESPOT local infrastructure their position and dynamics or the presence of obstacles on the road. Scenarios for the four component applications are:
• head on collision warning: early warnings for situations where vehicles, travelling on opposite directions, may face the risk of an head on collision; specific use cases are presented where the advantages of V2V communication respect to ADAS sensing are emphasised;
• rear end collision: warnings for head to tail collisions, where host vehicle is moving (static scenarios covered by the frontal collision warning function) and it risks the rear end collision due – for instance – to a slow down due to road shape (hills, curves);
• speed limitation and safety distance: early information and warning to the driver concerning the speed and the safety margin to keep in the black spot situations in front, such as road works, static obstacles, or other factors that may limit or dynamically change speed and safety distance;
• frontal collision warning: warnings for head to tail collisions, where host vehicle is moving or static, and it risks the frontal collision due – for instance – to the presence of static or reduced speed traffic.

Road departure applications (RODP) are related to the sharing with other vehicles of the information of a slippery road status, or a bad road condition (can be due to weather condition, ice, fog...), or other factors – especially on bends - that may lead to the risk of a road departure. Scenarios for the two component applications are:

• road condition status – slippery road: a warning is broadcasted concerning the slippery road status or bad condition of the road;
• curve warning: information is gathered and delivered with a sufficient anticipation to the driver about the road curvature and the adequate speed to keep in the specific black spot. Conditions that may dynamically change the speed and the trajectory to avoid going off the road (road works, static obstacles) are also tackled.

Vulnerable Road User (VURU) is focusing on the propagation of information about a vulnerable user (detected by means of infrastructure or vehicles equipped with suitable ADAS, developed outside SAFESPOT – e.g. available by previous or on going projects, like Watch-Over) to other vehicles that do not have possibility to see or detect the vulnerable road user. Two basic scenarios are addressed in the Vulnerable Road User detection and accident avoidance application:

• after the detection of a VRU, the information is sent to the vehicle arriving from behind (scenario related to a 2 ways road in urban situation);
• To avoid accident with bicycle or motorcycle at the side of the vehicle when it decides to turn (frequent type of accident referring to the blind areas of trucks and commercial vehicles).

In the following some UCs of the SP4 Applications are reported. UCs are grouped based on the cluster of the related vehicle based applications.
5.1.1. Intersection Safety application

Six UCs have been collected regarding the Intersection Safety application:

- Accident at intersections;
- Obstructed view at intersection;
- Permission denial to go-ahead;
- Defect traffic signs;
- Other vehicle brakes hard due to red light;
- Approaching emergency vehicle warning.

An example of Use Case for the Road Intersection Safety (UC 1a) application is the following one, related to Accidents at Intersections:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Accident at intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_Accident at intersection – 1a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V1.2</td>
</tr>
<tr>
<td>Short description</td>
<td>A crash happens at an intersection resulting in a dangerous situation; the drivers approaching an intersection are warned about such event.</td>
</tr>
<tr>
<td>Purpose</td>
<td>Avoid critical situations resulting from an accident</td>
</tr>
<tr>
<td>Rationale</td>
<td>Intersections are probably the most complex part of road infrastructures and places where collisions result in serious injury or death. An accident at an intersection can result in other accidents as an unforeseen situation would exist. On intersections traffic-flow is very complex, so the driving behaviour of other drivers could change immediately, due to such unforeseen situations.</td>
</tr>
</tbody>
</table>

(*) Work on the IP project GST, or other e-call projects, should assist with this issue.
5.1.2. Lane change manoeuvre

Three UCs have been synthesized for the Lane Change Maneuver application:

- Lane change manoeuvre for trucks with blind spots;
- Lane change manoeuvre for car/trucks;
- Lane change manoeuvre for ramp in motorways.

In the following, the one related to Lane Change Maneuver for Trucks with blind spots is presented (UC 2a):

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Lane Change manoeuvre for Trucks with blind spot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_LaneChangeManoeuvre – 2a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V4.1</td>
</tr>
<tr>
<td>Short description</td>
<td>This scenario aims to inform and/or warn truck driver (V1) about the presence of other vehicle (V2) around him during manoeuvre, especially during lane change manoeuvre.</td>
</tr>
<tr>
<td>Purpose</td>
<td>Avoid accident due to blind spot with trucks during lane change manoeuvres</td>
</tr>
<tr>
<td>Rationale</td>
<td>Even if specific rear mirror help driver to have a good vision around its vehicle, some blind spot already exist in some situations. Due to the dimension of the truck, it is relevant in some situations to improve the driver information about the presence of other vehicles around him. The relative speed information with other vehicles can be taken into account to appreciate the safety of some manoeuvres. Some lateral collision or/and rear end collision can be avoided with other vehicles.</td>
</tr>
</tbody>
</table>
5.1.3. Safe Overtaking application

Three Use Cases are proposed for the:

- Safe overtaking in urban and semi urban roads with PTW already in overtaking;
- PTW overtaking OV while OV is turning left to park area;
- PTW overtaking OV while OV is turning left to park area.

In the following, the one related to Safe Overtaking in urban and semi urban roads with PTW already in overtaking is presented (UC 3a):

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Safe overtaking in urban and semi urban roads with PTW already in overtaking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_SafeOvertaking – 3a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V1.1</td>
</tr>
<tr>
<td>Short description</td>
<td>Host vehicle (1) starts to overtake vehicle (3) while a Powered Two Wheelers (2) is already in overtaking manoeuvre PTW (2) informs the host vehicle (1) about its manoeuvre.</td>
</tr>
</tbody>
</table>

Purpose
Avoid collision between PTW and car by giving warning to vehicle (1).

Rationale
This situation is critical for PTW users due to blinds spots and differential of speed between PTW and car that does not allow the driver to be aware about the presence of motorcyclist.

5.1.4. Head on collision warning

Three UCs are collected for the Head On Collision Warning function:

- Head On Collision Warning due to hazardous overtaking attempt by host vehicle;
- Head On Collision Warning due to hazardous overtaking attempt by a second vehicle;
• Head On Collision Warning due to the presence of a coach vehicle climbing down through a hairpin curve.

The first UC is related to a situation where host vehicle attempts an overtaking manoeuvre and is facing the risk of a head on collision due to the approaching of a second vehicle from the opposite lane. The second UC is describing the same situation, but the perspective (host vehicle) is the one of the vehicle which is driving normally and it is facing the head on collision risk due to a hazardous overtaking attempt started by a second vehicle. Third UC is referring to a completely different situation, where the risk of a head on collision is due to the presence of a coach climbing down through a hairpin curve. In the following, the one related to Head on collision warning due to hazardous overtaking attempt by host vehicle is presented:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Head On Collision Warning due to hazardous overtaking attempt by host vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_HeadOnCollisionWarning – 4a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V1.1</td>
</tr>
<tr>
<td>Short description</td>
<td>As in the pictogram below, host vehicle (1) attempts an overtaking manoeuvre to vehicle (3) which obstructs the driver’s (1) field of view, while vehicle (2) is approaching from the opposite lane.</td>
</tr>
<tr>
<td>Purpose</td>
<td>To warn the driver of vehicle 1 that an oncoming vehicle is in the adjacent lane and thus it is needed to delay or abort the overtaking manoeuvre</td>
</tr>
<tr>
<td>Rationale</td>
<td>To avoid or reduce the accidents linked to head-on collision situations</td>
</tr>
</tbody>
</table>

5.1.5. Rear end collision

Two Use Cases have been identified for the Rear End Collision application:

• Rear End Collision due to the presence of an heavy vehicle climbing up through an hairpin curve at a low speed;
• Rear End Collision due to the presence of a slower vehicle at the end of a hilly road segment.

In the following, the one related to Rear end collision due to the presence of an heavy vehicle climbing up through a hairpin curve at a low speed is presented:
### 5.1.6. Speed limitation and safety distance

Three Use Cases have been identified for the Speed Limitation and Safety Distance application:

- Speed limitation and Safety Distance and trucks driver recommendations;
- Safety Margin Assistant on black spots – tunnels;
- Safety Margin Assistant on black spots – reduction of lanes.

In the following, the one related to Speed limitation and safety distance and trucks driver recommendations is presented:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Speed limitation and Safety Distance and trucks driver recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_SpeedAndDistance – 6a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V2.1</td>
</tr>
<tr>
<td>Short description</td>
<td>This scenario aims to provide to the vehicle driver (2) some recommendations in term of speed and safety distance regarding the behaviour or status of the vehicle in front. Special focus can be done on trucks carrying dangerous goods.</td>
</tr>
</tbody>
</table>
Regarding the situation in front of the vehicle, it is possible to provide some recommendations to the driver (2) in order to take into account the status or the behaviour of the vehicle (1). For instance, if the vehicle (1) is carrying dangerous goods, the recommendation to the driver could be to increase the safety distance.

Rationale
Some existing recommendations on speed limitation and safety distance have been considered in some previous projects. Some new considerations can be added to improve the recommendation to the driver regarding additional information coming from other vehicles.

5.1.7. Frontal Collision Warning
Three UCs have been collected for the Frontal Collision Warning application:
- Frontal collision warning due to static obstacle in front;
- Frontal collision warning due to static obstacle in a tunnel;
- Frontal collision warning due to abnormal vehicle behaviour in front.

In the following, the one related to Frontal Collision Warning due to static obstacle in front is presented:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Frontal collision warning due to static obstacle in front</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_FrontalCollisionWarning – 7a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V2.1</td>
</tr>
<tr>
<td>Short description</td>
<td>This scenario aims to inform and/or warn truck drivers about the presence of a static obstacle in front.</td>
</tr>
<tr>
<td>Purpose</td>
<td>Inform or/and warn the driver in order to anticipate the vehicle deceleration caused by static obstacle on the road in front. It can be for instance due to accident or a vehicle breakdown...</td>
</tr>
</tbody>
</table>
Rationale
Radar or Lidar sensor performances are limited (distance around 200 meters), and in some cases, the driver can not be informed enough in advance about a risk in front. For instance, sensor performances can be limited if an accident occurs after a curve or due to bad weather conditions. Better anticipation for trucks is important to safely stop the vehicle.

5.1.8. Road condition status
Two UCs have been collected regarding the Road Condition Status – Slippery Road application:
- Road Condition Status – V2I Based;
- Road Condition Status - V2V Based.

In the following, the one related to Road condition status – V2I based is presented:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Road Condition Status – V2I Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_RoadConditionStatusV2I – 8a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V2.1</td>
</tr>
<tr>
<td>Short description</td>
<td>This scenario aims to inform and/or the driver in V2 about the road condition status detected by V1. The data is transferred via a road control centre.</td>
</tr>
<tr>
<td>Purpose</td>
<td>The driver in V2 shall be informed about the road condition status measured by V1 so that the driver of V2 can be informed about the current road condition. The infrastructure (road monitoring centre) is collecting and analysing the information.</td>
</tr>
<tr>
<td>Rationale</td>
<td>The infrastructure (road monitoring centre) can enhance the information on the road condition by taking into account information from several vehicles as well as incorporating other data such as weather data. The infrastructure is also monitoring the road condition by listening to the V2V communication between the vehicles.</td>
</tr>
</tbody>
</table>
### 5.1.9. Curve warning

One Use Case is proposed for the Curve Warning application: Curve Warning in rural black spots, based on a transponder in the infrastructure keeping memory of the speeds adopted by passing vehicles.

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Curve Warning in rural black spots, based on a transponder in the infrastructure keeping memory of the speeds adopted by passing vehicles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_CurveWarning – 9a</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V1.1</td>
</tr>
<tr>
<td>Short description</td>
<td>Host vehicle (1) transmits to an infrastructure transponder (3) its speed and (possibly) other vehicle dynamics information. Later, a vehicle approaching to the rural black spot (2) receives this information, adapting its speed depending on multiple parameters, including map and navigational information, if available, and the behavior of other vehicles.</td>
</tr>
<tr>
<td>Purpose</td>
<td>By broadcasting information from the host-vehicle, also a vehicle approaching a sharp curve without any digital maps or other navigation systems installed on-board, can travel inside the curve safely (with the suggestion of reference speed to keep) On the other hand, if the vehicle is already equipped with digital maps, the information of how other vehicle behold in the same situations can help to reduce the number of false and missing alarms.</td>
</tr>
<tr>
<td>Rationale</td>
<td>To avoid (or reduce) the accidents due to too high speed in approaching a sharp curve</td>
</tr>
</tbody>
</table>

### 5.1.10. Vulnerable Road User Detection and Accident Avoidance

The Vulnerable Road User Detection and Accident Avoidance function is the single function belonging to the VURU cluster of applications. For this application three Use Cases have been collected (first two belonging to the same situation related to the VRU crossing a road):

- Vulnerable road users crossing a road, based on on-board detection system;
- Vulnerable road users crossing a road, based on environment analyses;
- Vulnerable road users in blind spots of a truck.

In the following, the one related to Vulnerable road users crossing a road, based on on-board detection system is presented:

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Vulnerable road users crossing a road, based on on-board detection system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>SP4_UC_VRUAccidentAvoidance – 10a-1</td>
</tr>
<tr>
<td>Status</td>
<td>Final - V1.2</td>
</tr>
<tr>
<td>Short description</td>
<td>This scenario aims to inform/warn/recommend vehicle driver about the presence of a vulnerable road user who is crossing a road. The vehicle V1 is equipped with an on-board VRU detection system. A VRU is not detected by the driver V2 due to the bad visibility: hidden by a vehicle (V1 or V3) or due to bad weather condition</td>
</tr>
</tbody>
</table>

Road with two lanes on the same direction

**Purpose**

Avoid collision between vehicle and vulnerable road user (VRU), for instance pedestrian or bicycle

**Rationale**

Especially in urban and extra-urban roads with two or more lanes, the presence of vulnerable road user can be not detected by other vehicle drivers (V2) which are approaching. Several reasons for this:
- VRU are hidden by a vehicle (especially bus and trucks)
- There is bad visibility like sun reflection, bad weather, or during the night.
5.2. The infrastructure based applications

The SAFESPOT infrastructure based applications are those where data is processed and decisions are taken by the road infrastructure in cooperation with vehicles. This aspect is important as it enables these applications to implement control strategy of the road operator (for which it has legal responsibility); an example is a reduction of the maximum authorized speed. The applications detect potentially dangerous situations in advance and extend the driver’s awareness of the surrounding environment by generating warnings.

In order to design safety applications based on cooperative sensing technologies, a user centred approach was adopted. An extensive analysis of the accident data in Europe was carried out, for three different driving environments: urban areas, the motorways and rural areas, considering different European countries in order to find out what were the most relevant safety scenarios. This analysis was a necessary step in order to customize the applications to the needs and to derive a high benefit at the end.

Consequently, five infrastructure-based applications were defined: “Speed alert” (SPA), “Hazard and incident warning” (H&IW), “Road departure prevention” (Rdep), “Intelligent Cooperative Intersection Safety” (IRIS) and “Safety margin for assistance and emergency vehicles” (SMAEV). These applications aim to provide the most efficient recommendation to the driver through the onboard HMI and through road side communication devices like VMS or flashing lights (4).

5.2.1. Speed Alert

Speed alert applications deal with three topics: the definition of a legal speed limit, the calculation of a speed recommendation according dynamic events on the road and definition of a speed profile according to static black spots. All three topics are relevant to a large part of car accidents, as stated in the deliverable 5.2.2.

Although Speed Alert is often tackled from a vehicle point of view, these applications are infrastructure based. All processing is carried out in a roadside unit (RSU) which is set up at a black spot. Although the application is infrastructure based, processing is fed with data from the local dynamic map (LDM) which collects data coming from vehicle and infrastructure sensors. Once new driving rules are generated by the speed alert application, the related warnings to the drivers are sent through three vectors: via the ad-hoc network to the vehicles in the vicinity; via the variable message signs, to take into account non-SAFESPOT equipped vehicles; and information is also stored in the local dynamic map for oncoming vehicles at longer range.

Once the application is triggered by the events that are registered on the LDM the following tasks are performed (independently from the sub application concerned):
LDM Data receiving: The application receives relevant data from the LDM;

Situation analysis: Using the received data, the application aims to determine the speed limit or the speed profile according to the situation;

Message generation: This last part determines which the best suitable information vector is, according to the situation.

The application has been divided into three sub applications, according to the outcome of work package 2:

The first sub-application is **Legal Speed Limit**: the goal is to warn drivers on excessive speed with respect to the legal speed limit. The associate COSSIB use-cases are:

**SP5_UC32, Prevention of driver excessive Speed (Rule Violation).**
Given the various speed limits, regarding road type, weather conditions or pollution, it may be hard for the driver to know at each time what the exact speed limit is. Special conditions, for instance road work or traffic management, could locally modify the road speed limit. Moreover, with automated control system, drivers express the wish to be warned in case of speed limit enforcement. In this use case the infrastructure decides, regarding legal aspects, to give a speed limit prescription

The second sub-application is **Critical Speed Warning**. It is also aimed at warning drivers on excessive speed, but the speed limit is now dynamic and takes into account the environment and traffic condition. This sub-application collaborates with the Hazard and Incident Warning and it is related to several Use cases (including the previous one which corresponds to the case of ‘good’ environmental condition, so that the speed limit is the legal one) which are reported hereafter.

**SP5_UC11, Safety margin for maintenance vehicle on snow removal or salting operation**
A maintenance vehicle is performing salting or snow removal: It could be for instance to remove a dynamic black spot due to ice or snow. It shall limit the authorized speed behind it and it may prohibit or restrict its overtaking and the access to the dynamic black spot to ensure its safety and the safety of arriving vehicles. All vehicles arriving at the vicinity of the maintenance vehicle need to be aware of the speed limit, and they need to know whether maintenance vehicle overtaking is authorized.

**SP5_UC12, Assistance vehicle patrolling or signalling a traffic event on a road**
An assistance vehicle patrols or signals a traffic event (e.g.: accident, traffic jam, road works...). The vehicle is stopped or it’s moving slowly (backward or forward) on an emergency or a principal lane. All vehicles arriving or those being already in its proximity are warned about the presence of a slow or stopped vehicle. It may be associated with a speed limit and the additional alert that may be carried by the assistance vehicle.

SP5_UC13, Accident as an obstacle
A vehicle has had an accident on the road. All vehicles concerned (in the vicinity or incoming) are warned and possibly asked to change lane in order to avoid cumulative accidents. Furthermore, the infrastructure manager or assistance manager must be warned to react accordingly.

SP5_UC14, Traffic Jams as an obstacle (extension to Slow Moving Vehicle)
The end of a traffic jam shall be interpreted as an obstacle. In fact, especially on Highways where the speed limit is high, an incoming vehicle with some degraded conditions, either driver drowsiness or bad weather, may react lately. The driver must be warned with considerable advance before arriving at the traffic jam.

SP5_UC15, Traffic Jam as an obstacle results of an accident, with poor visibility
As the result of an accident on a motorway or non urban road, a queue is building up. Due to the speed of the vehicles and the lack of long distance visibility (due to a bend in the road), by the time the approaching vehicles become aware of the queue, there is insufficient stopping distance, even if they are not exceeding the official speed limit.

SP5_UC16, Deviations for road-works
A vehicle approaching a motorway deviation is faced to a number of risks: first, a possible slow-down, which could be sudden; then, the change of the lane (possibly getting into the opposite carriageway) is highly critical; moreover, road-workers may operate in the area. In the proposed system, about 200-500 meters before entering the tunnel the driver is warned about possible hazards (detected in real-time) including environmental conditions (e.g. wet road, fog, icy road, etc.). Obstacles, such as other cars in a queue, are also signalled in real-time. The warnings are provided either through configurable panels positioned in the infrastructure, or as warning messages that are displayed on enabled cars (similarly to the navigator's messages). Special attention is also devoted to the presence of road-workers that could be significantly highlighted. Their presence may imply a further dynamic reduction of the speed limit or of the road layout (virtual layout).

SP5_UC17, Pedestrian on motorway
Pedestrians can be encountered on motorway roads when they get out of a broken down vehicle, during road works or for other reasons. When the sensors of the infrastructure or those of equipped vehicles detect the presence of a pedestrian on the road, a warning is triggered to enhance their safety and the safety of oncoming vehicles.


**SP5_UC42, Prevention of Driver excessive Speed (critical environment conditions)**

Even below speed limit drivers might have an excessive speed regarding environmental condition. Indeed their speed can be too high at some infrastructure black spots, or in case of bad environmental conditions; often this kind of problem is not perceived. In this use case, the roadside infrastructure computes informs the safe speed to go through the difficulties taking as input the (time varying) local conditions.

**SP5_UC43, Entering into a tunnel**

A vehicle is approaching a tunnel in a motorway. The tunnel has a different illumination compared to the external environment. Additionally, the tunnel may be located in a sharp bend, which further reduces visibility. About 100-200 meters before entering the tunnel, the driver is warned about possible hazards, like a vehicle queue, people in the carriageway because of an accident, etc.

The third sub-application is called **Excessive Speed Alert**. Its objective is to define a speed limit with respect to the road, to its geometrical definition and its status. Furthermore, all drivers arriving at a black spot are warned. This application is linked to the Use Cases “Entering into a tunnel” and “Prevention of Driver excessive Speed (critical environment conditions)” and also to the following Use Cases.

**SP5_UC45, Sudden reduced visibility**

One of the major risks on the road is that the driver can be surprised by a sudden loss of visibility, due for instance to a turn after a long straight segment, or reaching of a hill top. Without frontal visibility the driver can not anticipate a trajectory due to the road geometry (hard turn) or to a possible obstacles on the road, like accidents, slow vehicles, traffic jams, deterioration of the roadway, large vehicles coming from other ways, pedestrians on the road, etc. The principle consists in detecting incoming vehicles, checking that their behaviours are compatible with the condition of the road stretch that’s invisible to the driver, and warning the driver in case of hazard. The approach of a vehicle close to the “black spot” (geometric loss of visibility) is detected either by an embedded equipment or by an infrastructure equipment located before the black spot. The check of compatibility between the vehicle behaviour and traffic condition after the loss of visibility is done by the infrastructure. Warnings are provided either by the infrastructure or by the embedded equipment on enabled vehicles.

**SP5_UC41, Prevention for the lack of adherence of the road:** Lack of adherence is caused by such phenomena as ice on the road or oil lost by a truck. Lack of adherence is hard for a driver to see at long range and often there is little time to react. Some specific factors as low temperature offer a first level of warning. But, based on the output of roadside sensors or data from oncoming equipped vehicles, the roadside unit can analyze the situation and detect low adherence. Drivers are then warned appropriately.
5.2.2. **Hazard and Incident Warning**

The objective of the Hazard and Incident Warning is to provide drivers with a warning of potentially dangerous ‘events’ or conditions affecting the road ahead. The type of road environment foreseen for this application consists of motorways, inter-urban or rural roads.

The dangerous events or conditions include:

- **Obstacles**: including stationary vehicles, queues, accidents, animals or pedestrians on the road.

- **Wrong way driving**: i.e. a vehicle travelling in the opposite direction to the main traffic stream, resulting either from a dangerous overtaking manoeuvre on a two-way road or to ‘ghost driving’ (where the vehicle is travelling against the flow on a motorway).

- **Low friction/Low Visibility**: the presence of bad weather conditions (e.g. rain, ice or fog) which pose a hazard due either to reduced tyre friction or low visibility.

Typical implementations will be at black spots, such as bends, tunnels, or other road sections which are known to have a high risk factor, for example due to a sharp curve, frequent queue formation or susceptibility to fog or ice.

Warnings will be communicated to drivers both via roadside devices (LED warning lights along the road or VMS panels) and, in the case of SAFESPOT vehicles, via the VANET (ad hoc vehicle network).

The execution of the H&IW applications follows a sequence of steps which are briefly described below.

1. **Event catching**
   - Notification of an EVENT (hazard or dangerous condition) which has been detected within the area covered by the application. This is provided by the LDM through a ‘data push’ mechanism and serves as a trigger for the application to start. The conditions which need to be met for the recognition of the event will be set for each specific version of the application.

2. **Scenario analysis**
   - Detailed characterisation of the EVENT. This allows the acquisition of further information which will increase the level of reliability, accuracy and detail of the EVENT characterisation.
   - Detailed characterisation of the SCENARIO (surrounding road environment) is carried out by the ‘BLACK SPOT ANALYSER II’ module. The LDM will be queried to obtain updates which can provide information about the area upstream and downstream of the EVENT. This will include information about a) vehicles...
approaching the location, and b) road status e.g. presence of rain, ice or fog in the monitored area.

3. Risk evaluation

- Calculation of the safety-criticality level of the EVENT, which is carried out by the ‘THREAT ASSESSOR’ module. This consists of an assessment of the likelihood of an accident occurring.

4. Safety Margin computation

- The DECISION MANAGER will determine whether a warning should be sent, the type of warning and how it should be communicated to road users. In deciding the relative priority of the message, this module collaborates with APPLICATIONS COORDINATOR.

5. Warning strategy realisation

- Actuation of the commands to activate and deactivate the signals or messages displayed by roadside warning devices is carried out by the ‘WARNING SYSTEM ACTUATOR’ module.

- Management of messages (information) to be communicated via the VANET to SAFESPOT equipped vehicles is undertaken by the ‘MESSAGE GENERATION’ module.

Use cases

H&IW_01: Obstacle: deals with safety-critical situations in which an obstacle is blocking part or all of a carriageway. The objective of this sub-application is to send appropriate warnings to all approaching vehicles when an obstacle has been detected. The warnings may be communicated through roadside devices (LED warning lights or VMS), through the VANET directly to vehicles and, in specific cases, by an ‘Assistance and Emergency Vehicle’.

H&IW_02 Wrong Way Driving: this sub-application will provide warnings in the case of any vehicle travelling in the wrong direction, to warn approaching vehicles to reduce speed and/or change lane, and also to warn the driver of the overtaking vehicle. In the case of overtaking, the vehicles being overtaken may be alerted to facilitate a return to the correct lane.

H&IW_03 Abnormal road conditions: it deals with a black spot which could be found on any type of infrastructure, but is more frequent on motorways and rural or inter-urban roads. The objective is to warn oncoming drivers of a stretch of road in which critical conditions exist in relation to the road surface status or a meteorological condition. A further aim of this sub-application is to define the braking distance for other H&IW sub-applications. The warning is sent to the road user using VMS, or VANET, and a new braking distance rule is also defined.

5.2.3. Intelligent Cooperative Intersection Safety
Besides motorways and rural roads the major areas of interest are the urban
intersections, which usually are accident-prone areas. This common
knowledge has been testified within a detail accident analysis at the beginning
of the project. The task of the infrastructure-based application monitoring an
urban intersection called "Intelligent Cooperative Intersection Safety System"
(IRIS) is to achieve the objective of a safe urban intersection with significantly
less accidents.

The roadside application IRIS surveys signalized urban intersections by
tracking all individual movements of road users (drivers, pedestrian and
bikers), an operation that can be regarded as a microscopic procedure. By
analyzing the individual vehicle movements, IRIS tries to identify dangerous
situations as early as possible in order to warn or intervene as effectively as
possible.

The whole IRIS procedure, which is performed periodically in a loop, splits
into five subsequent main parts:

1. **Receive LDM data**: Here the static data describing the intersection
geometry are retrieved from the LDM data base when the procedure is
started up.

2. **Trajectory forecast**: The prediction of vehicles’ trajectories is based on
“reference tracks”, which can be regarded as static representations of the
typical driving lines of vehicles at intersection. For forecast purposes the
static reference track is extended by a dynamic layer, which is named
“VMART” (Vehicle Movement Assignment on Reference Track).

3. **Situation analysis**: All potential conflict points of vehicle movements are
determined together with probabilities by examining all combinations of
VMARTs with stop lines or pedestrian / biker crossings. The traffic light
states are also taken into account. The result is a list of critical / dangerous
situations together with expected time points and their likelihood to
happen.

4. **Measure generation**: To select or determine a measure two main things
are considered: the probability that a vehicle is involved in a particular
hazardous situation and the time-to-collision to determine the safety
margin area. Thus, each scenario requires a different decision from IRIS,
what may result in different sets of messages in order to prevent collisions.

5. **Alert device control**: The last action in the course of events is the control
of the corresponding alert sub-systems or devices, respectively. In
principal two different classes of measures are realized: (1) warning
messages that will be send to the drivers by using wireless communication
and (2) local traffic light control changes in order to lengthen red times of
certain signal groups.

**Use cases**
The following four use cases are considered by the IRIS application.
SP5_UC22 Safe signalized intersection (crossing and turning)
A vehicle driver at an intersection has four possibilities for his intended driving direction: crossing the intersection, turning left, turning right and u-turning. Hence the situation at an intersection is complex. The driver of the vehicle has to keep an eye on several points to avoid any misjudgement even if everybody is obeying the traffic rules. He must pay attention to pedestrians, cyclist and other potential vehicles crossing his way.

SP5_UC31 Safe signalized intersection (red light violation)
In the case of an imminent red light violation (short distance to stop line in combination with high speed) warnings shall be send out to the drivers concerned. The purpose of this use case and the corresponding application is as follows: imminent red light violation shall be detected as early as possible in order to warn all the road-users concerned. The goal is to significantly decrease the number of accidents of this type by deploying such cooperative systems. This use case is divided into two stages. The first stage is to warn the driver in order to avoid the red light violation. The second stage is to warn other affected road users if the driver does not stop in front of the red light.

SP5_UC52: Emergency vehicle approaches a controlled intersection
When an emergency vehicle is approaching the urban intersection the other vehicles concerned (e.g. downstream or in the vicinity of the intersection) are warned and possibly asked to give way. This would include a response signal from the traffic light control to the emergency vehicle.

SP5_UC33: A vehicle approaches an uncontrolled intersection, where it has to give right of way and has to stop (stop sign). Potentially there are priority conflicts (e.g. four way stops), complex situations and inappropriate driver behaviours. The driver is warned in case of dangerous situations and is informed in case potential infringement of the traffic rules. The purpose of this use case is to decrease the number of accidents at uncontrolled intersections.
by employing cooperative systems. The risks related to this use case are:
inappropriate speed of approaching vehicles, low visibility or obstructed view
and perceived precedence conflicts (e.g. at a four-way stop).

5.2.4. Road Departure

Road departure and lane departure represent a significant amount of
accidents (30-40% of the accidents in rural areas, 20% in motorways). A
number of systems have been developed in order to reduce such figures.
These range from the camera-based on-vehicle Lane Warning Systems, to
the noisy lanes at the side of the motorways, that are typically available in
foggy areas.

To the best of our knowledge, SAFESPOT is the first project that addresses
the road departure problem through a vehicle-infrastructure cooperation.
Infrastructure support poses advantages, since it allows monitoring and
managing also non-equipped vehicles. However, it poses also challenges,
such as the difficulty in recognizing a road-departure situation, and
constraints, especially in the costs due to the deployment of a number of
short-range wireless network access points.

In order to have a reasonable cost/performance ratio, SAFESPOT decided to
focus on a black-spot situation (typically, a dangerous bend), that is covered
by only one Road Side Unit (RSU), possibly hosting also other cooperative
applications, such as Hazard and Incident Warning.

The Road Departure (RD) application is a module fully integrated in the
SAFESPOT-defined architecture, with a server on a Road-Side Unit (the
RSU, with access to the Local Dynamic Maps, LDMs), sensors ad actuators
distributed in a limited coverage area (the area around the covered black-
spot) and software clients installed in Safespot-equipped vehicles.

The Road Departure application relies on the concept of Safe Driving Maps
(SDMs). The idea is that, for the covered area (a black-spot) recorded data
are available of “optimal” behaviours for passing by-vehicles.
Fig. 5-2: An exemplification of the SDM concept in a dangerous bend. The lighthouse represents a flash that blinks (in yellow or red colour) whenever a dangerous situation is detected.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>speed</th>
<th>heading</th>
<th>yaw</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>5-5</td>
<td>&lt;90</td>
<td>170-175</td>
<td>&lt;5</td>
</tr>
<tr>
<td>10</td>
<td>0-8</td>
<td>&lt;95</td>
<td>165-170</td>
<td>&lt;5</td>
</tr>
<tr>
<td>20</td>
<td>7-0</td>
<td>&lt;80</td>
<td>165-170</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

The SDM specifies, for each position of a vehicle in a curve, along an independent variable (the X axis, in this case), the “right” value for all the other relevant parameters, such as y, speed, heading, yaw, etc.

The “right” values are recorded by special probe vehicles that go through the black-spot during dedicated recording sessions. These data are then elaborated by experts and stored (as tables or sets of possible rules based on such values) in the local Road Side Unit (RSU) that manages the black-spot. Once ready, these tables are queried by the RD application for every vehicle passing along the covered area. If a vehicle’s dynamic parameters are outside from the suitable range, then warnings are delivered to that vehicle and possibly to other vehicles in the area.

In order to have a concrete idea, the final application may be conceived as an Electronic Traffic Convex Mirror (ETCM), with flash signals (yellow or red light according to the level of danger), additional acoustic warning (e.g. for road-workers) and warning messages delivered to equipped vehicles.

Fig. 5-3: A traffic convex mirror
The SDM concept may be applied also to other applications beyond RD (e.g. Speed Alert), and not only in a Roadside Unit, but also on a vehicle. This leads to synergies with other SAFESPOT applications and sub-projects. Moreover, this work can be considered as a significant case study of a technique that may be inserted as an additional layer into new generation, safety-oriented, Local Dynamic Maps.

**Use cases**

In order to develop a COSSIB application that can be meaningfully tested (and at reasonable costs), two use cases have been considered where RD shows a certain degree of locality (and thus it can be implemented at relatively low cost). These use cases are: Deviation for Road-Works and Dangerous Curve management. In these cases, the road configuration is such that RD is more likely to happen and more dangerous than elsewhere since it may involve more vehicles – e.g. in a curve with limited visibility - and vulnerable road users as well – e.g. road-workers. The Deviation for Road-Works case is particularly significant because it considers a semi-static blackspot that may be a significant place where portable SAFESPOT infrastructure may be temporarily mounted as standard regulatory equipment.

![Fig. 5-4: The Deviation for RoadWorks and the Dangerous Curve use cases](image)

**5.2.5. Safety Margin for assistance and emergency vehicle**

Safety margin for Assistance and Emergency Vehicle (SMAEV) is a SAFESPOT CoSSIB application which intends to enhance safety and efficiency of Assistance and Emergency Vehicles (AEV) and to optimize their management. It is indeed an application running on the On Board Unit of the Assistance and Emergency Vehicles and allowing them to reach the site where an event (i.e congestion, accident, road maintenance) has happened/is happening, and perform event signalling in a SAFESPOT compliant way. Signalling strategy is loaded on the basis of the LDM content, and warning itself is performed through the VANET and using Variable Message Signs placed on the rear-top of the AEV. Moreover, this application allows service
vehicles to cross a SAFESPOT intersection in safe conditions during emergency rescue missions, through the communication with a Roadside Unit that implements the Intelligent Cooperative Intersection Safety Application.

These functionalities are performed in a semi-autonomous way: it is the on-board system that decides warning strategies, actuates signals, communicates with external entities, but it is actually the AEV operator that chooses the basic actions to undertake and confirms/denies signalling changes through an appropriate Human Machine Interface. Therefore SMAEV application fits into the SAFESPOT Applications general scheme, but with the peculiarity that the AEV sensing peripheral is the Human Machine Interface (HMI) of the AEV operator.

Moreover, AEVs have the ability to complete the SAFESPOT system coverage by acting as mobile Road Side Units, providing detection and communication means in areas where infrastructure is not available or not sufficient to manage a certain type of road event

Use cases

The SMAEV application is based on three road operation scenarios:

- **Safety Margin for Maintenance Vehicle on Snow Removal or Salting Operation**: This use case describes a repeatable interaction when a maintenance vehicle on snow removal or salting operation is acting on a zone of risk. The Assistance Vehicle intervenes to manage with safety the situation by broadcasting through the VANET a message containing the description of the restricted zone and driving instructions.

  ![Fig. 5-5: Maintenance Vehicle on Snow Removal or Salting Operation](image)

- **Assistance Vehicle Patrolling or Signalling a Traffic Event on a Road**: Assistance Vehicle patrols or signals a traffic event (e.g.: accident, traffic jam, road work…). It can be stopped or moving slowly (forward or backward) on an emergency or one of the principal lanes. All vehicles arriving or those being already in its vicinity are warned about its presence. It broadcasts a message containing instructions of speed limit, number of lanes affected and the position of the obstacle (or the distance up to the event).
Fig. 5-6: AV Signaling a Traffic Event on a road

- **AV Signalling a Traffic Event on a Road**: This use case is a specialization of the previous one, especially when the Assistance Vehicle is stopped. This use case may be used for intervening in urban roads and second level incidents.
5.3. The On board HMI

In SAFESPOT a specific analysis based on the criticality of the messages and their possible representation were analysed as well as the related architecture (Fig. 5-7).

A more general HMI architecture was developed in another IP devoted to HMI, AIDE [19].

The SAFESPOT HMI is designed as an environment where different applications can present their warning messages to the user. In fact the basic idea of the SAFESPOT HMI is to implement an open and interoperable module, capable of supporting HMI information provided by different applications. These applications can be those developed within the SAFESPOT project or not (i.e. those developed in the CVIS IP). The same HMI, in different implementation flavours, should be able to support in a unified frame of reference, the drivers of different type of vehicles (e.g. passenger cars, trucks, motorbikes).

The application level shows all the possible applications which would like to send a message to the HMI, in order to visualize the warning messages for to driver. Built in application (the ones designed and developed within SP4) have the full control of the HMI resources, using in the most suitable way the available information channels (visual, acoustical, haptical) depending on the specific applications and use case. In order to provide a general and open access to the vehicle HMI from external (and eventually unknown) applications, the access to the HMI resources for “foreign” compliant applications is limited to the visual channel, and mostly based on plain test messages and icons.

All the requests of using the HMI by these different applications must be scheduled by the Application Manager. The Application Manager is seen like a referee who has to decide, on the basis of the state of all the applications, which one must be activated firstly.

The priority scheme adopted for controlling the access to the HMI resources is described in a dedicated HMI management chapter. For the built in applications, the priority is function of the internal state (comfort, safety, critical) of each application.

Moreover, a choice among the priority levels between SP4, SP5 and other applications must be done, in order to allow the Application Manager to drive the HMI toward the most critical application which is requiring an action.

The application selected by the Application Manager is allowed to send its message to the HMI. This selected application is at the same level of other applications coming from different projects (like CVIS). The referee for the priority among these applications which not necessary share the same standard of messages is the HMI manager, which is the core component of the HMI architecture.

The HMI manager has two main roles: as first, it has to schedule the priority among applications coming from different projects; once chosen the application to schedule, it has to decide how to represent on the HMI
actuators the warning signals sent by the application. These several signals are of different types: acoustics, visuals, and haptics. In addition, the HMI manager receives not only the signals from the selected application, but also other inputs, representing the current situation of the environment and the driver state. The HMI manager will decide which signal, among the available signals of the selected application, is the most appropriate to the current state, and then it will send this signal to the HMI lower level, which is the actuator. The HMI manager will decide the signal to send to the HMI actuator also by considering the type of vehicle that has to be supported, because for each type of vehicle, a different HMI actuator will be available.

The **HMI actuator** is the lower level of the HMI. It is dependant on the particular vehicle, as will be defined in the following paragraph.

As shown in Fig. 5-7 the arrows between HMI and vehicles are bidirectional because it could be possible for a driver to select some options of visualization (as an example, the driver could decide to disable all the comfort signals because he does not want to be distracted for non-critical warnings).

The warning design guidelines are to be applied at each Safety Margin Assistant warning level. The different levels of urgency must be realised by carefully choosing appropriate warning modalities. In the comfort stage, a signal should draw attention to the central screen of the vehicle which shows information about the type and the distance of the hazard. In the safety stage a suitable signal should attract the driver’s attention and also indicate the direction of the hazard. Short and intuitive visual information should inform the driver to perform the correct actions. The character of the warning should be more urgent than the one for the comfort stage since the time horizon is shorter. In the critical stage a clear signal must direct the driver’s attention towards the hazard. Since the time horizon is very narrow in this situation slight system intervention could suggest the correct action in an intuitive and quick manner.

It is proposed to closely link the third element of the warning design guideline “Recommend corrective actions” to the second element “Inform about type and criticality of hazard”. The reasons are the following: It might be technically difficult to always recommend the correct action especially in complex traffic situations. Providing inadequate recommendations could be very irritating for the driver and could even raise product liability issues for the manufacturers. Also obvious recommendations like “Slow down” can be distractive since drivers have usually encountered the situation several times and know how to react in the most appropriate way. The presented warning concept rather proposes to design the warning itself in a way that already incorporates the recommendation.
Driver is informed about future, potentially critical event. He/she should be (mentally) prepared to take an appropriate action soon.

Driver is alerted to take corrective action (slightly above normal intensity) in order to avoid a critical situation.

Driver is alerted to take immediate corrective action (emergency type) in order to avoid a critical situation.

**COMFORT message**

**SAFETY message**

**CRITICAL message**

<table>
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<td><strong>COMFORT message</strong></td>
<td><strong>SAFETY message</strong></td>
<td><strong>CRITICAL message</strong></td>
</tr>
<tr>
<td><strong>COMFORT message</strong></td>
<td><strong>SAFETY message</strong></td>
<td><strong>CRITICAL message</strong></td>
</tr>
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Based on the warning design guidelines and the discussion carried out among HMI experts of the project, an additional list of design statements has been compiled:

1. For each application three warning levels (comfort, safety, critical) are foreseen according to required urgency and intensity of intervention.

2. Safety and critical messages are multimodal involving at least an appropriate acoustic signal (earcon) complemented by visual/kinesthetic/haptic stimuli. If preferred, comfort messages can be designed without acoustic warning stimuli, given that they attract the driver’s attention in time.

3. Visual screen information should be visible and dynamically updated within the comfort, safety and critical stage. It must be guaranteed that visual information is displayed long enough to be read by the driver.

4. HMI should be partially configurable by the driver in particular for comfort messages (e.g. deactivation or selection of warning sound for comfort messages).

5. HMI should be effective and accepted independently from the type and class (cost) of the vehicles.

6. HMI needs to be adapted / simplified for PTW.
6. Conclusions

A description of the SAFESPOT applications is presented aimed to provide the rationale, the concepts and the architecture of these applications.

The role of primary and secondary actor in SAFESPOT is widely discussed and the specific applications demonstrated in the timeframe of the project presented. This set of applications was chosen to demonstrate the potentiality of the SAFESPOT concepts, to extend the technology validation and to provide a first implementation of future real-life applications.

The complexity and performance issues as well as concept like the Message Manager and Application Manager will be tested in several demonstrators.

Although not covering all the possible parameters of the V2I applications the “external message application” was designed to provide a good set of parameters for a detailed delivery of messages from infrastructure to vehicles. This transversal application will allow to all the SAFESPOT vehicles implementing it to run any V2I application implemented according to the SAFESPOT rules and will provide interoperability of vehicles in different Test Sites.

7. References

SAFESPOT Deliverables:

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[2] SAFESPOT deliverable D4.3.2 Driving Safety Margin Functional specification
[3] SAFESPOT deliverable D4.3.3 Application communication for co-operative vehicles and infrastructure
[4] SAFESPOT deliverable D4.3.4 Conceptualisation of on-board information system and extended HMI
[5] SAFESPOT deliverable D5.3.1 Specifications for Speed Alert
[6] SAFESPOT deliverable D5.3.2 Specifications for Hazard and incident Warning
[7] SAFESPOT deliverable D5.3.3 Specifications for Cooperative intersection collision prevention systems
[8] SAFESPOT deliverable D5.3.4 Specifications for the Road Departure Application
[9] SAFESPOT deliverable D5.3.5 Specifications for Safety margin for assistance and emergency vehicles
[10] SAFESPOT deliverable D7.3.1 Global System Reference Architecture specification
[11] SAFESPOT deliverable D8.4.2 Description of the integrated vehicle and infrastructure platform
[12] SAFESPOT deliverable D4.2.3 Use case and typical accident situation
[13] SAFESPOT deliverable D4.2.4 Needs and Requirements (SCOVA)
[14] SAFESPOT deliverable D5.2.3 Area specific needs and requirements and Application Scenarios
[15] SAFESPOT deliverable D5.2.1 Definition of use case and user requirements
[16] SAFESPOT deliverable D5.2.2 Common Architecture and Communication
[17] SAFESPOT deliverable D5.2.4 Accident data review and potential impact of each function
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