SAFESPOT INTEGRATED PROJECT - IST-4-026963-IP

DELIVERABLE

SAFESPOT
COOPERATIVE SYSTEMS FOR ROAD SAFETY

HOLA - HOrizontaL Activities

SAFESPOT Final Report – Public version

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Abbreviation List

ADAS	Advanced Driver Assistance System
AEV	Assistance and Emergency Vehicle
AM	Application Manager
API	Application Programming Interface
BLADE	Business models, Legal Aspects, and Deployment
C2C-CC	Car to Car Communication Consortium
CALM	Continuous Air interface for Long and Medium range
CAN	Controller Area Network
CCTV	Closed Circuit Television
CoSSIB	Cooperative Safety Systems Infrastructure Based
CSA	Cooperative Support Application
DAA	Driver Assistance Application
DG	Directorate General
EC	European Commission
ECAID	Extended Cooperative Automatic Incident Detection
ETSI	European Telecommunications Standards Institute
EUCAR	European Council for Automotive R&D
GPS	Global Positioning System
H&IW	Hazard and Incident Warning
HMI	Human Machine Interface
HOLA	HorizontaL Activities
HW	Hardware
I2V	Infrastructure to Vehicle
ICT	Information and Communication Technologies
ID	Identifier
IEEE	Institute of Electrical & Electronics Engineers
INFRASENS	Infrastructure sensing and platform
IP	Integrated Project
IRIS	Intelligent Cooperative Intersection Safety
ITS	Intelligent Transport Systems
LAN	Local Area Network
LDM	Local Dynamic Map
LED	Light Emitting Diode
MM	Message Manager
NTP	Network Time Protocol
OBU	On Board Unit
OEM	Original Equipment Manufacturer
PC	Personal Computer
PTW	Powered Two Wheelers
R&D	Research and Development
RFID	Radio Frequency Identification

RSU	Road Side Unit
SAFEPROBE	In-Vehicle Sensing and Platform
SCORE	SAFESPOT Core Architecture
SCOVA	Cooperative Systems Applications Vehicle Based
SDM	Safe Driving Map
SINTECH	Innovative Technologies
SMA	Safety Margin Assistant
SMAEV	Safety Margin for Assistance and Emergency Vehicle
SP	Sub Project
SPA	Speed Alert
SW	Software
TS	Test Site
UC	Use Case
UML	Unified Modelling Language
UWB	Ultra Wide Band
VANET	Vehicle Ad Hoc Network
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2V2I	Vehicle to Vehicle plus Vehicle to Infrastructure (hopping)
VMART	Vehicle Movement Assignment on Reference Track
VMS	Variable Message Sign
WP	Work PAckage
WSN	Wireless Sensor Network

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EXECUTIVE SUMMARY

This document is the public version of the Final Activity Report of the European 6th Framework Programme Integrated Project SAFESPOT. SAFESPOT was a 54 month project, running from February 2006 to July 2010, coordinated by Centro Ricerche FIAT (Italy). Its project consortium included 52 partners among OEMs, suppliers, road operators, public authorities, service providers, associations, universities and research institutes from twelve European Member States. SAFESPOT has been co-funded by the European Commission DG Information Society and Media, ICT for Transport, and has been supported by EUCAR. The total SAFESPOT project cost is 38 M€, of which 20,5 M€ have been funded by the European Commission.

During its life time, SAFESPOT established a number of active cooperation in particular with the Car2Car Communication Consortium (C2C-CC), with COMeSafety, and with the integrated projects CVIS and COOPERS that have been running at the same time on complementary activities.

In its four and half project years SAFESPOT organised numerous thematic workshops open to different stakeholders and participated to major congresses and events, e.g. the C2C-CC Forum and Demonstration 2008, the ETSI TC ITS Workshops, etc.

SAFESPOT presented its major project results at world wide level in cooperation with CVIS and COOPERS at the Cooperative Systems Showcase 2009, held during the ITS 2009 World Congress, and at the Cooperative Mobility Showcase held in Amsterdam in 2010. Both events have been jointly organised by SAFESPOT, CVIS, COOPERS, the European Commission and local organisers. More than 1000 people had the chance to see, test and discuss the SAFESPOT project results in the framework of cooperation that is creating the so-called “mobility network”.

Passive and active safety has made formidable progress in the past decades, nowadays communication technologies can create the leap towards the zero accident vision. The SAFESPOT integrated project created the technological building blocks and the reference applications based on vehicles and infrastructure sensing of the traffic and of the environment and on the creation of ad hoc communication networks among vehicles and with the infrastructure to provide time critical safety information in advance.

Among its majour achievements, SAFESPOT developed the so-called “safety margin assistant” that can provide drivers all essential information about a potential risk sufficiently in advance to avoid the need to undertake emergency and risky manoeuvres, having sufficient time to properly react to collision risks.

SAFESPOT cooperative systems based reference applications have been developed to face a number of selected representative cases of use and have been successfully tested and validated in a number of test sites located in Italy, Germany, Sweden, the Netherlands, France and Spain.

SAFESPOT demonstrated that the so-called “cooperative safe mobility network” is feasible today and is a key milestone towards a future with a safe and efficient mobility.

The project, being an Integrated Project, was divided into eight Sub-projects, each addressing a different aspect of the overall goal, as described hereafter. Since the initial project phase all subprojects have been working together in cross-subproject working teams on the different topics, to guarantee the consistency and the uniformity of project outcomes. Once installed, this working process and approach has been kept for the whole project time frame.

In-vehicle sensing and platform: the SAFEPROBE subproject

This sub-project defined which safety related information can be extracted from the vehicle, considering traditional sensors and also innovative ones (like ADAS sensors). A solution for the vehicle platform has been specified and developed, to enable the exchange of this sensing information with other vehicles and the infrastructure, using a data protocol that allows the maximum flexibility and upgradability of the technological solution, keeping into account the requirement of safety applications (low latency time).

Infrastructure sensing and platform: the INFRASENS subproject.

This sub-project identified the safety-related information that can be obtained from the on-road infrastructure, considering traditional sensors and also innovative ones (like wireless micro-sensor networks). A solution for the infrastructure platform has been defined and developed so that this sensing information can be exchanged with the vehicles and the infrastructure, using the same flexible protocol that the in-vehicle platform is using.

Innovative technologies: the SINTECH subproject.

The key enabling technologies have been developed in this subproject. Three technologies were foreseen: accurate relative localisation between vehicles (and, in some cases, also infrastructure), local dynamic maps and ad-hoc communication networking among vehicles. All these three technologies have been specified and developed considering the cooperative approach as the base for the solution adopted. This subproject provided also substantial inputs to the standardisation process and defined, in cooperation with the C2C-CC, the best candidate communication technology, IEEE.802.11p, to create the network of exchange of safety related time critical information.

Cooperative system application vehicle based: the SCOVA subproject

This subproject designed and developed selected reference cooperative system based safety applications, considering vehicle-to-vehicle communication as the basis for their development. Only very “light” infrastructure support has been considered, for example small transceivers in dangerous locations, to serve as data storage when there are no vehicles in the local area.

Cooperative safety system infrastructure based: the CoSSIB subproject

This subproject designed and developed selected reference cooperative system based safety applications, considering vehicle-to-infrastructure communication as the basis for their development. Vehicles have been equipped with “light” equipment (e.g. transceiver), also non equipped vehicle have been addressed in this subproject. This approach has been the basis for providing effective solutions for specific dangerous road segments without the need to have all vehicles equipped.

Business models, legal aspects and deployment: the BLADE subproject.

The future cooperative mobility network will enable a safe, efficient and clean mobility. The SP6-BLADE subproject had the very challenging tasks to draw the line towards future implementation.

Cooperative systems are “new” and involve a number of stakeholders; therefore also the approach to deployment has to be “new”. BLADE analysed potential solutions, cost benefits ratio, legal implications and liabilities creating the ground for a future effective and sustainable deployment.

SAFESPOT core architecture: the SCORE subproject.

In this subproject the overall communication system architecture has been defined in team with the task force led by the COMeSafety Support Action, a team that included also (and not only) the CVIS and the COOPERS projects. Today, thanks to the work of the task force the Common European Architecture for cooperative systems is defined, the related frequency band is allocated and the forthcoming phase of extensive field trials of cooperative systems can be held at European level: a key milestone for the future deployment.

Horizontal activities: the HOLA subproject.

The activities of this subproject were focused on the IP project management and controlling, undertaken by Centro Ricerche Fiat with the support of the Core Group.

In addition this subproject included also the development and implementation of proper strategies for project quality and assessment, project results dissemination and clustering, project exploitation and training activities.

This document reports in details all SAFESPOT Integrated Project activities and results.

1 Introduction

The present document is the final report of the EU 6th Framework Programme Integrated Project SAFESPOT. An overall description is given of the project initial objectives, together with the work carried out to achieve these objectives. It is also reported about how it was organised and what results were obtained.

Concerning the SAFESPOT applications, an introductory chapter reports the system characteristics and architecture. Both of these elements are reported to describe the validated safety applications and how these applications were conceived and designed. Moreover the concept of vehicle based and infrastructure based application is introduced.

A chapter follows detailing 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.

The description of the vehicle HMI is then presented, giving particular emphasis to the three level of risk associated to the SAFESPOT messages: Comfort, Safety and Critical.

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 sections the SAFESPOT Test Sites are described, where the developed applications have been tested and validated.

2 Background

The growing mobility of people and goods has a very high societal cost in terms of traffic congestion and of fatalities and injured people every year. Several studies have shown that the driver is responsible of more than 90% of accidents, mainly for distraction or misjudgment of the current traffic and environmental situations.

In the past decade a lot of research has been dedicated to solve these problems by the development of driver assistance systems based on autonomous sensor technologies that are able to perceive the traffic situation surrounding the vehicle and, in case of danger, to properly warn the driver.

Sensing technologies, essentially based on radar and video systems, enables the possibility to have in real time a picture of the vehicle surroundings, thus improving road safety by avoiding an important number of accidents, or at least reducing their effects. The research and development in this field allowed a complete understanding of pro and contra. Specifically:

- the extent to which autonomous systems are operable cannot go beyond their sensing range, for example after a sharp curve;
- the sensor systems are not able to manage all the traffic scenarios, thus missing some alarms or producing false alarms;
- in several cases the sensor systems could not perceive the danger with a sufficient time in advance for the driver to perform the maneuvers and avoid the accident.

Reliability, time and spatial horizon are then open issue for the autonomous solutions, based on sensor systems installed on vehicles.

Last but not least these systems are still expensive in view of the fact that nowadays they are sold as comfort functions and not as safety functions, additionally their market penetration is limited by the liability risk of car makers and automotive suppliers.

In these years telematic technologies are entering on vehicles as information and support systems supported by the growing consumer market that offers systems and services with high reliability at low cost.

The vision of the cooperative approach is born in view of joining the advantages of the telematic technologies and of their diffusion on the market to enable the development of reliable and extended driving support systems for road safety.

The cooperative approach envisages a scenario in which the vehicles and the infrastructure cooperate to perceive potential dangerous situations extended in space and time horizon that will only be limited by the range of the radio communications. The reliability will be very high as it will depend mainly on the reliability of the communication.

The safety “added value” of the proposed activities is to look for the “combination” of the information from vehicles and from the infrastructure, the focus is on R&D activities regarding the identification of co-operative solutions that will firstly be applied to the critical areas ("black spots") whose danger is quantified by statistical data.

The key aspect of the project is to expand the time horizon for acquiring safety relevant information for driving, as well as to improve the precision, the reliability and the quality of driver information, and to introduce new information sources. As shown in the following figure, the time horizon of the SAFESPOT applications will allow an extension of the "safety margin", namely the time in which a potential accident is detected before it can occur, from the range of "milliseconds" up to "seconds". This extension, named "green area" will reduce the risk of the accident to happen as more time will be given to drivers to realize that there is a potential danger and to undertake the appropriate maneuvers.

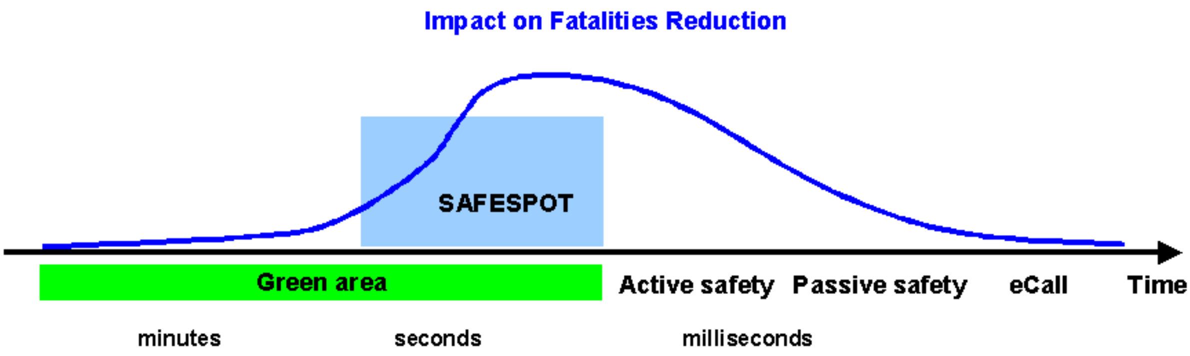


Figure 1: Impacts on fatalities reduction

So the support from road infrastructure is needed to provide earlier information on driving or driving conditions, complementary to the autonomous systems, with increased precision in time, space and quality.

The step beyond is represented by the extended coverage that can be offered by the road infrastructure and by the network of cooperating vehicles to guarantee a complete coverage of all different potential dangerous situations.

The challenge is to correctly define the matrix of cooperation and responsibilities in view of future involvement of new actors in the field of road safety systems such as road operators and service providers.

The expected benefits will also derive from the possibility to design a proper deployment strategy that will involve all ranges of vehicles, given the availability of the communication technology at low cost.

SAFESPOT takes the opportunity of joining the results of the past and current activities in the field of sensor and telematic technologies.

3 The SAFESPOT system objectives

The SAFESPOT concept is aimed at improving road safety by using Co-operative systems. A set of new applications and a “Safety Margin Assistant” have been defined that:

- detects in advance potentially dangerous situations,
- extends “in space and time” drivers’ awareness of the surrounding environment.
- provides recommendations to keep the driver inside a safety margin with warnings to avoid emergency situations when they occur.

More in detail, the main objectives of SAFESPOT are the following:

- To develop the Safety Margin Assistant (SMA), that is an integrated application framework using the safety-related information, provided by infrastructure or other vehicles through an ad hoc network, properly fused with the on board sensors.
- To develop or improve and assess the key enabling technologies:
    - Communication through ad-hoc dynamic network whose nodes are vehicles and road side units. The objective is to enhance the existing C2C-CC protocol with geo-broadcast addressing, stored geobroadcasting and other mechanisms.
    - To achieve an accurate positioning. The needed precisions are beyond the standard GPS and Galileo performances and some additional technologies will be analyzed and evaluated.
    - Local dynamic maps (LDM). This is a central concept in SAFESPOT. All the static and dynamic information available through sensors and communication are reported, after a proper process of data fusion, in a structured geo-referenced local database in each node of the network. This database act as a common layer accessed by all the applications.
    - Analysis and experimentation of available and new sensors to be used at infrastructure level. New sensing techniques and wireless sensor networks are analyzed.
- To define in commonality with other EC projects (especially with the CVIS Integrated Project) an open flexible and modular architecture. This is a very important issue which will provide the guidelines for the future evolution of the system.
- To evaluate the impacts and the end-user acceptance. Estimated potentialities of the SAFESPOT project are quite promising. Nevertheless a more accurate impact analysis will be possible only once the system and the applications are well consolidated, and end-user acceptance is a key point. Considering different penetration hypothesis and potential risks, it will be possible to evaluate implementation strategies compatible with a favourable cost/benefit ratio.
- To evaluate the liability aspects, regulations and standardisation issues which can affect the implementation. These systems will deeply involve the whole society and a lot of organizational and political issues at regional, national and European level will surely be raised.

4 IP-level description of work performed

4.1 Project partners

In Table 1 below, the partners of the SAFESPOT IP are listed, together with the corresponding acronym, and the countries in which these project partners are based. In some cases partner names have changed during the course of the project; for this reason only the most recent name is reported.

Table 1: SAFESPOT Integrated Project partners

	ORGANIZATION	Country	Acronym
1	Centro Ricerche Fiat ScpA	IT	CRF
2	Daimler AG	DE	DAI
3	Renault FRANCE, REGIENOV	FR	RENAULT
4	Volvo Technology Corporation	SW	VOLVO
5	Robert BOSCH GmbH	DE	BOSCH
6	Siemens A.e.g.	DE	SIEMENS
7	ANAS SpA	IT	ANAS
8	COFIROUTE	FR	COFIROUTE
9	TNO	NL	TNO
10	MIZAR Automazione S.p.A.	IT	MIZAR
11	Piaggio & C. SPA	IT	PIAGGIO
12	Continental Teves AG & Co oHG	DE	CAS
13	IBEO Automobile Sensor GmbH	DE	IBEO
14	Kapsch TrafficCom AB	SW	KAPSCH
15	Lacroix Trafic	FR	LAC
16	NAVTEQ Europe B.V.	NL	NAVTEQ
17	Planung Transport Verkehr AG	DE	PTV AG
18	Q-Free ASA	NW	QFREE
19	Continental Automotive GmbH	DE	CA
20	Tele Atlas NV	DE	TA
21	VTT Technical Research Centre of Finland	FI	VTT
22	Autostrada Brescia Verona Vicenza Padova S.p.A.	IT	BSPD
23	CG Côtes d'Armor	FR	CG22
24	Swedish Road Administration	SW	SRA
25	CIDAUT: Fundación para la Investigación y Desarrollo en Automoción	ES	CIDAUT
26	Centro Studi sui Sistemi di Trasporto	IT	CSST
27	Università degli Studi di Genova DIBE	IT	DIBE

28	Centre for Research and Technology - HELLAS	GR	CERTH
29	Institute of Communication and Computer Systems	GR	ICCS
30	LCPC	FR	LCPC
31	Istituto Superiore Mario Boella	IT	ISMB
32	MIRA Limited	UK	MIRA
33	Société pour le Développement de l'Innovation dans les Transports	FR	SODIT
34	Ministerie van Verkeer en Waterstaat	NL	RWS
35	Technische Universität Chemnitz	DE	TUC
36	Technische Universität München	DE	TUM
37	Universität Stuttgart	DE	USTUTT
38	German Aerospace Center	DE	DLR
39	ERTICO	BE	ERTICO
40	CREATE-NET	IT	CREATE-NET
41	Politechnika Warszawska	PL	IRE PW
42	Budapest University of Technology and Economics	HU	BME
43	Centre National de la Recherche Scientifique	FR	CNRS
44	BASt	DE	BAST
45	Thomas Miller	UK	MILLER
46	Provincie Noord-Brabant	NL	PNB
47	RENAULT España	ES	RNS
48	Universidad Politécnica de Madrid	ES	UPM
49	Telefonica	ES	TEL
50	AT4wireless	ES	AT4
51	Magneti Marelli Electronic Systems	IT	MMSE
52	PEEK Traffic B.V.	NL	PEEK
53	TRANSVER GmbH	DE	TRV
54	Swedish Traffic Administration	SW	STA

4.2 Organisation of work

4.2.1 Project structure

SAFESPOT was structured in 8 sub-projects. Each vertical sub-project is characterized by a number of transversal work packages. Three of them are technological (SP1, 2, 3), two are focused on applications (SP4, 5) and three are transversal (SP6, 7, 8). The activity was split into 5 work packages corresponding to the different steps of development:

- Needs and requirements,
- Specifications,
- Implementation and prototypes development,
- Test and validation,
- Evaluation and Test trials

In particular this structure was adopted by those sub-projects which specified and developed prototypes and demonstrators. The transversal SPs were related to the project management and to the deployment, legal aspects and business model as represented in the following figures.

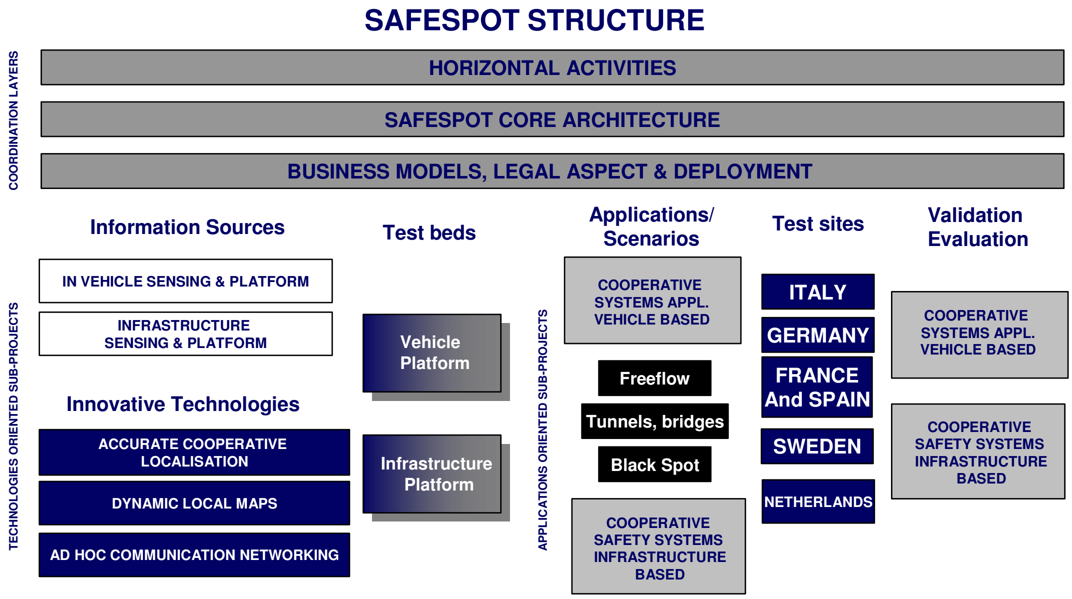


Figure 2: Sub-project structure of the SAFESPOT IP

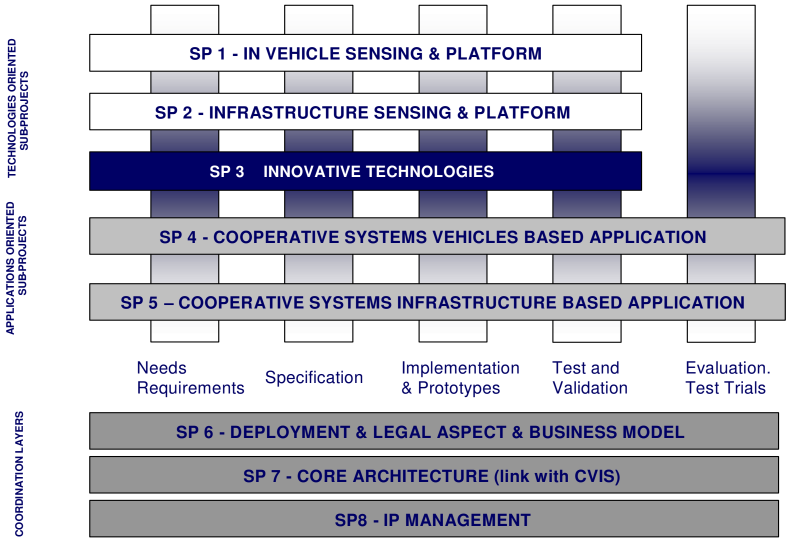


Figure 3: Work package structure of the SAFESPOT IP

Moreover there have been evaluation and demonstration activities grouped in 5 Test Sites (TS). The specification and implementation of the TSs were also considered as transversal activities and for this reason they were not included in a workpackage structure. The TSs are the following:

- TS1 – Italian TS
- TS2 – West (France and Spain) TS
- TS3 – German TS
- TS4 – Dutch TS
- TS5 – Swedish TS

The SAFESPOT IP opened from February 1, 2006, and closed on July 31, 2010 after a six month extension of the originally planned 48 month duration. The overall budget for SAFESPOT IP was about 38 M€, of which 20,5 M€ were EC funding.

Fig. 4 below shows the general IP work plan, and its division into the main activity steps as well as the major milestones. Moreover the diagram includes three major dissemination and demonstration events organized with CVIS and COOPERS, two other IPs of the same call dedicated to co-operative systems.

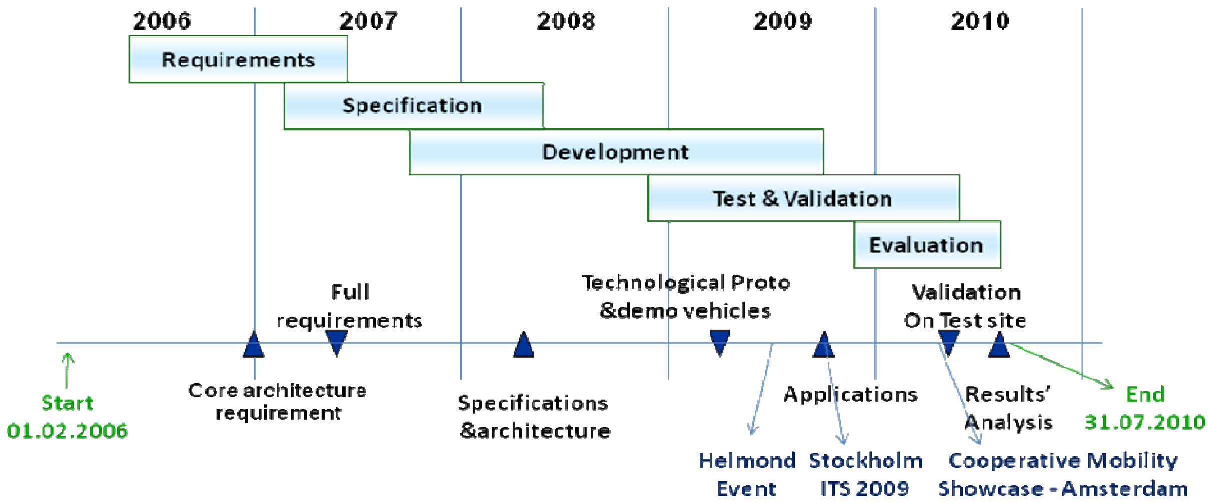


Figure 4: Schematic illustration of the SAFESPOT IP work plan, with its main phases

4.3 Internal interactions

To ensure that work in the SPs and TSs stayed in line with overall IP objectives, and that results from one part of the IP could be efficiently adopted in other parts of the IP, it was understood from the start of the project that good internal interactions between SPs and WPs was a crucial point, and much effort went into setting up and maintaining such interactions.

Fig. 5 illustrates the activity flow and the main interactions between SPs. Moreover in each SP a technical coordination work package (WP1) was responsible for both internal and external interactions.

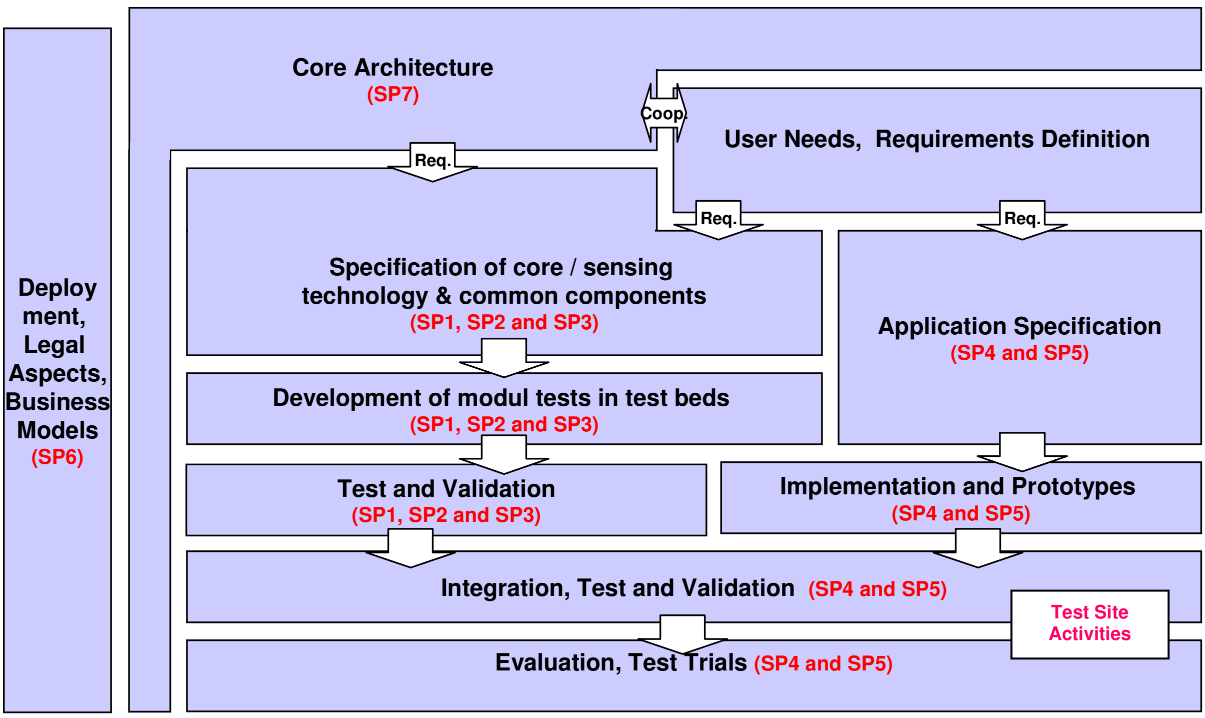


Figure 5: Main interactions between SAFEPOT SPs and WPs

SP7 (SAFESPOT Core Architecture) had also the task of driving and monitoring the harmonization and integration activities.

4.4 External interactions

Interaction with outside research activities and efforts was a key aspect of the performed work. External interactions served both to ensure compatibility of SAFESPOT solutions with a wide range of applications and functions, and also as part of the dissemination/exploitation strategy, promoting the uptake of SAFESPOT results in other research projects. Several projects in the 6th and 7th Framework Programme in general addressed issues related to the ones dealt within the project SAFESPOT. Specific cooperation was established with the projects in the EUCAR Integrated Safety Program: AIDE, COMeSAFETY (a European Support Action), CVIS, GST, PREDRIVE-C2X, PReVENT, WATCH-OVER and COOPERS.

Moreover SAFESPOT closely cooperated with the C2C-CC. A proper memorandum of understanding was signed in order to freely exchange information and results in bidirectional way.

Key results of the external interactions were:

- the contribution to the harmonised European architecture provided through intensive participation to task-force leaded by COMeSAFETY,
- three common dissemination and demonstration events with CVIS and COOPERS which provided a tangible proof of interoperability,
- support of ETSI – ITS TC standardisation activity.

All the external interactions were directly coordinated by SP7 with the support of SP8.

5 The SAFESPOT nodes architecture

The SAFESPOT 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. 6).

LDM contains four different layers where the node information is maintained, characterised by an increasing level of dynamic update of the represented content:

- Static Maps
- Landmarks (fixed objects in the road, e.g. trees, buildings, road signs)
- Temporary Objects (e.g. fog area, road works)
- Dynamic Objects

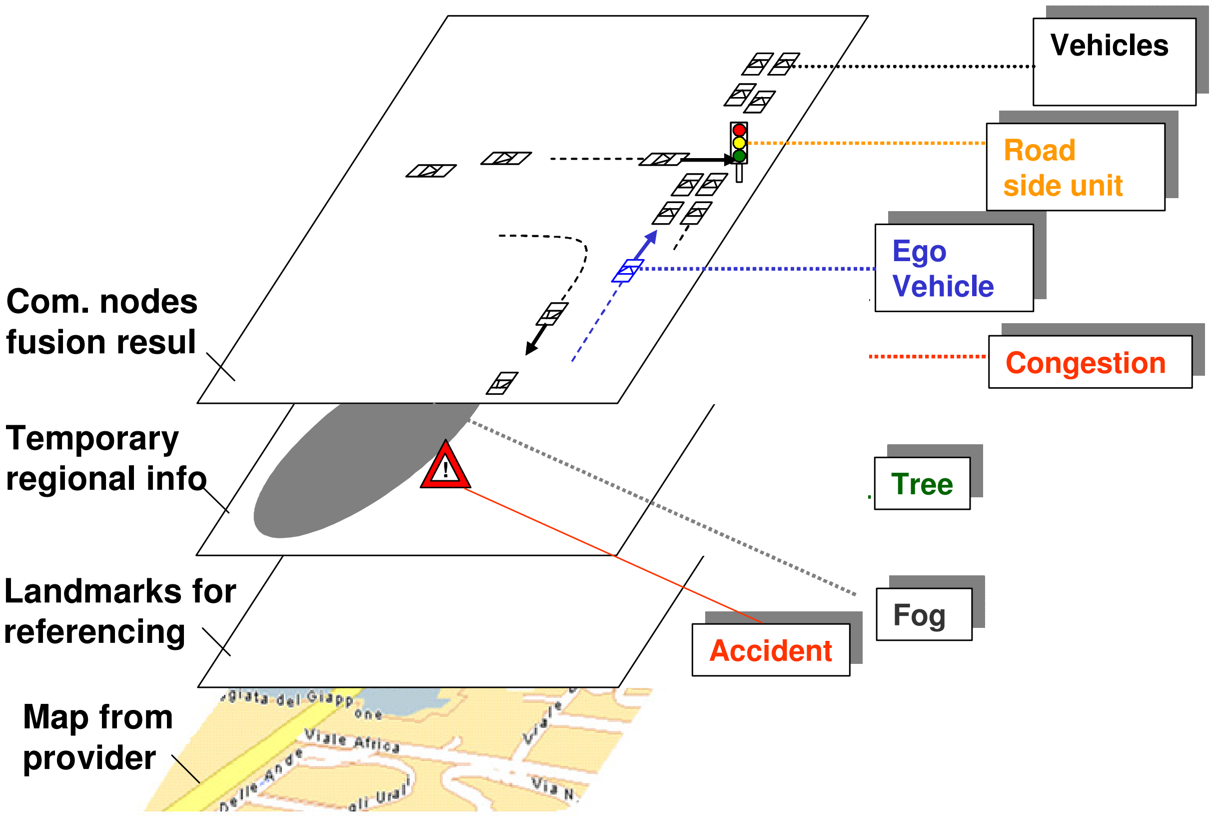


Figure 6: The four layers LDM structure

The internal architecture of a node is depicted in Fig. 7 where the main data flows are reported.

In the SAFESPOT architecture, 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 detailed in the following sections.

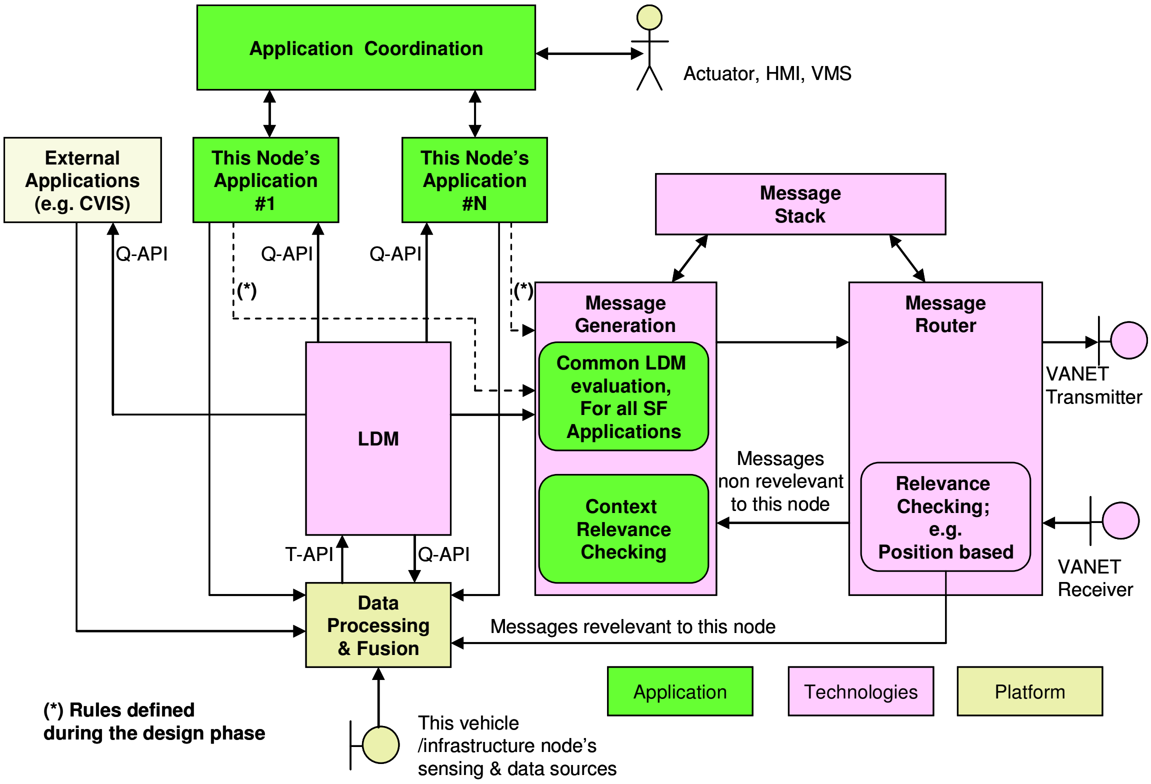


Figure 7: The SAFESPOT nodes architecture

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 in terms of a framework integrating several applications, designed to operate in any road scenario.

In the SAFESPOT project timeframe a number of applications and use cases have been selected, analyzed, developed and 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. 8 represents the scenario with the highest level of integration, where V2V and V2I operate concurrently.

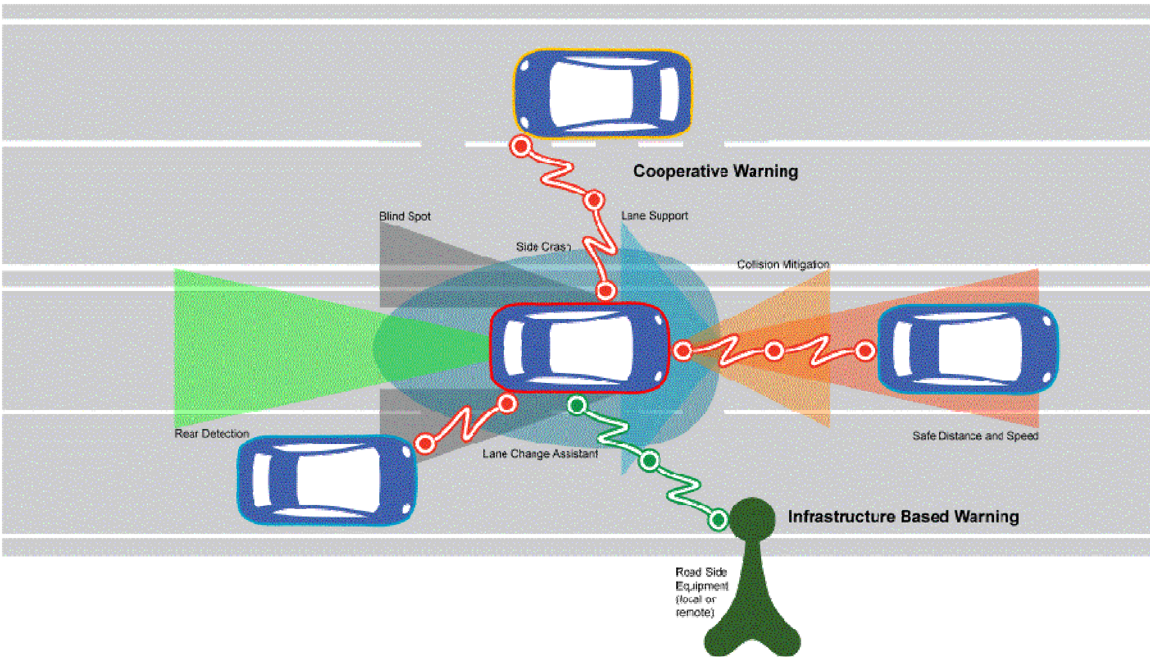


Figure 8: The Cooperative warning scenario

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 next chapter the reference model adopted for both classes of applications is described.

6 Reference model for the SAFESPOT applications

In the SAFESPOT approach, several applications are normally running within each vehicle system. According to the adopted general architecture, 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.

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

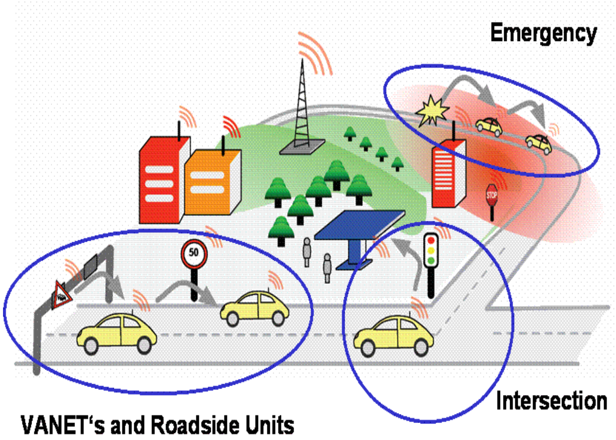


Figure 9: Classical reference scenario for the C2C-CC

Within the C2C-CC Scenario, 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).

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:

Transmission Duration	RSU	OBU
Maximum Data Transmission Duration	750 μsec	580 μsec
Minimum Interval between Data Transmissions	100 msec	750 msec

Figure 10: 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):

rOBU = 3 Mbit/s * 580 μs / 750 ms = 2320 bit/s

rRSU = 3 Mbit/s * 750 μs / 100 ms = 22500 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.

As a consequence, it becomes evident 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.

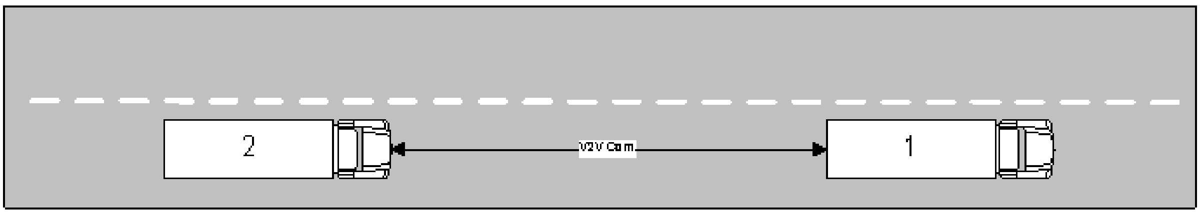


Figure 11: Pictogram for the Speed Limitation and Safety Distance application

In order to obtain speed and distance recommendations, the application running on vehicle 2 (the *ego-vehicle*, in Fig. 11 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.

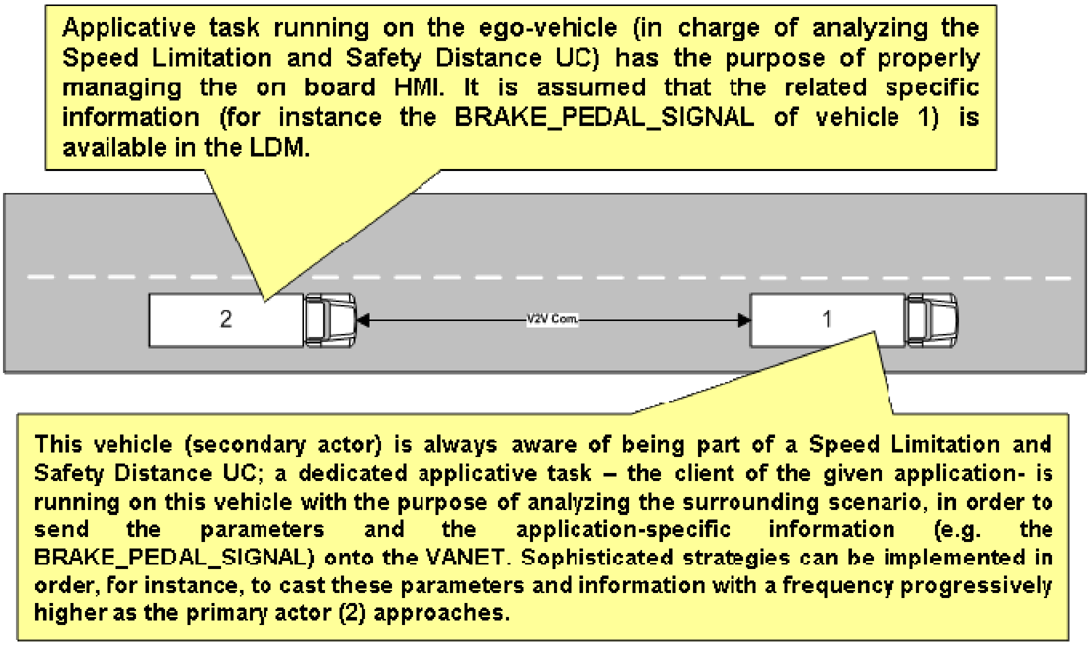


Figure 12: Key elements of the reference model for the SCOVA applications

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. 13**Errore. L'origine riferimento non è stata trovata.** 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 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 7.3 is the risk classification. Three levels of risk (Comfort, Safety, and Critical) are considered in SAFESPOT.

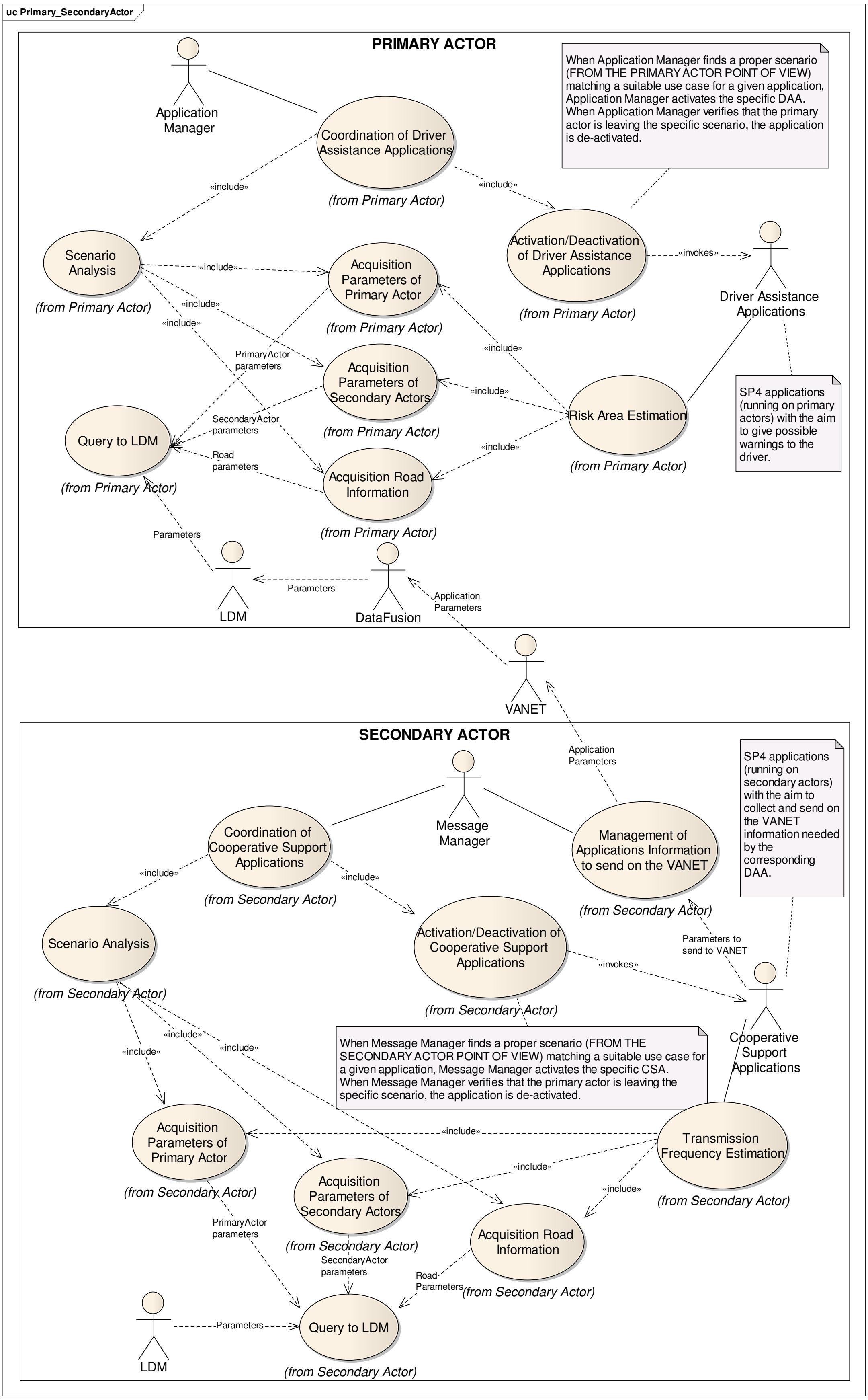


Figure 13: Description of the roles for primary actor and secondary actor

6.1 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 – "Driving Safety Margin Functional specification" and in D4.3.4 – "Conceptualisation of on-board information system and extended HMI".

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.

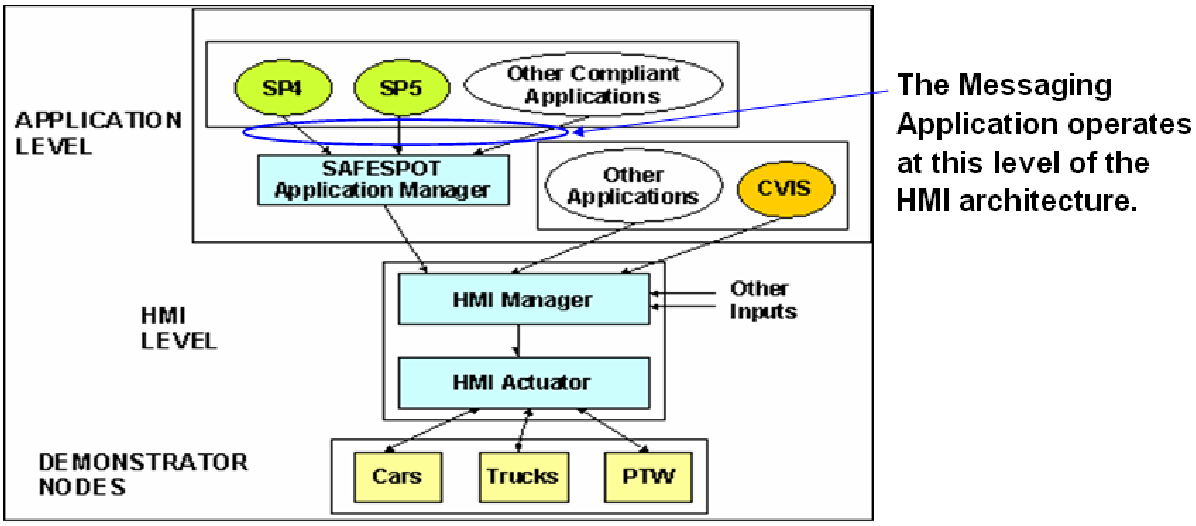


Figure 14: Interaction of the "External Message Application" with the vehicle HMI

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 – "Conceptualisation of on-board information system and extended HMI". 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":

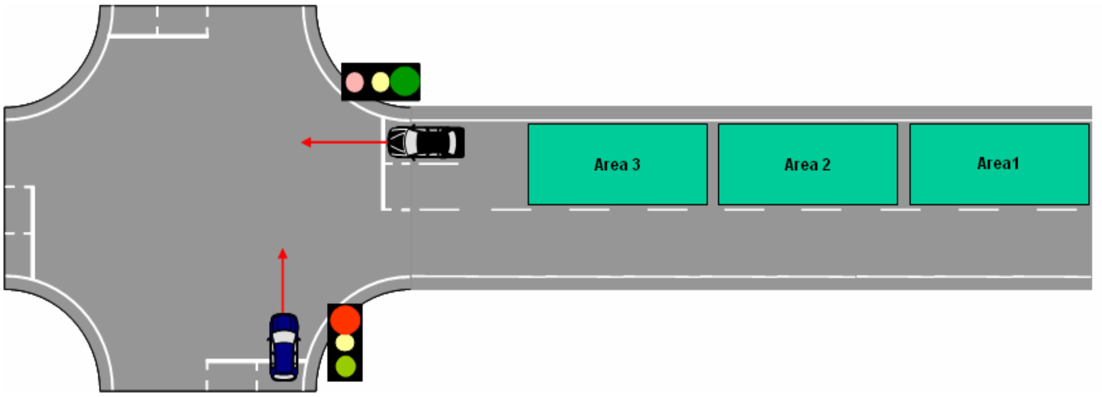


Figure 15: Assistance to a vehicle about the presence of vehicle crossing with the "red" provided by means of the "Messaging Application"

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 D4.3.4 – "Conceptualisation of on-board information system and extended HMI".

7 The intelligence partitioning (Vehicle and infrastructure based applications)

7.1 The Vehicle based applications

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

Table 2: Clusters and Applications developed in SP4 – SCOVA

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

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).

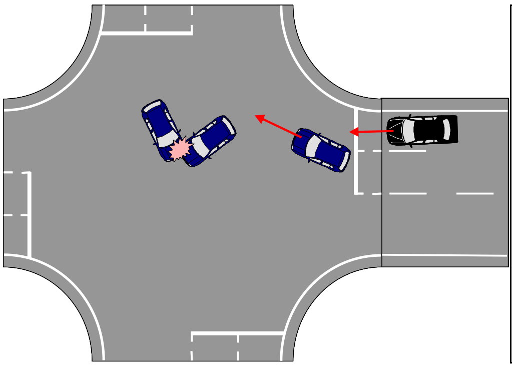
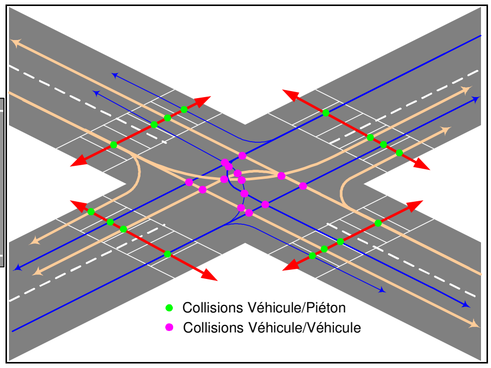
In the following some UCs of the SP4 Applications are reported. UCs are grouped based on the cluster of the related vehicle based applications.

7.1.1 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:

Case Name	Accident at intersections
Case ID	SP4_UC_Accident at intersection – 1a
Status	Final - V1.2
Short description	A crash happens at an intersection resulting in a dangerous situation; the drivers approaching an intersection are warned about such event.  
Purpose	Avoid critical situations resulting from an accident
Rationale	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.

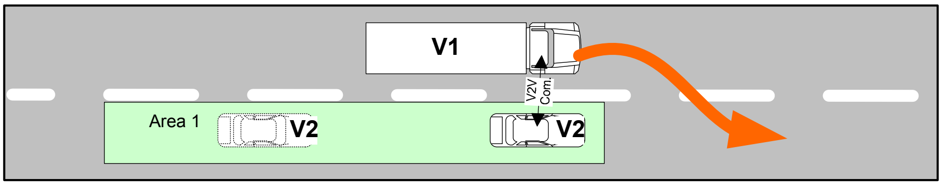
(*) Work on the IP project GST, or other e-call projects, should assist with this issue.

7.1.2 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):

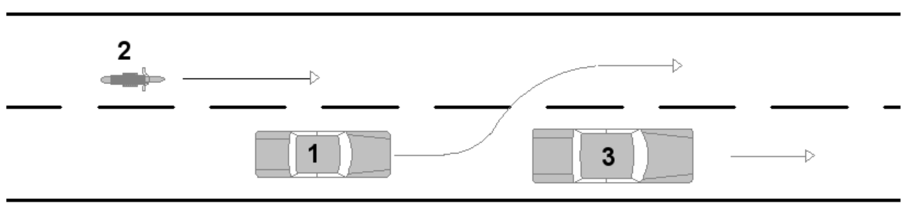
Case Name	Lane Change manoeuvre for Trucks with blind spot
Case ID	SP4_UC_LaneChangeManoeuvre – 2a
Status	Final - V4.1
Short description	This scenario aims to inform and/or warn truck driver (V1) about the presence of other vehicle (V2) around him during manoeuvre, especially during lane change manoeuvre. 
Purpose	Avoid accident due to blind spot with trucks during lane change manoeuvres
Rationale	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.

7.1.3 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):

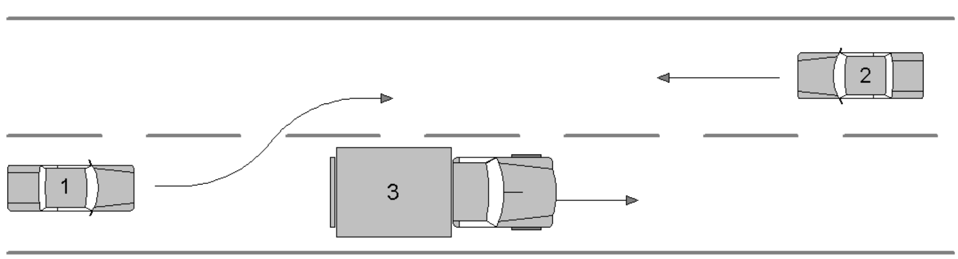
Case Name	Safe overtaking in urban and semi urban roads with PTW already in overtaking
Case ID	SP4_UC_SafeOvertaking – 3a
Status	Final - V1.1
Short description	Host vehicle (1) starts to overtake vehicle (3) while a Powered Two Wheelers (2) is already in overtaking manoeuvre PTW (2) informs the host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

7.1.4 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:

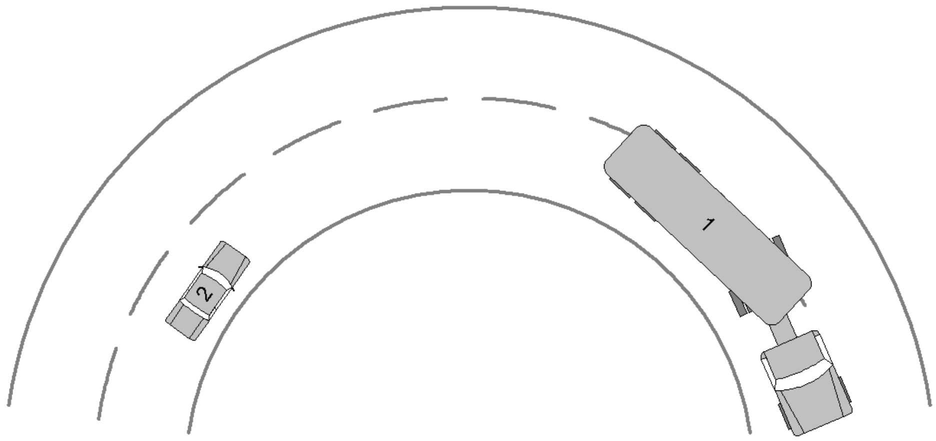
Case Name	Head On Collision Warning due to hazardous overtaking attempt by host vehicle
Case ID	SP4_UC_HeadOnCollisionWarning – 4a
Status	Final - V1.1
Short description	As in the pictogram below, host vehicle (1) attempts an overtaking manoeuvre to vehicle (3) which obstructs the driver's (1) field of view, while vehicle (2) is approaching from the opposite lane. 
Purpose	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
Rationale	To avoid or reduce the accidents linked to head-on collision situations

7.1.5 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 a heavy vehicle climbing up through a hairpin curve at a low speed is presented:

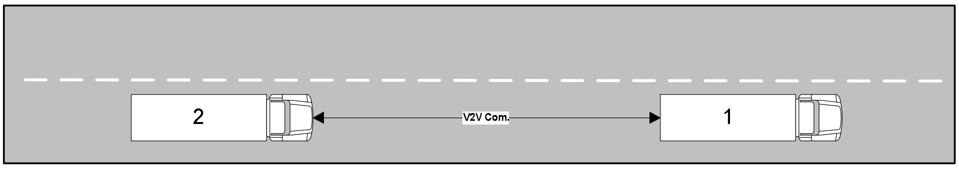
Case Name	Rear End Collision due to the presence of an heavy vehicle climbing up through an hairpin curve at a low speed
Case ID	SP4_UC_RearEndCollision – 5a
Status	Final - V1.1
Short description	A vehicle (2) is climbing up a sharp hairpin curve, while a heavy vehicle (1), short ahead, is driving at a low speed due to the steep road. 
Purpose	To warn the driver (1) of a possible danger of rear-end collision
Rationale	To inform the driver of the host vehicle in a situation where the direct sensing capabilities of the involved vehicles cannot detect the potential risk

7.1.6 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:

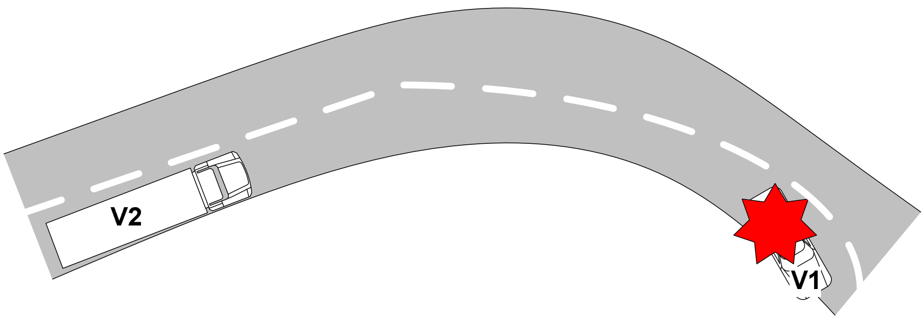
Case Name	Speed limitation and Safety Distance and trucks driver recommendations
Case ID	SP4_UC_SpeedAndDistance – 6a
Status	Final - V2.1
Short description	This scenario aims to provide to the vehicle driver (2) some recommendations in term of speed and safety distance regarding the behaviour or status of the vehicle in front. Special focus can be done on trucks carrying dangerous goods. 
Purpose	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.

7.1.7 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:

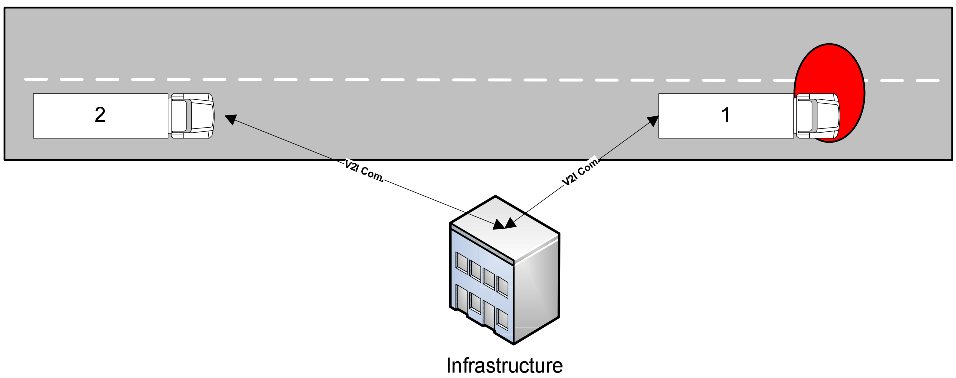
Case Name	Frontal collision warning due to static obstacle in front
Case ID	SP4_UC_FrontalCollisionWarning – 7a
Status	Final - V2.1
Short description	This scenario aims to inform and/or warn truck drivers about the presence of a static obstacle in front. 
Purpose	Inform or/and warn the driver in order 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…
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.

7.1.8 Road condition status

Two UCs have been collected regarding the Road Condition Status – Slippery Road application:

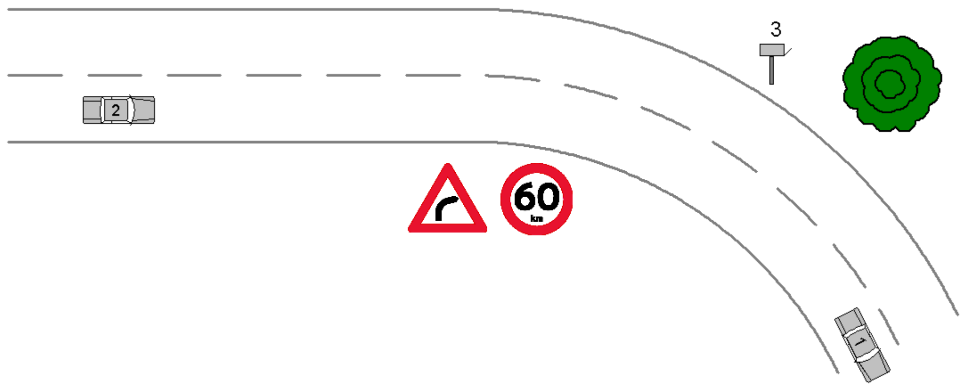
- Road Condition Status – V2I Based;
- Road Condition Status - V2V Based.

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

Case Name	Road Condition Status – V2I Based
Case ID	SP4_UC_RoadConditionStatusV2I – 8a
Status	Final - V2.1
Short description	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. 
Purpose	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.
Rationale	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.

7.1.9 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.

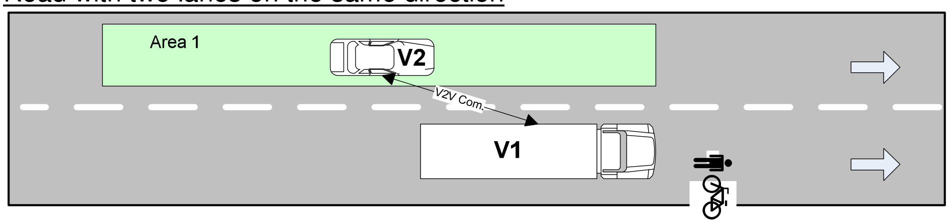
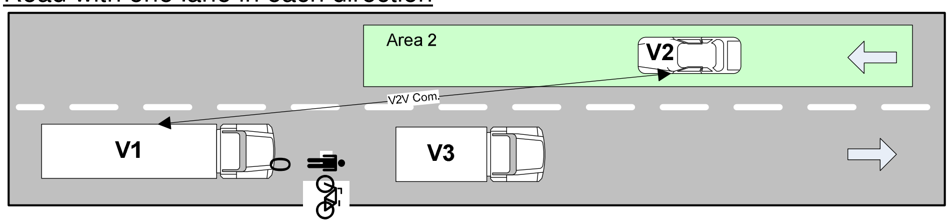
Case Name	Curve Warning in rural black spots, based on a transponder in the infrastructure keeping memory of the speeds adopted by passing vehicles.
Case ID	SP4_UC_CurveWarning – 9a
Status	Final - V1.1
Short description	Host vehicle (1) transmits to an infrastructure transponder (3) its speed and (possibly) 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 behaviour of other vehicles. 
Purpose	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.
Rationale	To avoid (or reduce) the accidents due to too high speed in approaching a sharp curve

7.1.10 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:

Case Name	Vulnerable road users crossing a road, based on on-board detection system
Case ID	SP4_UC_VRUAccidentAvoidance – 10a-1
Status	Final - V1.2
Short description	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 <u>Road with two lanes on the same direction</u>  <u>Road with one lane in each direction</u> 
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.

7.2 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).

7.2.1 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 D5.2.2.

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 these 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.

7.2.2 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.

7.2.3 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.

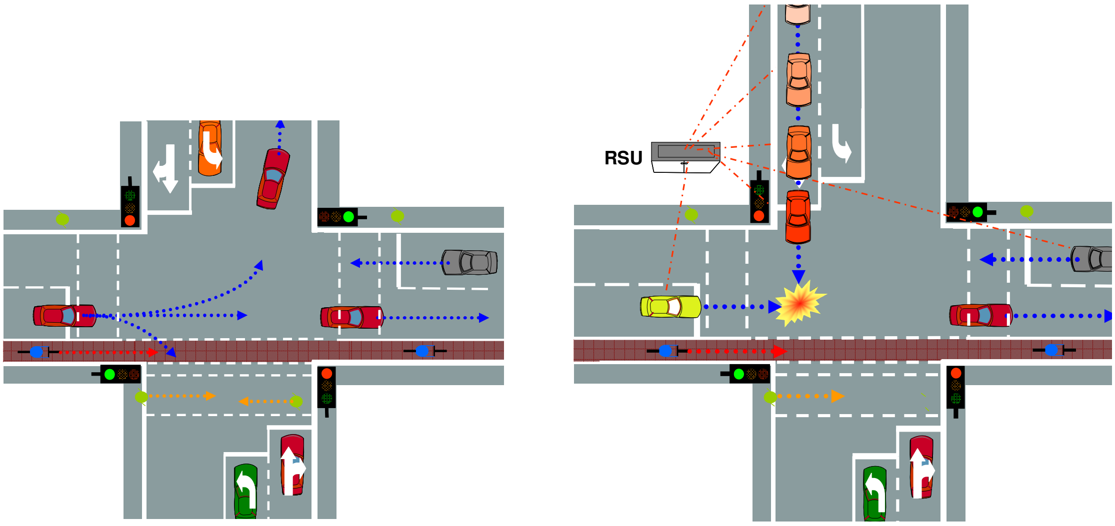


Figure 16: Sample intersection scenarios

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).

7.2.4 Road Departure

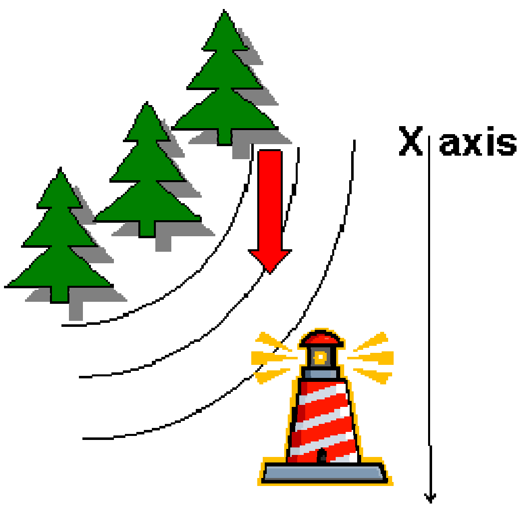
Road departure and lane departure represent a significant amount of accidents (30-40% of the accidents in rural areas, 20% in motorways). A number of systems have been developed in order to reduce such figures. These range from the camera-based on-vehicle Lane Warning Systems, to the noisy lanes at the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



x	y	speed	heading	yaw
0	5-7	<90	170-175	<5
10	6-8	<85	165-170	<5
20	7-10	<80	165-170	<5

Figure 17: 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

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.

Figure 18: 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.

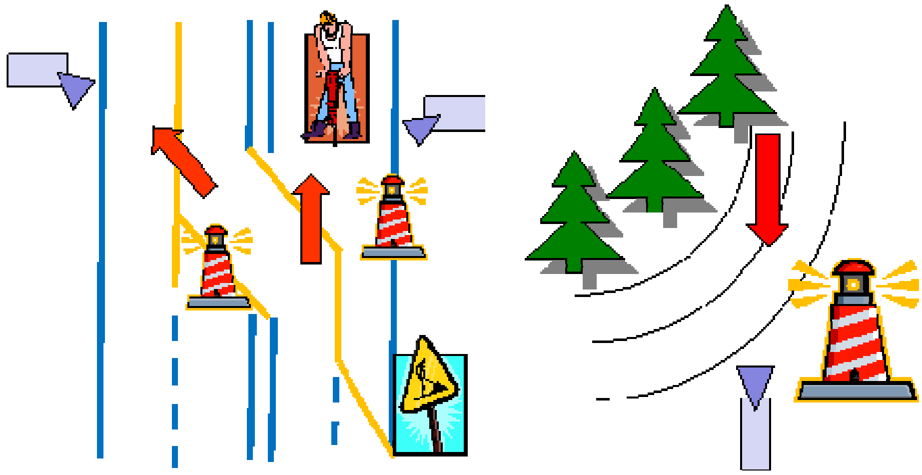


Figure 19: The Deviation for RoadWorks and the Dangerous Curve use cases

7.2.5 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.

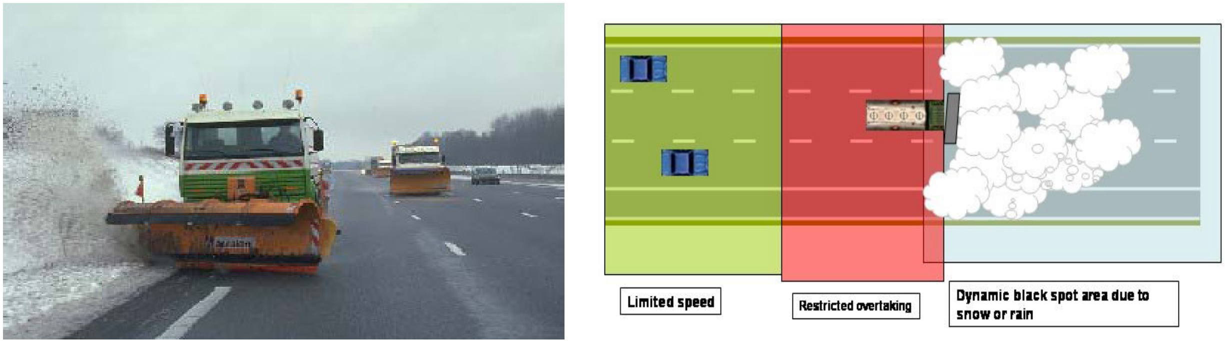


Figure 20: Maintenance Vehicle on Snow Removal or Salting Operation

- *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).

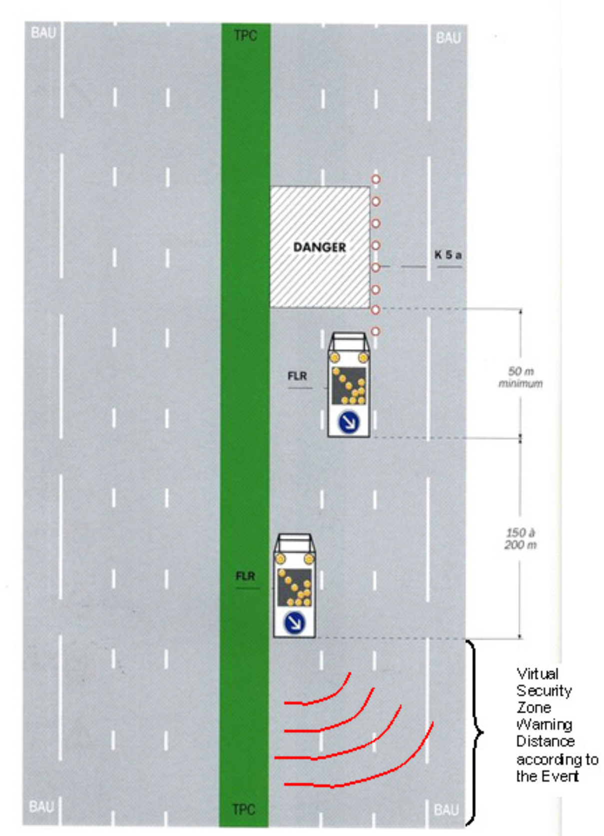


Figure 21: AV Signaling a Traffic Event on a road

- *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.

7.3 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. 22).

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

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. 22 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.

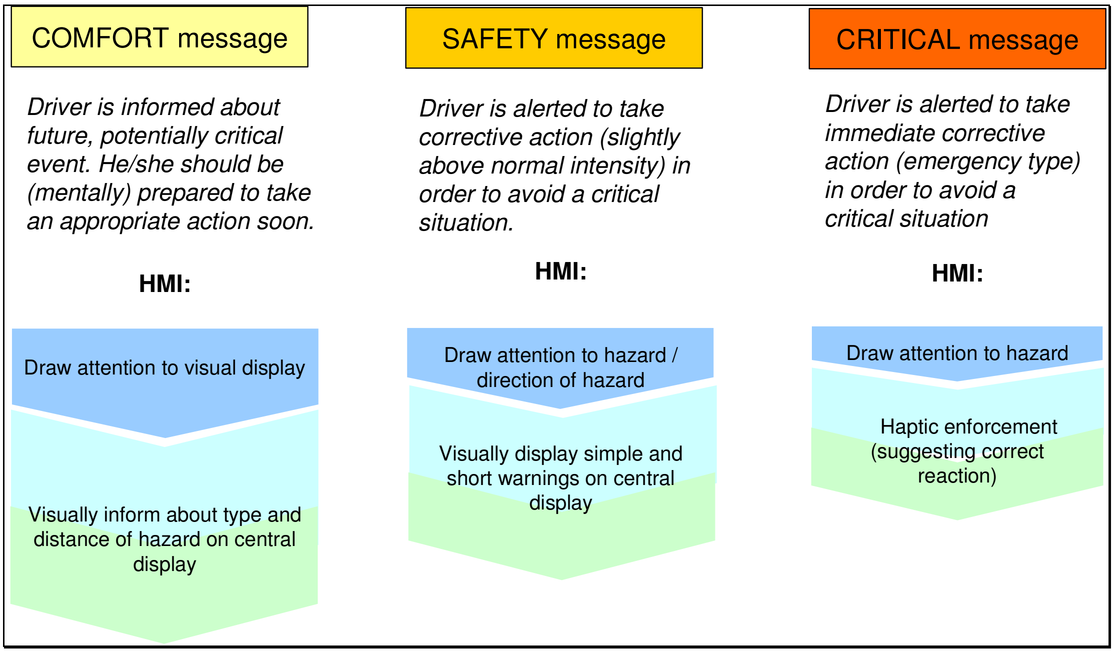


Figure 22: Applying warning design guidelines to SMA concept

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/ kinaesthetic / 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.

8 Summary of key exploitable results

In Table 3 below, the key exploitable results, as identified in the final Technological Implementation Plan (deliverable D8.2.4), are listed. In this deliverable more information is given on each individual result, its planned or potential exploitations, and contact details are also given for suitable contact persons within the SAFESPOT consortium.

Table 3: Key exploitable results of SAFESPOT IP, as identified in D8.2.4.

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) exploiting the result, year of deployment on the market	Contact Person Name, Company, Email
SW & HW PACKAGES				
1	Relative positioning (SP3)	A	CRF, TUC, DLR 2016	Carlo Liberto Centro Ricerche FIAT S.c.p.A. carlo.liberto@crf.it
2	VANET (SP3)	A	CRF, DAI 2015	Giuliana Zennaro Centro Ricerche FIAT S.c.p.A. giuliana.zennaro@crf.it
3	Local Dynamic Maps (SP3)	A	Teleatlas, Navteq 2015	Oliver Kannenberg Teleatlas oliver.kannenberg@teleatlas.com
4	In-vehicle SAFEPROBE platform (SP1)	A	Bosch 2016	Sheung Ying Yuen-Wille Bosch GmbH sheungying.yuen@de.bosch.com
5	Data Acquisition Module (SP1)	A	Continental Automotive 2014	Hongjun Pu Continental Automotive GmbH hongjun.pu@continental-corporation.com
6	Situation refinement (SP1)	A	ICCS 2015	Angelos Amditis Institute of Communication and Computer Systems (ICCS) a.amditis@iccs.gr
7	Object refinement (SP1)	A	CRF 2015	Andrea Saroldi Centro Ricerche FIAT S.c.p.A. andrea.saroldi@crf.it

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) exploiting the result, year of deployment on the market	Contact Person Name, Company, Email
8	Laserscanner system for vehicles (SP1)	A	IBEO 2015	Florian Ahlers Ibeo Automobile Sensor GmbH florian.ahlers@ibeo-as.com
9	Road state monitoring camera (SP2)	A	VTT 2014	Matti Kutila VTT Technical Research Centre of Finland matti.kutila@vtt.fi
10	Thermal imaging for pedestrian/animal detection (SP2)	A	VTT 2014	Johan Scholliers VTT Technical Research Centre of Finland johan.scholliers@vtt.fi
11	Wireless Sensor Network (SP2)	A	MIZAR 2012 First phase 2013 Second phase	Angela Spence MIZAR angela.spence@torino.miz.it
12	WSN for Intelligent Transportation Systems (SP2)	A	ISMB 2014	Giuseppe Franco ISMB giuseppe.franco@ismb.it
13	CCTV camera for environmental conditions detection (fog, rain, …) (SP2)	A	LCPC 2011-2013 Industrial project to develop and test the product. 2014 Deployment on the market	Nicolas Hautière Laboratoire Central des Ponts et Chaussées (LCPC) nicolas.hautiere@lcpc.fr
14	Data Fusion Logic for RSU (SP2)	A	TUM, MAT.TRAFFIC 2014	Tobias Schendzielorz Technische Universität München, Chair of Traffic Engineering and Control tobias.schendzielorz@vt.bv.tum.de
15	Laserscanner system for infrastructure (SP2)	A	IBEO 2014	Florian Ahlers Ibeo Automobile Sensor GmbH florian.ahlers@ibeo-as.com

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) exploiting the result, year of deployment on the market	Contact Person Name, Company, Email
APPLICATIONS				
16	Extended Cooperative Automatic Incident Detection - ECAID (SP2)	A	CSST 2013	Morello Eugenio Centro Studi sui Sistemi di Trasporto SpA - CSST eugenio.morello@csst.it
17	Safety Margin Assistant – application framework and HMI (SP4)	A	CRF 2016	Giulio Vivo Centro Ricerche FIAT S.c.p.A. giulio.vivo@crf.it
18	External Message Application (SP4)	A	CRF 2016	Giulio Vivo Centro Ricerche FIAT S.c.p.A. giulio.vivo@crf.it
19	Road Intersection Safety (SP4)	A	CAS, Renault 2016	Ulrich Stählin Continental Teves AG & Co. oHG ulrich.staehlin@continental-corporation.com
20	Lane Change Manoeuvre (SP4)	A	Piaggio 2016	Paolo Cravini Piaggio & C. S.p.a. paolo.cravini@piaggio.com
21	Safe Overtaking (SP4)	A	Piaggio 2015	Paolo Cravini Piaggio & C. S.p.a. paolo.cravini@piaggio.com
22	Head On Collision Warning (SP4)	A	CRF 2016	Giulio Vivo Centro Ricerche FIAT S.c.p.A. giulio.vivo@crf.it
23	Rear End Collision (SP4)	A	CRF 2016	Giulio Vivo Centro Ricerche FIAT S.c.p.A. giulio.vivo@crf.it
24	Speed Limitation and Safety Distance (SP4)	A	MMSE 2015	Piero Mortara Magneti Marelli S.p.A. piero.mortara@magnetimarelli.com

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) exploiting the result, year of deployment on the market	Contact Person Name, Company, Email
25	Frontal Collision Warning (SP4)	A	VOLVO 2015	Erik Nordin Volvo Technology Corporation erik.nordin@volvo.com
26	Road Condition Status – Slippery Road (SP4)	A	VOLVO 2015	Erik Nordin Volvo Technology Corporation erik.nordin@volvo.com
27	Curve Warning (SP4)	A	CRF 2015	Giulio Vivo Centro Ricerche FIAT S.c.p.A. giulio.vivo@crf.it
28	Vulnerable Road User Detection and Accident Avoidance (SP4)	A	VOLVO 2014	Erik Nordin Volvo Technology Corporation erik.nordin@volvo.com
29	Speed Alert - Critical speed warning - legal (SP5)	A	LCPC, COFIROUTE 2015	Sébastien Glaser LCPC glaser@lcpc.fr
30	Speed Alert - Critical speed warning - dynamic (SP5)	A	LCPC, COFIROUTE 2015	Sébastien Glaser LCPC glaser@lcpc.fr
31	Hazard and Incident Warning – Obstacle on the road (SP5)	A	COFIROUTE 2015	Fahim BELARBI COFIROUTE fahim.belarbi@cofiroute.fr
32	Hazard and Incident Warning – Wrong Way Driving (SP5)	A	MIZAR, COFIROUTE 2015	Angela Spence MIZAR angela.spence@torino.miz.it
33	Intelligent Cooperative Intersection Safety - IRIS (SP5)	A	TUM; MAT.TRAFFIC, PEEK 2015	Tobias Schendzielorz Technische Universität München, Chair of Traffic Engineering and Control tobias.schendzielorz@vt.bv.tum.de
34	Road Departure Prevention (SP5)	A	DIBE 2015	Andre Possani University of Genoa, DIBE possani@elios.unige.it

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) exploiting the result, year of deployment on the market	Contact Person Name, Company, Email
35	Safety Margin for Assistance and Emergency Vehicles	A	SODIT, CRF 2015	Nicolas ETIENNE SODIT etienne@sodit.eu
36	Vehicle client application for IRIS (SP4)	A	CA 2015	Hongjun Pu Continental Automotive GmbH hongjun.pu@continental-corporation.com
METHODOLOGIES/CONTRIBUTIONS TO STANDARDISATION				
37	SAFESPOT deployment programme	A	TNO, All 2010	Han Zwijnenberg Technical director TNO han.zwijnenberg@tno.nl
38	SAFESPOT Certification Reference Framework	A	Renault, AT4 wireless, All 2010	Abdel Kader Mokaddem RENAULT abdelkader.mokaddem@renault.com
39	SAFESPOT Contribution to the European Harmonised Cooperative Architecture	A	CRF, Renault, DAI, VOLVO 2010	Roberto Brignolo Product Research Centro Ricerche FIAT S.c.p.A. roberto.brignolo@crf.it
40	SAFESPOT Conformance Test System (SP7)	A	AT4 wireless 2010	Antonio Plaza Ortega AT4 wireless S.A. aplaza@at4wireless.com
41	SAFESPOT Organisational Architecture (SP6)	A	CSST, All 2014	Morello Eugenio Centro Studi sui Sistemi di Trasporto SpA - CSST eugenio.morello@csst.it

9 Summary of dissemination efforts

During the SAFESPOT duration a sum of 8 publications to scientific journals and books were achieved, presenting the work of the project. In addition a total of 126 technical papers were presented to scientific conferences, workshops and congresses and 42 were included to the respective proceedings. 8 more papers are already accepted and scheduled for 3 events in the upcoming months. These publications emanating from the SAFESPOT research activities greatly enhanced the efficiency of the dissemination task by reaching the expert target group of key stakeholders in industries, research and national or international authorities. Specifically, Table 4 lists the SAFESPOT publications and the respective first author and company.

Table 4: SAFESPOT publications

SAFESPOT Publications to Journals and Books	
IEEE Transactions On Intelligent Transportation Systems, Special Issue On "ITS AND ROAD SAFETY", 2008	"Lane Level Positioning for Automotive Applications using Image Landmarks", Norman Mattern, Robin Schubert, and Gerd Wanielik (TUC) Road surface classification using methods of polarised light Casselgrein, J., Kutila, M. & Jokela, M. 2009.
Scientific activities in transport telematics 2008, published by VTT, p.24-27	"Road State Monitoring for Cooperative Traffic Safety System" , Matti Kutila (VTT)
Vision Zero International, A Traffic Technology International publication June 2009, p. 66-69	"The Safety equation"; Roberto Brignolo(CRF)
Traffic Technology International August/September, p. 34, Special section dedicated to ITS 2009 World Congress	Integrated Communication increases Driver Awareness
IEEE Communication Magazine November 2009. 84 - 95	"Vehicular communication systems: Enabling technologies, applications, and future outlook on intelligent transportation", Panagiotis Papadimitratos(EFTL), Arnaud de La Fortelle (INRIA), Knut Evenssen(QFREE). Roberto Brignolo and Stefano Cosenza(CRF)
IEEE Transactions on Intelligent Transportation Systems, 2009	An Ultra-Wideband System for Vehicle Positioning, IRE_PW, TUC
Dutch Journal on Traffic Law, 2008	Intelligente voertuigen, slimme wegen en aansprakelijkheid (Intelligent cars, smart roads and liability), TNO
Traffic Technology International, August/September 2009 issue	V2V Applications in the SAFESPOT European Project: The OEMs Experience, CRF

Paper and presentations in Conferences and workshops (*) = published on proceedings	
"APSN Network and APROSYS Integrated Project" 6th Annual Conference, Vienna, Austria, May 12th 2006.	Project presentation, Roberto Brignolo (CRF)
"2nd SAFE&RELIABLE TUNNEL" Symposium Lausanne, Switzerland, May 30th - 31st 2006	Project presentation: "Infrastructure/Vehicle Communication", Roberto Brignolo (CRF).
SAFESPOT presentation to TRA "Transport Research Arena 2006" conference Göteborg, Sweden, June 12th - 15th 2006	"The SAFESPOT Integrated Project Co-operative systems for road safety of SAFESPOT Activities", Roberto Brignolo (CRF) et al. (*) "Cooperative Systems increase safety for all road users", Luisa Andreone (CRF)
Saint-Brieuc Congress 2006 - Intelligent Transport Systems "New Applications for New Markets", Saint-Brieuc, Côtes d'Armor, France, June 15th – 16th 2006	Project presentation, Guy Fremont (COFIROUTE)
10th Annual Meeting of International Task Force on Vehicle-Highway Automation, October 8th 2006, London, England	Project presentation and advancement status, Roberto Brignolo (CRF)
"ITS World Congress" London, UK, October 9th - 12th - 2006	"Co-operative systems for Road Safety" , Roberto Brignolo (CRF) presented to Executive Session No6 "Integrating different systems to deliver cooperative vehicle safety". "Co-operative Systems for Road Safety - Smart Vehicles on Smart Roads" by Christine Bartels (TA) presented to Maps II Technical Session (*) "Cooperative Systems' applications to improve Road Safety: the SAFESPOT and WATCH-OVER projects", Luisa Andreone(CRF) et alii presented to Special Session No 31, "Applications for cooperative systems – The EU approach".
"EUCAR 2006" Conference, November 23th 2006, Brussels, Belgium	Project presentation, Roberto Brignolo (CRF)
"EUCAR Integrated Safety Program Board", December 13th 2006, Brussels, Belgium	Project presentation, Roberto Brignolo (CRF)
"Communication Technologies for Vehicles Trends & actual situation conference, December 14th 2006, Essene, Belgium	"Local dynamic maps in cooperative systems" , Christine Bartels (TA) "Vehicle to Vehicle communication applications and cooperative driving" , Dirk Jan Verburg (TNO)

PReVENT Fusion Forum 2nd Workshop Paris, March 14th - 15th 2007	"The SAFEPROBE approach to cooperative data fusion", Christain Zott, (BOSCH) "The SAFESPOT Local Dynamic Map Concept", Christine Bartels (TA)
"European Mobility Forum", Torino, Italy, April 11th , 2007	"Enabling technologies for vehicle to vehicle and to infrastructure cooperation in SAFESPOT", Christine Bartels (TA)
"IEEE VTC 2007 Spring" Dublin, Ireland, April 23th – 26th , 2007	"Accurate Positioning for Vehicular Safety Applications - the SAFESPOT approach" Heiko Cramer (TUC) &alii. (*)
"AMAA" Annual conference Berlin, Germany May 9th 2007	Project presentation, Roberto Brignolo (CRF)
"ATA International Workshop on Cooperative systems" Bard (Aosta), Italy May 17th - 18th 2007	"The Vehicle as a Mobile Sensorof the Traffic and the Environment:SAFEPROBE, a SAFESPOT subproject", Christian Zott(BOSCH) "Local dynamic maps in cooperative systems", Christine Bartels(TA) "Role of the Road Infrastructures in the development of Co-operative Safety Systems", Guy Fremont (COFIROUTE) "Towards an overall arechitecture for cooperative systems" Abdel Kader Mokaddem(RENAULT) "Extended Cooperative algorithm for Automatic Incident Detection on motorways", Simonetta Manfredi (CSST)
"Intelligent Vehicle 2007 – IV07" Istanbul, Turkey, June 13th -15th 2007	Project presentation to plenary session Giulio Vivo (CRF)
"Car2Car Forum", Ingolstadt, Germany, May 22nd – 23rd 2007	Project presentation Luisa Andreone(CRF)
"ASECAP 2007" - Annual Congress, Crete, Greece, May 27th – 30th 2007	Cooperative systems: The SAFESPOT and CVIS projects, Guy Fremont(COFIROUTE) & alii

“ITS in Europe” Congress June, Aalborg, Denmark, 18th – 22nd 2007	Infrastructure to Vehicle Co-operative Safety Applications, Guy Fremont(COFIROUTE) Vehicles as Sensors for Cooperative Systems; Christopher Brown(BOSCH) Architecture for cooperative systems in Europe : “The SAFESPOT Approach”; Abdel Kader Mokaddem(RENAULT) The SAFESPOT applications, Roberto Brignolo(CRF); SAFESPOT: Cooperative systems to improve road safety, Roberto Brignolo(CRF) SAFESPOT: The infrastructure platform, Angela Spence(CRF) SAFESPOT: V2V and V2I Communication; Luisa Andreone(CRF) & al
FOT & intersection Workshop Versailles, France, September 18th 2007	Discussions and presentations with USA experts of cooperative systems - SAFESPOT representatives; Roberto Brignolo(CRF), Tobias Schiendzelors(TUM)
PReVENT Exhibition, Versailles, France, September 18th – 21st 2007	Project stand (joint with CVIS) at the exhibition
23rd World Road Congress (PIARC) - Round table and Workshop:Impact of Emerging Vehicle, Pavement and Monitoring Technologies on Road Vehicle: where will we be in 30years? Paris, France. September 20th 2007	Project presentation, Roberto Brignolo (CRF)
11th Annual Meeting of International Task Force on Vehicle-Highway Automation, Versailles, France, September 21st 2007	Project presentation and advancement status, Bart Van Arem(TNO)
ITS 2007 conference, Beijing, China, October 9th – 13th 2007	Specifying applications for infrastructure-based co-operative road-safety, Fabien Bonnefoi (COFIROUTE) (*) SAFESPOT Local Dynamic Maps – Virtual Worlds for Safety Applications, Christine Bartels(TA) (*)
“Joint SAFEPOT-Watch-Over workshop” , Stuttgart, Germany, 26th – 27th 2008	Open workshop with 80 participants.
Verkehrsinformationssysteme. Berlin, Germany, February 14th 2008	Innovative Ortungsverfahren für kooperative Systeme in den EU-Projekten: CVIS & SAFESPOT, Marius Schingelhof (DLR)
“The fully networked car 2008”. Geneve, Switzerland, March 7th 2008	The SAFESPOT Integrated Project - Overview of the architecture, technologies and applications; Roberto Brignolo (CRF)

"AMAA 2008 :International Forum on advanced Microsystems for Automotive Apllications". Berlin, Germany, March 11th 2008	SAFESPOT: Laserscanner based Co-operative Pre Data Fusion, Florian Ahlers (IBEO) (*)
"ATA Road Safety Workshop", Courmayeur, Aosta, Italy, March 3rd 2008	Sensor Networks used for safety; Giuseppe Franco (ISMB) & alii
"TRA 2008 conference", Ljubljana, Slovenia, April 21st – 24th 2008	Co-operative driving and vehicle-based safety applications: the perspective of the European IP "SAFESPOT", Giulio Vivo(CRF) & alii (*)
"IV'08: IEEE Intelligent Vehicles Symposium 2008" Eindhoven, The Netherland, June 4th – 6th 2008	World Modeling for Cooperative Intelligent Vehicles; Zoltan Papp(TNO), (*) Optical Road State Monitoring for Infrastructure Side Co-operativeTraffic Safety System, Matti Kutila(VTT) (*)
"ITS in Europe 2008" congress. Geneva, Switzerland, June 4th – 6th 2008	SAFESPOT Special Session (chairman Irmgard Heiber - EC) Driving Simulator Study For Intelligent Cooperative Intersection Safety System (IRIS); Jaap Vreeswijk (PEEK) & alii
Eucar Integrated Safety Programme Board meeting, Brussels, Belgium. September 3rd - 4th 2008	Project presentation and progress status; Luisa Andreone(CRF)
Car-2-Car Forum and demonstration, Dudenhofen, Germany, October 22nd 2008	Project presentation, Luisa Andreone(CRF)
10th eSafety Forum Plenary Meeting. Brussels, Belgium, November 6th 2008	Project presentation, Roberto Brignolo (CRF)
Telematics Munich 2008, Munich, Germany, November 7th 2008	Project presentation, Roberto Brignolo (CRF)
"ITS2008 World Congress" New York, USA, November 15th – 20th 2008	Special Session : Vehicle - Infrastructure Cooperative Intersection Safety Systems, organized by Tobias Schiendzielorz(TUM) A Comparison of U.S. and European Cooperative System Architectures,Cecil Goodwin (TA) & alii (*) Cooperative Laserscanner Fusion System; Florian Ahlers(IBEO) & alii (*) Vulnerable road user protection at intelligent intersection, Jaap Vreeswijk (PEEK) & alii SAFESPOT Local Dynamic Maps – Generation of Views of a Platform's State and Environment for Situation-Aware Applications; Christian Zott(BOSCH) & alii (*)

"4th International workshop on vehicle communication", Ney York, USA, November 21st 2008	Cooperative applications, Roberto Brignolo(CRF)
Eucar Conference 2008 Brussels, Belgium November 26th 2008	Project presentation, Roberto Brignolo (CRF)
"CVIS Forum", Berlin, Germany, December 10th - 11th 2008	SAFESPOT/C2C Communications; Achim Brakemeier (Daimler) SAFESPOT Positioning; Robin Schubert (TUC) The local dynamic map: the point of view from a map provider; Stephane Dreher (NAVTEQ)
"TRB 88th Annual Meeting" Washington D.C., USA, January 11th - 15th 2009	Driving Simulator Study to support the Design of an Intersection Safety Application, Philippus Feenstra (TNO) & alii (*)
Congres International ATEC-its France Versailles, France, February 4th - 5th 2009	Synthèse Comparative des projet ITS Européens: CVIS, COOPERS, SAFESPOT; et participation de l'ASFA, Bonnefoi Fabien (COFIROUTE)
1st ETSI TC ITS Workshop, Sophia Antipolis, France, February 4th – 6th 2008	Project presentation, Roberto Brignolo (CRF) ITS Challenges: Standardization, Certification and Testing; Antonio Ortega (AT4)
Forum "CeBIT in Motion", Hannover, Germany, March 6th 2009	Die Intelligente Kooperative Kreuzung; Tobias Schendzielorz (TUM)
Workshop on Intelligent Transportation (WIT 2009), Hamburg, Germany, March 24th – 25th 2009	Improved Object Tracking through Laserscanner and High-Definition Map Fusion" , Christian Stimming (IBEO) & alii
Workshop ATA - La gestione del traffico: prospettive per la mobilita´e la sicurezza della rete transalpina; Susa, Italy, April 2nd 2009	Project presentation, Roberto Brignolo (CRF)
"2009 IEEE 69th Vehicular Technology Conference: VTC2009-Spring", Barcelona, Spain, April 26th – 29th 2009.	"Wireless Sensors Network for Intelligent Transportation Systems", P. Civera(ISMB) & alii, (*)
Cooperative Systems on the road, Helmond, the Netherland, May 13th 2009	Press Conference, Roberto Brignolo Presentation to a Dutch Conference . Jaap Vreeswijk (PEEK) Practical demonstration to journalist and technical experts
Cooperative road transport systems - Franco-Californian Workshop, June 10th 2009	The European project SAFESPOT, LCPC

Models and Technologies for Intelligent Transportation Systems, June 22-23, 2009 , Università La Sapienza, Roma - Italy	Extended Cooperative Automatic Incident Detection. An innovative algorithm for incident detection in cooperative environments, Stefano Marco (CSST) & alii (*)
10 years of LIVIC, 26 June 2009, Satory Versailles (France)	Demonstration of Fog detection and Speed Alert, LCPC
4th International Conference on Broadband Communications, Information Technology and Biomedical Applications, 15-18 July 2009, Wroclaw, Poland	A Reduction of Systematic Errors in the UWB Positioning System, IRE_PW
Tyrrhenian 2009, 20th Tyrrhenian Workshop on Digital Communications, September 2-4, 2009, Pula, Sardinia, Italy	Performance Evaluation of Routing Protocols in Wireless Sensor Networks Arranged in Linear Topologies, ISMB
6th IEEE International Conference on Advanced Video and Signal Based Surveillance, September 2-4, 2009, Genoa, Italy	Extensive Monitoring of Visibility Range through Roadside and In-Vehicle Sensors Combination, LCPC

ITS 2009 World Congress, Stockholm, Sweden, September 21st – 25th 2009	Live demonstration in the conference area. Paper& presentations: "Precise Laserscanner-based positioning on intra-urban crossings" , Florian Ahlers, (IBEO) & alii (*) "Cooperative Situation Refinement for Vehicular Safety Applications: the SAFESPOT approach" , Panagiotis Lytrivis (ICCS) & alii (*) "The SAFESPOT Vehicular Platform – Environmental Perception From Sensors and Wireless LAN Messages" , Christian Zott (BOSCH) & alii (*) "V2V Applications in the SAFESPOT European Project: The OEMs Experience" , Giulio Vivo (CRF) &alii (*) "HMI considerations for the NL CVIS - SAFESPOT test site", Philippus Feenstra (TNO) (*) "The business case of cooperative systems for road operators" , Martijn de Kievit (TNO) (*) "ESPOSYTOR: The SAFESPOT System Monitor", Maria Carmela De Gennaro (MMSE) & alii (*) "Verification and Validation of SAFESPOT Vehicle Based Applications", Piero Mortara (MMSE) & alii (*) "Sensing the visibility range at low cost in the SAFESPOT road-side unit" by Nicolas Hautière (LCPC) & alii, (*) "Lane Level Positioning using Image Landmarks and high accurate maps" , Norman Mattern(TUC) & alii (*) "Vehicle Positioning for Cooperative eSafety Applications" , Robin Schubert (TUC) (*) "Vehicle to vehicle Versus vehicle to infrastructure Communication systems – An economic assessment of the SAFESPOT application bundles" , Roland Schindhelm (BAST) & alii (*) "Organizational Architecture of Road Safety Cooperative Systems. The SAFESPOT case" by Stefano Marco (CSST) & alii (*) "Intelligent Cooperative Intersection Safety Implementation, Test And Evaluation", Tobias Schendzielorz (TUM) & alii (*) "Towards safer, cleaner and smarter mobility with cooperative systems" special session jointly organized by COOPERS, CVIS and SAFESPOT chaired by Stefanos Gouvras(EC) "SAFESPOT Local Dynamic Maps: Leaving the labs and hitting the road", TA (*)
POSNAV 2009 (DGON Positionierung und Navigation Symposium), 2009-10-27/28, Dresden, Germany	Fahrzeuglokalisierung unter Verwendung von Bildlandmarken und detaillierten digitalen Karten, TUC Fahrzeugpositionierung für kooperative Verkehrssysteme – Beiträge des Europäischen Projektes SAFESPOT, TUC

Meeting of 2 POLIS working groups on Environment & Health and Road Safety, 8 - 9 October 2009	Intelligent Cooperative Intersection Safety system (IRIS) - A SAFESPOT application, PEEK
CAR 2 CAR Forum 2009, Wolfsburg, Gernmany, November 3rd – 4th 2009	Project presentation, Giulio Vivo(CRF) National road authorities' views on cooperative systems and their deployment, Bengt Hallström (SRA)
NAV09 Land Conference, 9-11-2009, National Physical Laboratory, Teddington, UK	The Local Dynamic Map - a data store for cooperative applications, NAVTEQ
ETSI TC ITS meetings Sophia Antipolis, France, January 25th – 26th 2010	Participation of the SP3 leader, Achim Brakemeier(DAI)
Cooperative Mobility Showcase 2010, Amsterdam, The Netherland, March 24th - 25th 2010	Keynote address - Toward continuous communication for cooperative systems Achim Brakemeier (DAI) Innovative architecture for innovative applications, Abdel Kader Mokaddem(RENAULT) Toward a real in vehicle SAFESPOT future deployment: From Demonstration Prototypes to a Real Product - Perspectives from an Electronic Automotive Supplier; Piero Mortara(MMSE) Keynote address - Location is (almost) everything for cooperative systems… Rob Van Essen (TA) Positioning among Vehicles –How precise can we be?, Robin Schubert(TUC) Local Dynamic Map –Future of Navigation Map, Sheung Ying Yuen-Wille(BOSCH) Key Achievements of the SAFESPOT IP, Giulio Vivo(CRF) How effective are cooperative safety & traffic efficiency applications?, SiebeTurksma (PEEK) Eemoving barriers to deployment SAFESPOT – BLADE (Business modelling Legal Analysis and Deployment), Han Zwijnenberg(TNO)
TÜV-Conference: „Sicherheit durch Fahrerassistenz",15 – 16 April 2010, Munich, Germany	Ökonomische Bewertung kooperativer Fahrerassistenzsysteme aus Sicht der Nutzer und Infrastruktur-Betreiber – Ergebnisse des SAFESPOT-Projektes, BASt, UoC, TNO
AmE 2010: Automotive meets Electronics, April 15 - 16, 2010, Dortmund, Germany	Cooperative C2X Applications in Intersection on Example of the SAFESPOT Project, CA
Move On Workshop: ICT for motorcycles and riders, investigating the state-of-the-art and beyond, 29th of April, 2010, Athens Greece	The SAFESPOT Integrated Project: PTWs are in the safety network, ICCS, CRF, Piaggio

International Road Federation World Meeting, May 25 -28, 2010, Lisbon, Portugal	Intelligent Barriers, MIZAR
TRA 2010 conference. Brussels, Belgium, June 7th – 10th 2010	Cooperative systems for road safety: the SAFESPOT integrated project, Filippo, Visintainer (CRF) & alii (*) Road departure application based on cooperative systems, Andre Possani Espinosa (*)
Conférence Sécurité Routière : Prévention des Risques et Aides à la Conduite,	Detection de Conditions Reduites de Visibilite Par Camera Bord de Voies, LCPC
13th International IEEE Conference on Intelligent Transportation Systems, Madeira Island, Portugal, 19-22 September 2010	Situation refinement for in-vehicle platforms in vehicular networks, TNO (*) Simulator Test Bench for Cooperrative Systems, TNO (*) Vehicle to Vehicle communications applied to Road Intersection Safety, ICCS (*)
Wireless Technologies, 12. Kongress, 2010-09-22/23, Bochum, Germany	Fahrzeugpositionierung für kooperative Verkehrssysteme – Beiträge des Europäischen Projektes SAFESPOT, TUC (*)
ITS 2010 World Congress, Busan, Korea, September 23st – 29th 2010	Iterative Design and Assessment of an Audio Visual Warning Concept for Car2x Communication Systems, USTUTT(*) Cooperative safety systems in 2020, TNO (*) White paper for deployment of cooperative systems focusing on non-technical issues, TNO (*) Presentation of results of traffic simulation for V2V and V2I, TNO (*)

SAFESPOT also was presented to a large number of various events and appeared to special broadcasts of European channels, press releases of various organisations and companies and to informative websites.

Events including major demonstrations of SAFESPOT results

- Cooperative Mobility Showcase 2010, Amsterdam, The Netherland, March 24th - 25th 2010 (see section 11.4.5)
- ITS World Congress, Stockholm , Sweden, September 21st – 25th 2009 (see section 11.5.4)
- Cooperative Systems on the road, Helmond, the Netherland, May 13th 2009 (see section 11.4.4)

All the these three events where jointly organized with CVIS and COOPERS.Complexity of demonstrations grew each times and the last exhibition resulted, according to the consortium knowledge, the largest event dedicated to Mobility Cooperative Systems worldwide.

Other showcases were locally organized by Test Sites.

Other important dissemination actions

To support the dissemination work, a range of dissemination material was developed during the project, including posters, two sets of leaflets (initial and final), the project website (www.safespot-eu.org), a number of Videos dedicated to applications and Test Site and a professional video on Cooperative Mobility Systems.

10 Summary of project deliverables

Table 5 below lists all deliverables generated by SAFESPOT IP, their dissemination level, the corresponding lead contractor, and the project month at which the delivery was made.

Legenda:

Nature codes

- R → Report
- P → Prototype
- D → Demonstrator
- O → Other

Dissemination Level Codes

- PU → Public
- PP → Restricted to other 6th Framework Programme participants (including the Commission Services)
- RE → Restricted to a group specified by the commission (including the Commission Services)
- CO → Confidential, only for memberso of the consortium (including the Commission Services)

Public deliverables, as well as public summaries of non-public ones, can be downloaded from the SAFESPOT web site www.safespot-eu.org

Table 5: SAFESPOT deliverables

Number	Title	Delivery date	Nature	Dissemination level
D1.1.1	Sub-project technical and financial progress report to the IP management	every 3 months	R	CO
D1.2.1	Vehicle probe use cases and test scenarios	M6	R	PU
D1.2.2	System Analysis	M9	R	RE
D1.2.3	Requirements for the vehicle probe platform	M12	R	RE
D1.3.1	Data fusion specifications	M23	R	RE
D1.3.2	HW and SW Platform specifications	M22	R	CO
D1.3.3	Data fusion public specification	M26	R	PU
D1.3.4	HW and SW platform public specification	M26	R	PU
D1.4.1	Platform prototype and test bed architecture details	M30	R	RE
D1.4.2	HW and SW specifications of prototype and test bed components	M30	R	CO
D1.4.3	Algorithms and SW Prototypes	M30	P	RE
D1.4.4	In-vehicle SAFEPROBE platform	M27	P	RE
D1.4.5	Probe vehicles prototypes	M30	D	PU
D1.5.1	Test plan design	M38	R	RE
D1.5.2	In-vehicle platform test results	M39	R	PU

Number	Title	Delivery date	Nature	Dissemination level
D1.5.3	Performance analysis	M39	R	RE
D2.1.1	Sub-project technical and financial progress reports	Every 3 months	R	CO
D2.2.1	Interim Report: Needs and requirements for infrastructure-based sensing	M6	R	PP
D2.2.2	Final Report: Needs and requirements for infrastructure-based sensing	M8	R	PU
D2.3.1	Interim Report: Specifications for infrastructure-based components	M12	R	PP
D2.3.2	Final Report: Specifications for infrastructure-based components	M18	R	PU
D2.4.1	Interim Report: Implementation and prototypes for infrastructure-based components	M27	R	PP
D2.4.2	Final Report: Implementation and prototypes for infrastructure-based components	M38	R	PU
D2.4.3	Prototypes: sensing networks and systems	M30	P	PP
D2.4.4	Prototypes: algorithms for detection of safety-related events	M30	P	PP
D2.4.5	Prototypes: data fusion methods	M30	P	PP
D2.4.6	Prototypes: distributed actuation systems	M30	P	PP
D2.4.7	Prototypes: integration of SAFESPOT with traffic management systems	M30	P	PP
D2.5.1	Plan for testing and validation activities	M38	R	PP
D2.5.2	Final Report: Results on test and validation	M39	R	PU
D3.1.1	Sub-project technical and financial progress report to the IP management	every 3 months	R	CO
D3.2.1	Technical Scenario Description for Positioning, Local Dynamic Maps and Vehicle Ad Hoc Networks	M4	R	RE
D3.2.2	User Needs and Requirements for Positioning, Local Dynamic Maps and Vehicle Ad Hoc Networks	M7	R	RE
D3.2.3	Consolidation Report of User Needs and Requirements	M9	R	RE
D3.3.1	Mapping of known Technologies for Positioning, Local Dynamic Maps and Vehicle Ad Hoc Networks	M12	R	RE
D3.3.2	Positioning Specifications	M18	R	RE
D3.3.3	Local Dynamic Maps Specifications	M18	R	RE
D3.3.4	Vehicle Ad Hoc Networks Specifications	M18	R	RE
D3.4.1	Algorithmic and simulation results	M20	R	RE
D3.4.2	Implementation Plan	M20	R	RE

Number	Title	Delivery date	Nature	Dissemination level
D3.4.3	Prototypical Implementation	M30	R	RE
D3.4.4	ESPOSYTOR Architecture and SW Design Description	M31	R	RE
D3.4.5	ESPOSYTOR Prototype Implementation	M37	P	RE
D3.5.1	Validation Report for Positioning	M37	R	RE
D3.5.2	Validation Report for Local Dynamic Maps	M42	R	RE
D3.5.3	Validation Report for Vehicular Ad-Hoc Networks	M39	R	RE
D3.5.4	Key Concepts and Exploitation	M39	R	PU
D3.5.5	ESPOSYTOR Validation Report	M39	R	RE
D4.1.1	Sub-project technical and financial progress report to the IP management	every 3 months	R	CO
D4.2.1	Actual safety application V2V based	M4	R	PU
D4.2.2	Safety Margin concept	M12	R	RE
D4.2.3	Use case and typical accident situation	M12	R	PU
D4.2.4	Needs and Requirements	M12	R	RE
D4.2.5	Open Web technology observatory (draft)	M3	P	PU
D4.2.5	Open Web technology observatory (final)	M53	P	PU
D4.3.1	Safety Margin Application Parameters: Analysis and Characterisation	M18	R	RE
D4.3.2	Driving Safety Margin Functional specification	M18	R	RE
D4.3.3	Application communication for co-operative vehicles and infrastructure	M18	R	RE
D4.3.4	Conceptualisation of on-board information system and extended HMI	M21	R	RE
D4.3.5	On Vehicle diagnostics and monitoring specification	M24	R	CO
D4.4.1	Safety Margin algorithms	M24	P	CO
D4.4.2	Equipped cars integrating the Safety Margin applications	M39	D	PU
D4.4.3	Equipped trucks integrating the Safety Margin applications	M39	D	PU
D4.4.4	Equipped motorcycles integrating the Safety Margin applications	M39	D	PU
D4.5.1	Technical and functional test	M35	R	RE
D4.5.2	Validation of the Safety Margin	M50	R	RE
D4.6.1	Pilot Plan	M36	R	PU
D4.6.2	Pilot Plan assessment	M46	R	RE
D4.6.3	Results Evaluation	M54	R	RE
D4.6.4	Evaluation of accident impact through simulation	M49	R	PU

Number	Title	Delivery date	Nature	Dissemination level
D5.1.1	Sub-project technical and financial progress report to the IP management	every 3 months	R	CO
D5.2.1	Definition of use case and user requirements	M6	R	RE
D5.2.2	Common architecture and communication network	M9	R	RE
D5.2.3	Area specific needs and requirements and Application Scenarios	M12	R	RE
D5.2.4	Accident data review and potential impact of each function	M12	R	RE
D5.3.1	Specifications for Speed Alert	M21	R	RE
D5.3.2	Specifications for Hazard and incident Warning	M21	R	RE
D5.3.3	Specifications for Cooperative intersection collision prevention systems	M21	R	RE
D5.3.4	Specifications for the Road Departure Application	M21	R	RE
D5.3.5	Specifications for Safety margin for assistance and emergency vehicles	M21	R	RE
D5.4.1	Application algorithms	M36	P	CO
D5.4.2	Application prototypes	M36	P	CO
D5.5.1	Test and validation plan	M41	R	PU
D5.5.2	Test and Validation results	M40	R	PU
D5.6.1	Evaluation Plan	M41	R	PU
D5.6.2	Evaluation on Urban Roads	M50	O	PP
D5.6.3	Evaluation on Highways, Expressways and Tunnels	M50	O	PP
D5.6.4	Evaluation on Rural and Secondary Roads	M50	O	PP
D5.6.5	Evaluation Final Report	M52	R	PU
D5.6.6	Specification readjustment on the base of the validation results	M53	R	PP
D6.1.1	Sub-project technical and financial progress report to the IP management (every 3 months)		R	CO
D6.2.1	Report on preliminary analysis and initial deployment programme	M6	R	PU
D6.3.1	Preliminary Organisational Architecture	M21	R	PU
D6.3.2	The Organisational Architecture - final	M48	R	PU
D6.4.1	Constraint analysis: identification of risks	M18	R	PP
D6.4.2	Analysis of legal aspects	M24	R	PP
D6.4.3	Mitigation of risks	M24	R	PP
D6.4.4	Stakeholder consultation report	M27	R	PU
D6.4.5	Preliminary recommendations dealing with risks and legal aspects	M27	R	PU

Number	Title	Delivery date	Nature	Dissemination level
D6.4.6	Consolidated recommendations dealing with risks and legal aspects	M50	R	PU
D6.5.1	Report on socio-economic, market and financial assessment	M46	R	PU
D6.6.1	Service and business models definition	M27	R	PU
D6.6.2	Preliminary ranking of alternative business models	M39	R	PU
D6.6.3	Final ranking and selection of service and business model	M47	R	PU
D6.7.1	The SAFESPOT deployment programme	M50	R	PU
D6.7.2	Report of the workshop on the SAFESPOT deployment programme	M54	R	PU
D7.1.1	Technical and financial progress report	Every 3 months	R	CO
D7.2.1	Core architecture requirements	M7	R	PU
D7.3.1	Global System Reference Architecture specification	M21	R	RE
D7.3.2	Global System Reference Architecture building guide	M21	R	RE
D7.4.1	SCORE subproject contribution to the C2C and C2I exploitation plan convergence	M50	R	CO
D7.4.2	MOU signed with the C2C Communication consortium	M12	R	CO
D7.4.3.1	SAFESPOT Certification Reference Framework – part A	M18	R	PU
D7.4.3.2	SAFESPOT Certification Reference Framework – part B	M24	R	PU
D7.4.4	Conformance & Interoperability test system mock-up ready	M30	P	PU
D7.4.5	System Conformance & Interoperability Tests	M54	R	PU
D8.1.1	Annual Project Management and Technical Report	Every year	R	CO
D8.1.2	Quality Plan	M5	R	PU
D8.2.1	Training and Gender Equality Plan	M12	R	PU
D8.2.2	Report on results of User Forum	M24	R	PU
D8.2.3	Dissemination materials including web site and plans	M12	O + R	PU
D8.2.4	Technological Implementation Plan	M54	R	PU + CO
D8.3.1	Assessment and Review Methodology	M5	R	PU
D8.3.2	Assessment Reports	Every year	R	IR
D8.4.1	SAFESPOT Interaction Plan	M9	R	PU

Number	Title	Delivery date	Nature	Dissemination level
D8.4.2	Description of the integrated vehicle and infrastructure platform	M24	R	PU
D8.4.3	Description of the common validation plan for test sites	M38	R	CO
D8.4.4	Use cases, functional specifications and safety margin applications for the SAFESPOT project	M24	R	PU

11 Test Sites

Test Sites activities in SAFESPOT were finalized to the validation and evaluation of the applications developed by SCOVA and CoSSIB. The activities were assigned to five Test Sites located into six different countries (France, Germany, Italy, Spain, Sweden and Netherland). France and Spain were grouped into a single WEST TS. In this chapter the some details of the demonstrators (infrastructures, vehicles and locations) of each Test Site are reported. More details of each TS are contained in the deliverable D8.4.3 (Common Validation Plan). The use cases tested in different TSs are reported in Annex 1. The full descriptions of the results of validation and evaluation made in the different TSs are reported in D4.5.2, D4.6.2, D4.6.4, D5.5.2, D5.6.X (X=2-5). Moreover many test sessions were filmed and video presenting the demonstrations have been realized by each TS. Finally it should be underlined that the three Showcases operated as common TSs to which participated a large number of partners from other TSs.

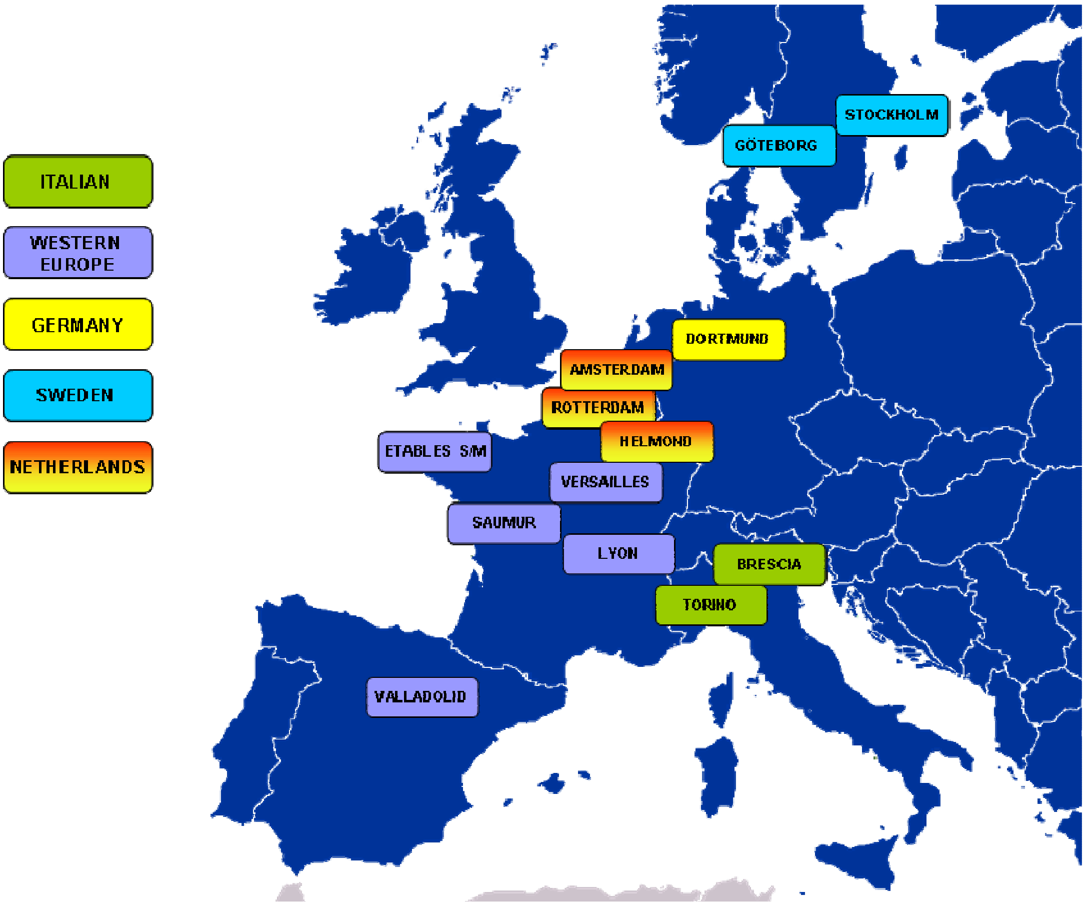


Figure 23: The distribution and main locations of the SAFESPOT Test Sites in Europe

11.1 Italian Test Site.

This Test Site coordinated the validation and evaluation activities for the Italian partners of the project. Most of the activities were concentrated in the Turin area, where the major part of the technical developments took place.

In this Test Site both vehicle-to-vehicle and vehicle-to-infrastructure solutions were evaluated.

11.1.1 Partners

Short Name	Extended name and role	Role	Country
CRF	Centro Ricerche Fiat	Test Site Leader Vehicle OEM	IT
ANAS	ANAS	Road operator	IT
MIZAR	MIZAR	WSN and RSU supplier	IT
CSST	Centro Studi sui Sistemi di Trasporto	Transport and traffic system expert	IT
PIAGGIO	Piaggio & C. S.p.A.	Vehicle OEM	IT
ISMB	Istituto Superiore Mario Boella	WSN supplier	IT
BSPD	Autostrada Brescia Verona Vicenza Padova S.p.A.	Road operator	IT
MMSE	Magneti Marelli Electronic Systems	Esposytor supplier	IT
VTT	Technical Research Centre of Finland	Pedestrian detection system supplier	FI
TUM	Technische Universität München	Situation refinement	DE
BME	Budapest University of Technology and Economics	RFID detection system supplier	HU

VTT, TUM and BME, even if not formally involved, actively participated providing the results achieved into the SP2 project.

11.1.2 Test locations

Four different locations were used:

- **Torino-Urban Area, via Bologna**, represents an important street of the city with buildings and junction. In this scenario it was evaluated the preliminary interoperability communication with CVIS cars;
- **RA10: Torino-Caselle Airport Expressway**, represents an important junction to reach the Turin Airport, characterized by medium to high traffic density. In a preliminary phase this location was used to verify and validate the infrastructure equipment and the IEEE 802.11p communication with the vehicles;
- **A4: Brescia-Padova Motorway,** three plus emergency lanes highway. Due to the presence of a number of traffic monitoring system it was possible to show integration and cooperation with legacy system as

well as data fusion and incident detection algorithms. Moreover a communication system was installed to test V2I and “hopping” (V2V2I) applications with the support of the SMAEV car (mobile road side unit).

- **CRF test track,** which had the following roles:
  - a private test track, closed to the public traffic and “totally under control” in terms of safety, in which it was possible to test, to demonstrate and to evaluate many specific V2V applications related to dangerous maneuvers;
  - a suitable area for integration and preliminary system debug;
  - thanks to above features it was possible to emulate the conditions of the locations for the Stockholm and Amsterdam showcases to which the Italian TS partners provided a very significant contribution.

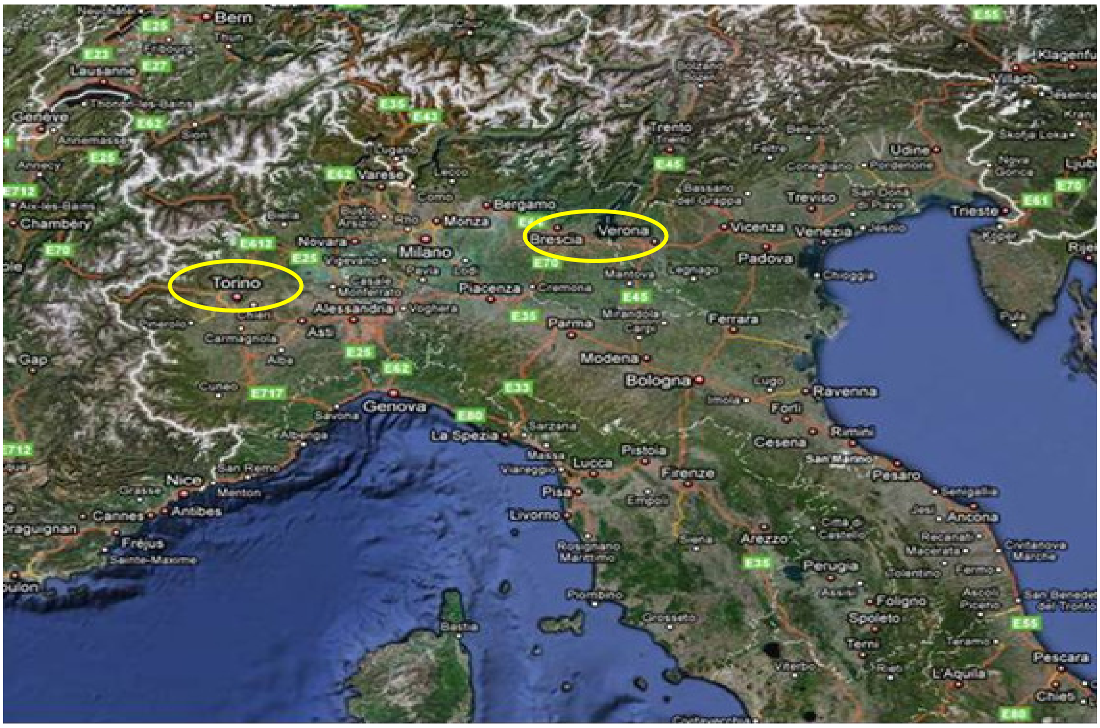


Figure 24: The different locations of the Italian Test Site

11.1.2.1 Turin - Urban: Via Bologna

In the urban area of the TS-IT some preliminary and qualitative tests of interaction between the CVIS and SAFESPOT vehicles have been carried out.

The tests performed on the urban scenario were focused on solving preliminary problems of communication between two vehicles. The results of these tests have contributed significantly to strengthen the solution applied, also for the benefits of the other test sites.

In the photo below it is possible to see the RSU close to the traffic light.

Figure 25: RSU in the urban test site

The next two photos are taken during the preliminary tests, in the first phases of communication and interoperability of the different systems.

Figure 26: Urban test site communication

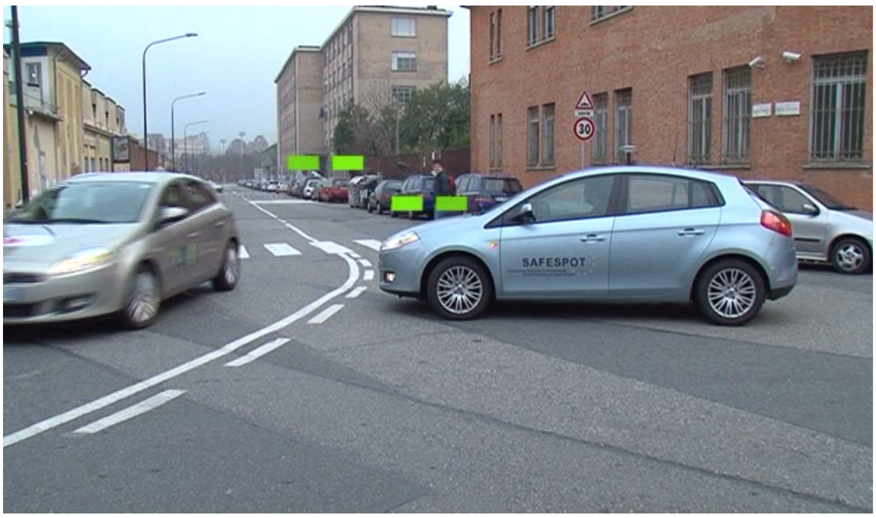


Figure 27: Urban test site CVIS interoperability

11.1.2.2 RA10 - Torino-Caselle Airport Expressway

Figure 28: The Turin- Airport freeway

The road infrastructure components used in this location of the TS-IT can be grouped in the following categories:

- DETECTION SYSTEMS
  - Wireless Sensor Network - Traffic monitoring
- SAFESPOT PROCESSING & VANET
  - RSU MAIN PC →LDM, data fusion and SAFESPOT SW architecture
  - Router -> VANET communication
- LEGACY SYSTEM
  - VMS – Handled by road operator for SAFESPOT applications
- REMOTE ACCESS as INTERFACE BETWEEN SAFESPOT AND ROAD OPERATOR
  - CRF remote control for management purpose

Installation needed in the site was not permanent and used only for preliminary tests and setup of the systems.

11.1.2.3 A4 Brescia-Padova Motorway

Figure 29: The Brescia-Padova motorway

The A4 Brescia-Padova Motorway is a 3 + 1 lanes road, characterized by high traffic density and critical meteo conditions.

The road infrastructure components used in this location of the TS-IT can be grouped in the following categories:

- DETECTION SYSTEMS
  - Wireless Sensor Network - Traffic monitoring
- SAFESPOT PROCESSING & VANET
  - RSU MAIN PC →LDM, data fusion, situation refinement (ECAID) and SAFESPOT SW architecture
  - Router → VANET communication
- LEGACY SYSTEM
  - VMS – Handled by road operator for SAFESPOT applications
  - Traffic flow measurement and monitoring system (based on magnetic coils, radar and camera)
- REMOTE ACCESS (Interface SAFESPOT - Road Operator network)
  - Internet connection to road operator control centre
  - CRF remote control for management purpose

11.1.2.4 CRF closed test track

Figure 30: The CRF closed test track in Orbassano

CRF test track, as already mentioned, had a double role for the TS-IT: principal site for integration and testing of critical V2I and V2V applications.

The installations needed in this location were not permanent.

Peculiarities and specific applications evaluated in the CRF test track were: Road Departure application using laserscanner and RFID detection system, Head on Collision Warning, Rear End Collision Warning, Speed Limitation and Safety Distance, Safe Overtaking. Several other applications and relevant cooperative use cases were set up and demonstrated on the location.

11.1.3 Short survey of Architecture, On-board and Roadside equipments

11.1.3.1 Vehicles and on-Board Units

Italian Test Site used 6 vehicles; five of them are SAFESPOT equipped while one is named “support vehicle”. Hereafter the main characteristics of these vehicles are reported.

- 1 CRF BRAVO, equipped as SAFEPROBE vehicle;
- 1 CRF BRAVO equipped as SCOVA vehicle;
- 2 Piaggio motorbikes;
- 1 CRF CROMA, equipped as CoSSIB vehicle (mobile RSU);
- 1 Additional support vehicle. It is a further supporting vehicle, not equipped. It was used in order to work for example as obstacle detected from vehicle laserscanner or to simulate the ghost driver detected by RSU sensors. The need and the specific usage of this vehicle depended on the given use cases that have been conducted.

Figure 31: The SAFEPROBE (details of Laser Scanner and Radar) and SCOVA vehicles

Figure 32: The CoSSIB Assistance Vehicle and the Piaggio motorbike (MP3) during joint tests with the SAFEPROBE vehicle

11.1.3.2 Road Side Units

The road side unit is characterized by a distributed hardware architecture.

In line with INFRASENS specification, the Test Site implementation of the SAFESPOT architecture is composed by the key components: detection systems, RSU Main PC, GPS receiver, VANET Router, Gateway connecting legacy systems and Esposytor PC. In addition, for the remote control of the individual components, it was adopted a solution similar to the one used in the A4 motorway, consisting in a wireless long range connection to remotely update software and monitoring data pre and post elaboration. Each location was characterized by a different configuration in terms of detection systems and applications. In Fig. 33 it is showed the physical architecture; the blocks represent the components adopted for the RSU in the A4 Brescia – Padova motorway location.

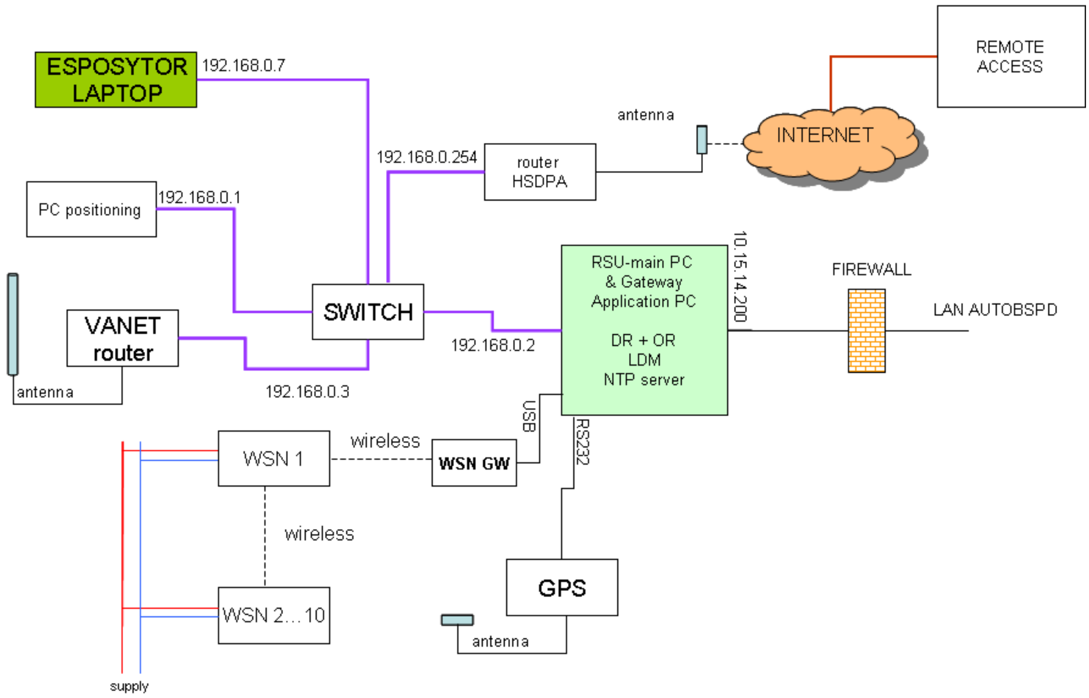


Figure 33: Physical architecture of A4 Brescia - Padova location

In the CRF test track a slightly simplified version of infrastructure was used.

In any case the architecture is compliant with the general RSU SAFESPOT architecture, whose core is the RSU - MAIN PC. With reference to the scheme showed in Fig. 33 it is possible to identify the components contained in the RSU and the connections with the other devices.

During the evaluation activities a special care was given to the antenna positioning, considering physical site constraints, as bridge, road signs, metallic barrier nearby the RSU location, which could impair the communication between vehicles and infrastructure. For that purpose a specific and detailed analysis was carried out considering main possible negative factors.

The GPS receiver, connected to the MAIN PC, provides a common reference time for synchronizing all components connected to the local Ethernet network. The synchronization was achieved by using a sophisticated configuration of the NTP server-client services, installed in all components connected to the LAN; the usage of NTP permitted to establish a solid time alignment among all of the nodes involved in the SAFESPOT ad-hoc network, both vehicles and infrastructure.

The TeleAtlas and Navteq LDM implementations were used in the TS-IT to carry out the verification, validation and evaluation tests.

In the A4 test site all the equipments were installed on the right side of the road, within a specific "emergency area", in order to have the possibility to work in a safe condition and to avoid any perturbation on the traffic flow. A dedicated cabinet contained the PCs, while the VANET router was directly coupled with an antenna installed on a pole. A special watertight box contains the VANET router. The external connection with equipment into the cabinet was achieved by means of the simple connection of the Ethernet and power cables. After many analyses and tests, this solution turned out as the optimal one: it allowed to remote the router (and the antenna) even at significant distances respect to the main PC and the other components of the SAFESPOT architecture, by keeping a very limited length for the signal coaxial cable and avoiding all signal losses.

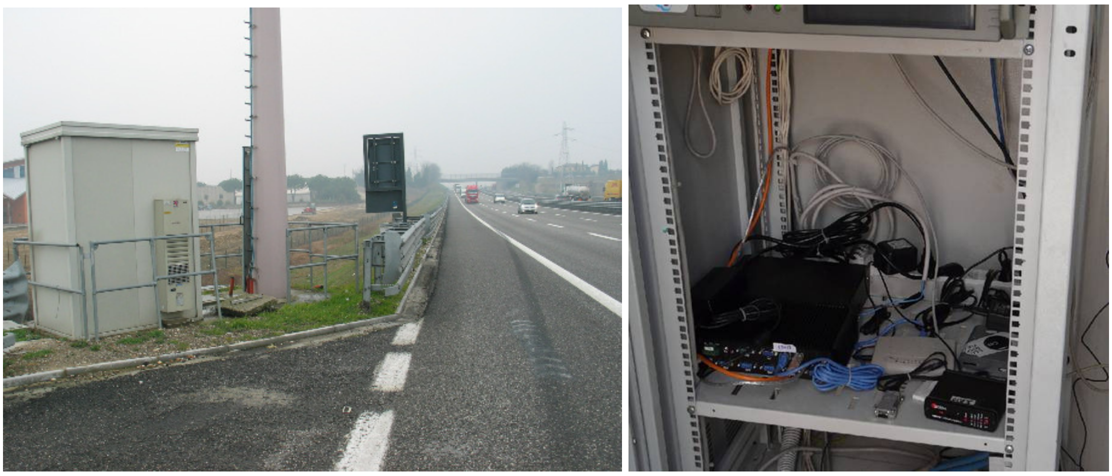


Figure 34: Shelter box hosting the RSU system devices

Figure above show images of the test site and the rack where the components of RSU were installed in the A4 Brescia-Padova location. In the left image it is shown an external view and in the right one the internal view of the shelter box is represented. The environment inside the box is conditioned in terms of temperature, humidity and network supply: in case of blackouts a backup battery ensuresthe continuity of the supply.

11.1.3.3 Infrastructure of the WSN

The wireless sensor network system was installed on the existing guard rails barrier by means of an ad-hoc designed case for a compact and reliable integration.

Figure 35: WSN ad-hoc case

The wireless sensor network system is composed by 11 nodes playing both the role of traffic monitoring and wireless communication systems.

Part of the information collected by each node is locally pre-processed and then transferred to the RSU data fusion module.

The distance between two consecutive nodes is about 23 m and the number of connected nodes is 11 to cover a distance of about 230 meters.

The WSN system provides the following outputs:

- Vehicles counting;
- Vehicles speed and direction measurement;
- Traffic density and medium speed evaluation.

Fig. 36 shows a photo of the A4 test site; in the photo it is possible to see the WSN nodes, the VANET router and the antenna of the SAFESPOT infrastructure node. The others devices are in the shelter, which is not visible in the photo.

Figure 36: A4 test site

11.2 West Test Site

11.2.1 Partners

Short name	Extended name	Role	Country
COFIROUTE	Cofiroute	Road operator	FR
CG22	Conseil Général des Côtes d'Armor	Road operator	FR
REGIENOV	Renault FRANCE, REGIENOV	Vehicle OEM	FR
LCPC	Laboratoire Central des Ponts et Chaussées	TS leader and application provider	FR
LAC	Lacroix Trafic	Road equipment supplier	FR
SODIT	Société pour le Développement de l'Innovation dans les Transports	Application developer and system integration	FR
VOLVO	Volvo Technology Corporation	Vehicle OEM	SE
NAVTEQ	NAVTEQ Europe B.V.	Map provider	BE
TNO	TNO	Application and vehicle providers	NL
CIDAUT	CIDAUT: Fundación para la Investigación y Desarrollo en Automoción	Sensors provider	SP
RNS	RENAULT España	Vehicle OEM	SP
UPM	Universidad Politécnica de Madrid	Application integration	SP
TEL	Telefónica Investigación y Desarrollo Sociedad Anónima Unipers.	Application integration	SP

11.2.2 Test locations

Figure 37: The different locations of the WEST Test Site

The particularity of the WEST Test Site was to be dispatched in several test locations, in France but also in Spain.

Two locations have been used for integration, validation, controlled environment preliminary tests and full tests too dangerous to be carried out on an open road:

- **#3**: the LIVIC closed test tracks in Satory (Versailles),
- **#2**: the Volvo closed test track in La Valbonne nearby Lyon.

Three real-world locations representing different types of network:

- **#5**: the A85 motorway sections, located at Vivy, near Saumur,
- **#1**: the RD 786 Etables s/ Mer rural section in the Côtes d'Armor,
- **#4**: the Spanish peri-urban sections in Valladolid technology park.

11.2.2.1 The closed test tracks

Pictures of two closed test tracks are reported in Fig. 38.

The Valbonne test tracks was used for validation and evaluation of the WEST SP4 *Longitudinal collision* applications involving trucks.

The Satory test tracks was used for:

- pilot integration technical workshops for all the WEST partners
- validation and evaluation of the WEST SP4 *Lateral collision* applications (See Annex 1),
- road departure prevention Evaluation.

Figure 38: The closed test track at Valbonne (Lyon-VOLVO) and Satory (Versailles-LCPC/LIVIC)

Two double-function Renault CLIO were prepared by LCPC which could be used as mobile RSU or as vehicle equipped with OBU (see Fig. 39).

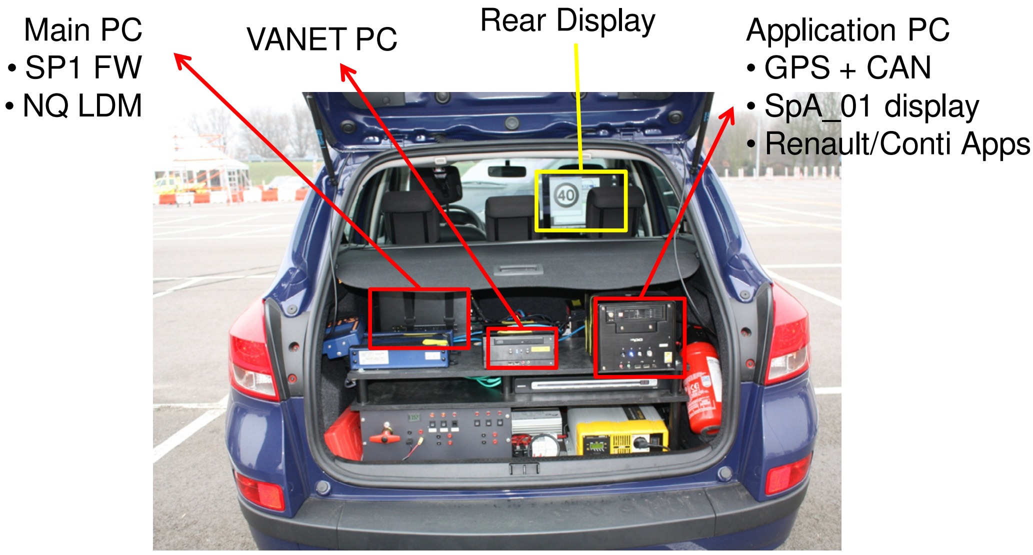


Figure 39: One of the two LIVIC CLIO functioning as RSU or OBU

11.2.2.2 A85 Vivy – Saumur

The specificity of this location is to offer a typical motorway environment, on relatively safe conditions given the relatively low traffic.

The Vivy-Saumur location was used for evaluation of SP5 *Speed Alert_01 & _03*, *Hazard and Incident Warning_01* and *SMAEV_01* applications in a motorway environment, for the cases of accidents and road-works as obstacles.

A road side unit was placed on the highway for the experimentation of the Speed Alert and Hazard&Incident detection. For SMAEV application an assistance vehicle with an on-board mobile RSU was used.

Figure 40: The COFIROUTE Road Side Unit on The A85 Vivy-Saumur Test Site

11.2.2.3 RD 786 Etables s/ Mer

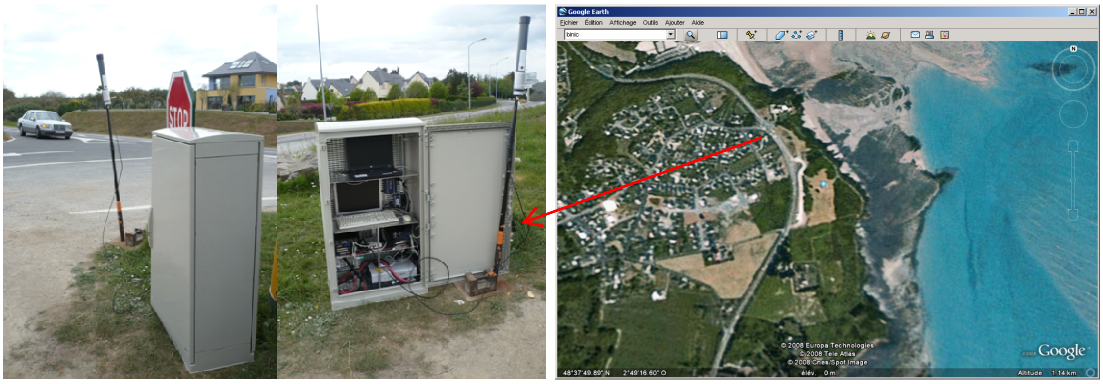


Figure 41: The RN 786 spot at Etables s/ Mer

The specificity of this location is to offer a typical rural environment, with frequent weather problems like fog or mist and to be already equipped with a weather station and mechanical & electrical facilities. The RN 786 location was used for:

- evaluation of the SP5 *Speed Alert_01 & 03* (due to bad weather conditions) and *SMAEV_01* applications in a rural environment;
- evaluation of the SP5 *Road Departure* application in a rural environment.

11.2.2.4 Valladolid

Figure 42: The technological park in Valladolid

The specificity of this location is to offer a safe environment for testing the intersection applications. The surroundings and access to the intersection were closed during test and demos.

The Valladolid location was used for validation and evaluation of some of the SP4 *Lateral collision* applications that were also tested in Satory, corresponding to Use Cases *Approaching emergency vehicle warning* and *Accident at intersections*.

11.2.3 The Vehicles

A total of 7 vehicles were prepared and used in the WEST TS. The images are reported from Fig. 43 to Fig. 46. The Volvo Car was shared with the SWEDISH TS.

Figure 43: RENAULT vehicles

Figure 44: The VOLVO truck and car

Figure 45: The COFIROUTE car

Figure 46: The LCPC/LIVIC cars

11.3 German Test Site

11.3.1 Partners

Short name	Extended name	Role	Country
BOSCH	Robert BOSCH GmbH	Automotive supplier	DE
CA	Continental Automotive GmbH	Automotive supplier	DE
DAIMLER	Daimler AG	Vehicle OEM	DE
IBEO	IBEO Automobile Sensor GmbH	Sensors Supplier	DE
PTV	Planung Transport Verkehr AG	Application Supplier	DE
TA	Tele Atlas NV	Map provider	DE
TUC	Technische Universität Chemnitz	Technology provider (positioning)	DE
TUM	Technische Universität München	Application provider and infrastructure integrators	DE
TRV	TRANSVER GmbH	Test Site Leader	DE

11.3.2 Test locations

11.3.2.1 Dortmund

The German SAFESPOT Test Site consisted of one urban intersection. This intersection is located in the city of Dortmund. The number of the intersection is 61. It is the crossing of the streets Hamburger Straße and Gerichtsstraße (Fig. 47). The TS-DE was integrated with the CVIS TS.

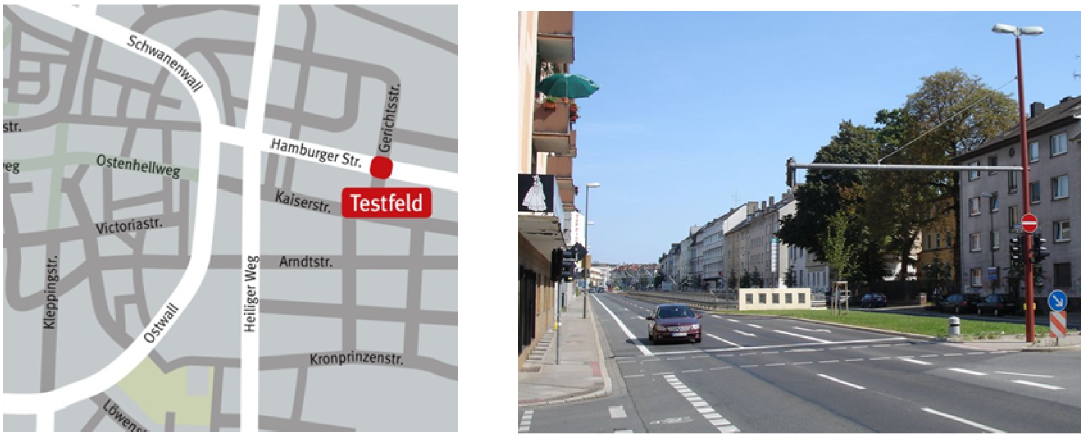


Figure 47: Location of the Dortmund Test Site

Figure 48: Equipment installed in the Dortmund Test Site

In the above pictures, some of the installed infrastructure components are showed.

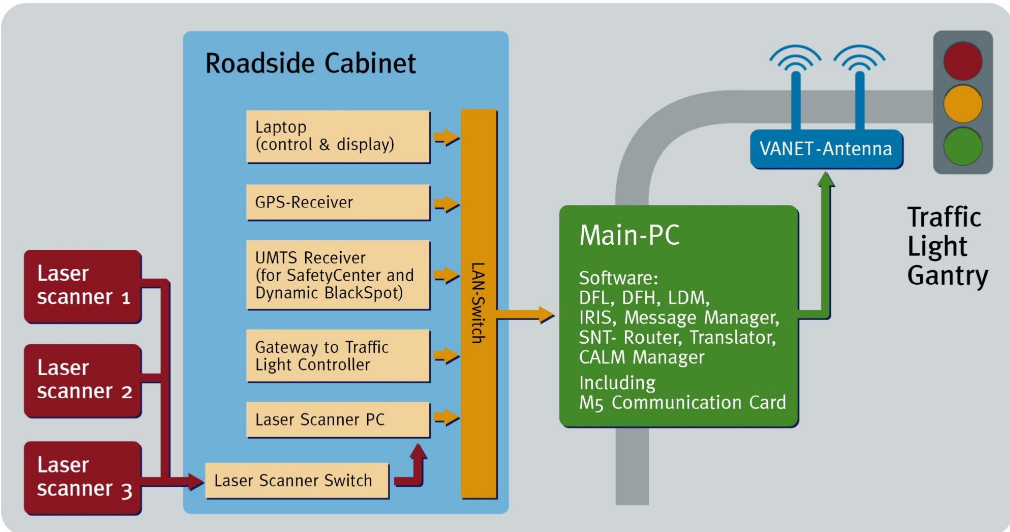


Figure 49: The block diagram of the TS equipments

Fig. 49 illustrates the Block Diagram of the infrastructure equipments which included three Laser Scanners.

Four vehicles were used (Fig. 50).

Figure 50: Location and images of the Dortmund Test Site

In the German TS the following Applications/Use Cases were validated and evaluated:

- IRIS: Red Light Violation, Left Turn - Oncoming Vehicle, Right Turn – Pedestrian & Ciclist, Remaining Green Light;
- Safety Centre / Dynamic Black Spot Recognition – Note: this use cases is not included in the UC table as it was part of SP2 and makes reference to the Data Fusion platform; results are reported in D2.5.2.

A National Showcase was held on February 25th 2010 which was attended by Experts, Public Authorities, Press and TV.

11.4 DUTCH TEST SITE

The Dutch Test Site area consisted originally of 3 locations, of which Helmond was the most important and the most various in the type of applications that have been tested and evaluated. The Dutch TS developed applications for usage in different road situations (urban, rural and motorway), including other road users, such as Vulnerable Road Users (cyclists), based on both V2I and V2V communication. V2V and V2I communication has been used in a combined setting (H&IW, slippery road) for creating a safety margin, supported by the usage of sensors (road condition). All the different aspects of SAFESPOT were successfully incorporated into the TS-NL. Besides the activities concerning testing and validation, numerical simulation of applications and their impact on specific traffic situations were taken into account as well. Morover the Dutch TS hosted two showcases. The first one was held in May 2009 in Helmond and the second, very large one, in Amsterdam on March 2010 in parallel to the Intertraffic Exhibition.

11.4.1 Partners

Short name	Extended name	Role	Country
TNO	**TNO**	Test Site Leader, Application provider and system integrator	NL
Peek	PEEK Traffic B.V.	Road equipment supplier and application provider	NL
PNB	Provincie Noord-Brabant	Road operator	NL
RWS	Ministerie van Verkeer en Waterstaat	Road operator	NL

11.4.2 Test locations

The Dutch Test Site had initially 3 different locations where different applications have been tested and evaluated. These locations are shown in Fig. 51. After some preliminary tests, one of these (the A16 Motorway) was integrated by the evaluation activities carried out in Amsterdam during the preparation of the Cooperative Mobility Showcase.

Figure 51: Detailed map of Dutch locations

11.4.2.1 Helmond, Urban intersection

At this location, both SP4 and SP5 applications were evaluated: respectively the *lane change manoeuvre* and the *IRIS* application. Furthermore, this location was used for the third year SAFESPOT Annual Review and for a joint Showcase in May 2009 together with CVIS. During the review, on the road demonstrations were held by various partners, showing both V2V (SP4) and V2I (SP5) applications. In addition, the interoperability of SAFESPOT and CVIS applications was shown to reviewers, partners, experts and public (more details on the subject in section 9.4.4 The Helmond event).

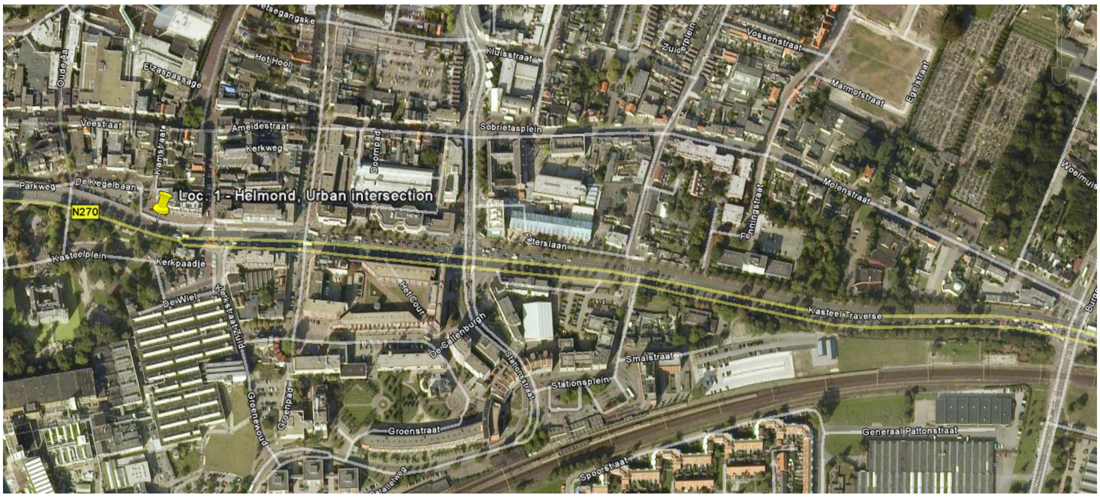


Figure 52: Part of City Centre Helmond showing the Test Site

11.4.2.2 N629, Rural road

The N629, Rural road, is located in the South of the Netherlands. At this location the Speed Alert application was evaluated. This application gives advice on speed limit and/or warn driver on excessive speed to improve road safety. In the case of the so called *informative road* the speed warning could be a less safety critical speed advice with which the next green traffic light can be passed.

Figure 53: Part of the N629, Rural road, showing the informative road

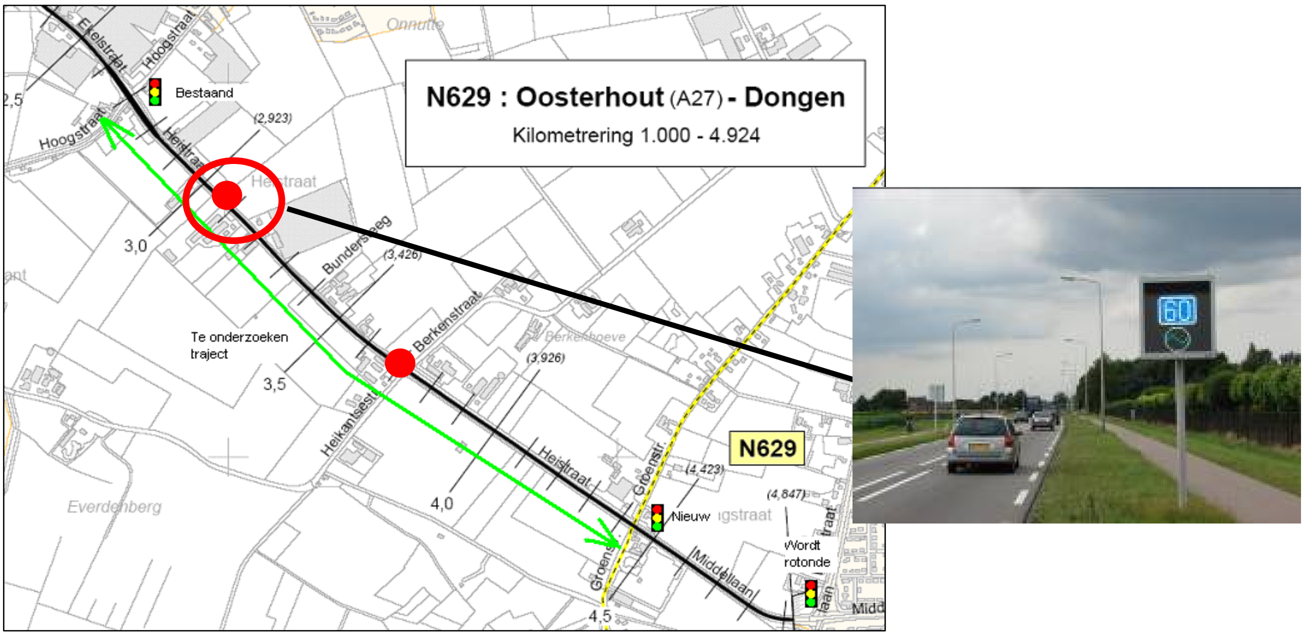


Figure 54: Map of N629, rural road and picture of the informative road

11.4.3 The Vehicles

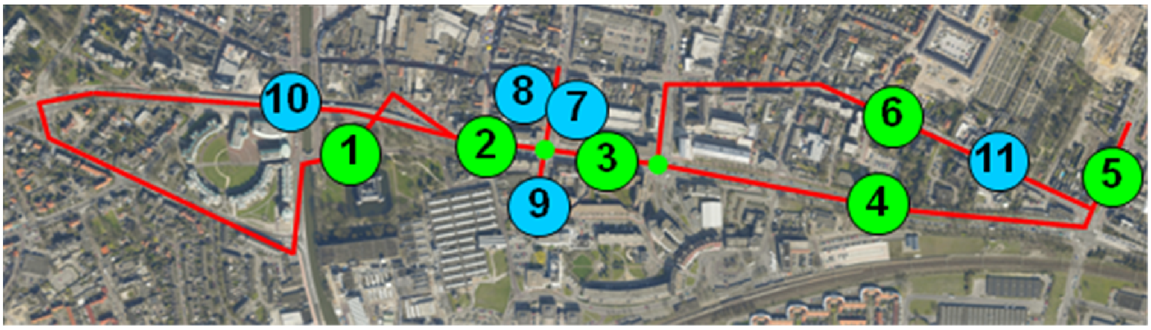
In the TS-NL three vehicles, at different stages, were used. A Citroen C4, a VW Passat and a BMW series 5. All vehicles, prepared by TNO, were equipped with the complete SAFESPOT and CVIS hardware and software. This allowed to use the vehicles for both projects and to show the interoperability of the two different platforms. The vehicles are shown in Fig. 55.

Besides the SAFESPOT and CVIS hardware, the VW Passat (INCA vehicle) has additional hardware for assessment and evaluation of driver behaviour. A typical example is e.g. a set of cameras that observe and register driver behaviour. Furthermore a wide range of HMI aspects can be measured and evaluated. In short, the INCA is fully equipped to measure driver behaviour, workload and performance.

Figure 55: TNO test vehicles

11.4.4 The Helmond event

In May 2009 a first showcase was organized jointly with CVIS, at the time of the third year project review. During this event, two TNO cars were used for the SAFESPOT and CVIS demonstrations to show the interoperability of the platforms. Eleven Applications (6 from CVIS and 5 from SAFESPOT) were shown on a predefined route (see Fig. 56). From the SAFESPOT side 5 vehicle, in total, participated from TNO, CRF and PIAGGIO.



1. Parking Zone (CVIS)
2. Priority Application with speed advice (CVIS)
3. Micro Routing (CVIS)
4. Enhanced Driver Assistance (CVIS)
5. Ghost driver (CVIS)
6. Access control (CVIS)
7. IRIS right turn warning (SAFESPOT)
8. IRIS red light violation (SAFESPOT)
9. IRIS left turn (SAFESPOT)
10. Lane change assistance (SAFESPOT)
11. Warnings from assistance vehicles (SAFESPOT)

Figure 56: The demonstration Route and the sequence of the presented applications

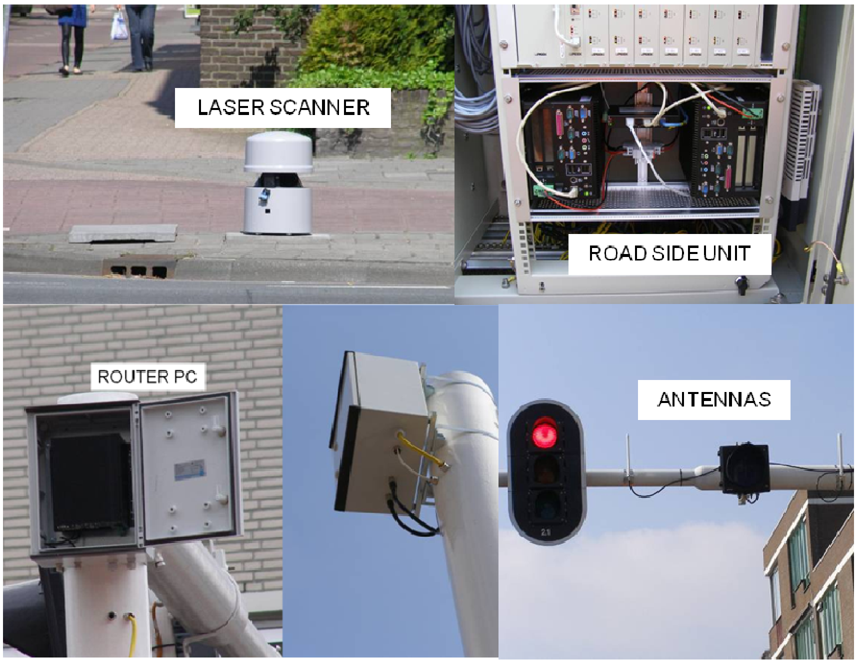


Figure 57: The Helmond INFRASTRUCURE equipments

A key node of the demonstration was the cross road of the Helmond location in which a high number of Infrastructure equipments were working (see Fig. 57 above). As already introduced, together with the Showcase event the 3rd

Year SAFESPOT review was carried out. So, the demonstration was shown directly and specifically to the SAFESPOT Officers and Reviewers. A National Conference was also associated to the joint event. Demonstrations were shown to a large audience of international journalists after a press conference in which the COOPERS, CVIS and SAFESPOT project were presented. This first showcase was very useful for technical reasons, because it allowed to perform cross project and cross TSs tests. It also provided experience for the next following showcases (Stockholm and Amsterdam).

11.4.5 The Amsterdam event

A world-class showcase of innovative vehicle-to-vehicle and vehicle-to-infrastructure technologies was held in and around Amsterdam RAI from 23 to 26 March 2010. The showcase featured the final results of the three major European integrated projects COOPERS, CVIS and SAFESPOT.

The SAFESPOT IP was present at the Cooperative Mobility Showcase 2010 in Amsterdam with live demonstration sessions concerning cooperative applications designed to prevent risky situations extending vehicles' awareness of the surrounding traffic conditions. The cooperative systems applications for road safety presented by the SAFESPOT IP in this event were:

- Assistance to safe lane change and overtaking manoeuvres
- Safety distance warning
- Frontal collision prevention
- Safe crossing of road intersections
- Wrong way driver detection warning
- Slippery road detection and warning
- Safety margin for assistance and emergency vehicles
- IRIS (Turning right Safely and Red Light Violation)
- SMAEV (Emergency vehicle)

In particular the joint CVIS, SAFESPOT, COOPERS live demonstration sessions highlighted the interoperability and the complementarities of the communication based scenarios involving the vehicles, the road network and the traffic control centres.

The Cooperative Mobility Showcase event as a whole comprised extensive on-road and indoor demonstrations, as well as a dedicated conference and exhibition.

The Demonstrations were composed by three parts:

- The Public Road Tour (PRT)
- The Safety Demonstration Area (SDA)
- The Traffic Management Center (TMC)

Fig. 58 shows the overall path of the applications. The Public Road Tour departed from RAI. The safety demo site was a stop within the public road tour. It consisted of a closed demonstration area, dedicated to the Safety

Applications, whose layout is shown in Fig. 59. This location hosted an exhibition tent for visitors assisting the live demonstrations and large displays showing the HMI of the demonstrating vehicles and supporting information. The Traffic Management Center (see Fig. 60) was organized in the Intertraffic Exhibition space in order to provide an even larger audience, from the Intertraffic exhibition, to remotely assist to the demonstrations carried out in the Safety Demo Area.

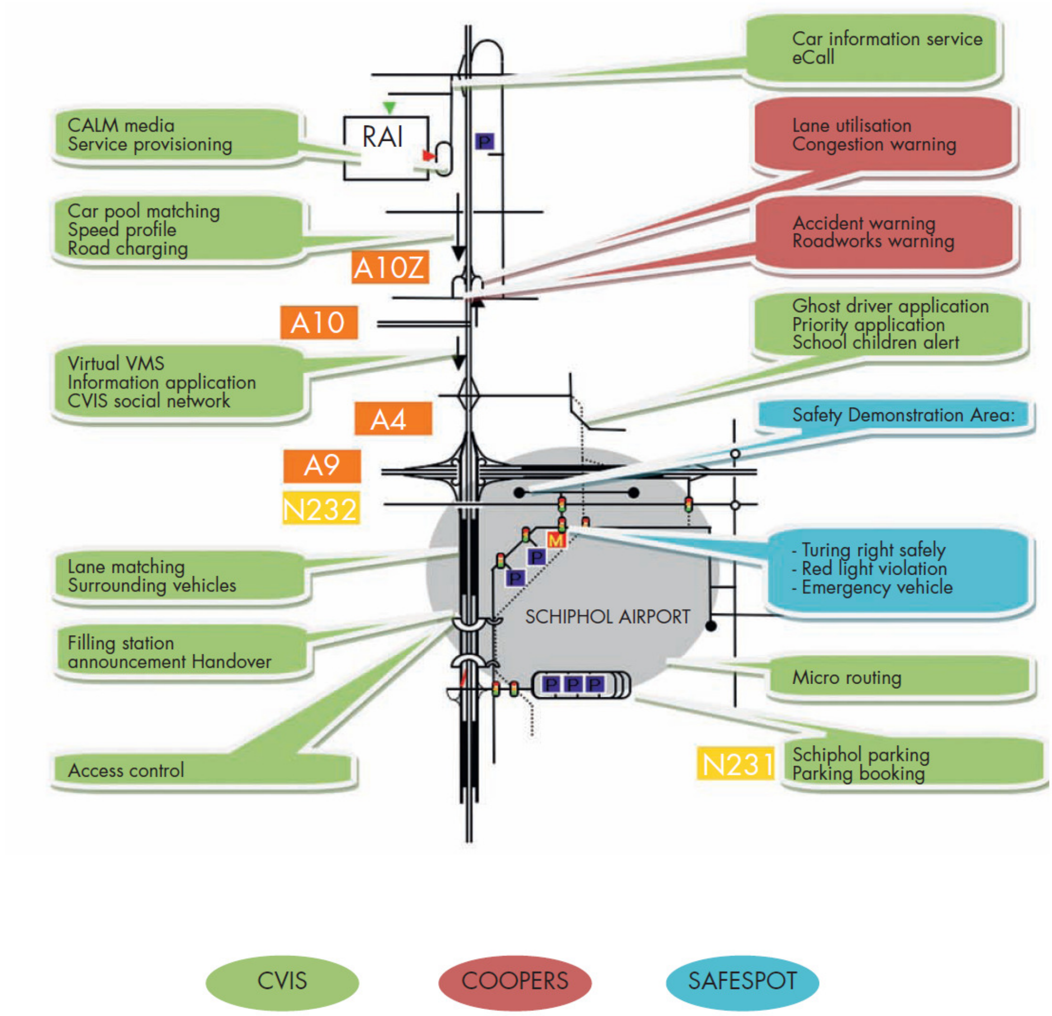


Figure 58: The overall schematics of the demonstrations areas

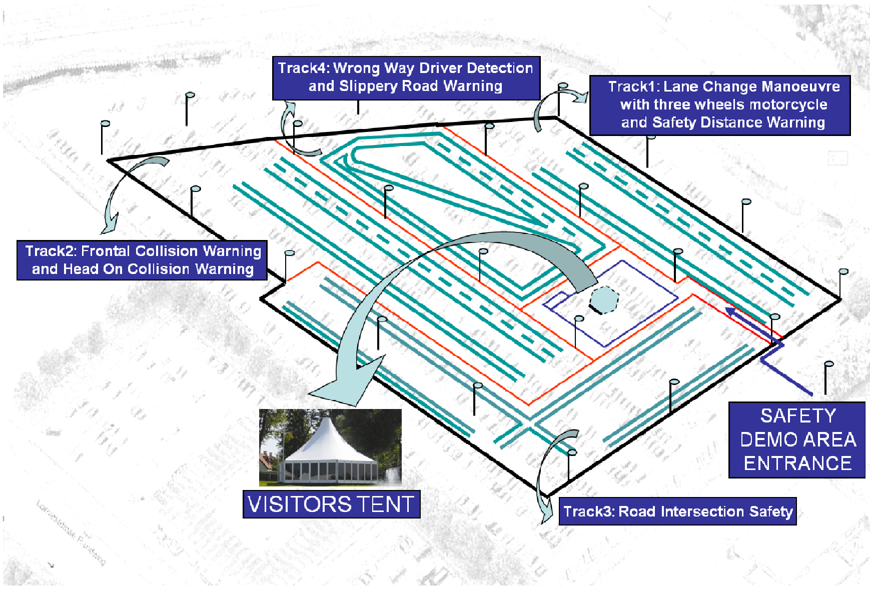


Figure 59: The Safety Demo Area layout

Figure 60: The Traffic Management Center

Figure 61: SAFESPOT Vehicles and Road side equipments in the Safety Demo Area

11.5 Swedish Test Site

The main test area was the city of Gothenburg, main ring roads, approaching highways and also a closed test track. The Test Site supported the SAFESPOT activities of the Swedish partners of the project. The main focus of the Test Site was on commercial vehicles and their limitations. The site was concentrating on Vehicle-Vehicle based applications with infrastructure support (see Annex).

11.5.1 Partners

Short name	Extended name	Role	Country
VOLVO	Volvo Technology Corporation	Test Site Leader Vehicle OEM	SE
SRA	Swedish Road Administration	Road operator	SE
KAPSCH	Kapsch TrafficCom AB	Road equipment supplier	SE

11.5.2 Test locations

The Test Site was distributed to different areas around the city of Gothenburg. The different sub areas had different characteristics and conditions for different tests and demonstration capabilities. The two main entrances E6 Highway to the city were equipped with RSUs for approaching vehicles. As a supplement to this, one of the city tunnels was also equipped for testing specific application elements. For testing of applications and situations that for safety reasons required closed areas, the proving ground at Stora Holm was used. Finally, there was a test area with an RSU at Lindholmen, close to the Control Centre of the Test Site, for easy demonstrations. One mobile RSU was used at Lindholmen and Stora Holm. Pictures of the TS locations are reported in Fig. 62 and images of the infrastructure installations are presented in Fig. 63. In the same figure a map of the preexisting installations and the architecture of the management center in Lindholmen are reported. The test site facilities, roads, RSUs and vehicles have been shared with the CVIS project.

Figure 62: The Swedish TS locations

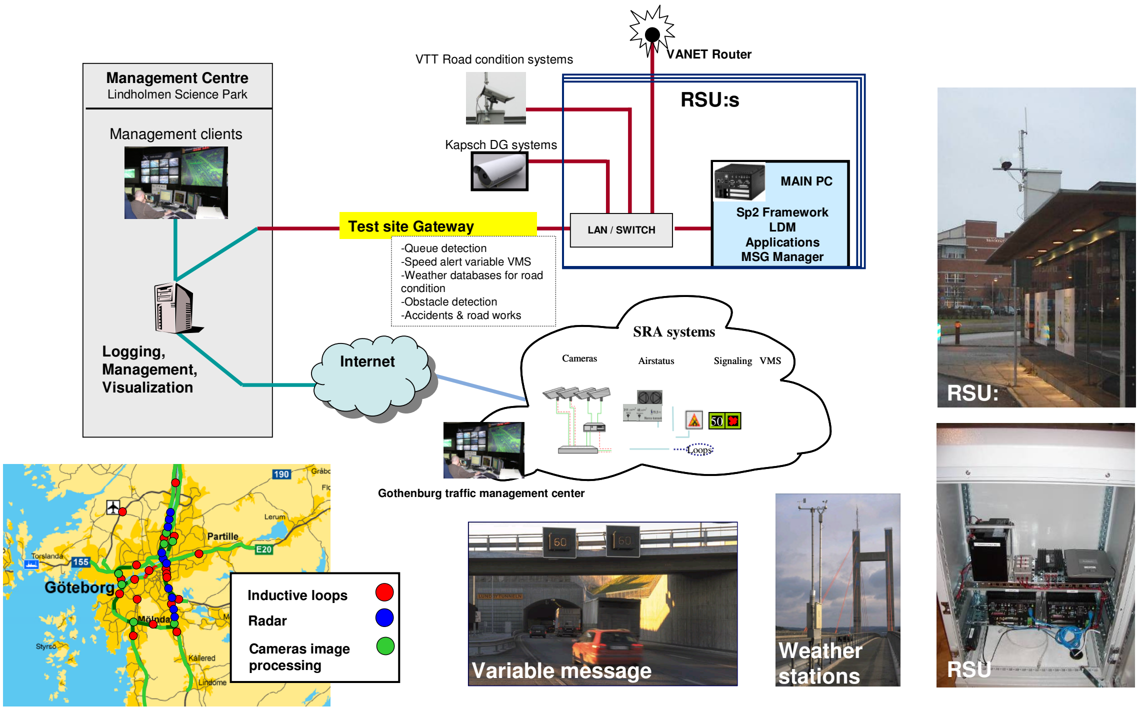


Figure 63: Infrastructure architecture and equipments of the Swedish TS

11.5.3 Vehicles and on-Board Units

The Swedish Test Site had three vehicles equipped for test, validation and demonstration campaigns.

Figure 64: The three vehicles in the Swedish Test Site: two trucks and one car

Each Vehicle has its own specific set of sensors, but all of them have basic SAFESPOT components: Vanet Communication, Positioning, Vehicle Gateway, Data Fusion, Map Matching, LDM, applications and message manager. As HMI a 7" touch display has been mounted as well as additional systems for system verification and demonstrations. The car was shared with the WEST TS and the trucks participated to the Amsterdam Showcase.

11.5.4 The ITS2009 Showcase

Beside the above mentioned locations which were devoted to validation and evaluation, the Swedish TS hosted a showcase in Stockholm during the ITS World Congress 2009. The demonstration was organized in common with COOPERS and CVIS. A proper parking area was adapted as closed track for demonstrating V2I and V2V application (see Fig. 65).

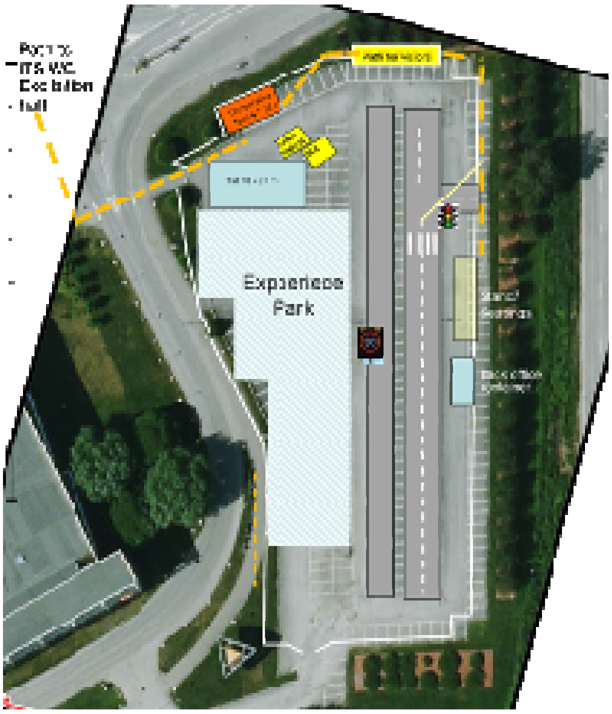


Figure 65: The ITS2009 demonstration area

A tribune hosting 50 people was prepared at the side of the track offering the possibility to almost 1600 congress visitors to assist at a 30 min. live demonstration (see Fig. 68). A number of partners from other TSs contributed to the demonstration showing internal (among different SAFESPOT TS partners) and external interoperability with CVIS and COOPERS through common Use Cases.

During the Stockholm event a Demo Theatre was set-up (see Fig. 69). The TS partners were the leaders of this activity with the support by other partners of the consortium. The Demo theatre illustrated the benefits for the different stakeholders when putting the applications in their context for the end users. This was done using a large delegated conference room at the exhibition area. The performance was done by professional actors. Four sessions were hold during the conference with full house every time (almost 400 guests/audience in total assisted to the performance).

Figure 66: Live demonstration at ITS2009 in Stockholm

Figure 67: The control center at ITS2009 in Stockholm

Figure 68: The tribune at ITS2009 in Stockholm

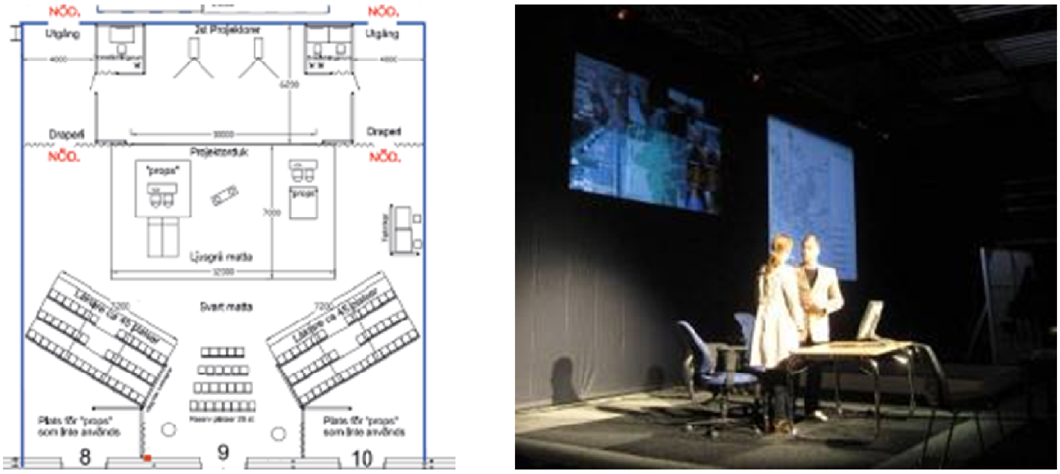


Figure 69: The Demo Theater at ITS2009 in Stockholm

11.5.5 The EU transport ministries meeting in Gothenburg

In October 27th 2009 one EU transport ministries meeting was held in Gothenburg. As part of this meeting the Swedish Test Site successfully performed live demonstrations of results from the SAFESPOT project. The demonstration reused the design and SW from the setup in Stockholm (the actual training ground in Gothenburg for the Stockholm event). During the 2,5 hours there were 4 demonstrations at 30 min each, which successfully covered the EU delegation of approximately 200 Guests.

11.5.6 Short survey of Architecture, On-board and Roadside equipments

The Swedish Test Site for SAFESPOT was shared with CVIS. Communication HW, Vehicle and infrastructure gateways and Vehicle HMI were some of the relevant components shared by both projects.

11.5.6.1 Road Side Units

Figure 70: Mobile RSU installation (Main PC, Router, 3G Gateway and internal power supply)

Five road side units were installed in infrastructure and one additional unit was mobile. All Road side units were equipped with SAFESPOT Main PC (SP2, LDM, HMI & Applications) and a VANET Router. The mobile RSU showed in Fig. 70 adopted 3G communication; the Lindholmen RSU was connected by means of a dedicated Ethernet link. Except for the connection to legacy systems two specific SAFESPOT sensor systems were installed: at Lindholmen a road condition cameras from VTT; at Lundby tunnel a dangerous goods camera system.

11.5.6.2 Legacy systems

Legacy systems were connected through SRA network. All data was transferred from SRA system through the SRA network to a Traffic management server at Lindholmen Science Park. Test Site architecture (RSU, Vehicles etc.) accessed to the traffic management server through a Test Site defined interface/gateway at Lindholmen Science Park network.

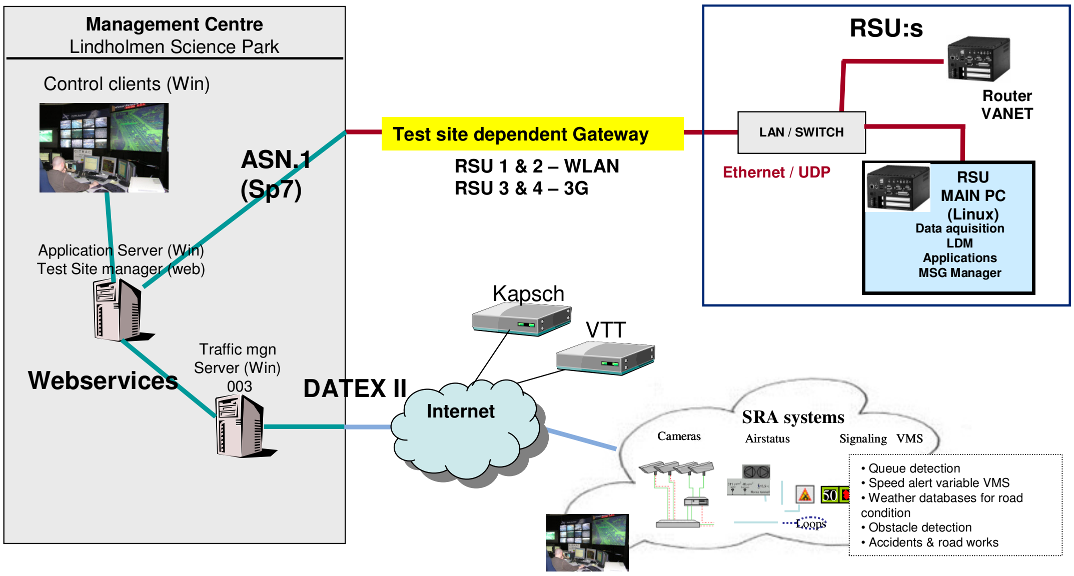


Figure 71: Description of the connection between RSUs, legacy systems and management center

Legacy systems at STA were connected to the SAFESPOT System. Infrastructure features available in this location included:

- Queue detection;
- Speed alert variable VMS;
- Weather databases for road condition;
- Obstacle detection;
- Accidents & road works.

12 IP-level discussion and self-assessment: results versus objectives and state-of-the-art

SAFESPOT had a number of technical and non technical objectives which can be summarized as: *provide a significant step forward to the application of the cooperative systems to the road safety improvement*. According to project self-assessment this general objective was achieved. This was possible through the internal activities and the integration with the work of other projects and organizations. In the following the list of key objectives is reported together with the related results:

- T*o develop or improve and assess Communication through ad-hoc dynamic network whose nodes are vehicles and road side units.*
    - Geo-broadcast addressing, Congestion control were analyzed and new algorithms implemented. A full set of messages was produced extending the ones defined by C2C-CC. This set was enclosed in the first version of the European ITS Communication Architecture and offered to the ETSI ITS TC standardization group. Interoperability with the CVIS project was achieved and practically demonstrated.
- *To achieve an accurate positioning*.

  A number of techniques for enhancing the GPS accuracy were analyzed, implemented and integrated through the fusion algorithms developed:
    - Laserscanner-based landmark navigation approach
    - Infrastructure-based positioning using Ultra Wide Band signals
    - Image-based positioning for improving lateral precision
    - GNSS-based relative positioning

  While the first three techniques provided good results in terms of precison accuracy the relative positioning based on the elaboration of the satellite raw-data requires further investigation.
- *To develop the Local dynamic maps (LDM)*.

  This is a key original result of SAFESPOT and entered as a topic in the ETSI ITS TC standardization activity. A common object model was defined and two different implementation (NAVTEQ and BOSCH/TA) were realized and tested.
- *Analysis and experimentation of available and new sensors to be used at infrastructure level.*

  New sensing techniques were analyzed. Particularly important were the results on wireless sensor networks and the further development of Laser-Scanner used both on vehicle and at Infrastructure level. Enhancement of Infrared techniques for animals and pedestrian detection was achieved as well as techniques for road condition detection by means of cameras.

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

  SAFESPOT significantly contributed to the European ITS Communication Architecture produced by a task-force leaded by COMeSAFETY.

- *To develop the Safety Margin Assistant (SMA)*

  The SMA was specified, designed, implemented and validated. SMA consists (as foreseen in technical annex) of an integrated application framework using the safety-related information, provided by infrastructure or other vehicles through an ad hoc network, properly fused with the on board sensors. A significant number of vehicles (21) hosting the SMA and road stations on TSs were prepared and used in common experiments. The applications described in sections **Errore. L'origine riferimento non è stata trovata.** and **Errore. L'origine riferimento non è stata trovata.** were developed and integrated in different combination on the vehicles and road stations. A special application is the “External message application” which allows each vehicle hosting it to manage the Infrastructure based applications. It is important to underline that all the demonstrators implemented the common architecture and used the technologies developed inside the project.

- *To evaluate the impacts and the end-user acceptance.*

  Through the SP6-BLADE and TS activities this evaluation was performed confirming the positive cost/benefit ratio for a range of deployment scenarios.

- *To evaluate the liability aspects, regulations and standardization issues which can affect the implementation.*

  SP6-BLADE produced a set of deliverables which collects facts which can slow down the deployment which include legal, organizational and technical aspects. The deliverable D6.4.6 (Consolidated recommendations) dealing with risks and legal aspects provides a summary of the analysis performed and the recommendations to avoid or minimize these risks.

13 Summary of recommendations for future work

Summarising what has been reported in the previous sections of this document on suitable continuations to what has been studied and achieved in SAFESPOT, some main items for future work are listed below:

- Standardization activities. The ETSI started the standardisation of the communication protocol. The subsequent steps should be standardisation of the higher levels and the applications.
- Further work on accurate positioning.
- Further work on Local Dynamic Maps. SAFESPOT defined the basic concept, the Object model and a set of API for data access independent from the underlying Data Base. All this matter should be extended and standardized. Relating to LDM there is also the need of high performance DBs specifically designed for real time applications.
- HMI specific activities. SAFESPOT used for HMI the basic guidelines defined in the AIDE IP. However further work is recommended that must be customized for each single applications and in scenarios with fast alternation of messages from different applications which can be tested only in complex traffic scenarios.
- Pilots and Field operational tests.
- Support to transversal organization focused on the promotion and deployment of cooperative systems. C2C-CC is a key organization which closely cooperated with SAFESPOT and provided the basic input to the ETSI IST WGs. The enlargement to road operators and public authorities together with the establishment of a common task force with existing Working Groups are mandatory steps for deployment.
- Further work on Business modelling. This task turned out to be very complex and the evolution should be maintained in parallel to technical advancements.
- Further work on including and integrating the simulation tools in system and HMI developments, as well as concerning the evaluation processes within industry and academia.
- Development of a common understanding on how to handle missing data (e.g. due to sensor limitations, presence of unequipped vehicles in the scenarios) in system evaluation and in the experimental data analysis.
- Exploitation of SAFESPOT results by SAFESPOT partners and others. See D8.2.4 for more details.

14 Conclusions

The connected vehicle: what value for drivers, industry, operators and authorities at European level?

In the last five years OEMs, automotive and technology suppliers, road operators, service providers, research institutes all over Europe had been working together to create the technological building blocks of the cooperative mobility network. In this framework the SAFESPOT Integrated Project designed and developed the technological building blocks of the network of exchange of safety critical information.

The European Commission, industries, road operators, service providers and research institutes invested in the creation of the “cooperative mobility network” as the number of road accidents in Europe is still very high, roads and cities are more and more congested resulting in a reduced quality of life for all citizens and in a polluted environment. European citizens are still losing their lives or are seriously injured in road accidents and the number of hours spent in traffic jams is increasing every year.

The cooperative mobility network should be implemented to enable applications to prevent road accidents for all road users, cars, trucks, motorbikes, pedestrians, cyclists and to improve traffic efficiency, with a consequent reduction of CO_2 emissions. Additional customised services for the users should also be made available to enable a sustainable deployment.

As demonstrated by the SAFESPOT project, in cooperation with COMeSafety, C2C-CC, CVIS, COOPERS, the cooperative mobility network should enable the use of different communication channels depending on the application:

- a “fast” and “always available” channel used to exchange time critical safety related information in real time (that is the channel used by the SAFESPOT project to implement cooperative safety applications),
- the same or another available communication channel used to create local “dynamic networks” among vehicles and the road infrastructure to propagate safety & congestion related information that are not time critical anymore but are crucial to inform in advance the surrounding road users for example of a potential danger or of a traffic jam,

Additionally, making an optimised use of all available communication channels, it is possible to extend the mobility network to a centralised level, for example to traffic control centres, for dynamic re-routing, to prevent traffic blocks or to optimise the intervention of all kinds of emergency vehicles.

The overall idea developed in the SAFESPOT integrated project, coordinated by Centro Ricerche FIAT, co-funded by the European Commission Information society and Media, ICT for Transport, and supported by EUCAR, is that the cooperative mobility network should be created:

- instantaneously, between two vehicles in case of imminent risks of accidents,

- locally, among vehicles and road infrastructures whenever any kind of traffic related problem is created and can be solved locally thanks to the exchange of information,
- at overall network level, where all traffic control centres will know in real time how to best “inform” and “distribute” the traffic flow.

Today the mobility network is technologically feasible as demonstrated in the Cooperative Mobility Showcase organised in Amsterdam in March 2010. In this event SAFESPOT demonstrated also a number of common use cases with the CVIS and COOPERS projects to validate the interoperability of the implemented solutions. Examples of safety use-cases implemented by the SAFESPOT Integrated Project are:

- *Emergency vehicle warning,*
- *Wrong way driving warning,*
- *Overtaking vehicle warning,*
- *Intersection collision warning,*
- *“Traffic jam ahead” warning,*
- *Lane change assistance,*
- *Curve speed warning,*
- *Road works warning,*
- *Vulnerable road user warning.*

How shall we move forward?

However to create the “cooperative mobility network” all stakeholders should:

- move together from technological prototypes that are proving the feasibility to robust components for vehicle and infrastructure communication,
- create interoperable and standardised solutions at European level,
- implement a sustainable deployment roadmap that is affordable for all stakeholders involved,
- create a high level of acceptance in the wide public.

Therefore in the coming years the actions should be concentrated on:

- performing a technological validation phase where the technological bottlenecks can be identified and removed: the cooperative mobility network will never become a reality if the weakest ring of the chain is not removed,
- establishing priority services and functions and the related stakeholders’ investments,
- performing dedicated and extended dissemination campaign to raise the awareness of the whole public also addressing major European media. Public awareness creates a huge market demand, all citizens should perceive the benefits of applications and services that can improve and facilitate their mobility.

Road safety is a right for all European citizens and it is a high priority policy for private operators and public authorities. Additionally traffic efficiency and improved environment are felt as urgent needs at European level. The key of success is that all stakeholders involved in the next step of deployment should jointly offer a number of functions and services that together can create a sustainable deployment. Commercial customised services combined with traffic efficiency and safety functions can be perceived as an important added value to improve the individual mobility of people and the mobility of goods.

The ratio between technological solutions and costs should become affordable for the different actors for example to install the function on a motorbike or to install the communication services on highways. A sustainable balance should be reached guaranteeing the accessibility of the services and functions at affordable costs.

It should be noted that well perceived benefits can make:

- stakeholders ready to invest,
- people ready to pay for a combined set of functions and services,
- Member States ready to introduce specific incentives speed up the process of change to equipped vehicles.

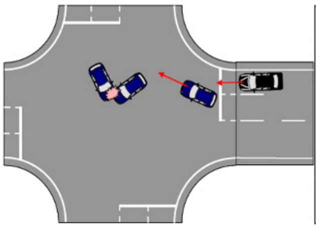
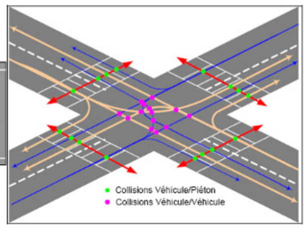
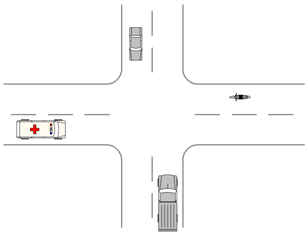
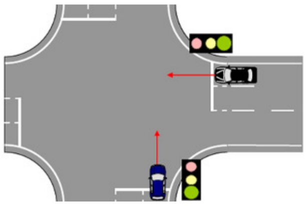
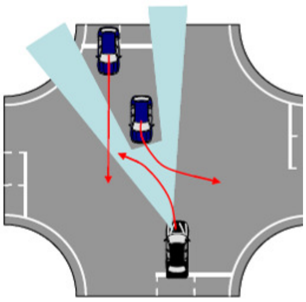
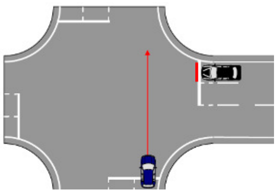
In particular, with the cooperative mobility network the movements of the individual citizen and of goods can become safe and efficient, reducing stress, waste of time, accidents and fuel consumption while additional customised commercial services can be made available.

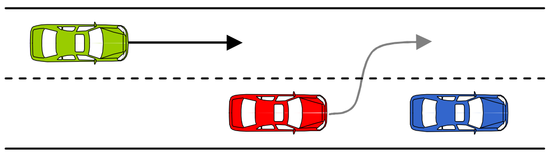
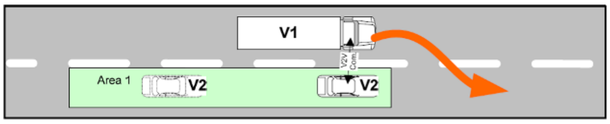
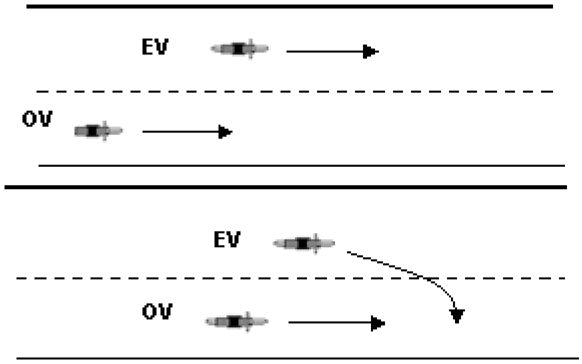
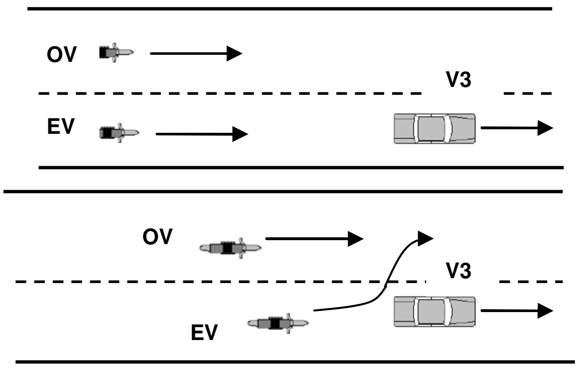
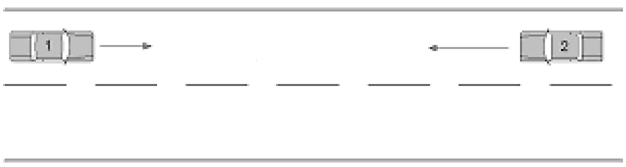
The OEMs can offer safer vehicles and a number of customised services for an efficient and comfortable journey. The road operators can offer an efficient use of the road network while decreasing the environmental burden and can make roads safer preventing accidents or effectively managing any kind of unexpected emergency. The city authorities can address specific urban policies that are an efficient mobility for people, an enhanced road safety, a clean environment, an improved local freight transport, a regulated access to certain city zones etc.

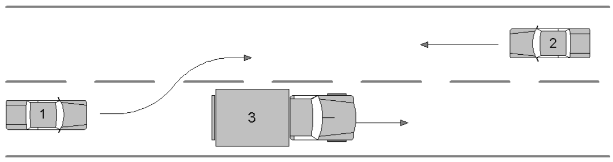
Today the industry is working to implement cooperative systems technology. The SAFESPOT project implemented the key enabling technologies and reference applications for a safe cooperative mobility. The standardisation process is in course. It is time now to move from technology to interoperability and standards measuring the impacts on a safe, efficient and clean mobility. It’s also time to act towards stakeholders’ & public awareness creating a ground of sustainability for all stakeholders and setting up a commonly agreed stakeholders’ action roadmap.

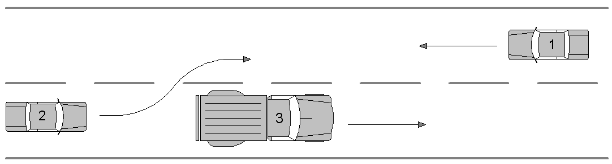
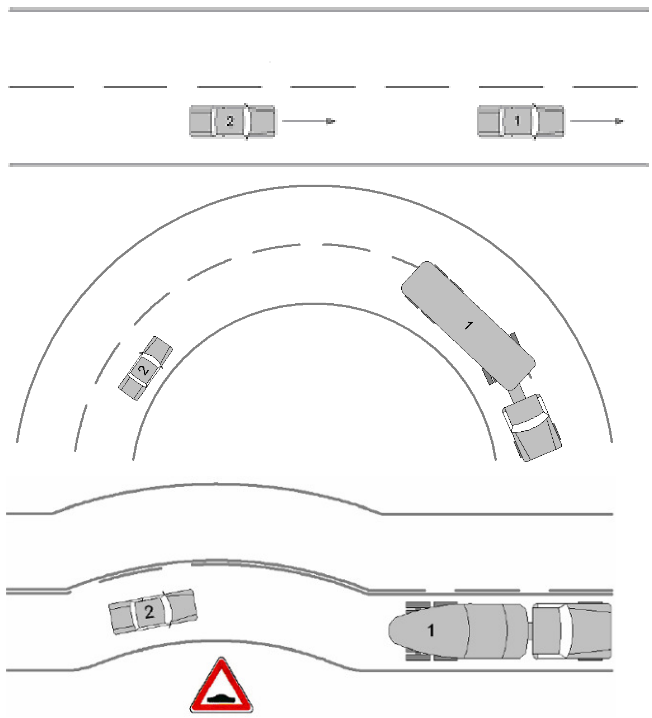
15 Annex 1

15.1 Use cases at test sites

Application	Test Site	Use Case
1 Road Intersection Safety	Test Site West Satory tracks Valladolid technology park	Road Intersection Safety - Accident at intersections - UC1A  
	Test Site West Satory tracks Valladolid technology park	Road Intersection Safety - Approaching emergency vehicle warning - UC1F 
	Test Site West Satory tracks	Road Intersection Safety - Defect traffic signs - UC1D 
	Test Site West Satory tracks	Road Intersection Safety - Obstructed view at intersections - UC1B 
	Test Site West Satory tracks	Road Intersection Safety - Permission denial to go-ahead - UC1C 

Application	Test Site	Use Case
2 Lane Change Manoeuvre	Test Site NL Helmond	Lane Change manoeuvre for a car with blind spots – UC2A 
	Test Site NL Satory tracks	Lane change manoeuvre for trucks with blind spots - UC2A 
	Test Site Italy Politecnico of Milan (internal road)	Use Case - UC2GC 
3 Safe Overtaking	Test Site Italy Politecnico of Milan (internal road)	Safe Overtaking General Case - UC3GC 
4 Head On Collision Warning	Test Site Italy CRF Test Track	Head On Collision Warning General Case - UC4GC 

<table>
<tr><th>Application</th><th>Test Site</th><th>Use Case</th></tr>
<tr><td></td><td>Test Site Italy
CRF Test Track</td><td>Head On Collision Warning due to hazardous overtaking attempt by host vehicle - UC4A


Head On Collision Warning due to hazardous overtaking attempt by a second vehicle - UC4B

</td></tr>
<tr><td>5 Rear End Collision</td><td>Test Site Italy
CRF Test Track</td><td>Rear End Collision General Case - UC5GC

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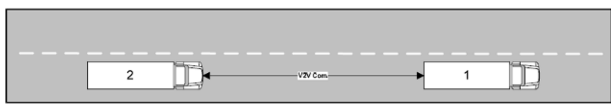
<tr><td>6 Speed Limitation Safety Distance</td><td>Test Site Italy
CRF Test Track</td><td>Speed Limitation and Safety Distance between vehicles General Case - UC6GC

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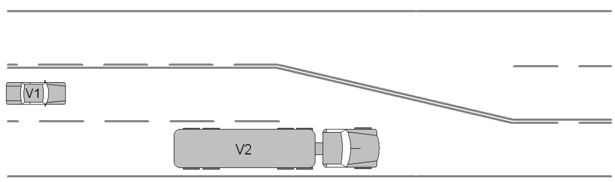
<tr><td></td><td>Test Site Italy
CRF test track</td><td>Speed Limitation and Safety Distance on black spots – reduction of lanes - UC6C

</td></tr>
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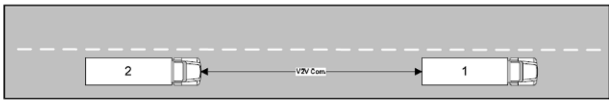
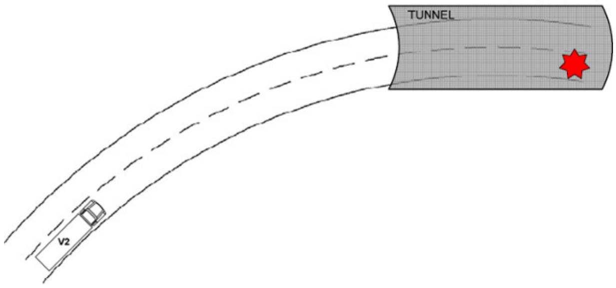
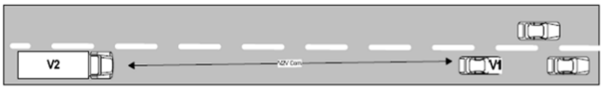
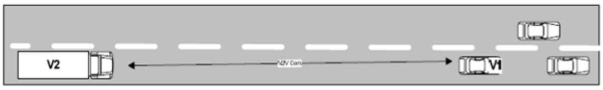
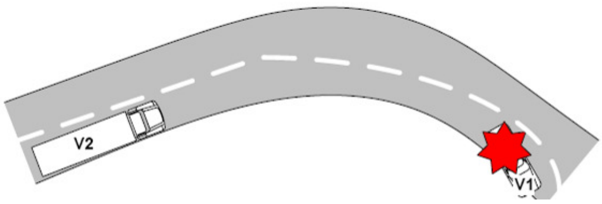
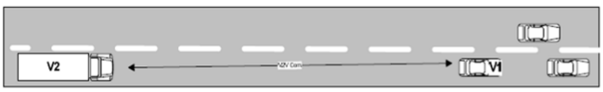
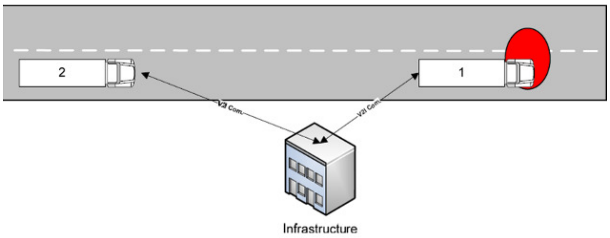
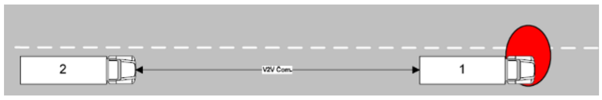
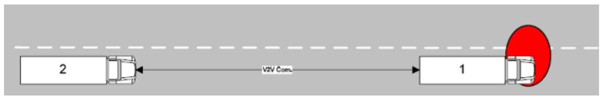
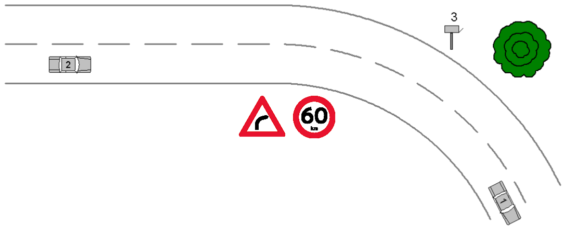
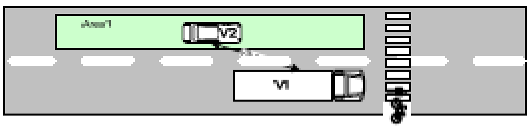
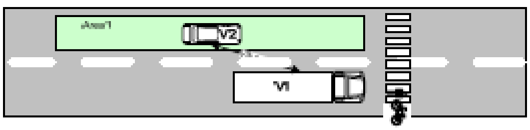
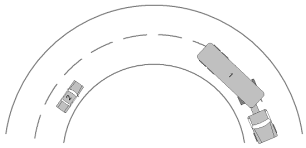
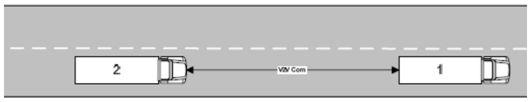
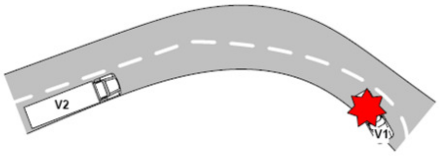
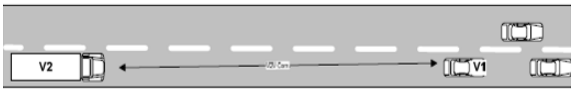
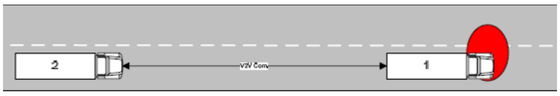
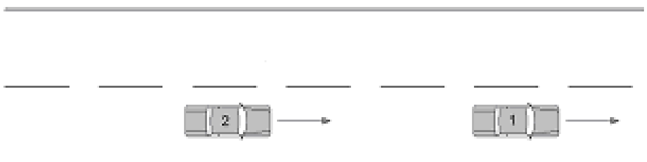
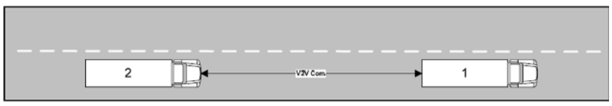
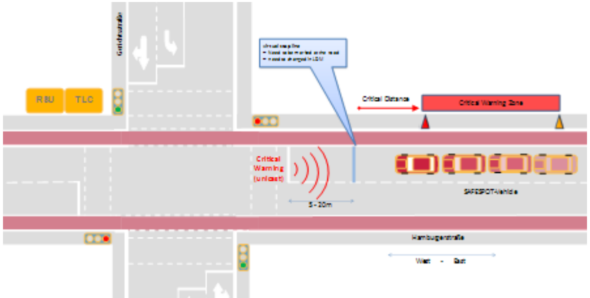
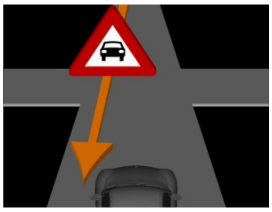
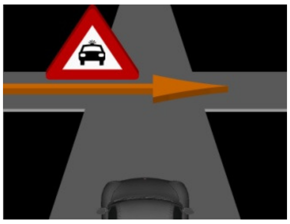
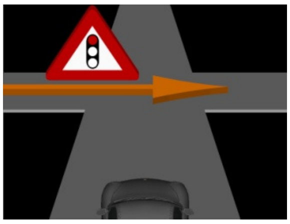
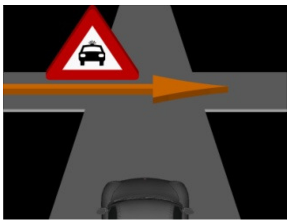
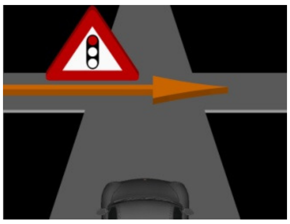
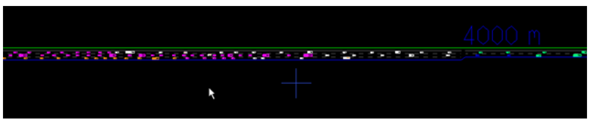
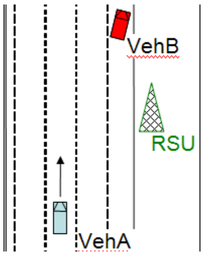
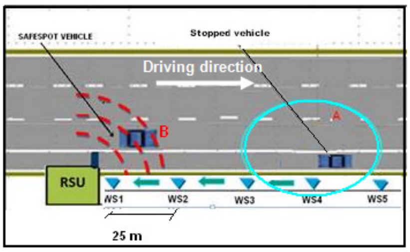
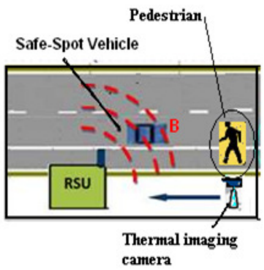
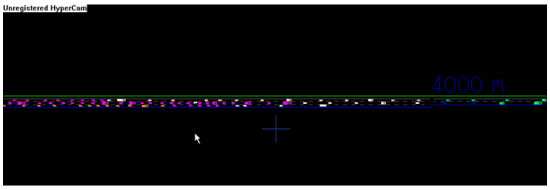
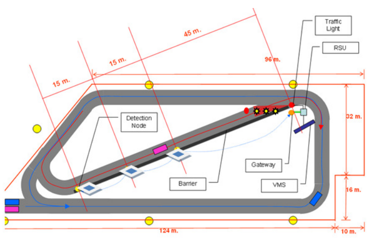
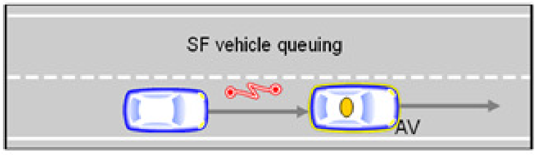
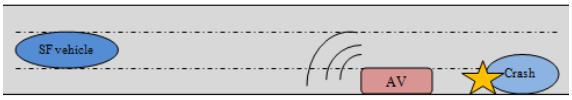
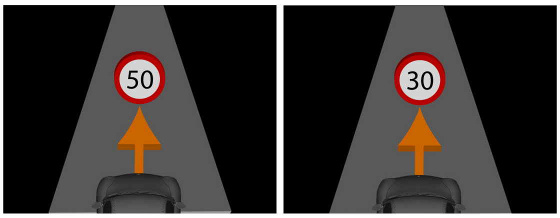
Application	Test Site	Use Case
	Test Site WEST La Valbonne	Speed Limitation and Safety Distance between vehicles - UC6A 
7 Frontal Collision Warning	Test Site Sweden Lundby tunnel	Frontal Collision Warning due to static obstacle in a tunnel – UC7B 
	Test Site Sweden Stora Holm	Frontal Collision Warning due to abnormal vehicle behaviour in front – UC7C 
	Test Site West La Valbonne	Frontal Collision Warning due to abnormal vehicle behaviour in front – UC7C 
	Test Site West La Valbonne	Frontal Collision Warning due to static obstacle in front – UC7A 
	Driving Simulator Stuttgart (not Test Site)	Frontal Collision Warning due to abnormal vehicle behaviour in front – UC7C 

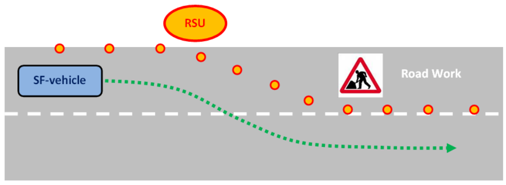
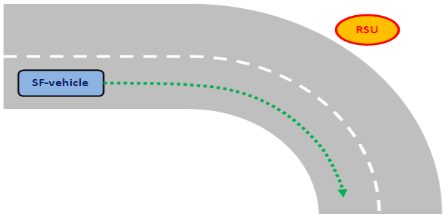
Application	Test Site	Use Case
8 Road Condition Status	Test Site Sweden Lindholmsallén	Road Condition Status warning due to slippery area ahead with information from infrastructure and detection of slippery area from sensor equipped truck - UC8A 
	Test Site Sweden Lindholmsallén	Road Condition Status warning due to slippery area ahead with information from vehicle to vehicle communication and detection of slippery area from sensor equipped truck - UC8B 
	Test Site Sweden Stora Holm	Road Condition Status warning due to slippery area ahead with information from vehicle to vehicle communication and detection of slippery area from sensor equipped truck - UC8B 
9 Curve Warning	Test Site Italy CRF Test Track	Curve Warning in rural black spots, based on a transponder in the infrastructure keeping memory of the speeds adopted by passing vehicles – UC9A-GC 
10 Vulnerable Road User Accident Avoidance	Test Site Sweden Lindholmsallén	Vulnerable Road Users crossing a road - UC10A 
	Test Site Sweden Stora Holm	Vulnerable Road Users crossing a road - UC10A 

Application	Test Site	Use Case
Multiple: REC SLSD FCW RCS	Traffic Simulation	Rear End Collision due to the presence of an heavy vehicle climbing up through an hairpin curve at a low speed – UC5A  Speed Limitation and Safety Distance and trucks driver recommendations - UC6A  Frontal Collision Warning due to static obstacle in front– UC7A  Frontal Collision Warning due to abnormal vehicle behaviour in front – UC7C  Road Condition Status V2V Based – UC8B 
Multiple: REC SLSD		Rear End Collision General Case - UC5GC  Speed Limitation and Safety Distance between vehicles General Case - UC6GC 

Application	Test Site	Use Case
IRIS_01 Urban	TS NL (Helmond)	Red light violation (SP5_UC31) Right Turn (SP5_UC22)
	TS DE (Dortmund)	Red light violation (SP5_UC31) Right Turn (SP5_UC22) Left Turn (SP5_UC22) 
	TS NL (Zeist)	Human Factors Instrumented vehicle study (SP5_UC52)  
	TS NL (Helmond)	IRIS expert evaluation
	Driving Simulator NL (Soesterberg)	Human Factors Driving simulator study (SP5_UC31)  
IRIS_02	Driving Simulator NL (Soesterberg)	Human Factors Driving simulator study (SP5_UC31)  
	TS NL (Helmond)	IRIS expert evaluation
SpA_01 Urban	Traffic simulation NL (Delft)	Traffic simulation: Excessive speeds (SP5_UC32) Traffic simulation: Obstacles (SP5_UC13,14) 

Application	Test Site	Use Case
H&IW_01 motorway	TS WE – A85 motorway	Obstacle on the road (SP5_UC13,14,15) 
	TS IT – Brescia-Padova motorway	Detection of obstacle/stopped vehicle on motorway (SP5_UC13,14,15) 
H&IW_01 motorway	TS IT – Torino-Caselle motorway	Detection of obstacle/stopped vehicle on motorway (SP5_UC13,14,15) Detection of a simulated pedestrian/animal (as “obstacle”) on road (SP5_UC17) 
	Simulation NL - Delft	Traffic impact assessment (SP5_UC13,14) 
H&IW_02 motorway	TS NL – Amsterdam – Intertraffic Showcase area	Detection of wrong way (Ghost) driver (SP5_UC34) 

Application	Test Site	Use Case
SMAEV_01 motorway	TS IT – CRF Test Track	Signalised slow vehicle (SP5_UC11) 
	TS IT – CRF Test Track	Assistance Vehicle – RSU cooperation (SP5_UC61 including UC51 aspects) 
	TS WE – A85 motorway	Assistance vehicle sending warning close to an event (SP5_UC51) 
SpA_01 rural	TS WE – CG22	Prevention of driver excessive speed (Rule violation) (SP5_UC32) 
	TS NL (Zeist)	Assessment of the SpA application by HF-experts (SP5_UC32) 
SpA_02 rural	TS NL – N629	Human factors assessment of SpA (SP5_UC42) 

Application	Test Site	Use Case
RDep_01	TS IT – CRF Test Track	Prevention of road departure caused by road works (SP5_UC16,45) 
	TS WE – Satory Test Track	Prevention of road departure caused by dangerous curve (SP5_UC21,41,42,45) 
SMAEV_01	TS WE – CRF Test Track	Event warning - vehicle stopped (SP5_UC51) 
	TS WE - CG22	Warning of incoming vehicle of event occurred (SP5_UC51)