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Acronym Table

AMO	Assistant Maitrise d'Ouvrage
CAM	Cooperative Aware Message
CEI	Maintenance and intervention centre
CIGT	Traffic control center (TCC) (Centre d'Ingénierie et de Gestion du Trafic)
CMMS	Computerized Maintenance Management System
DENM	Decentralized Environmental Notification Message
DIR	Interdepartmental Directorate of Roads (Direction Interdépartmentale des Routes)
DIRA	Interdepartmental Directorate of Roads (Direction Interdépartementale des Routes) Atlantique
DIRIF	Interdepartmental Directorate of Roads (Direction Interdépartementale des Routes) Ile de France
DIR Ouest	Interdepartmental Directorate of Roads in the West of France (Direction Interdépartementale des Routes Ouest)
DIT	Directorate of Transport Infrastructure (Direction des Infrastructures de Transport)
DOIR	Road Information Guidance Document (Document d'Orientation de l'Information Routière)
DOVH	Winter Viability Guidance Document (Document d'Orientation de la Viabilité Hivernale)
GIS	Geographic Information System
HES	Highways Engineering Service
FOT	Field Operational Test
GMAO	Gestion de Maintenance Assistée par Ordinateur
ITS	Intelligent Transport System
ITS-G5	Adaptation of the IEEE 802.11p
ITS-S	Intelligent Transport System Station
R-ITS-S	Roadside ITS Station
IVI	In Vehicle Information
LTE	Long Term Evolution
MTES	Ministère de la Transition Écologique et Solidaire
Nfr-ITS-S	French National ITS Station
OEM	Original Equipment Manufacturer
PFro	Road Operator's Platform

PFcm	Car Manufacturer's Platform
IVS	In vehicle Signage
POI	Point of Interest
SIG	Système d'Information Géographique
SIR	Service d'Ingénierie Routière
TMS	Traffic Management System
TMV OBU	Traffic Management Vehicle On-Board Unit
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	V2V and/or V2I
V-ITS-S	ITS-S Vehicle (user or road operator)
Vro-ITS-S	ITS-S-V Road Operator
Vru-ITS-S	ITS-S-V User
VMS	Variable Message Sign

1 Introduction

SCOOP@F objectives are:

1. Improving road safety and the safety of road operators

This technology is likely to improve safety by allowing vehicles to "talk" to each other and to the infrastructure. Thus, many crashes might be avoided by exchanging safety information. Moreover, through I2V information on roadworks, rescue and recovery actions, winter maintenance, etc. are directly given to the drivers inside their vehicles allowing them to adapt their driving behavior. This technology has the potential to bring improvement in several safety areas, among which the safety of road workers.

2. Making traffic management more efficient and contributing to the reduction of emissions

Through the collection of data from vehicles and/or infrastructure, cooperative ITS allow better management and efficiency of real time traffic information.

As a result, this will contribute to the overall reduction of greenhouse gas emissions of the transportation system. Moreover, as it becomes more and more possible to combine information related to Park-and-Ride sites (locations, availability of parking spaces) with information about public transportation systems (such as locations of the railway stations, bus stations or multimodal areas), new multimodal services arise, paving the way for a reinforced sustainable mobility (such as dynamic carpooling). In this paradigm shift, in the near future, cooperative ITS will therefore facilitate the modal transfer.

3. Optimizing infrastructure management costs, constructing vehicles fit for the future and developing new services

Interoperable and integrated deployment of cooperative ITS fits into a logic of optimizing the overall costs related to road safety and to infrastructure maintenance, while offering new and more pleasant services. For the latter, business models have yet to be tested. In fact, industries committed to the development of cooperative ITS have a significant potential for job creation across Europe and could enhance the ITS sector’s economic growth.

This report is a synthesis of different evaluations carried out during the project in order to evaluate SCOOP@F impact on these objectives.

One of the challenges of this project is to assess the impact of C-ITS on specific factors, namely:

- Impact on traffic
- Impact on electromagnetic exposure
- Impact on the organization of road operators' work
- Legal impact both in terms of users' privacy and the legal responsibilities of public authorities

In addition to the above-mentioned impacts, we carried out studies related to(a) the definition of to define the level of acceptability of C-ITS by drivers, (b) road safety assessment to assess road safety, (c) the technical evaluation or the cost-benefit analysis of C-ITS. The latter also involves the analysis of the value chain and the business model that can be associated with it.

All these evaluations are synthesized presented in this report, including methodology and results. They and are categorized in two groups:

- Ex-ante evaluations like:
  - Technological monitoring of vehicle On-board Units (OBUs), fixed and mobile Roadside Units (R-ITS-Ss)
  - Expected gains in road safety
  - Driver distraction – overview of the current situation
  - Impact assessment on roadworkers.

- Ex-post evaluations like:
  - Organizational impact study for traffic managers
  - Impact assessment on drivers acceptability
  - Impact assessment on road safety (accident analysis evaluation)
  - Impact on traffic regulation
  - Impact on costs/benefices (socio-economic evaluation and value chain analyses)
  - Impact on regulatory aspect and privacy
  - Health impact assessment
  - Technical evaluation

First a short description of the project is presented in order to introduce different concepts for evaluations.

2 Project description

2.1 General Overview

SCOOP is a pilot project for the deployment of cooperative intelligent transport systems, i.e. systems based on the exchange of information between vehicles, and between vehicles and road infrastructure. Vehicles are equipped with sensors to detect events such as a slippery road, an emergency brake, etc. and with on-board units (OBU) to transmit the information to vehicles behind (V2V) and to the road operator (V2I) through road side units (R-ITS-S). The road operator can also transmit information (roadworks, etc.) to the vehicles through their on-board units (I2V).

SCOOP federates numerous public and private partners around the Ministry of Ecological and Solidarity Transition (MTES: Ministère de la Transition Ecologique et Solidaire), who is the coordinator: local authorities, road operators, car manufacturers PSA and Renault, universities and research institutes. Since January 2016, a telecom operator, a trust services provider and Austrian, Spanish and Portuguese partners have also joined the project.

The exchange of information between the vehicles and the infrastructure are based on ITS G5 (Figure 1), a short-range communication technology designed for cooperative ITS.

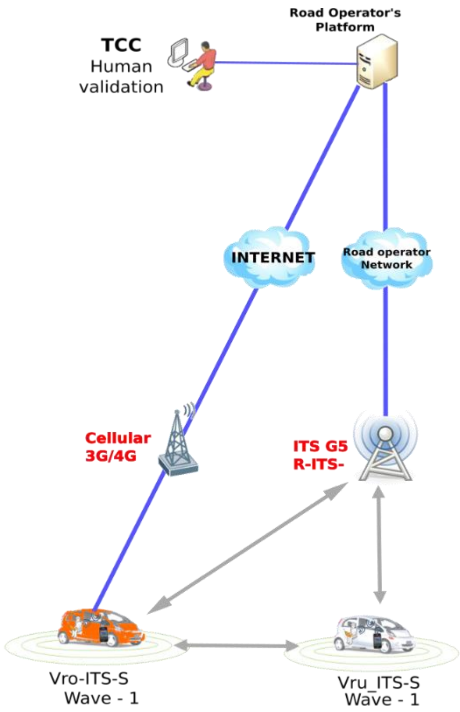

Figure 1: ITS G5 based architecture

In a second phase, new services were specified and a hybrid ITS G5/cellular technology was developed (Figure 2).

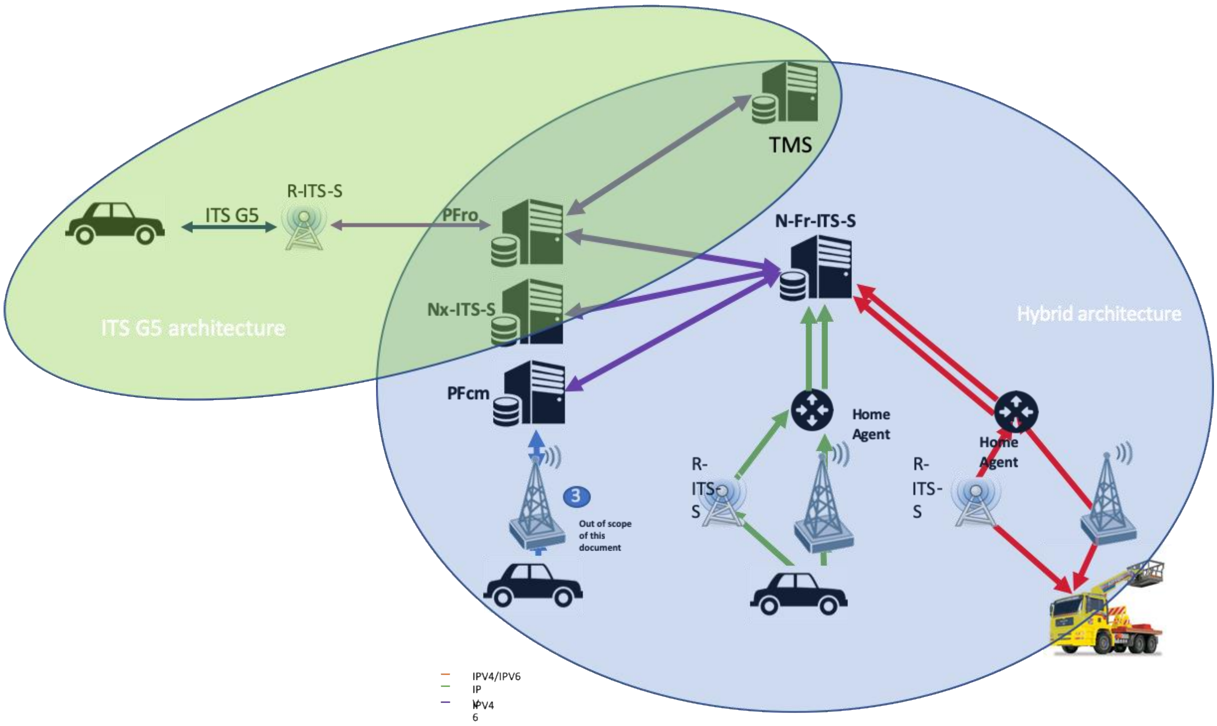

Figure 2: General SCOOP Architecture

2.2 Use Cases

Several use cases were specified, implemented, tested and evaluated in this project. Table 1 presents the complete list of SCOOP use cases.

Table 1: SCOOP use cases

List of SCOOP use cases
Traffic data collection
Data collection (automatic events)
Data collection (manual events)
Alert closure of part of a lane, whole lane or several lanes
Alert planned closure of a road or a carriageway
Alert planned road works – mobile
Alert Road operator in intervention
Alert end of queue by a road operator vehicle
Winter maintenance

Alert Temporary slippery road
Alert Animal or people on the road
Alert Obstacle on the road
Alert Stationary vehicle, breakdown
Alert Accident area
Alert Reduced visibility
Alert Unmanaged blockage of a road
Alert Emergency brake
Alert End of queue
Alert Extreme weather conditions
Alert Wrong-way driving
In-vehicle signage (embedded VMS)

2.3 Test sites

The project is based on **5 pilot sites** (

Figure 3), which have their own specificities due to their road-types, traffic-types and/or topographies:

- **Île-de-France**: the road network that will be equipped is composed of structuring roads in the metropolitan area. Among them, there are a large part of the second and third Paris ring roads that are used for both local and long-distance transit. (road operator: DIR Île-de-France)
- **"Corridor Est"**: between Paris and Strasbourg, the road network that will be equipped is composed of an interurban toll motorway, which is mainly used for long distance routes. (road operator: SANEF)
- **Ouest**: the road network that will be equipped is composed of peri-urban roads and interurban highways that connect medium-sized cities. (road operators: DIR Ouest, Région Bretagne, Côtes d'Armor, Ille et Vilaine, Agglomération de Saint Brieuc, ITS Bretagne)
  More information on DIR Ouest SCOOP@F website
- **Bordeaux**: the road network that will be equipped consists of the Bordeaux ring road. This pilot site will be an extension of the COMPASS 4D FOT, in terms of services deployed. (road operator: DIR Atlantique)
- **Isère**: the road network that will be equipped consists of secondary roads embedded in mountain areas. (road operator: Département de l'Isère)

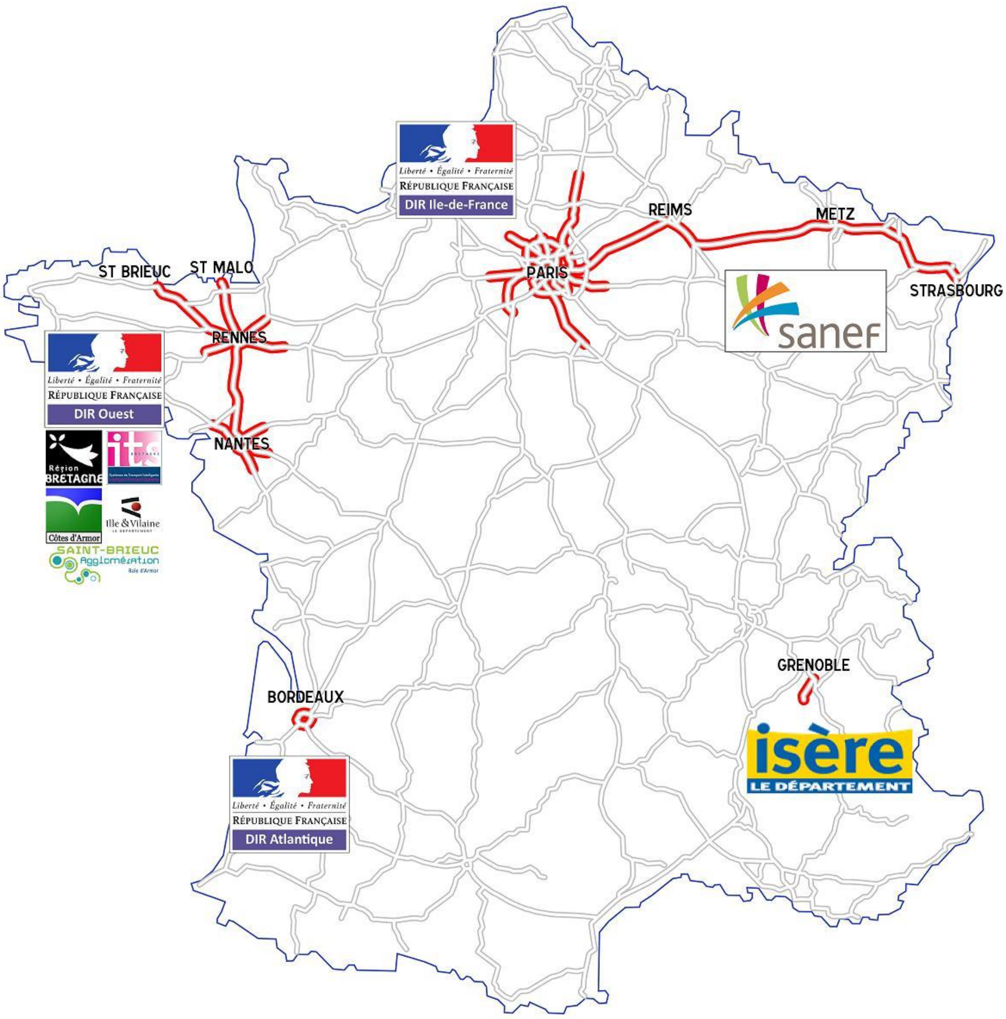

Figure 3: SCOOP@F test sites

3 Technological Monitoring of Vehicle On-board Units (OBUs), Fixed and Mobile Roadside Units (R-ITS-Ss)

3.1 Objectives

The objectives of this study are:

- To establish the list of Vehicle On-board Units (V-ITS-S), Fixed and Mobile Roadside Units (R-ITS-S) suppliers,
- And to provide a description of each product including the conformity with the standards and with the SCOOP specifications, the price…

These documents will help local pilots to establish the specifications of their tenders.

3.2 Methodology

It has been decided to decompose the deliverable in 4 documents:

- 2.3.9.1: suppliers data: contact name, entity description, list of marketed service and products, projects C-ITS...
- 2.3.9.2: the template survey grid,
- 2.3.9.3: an analysis of the completed grids,
- 2.3.9.4: all documents classified by suppliers: survey grids and product documentation or description.

Globally the methodology was:

1. Establishment of a first version of the first two documents,
2. Survey conducted with suppliers asking them to complete the criteria grid,
3. Update of the first document and creation of the last two documents,
4. Dissemination to the road operators for their tenders.

3.3 Experimental Framework

In 2014, an initial list of suppliers, the 2.3.9.1, has be drawn up from the different actors of French, European or international C-ITS projects likely to supply these products. The sources of information were the list of participants in the ETSI plug tests and the contacts of all SCOOP partners.

Then this list has been supplemented by literature and Internet searches.
The template survey grid, the 2.3.9.2, has two parts: the supplier data, and the products data.

- The supplier data part has the same structure as the list of suppliers. The purpose is to complete the deliverable 2.3.9.1.
- The products data part has been established based on the specification deliverables of the products: 2.4.2.1, 2.4.2.2, and so on. The purpose is to have a high-detailed description of the products. This will help to determine which products meet the criteria natively, and which products can evolve to meet them.

Then, an individual email has been sent to each contact in the list 2.3.9.1 asking them to complete the survey grid 2.3.9.2. A reminder by email, and then a phone call, has been sent to the non-responder of the first email.

After this survey period, the 2.3.9.1 has been updated. And an analysis of the answers, the deliverable 2.3.9.3, has been made.

Most of the received answers were associated with their own documentation. So, the analysis was completed with the 2.3.9.4, a zip document of all the documentation, for each supplier.

The SCOOP Steering Committee validated the four documents. So, they have been sent to all the road operators involved in the SCOOP project, for helping then for their tenders.

Name	Description	ITS Station hardware and software and products
Cohda Wireless Pty Ltd	Australian society, they commercialize R-ITS-S and V-ITS-S, and software. They or their products are involved in Scoop@F (F), European C-ITS Corridor (NL/D/A) and a lot of other projects.	MK5 OBU, MK5 R-ITS-S, and Software stacks (ETSI C-ITS and IEEE1609 WAVE), Applications (Day 1, Day 1.5, Day 2), also dedicated applications for Connected Autonomous Vehicles
Commsignia Ltd.	The society is based in USA (Headquarter), and Hungary (Engineering Office), They sell R-ITS-S and V-ITS-S, and software. They or their products are involved in Compass4D, C-Roads CZ, Rotterdam-Vienna C-ITS Corridor (German section) and a lot of other projects	Commsignia develops V2X stack for Automotive companies and HW+SW products for Smart City deployment projects.
FARECO	French society, they sell R-ITS-S and V-ITS-S, and software. They can install R-ITS-S. (Strong collaboration with Yogoko)	Roadside ITS Stations and accessories (antennas, tablets, etc). Always commercialized with software. For OBU (if needed, only in collaboration with YoGoKo) Based on Y-Smart software communication stack of YoGoKo, the software includes all use-cases and tools of Scoop@F (phase 1) and later will include other use-cases for Scoop@F (phase 2) or for C-ROADS. They sell the whole

Name	Description	ITS Station hardware and software and products
		product, and also C-ITS test system applications.
NEOGLS (GEOLOC SYSTEMS)	French society, they sell R-ITS-S and V-ITS-S. They can develop a lot of different modules, including Datex II. They or their products are involved in Compass4D, CO-GISTICS, Scoop@F, InterCor, C The Difference, C-Roads, C-Mobile.	R-ITS-S, OBU, and C-ITS platform
Kapsch TrafficCom AG	Austrian society, they sell R-ITS-S and V-ITS-S. They design, engineer and manufacture their products. (Note: They have a French branch)	Kapsch TrafficCom is a full range supplier of V2X products and solutions. Kapsch supplies V2X R-ITS-S, OBU, Tablet applications and V2X enabled Traffic Management Centre (ATMS).
LACROIX Neavia	French society, they sell R-ITS-S and V-ITS-S. They can develop a lot of different modules, including Datex II. They or their products are involved in Scoop@F, Drive C2X / Compass 4D, and a lot of other projects. (Member of LACROIX TRAFIC)	R-ITS-S (V2I Station), OBU (V2V Unit), Server platform (V2X Server) Roadworks V2X Traffic lights, V2X Traffic light controller, V2X VMS
Signature/SVMS (Eurovia)	French society, they sell R-ITS-S and V-ITS-S, and others road equipments. They or their products are involved in PAC V2X (SVMS is the project leader) (Member of EUROVIA Vinci)	Signature sell a full R-ITS-S including software.
STERELA	French society, they sell R-ITS-S.	Road Side Unit (prototype in progress)
V-tron BV	The society can provide small series of R-ITS-S and V-ITS-S. They or their products are involved in Compass4D, ITS-Corridor, and Intercor.	As well in-car OBU and roadside R-ITS-S. They are focused on the software and use different hardware platforms.
VALEO	French society, they sell R-ITS-S and V-ITS-S, and others vehicle equipments. They or their products are involved in Scoop@F (DIRIF) / ITS / ADAS	OBU and vehicle equipments.
YoGoKo	French society, they sell R-ITS-S and V-ITS-S, and some others C-ITS products. They or their products are involved in AutoCITS. AutoPilot. Scoop@F. SCA (IRT SystemX)	Roadside Units in partnership with FARECO, On-Board Units and accessories (antennas, tablets, etc) always commercialized with software stack, and C-ITS test system application

3.4 Results

The results presented here are the ones from the last available version of the deliverables.

Deliverable 2.3.9.1 Suppliers List

81 suppliers are referenced in the document.

For 61 of them, no answers have been received to the survey. The name and a high-level description of the society has been sent to the road operators, but they are not presented in this synthesis.

20 suppliers answered to the survey:

- 11 commercialize R-ITS-S or V-ITS-S, or part of a C- ITS Station:
- 2 commercialize only software for ITS stations, or for any other elements of a C-ITS architecture (TMS, or Datex II modules and so on),

Name	Description	ITS software and products
CLEMESSY	French society, they provide software. They or their products are involved in Scoop@ (Vro-ITS-S software, PFro software) and in the TMS of some French National road operators (DIR)	TRAF'X (Exploitation Support System) is fully configurable and Clemessy sells the whole product. Clemessy sells also Datex II Gateway between TMS and NAP or TIPI.
Marben Products SAS	French society, they provide software. They or their products are involved in Scoop@ (Vro-ITS-S software, PFro software) and in the TMS of some French National road operators (DIR), Scoop@F, PAC V2X, EVAPS, 5GCAR, and others.	MARBEN V2X is a complete software for accelerating OBU or R-ITS-S.

- 5 commercialize services or advices in the C-ITS domain,

Name	Description
Gildas Baudez Consultant	The society is a French consulting company in C-ITS, and contributes to the French (CN01 Télépéage - CN04 info voyageurs - CN08 Données routières) and international standardization.
ITS Mobilité Conseils EIRL	The society is a French consulting company in C-ITS, and contributes to the French (CN01 Télépéage - CN04 info voyageurs - CN08 Données routières) and international (CEN/TC 278/WG 7 (convenor), CEN TC 278/WG 8 (editor of prEN 16157-2, CEN/TS 16157-5 & CEN ISO/DTS 19468),

	ISO/TC 204/WG 9 & ISO/TC 204/WG 18(editor of CEN ISO/TS 17425)) standardization.
LOGMA Consulting sas	The society is a French consulting company in C-ITS, and contributes to the French (Chairman of CN16 (BNTRA), (Member of CN01-BNTRA, Member of CN03-BNTRA) and international (ISO/TC 204/WG 18 - Cooperative systems CEN/TC278/WG16; ISO/TC 204/WG 5 - Fee and toll collection CEN/TC278/WG1 CEN TC278 WG15 - eSafety (eCall)) standardization.
Telemotive	The society is a German consulting company in C-ITS. They contribute on projects: - C-ITS consulting for a japanese car manufacturer - C-ITS project management for a test tool for a Korean car manufacturer and a Korean supplier - C-ITS technical project management for C-Roads - Test tools for C-ITS: multiple vehicle test scenario manager, vehicle datalogger, C-ITS module for an autonomous vehicle prototype. - Use case investigation for 5G C-ITS.
VICI - Vehicle - Infrastructure Cooperative Innovations	The society is a French consulting company in C-ITS, and contributes to the French and international (ETSI & CEN) standardization. They are involved in French PAC V2X project.

- 1 does not commercialize C-ITS products or services for the moment but their current products contribute to the C-ITS deployment, and they aim to develop C-ITS products or services: Aximum provide FLR (Illuminated Arrow signs) with Road works warning and can install R-ITS-S.
- 1 does not commercialize C-ITS products or services. COROS Consultants can provide data to supply the ITS stations database (regulatory data on road signs for example).

Deliverable 2.3.9.2, 2.3.9.3 and 2.3.9.4 Products information

The overview of the products is presented here. The details can be found in the Deliverables 2.3.9.3 Products details and 2.3.9.4 suppliers' documentation.

	R-ITS-S	OBU
Number of declared suppliers:	11	9
Number of suppliers who provide documentation on their products:	6	6
Number of documented products	7	6

Based on the documented data, a table has been established about the prices. The purpose is to help a road operator to size its tender.

The price is set for one unit, and without VAT (Value Added Tax).

The prices always include all necessary elements for a normal running of the station, such as the ITS station intelligence, a waterproof and shock resistant container, wiring, equipment, antennas…

In general, supported standards versions are the latest published.

Generally, prices do not include specific software, or hardware. For better understanding, examples of particular software or hardware that is often proposed but not included in the price are mentioned below:

- For R-ITS-S:
  - Addition of a particular HMI, provision of a proprietary platform, integration into the existing supervision system...
  - External battery, configuration servers (nor the parameters nor the associated software)
- For Vro-ITS-S:
  - Integration of the "SCOOP application", development of special interfaces, provision of a proprietary platform…
  - External battery, bus can cable, configuration servers (nor the parameters nor the associated software).

	R-ITS-S		
	Min price	Max price	Elements influencing the price
Supply of one ITS station (without support)	1 000,00 €	4 000,00 €	The number of units, The functionalities and covered services: • CAM and DENM is always included, • IVI or POI or others are generally not covered The elements included: • Special cables, better antennas…
Installation of one ITS station	1 000,00 €	10 000,00 €	Same constraints than others dynamic equipments: post or not, trenches or not…
Maintenance of one ITS station	100,00 €	500,00 €	The number of R-ITS-S to supervise

Licence	0€ - No licenses for the responders products.		
Guarantee	0€ - Guaranties of 1 to 5 years is included in the supply price		
Totally cost of the product	2 100,00 €	14 500,00 €	

	Vro-ITS-S		
	Min price	Max price	Elements influencing the price
Supply of one ITS station	1 000,00 €	3 000,00 €	The number of units, The functionalities and covered services: • CAM and DENM is always included, • IVI or POI or others are not always covered The elements included: Special cables, better antennas…
Installation of one ITS station	500,00 €	10 000,00 €	Buscan analysis and connection, Peripheral equipment (such as Arrows or lightning panel) analysis and connection, Installation particularities (private vehicle installation are easier than in a professional truck with commands and screens already present in the driver's environment)
Maintenance of one ITS station	100,00 €	500,00 €	The number of Vro-ITS-S to supervise
Licence	0€ - No licenses for the responders products.		
Guarantee	0€ - Guaranties of 1 to 5 years is included in the supply price		
Totally cost of the product	1 600,00 €	13 500,00 €	

4 Expected benefits on road safety

The purpose of this section is to detail the expected gains in terms of road safety and the safety of the road operator's agents through the SCOOP@F project based on a bibliographic inventory of the findings of existing studies and research projects/FOT (field operational test) on cooperative intelligent transport systems in road safety before the beginning of SCOOP. This study was made at the beginning of the project in 2016. New information may exist but not include in that section.

This non-exhaustive inventory conducted highlighted the following points:

- No data were found on the safety of road operators' agents.
- While the positive impact of cooperative systems on road safety is well confirmed in the various projects, this impact is very rarely quantified and qualified, as the tests were not carried out on a large enough scale.
- It would have been beneficial to be able to present a summary of the road safety gains presented, particularly by use case. This was however not possible due to the small number of results, their disparity in terms of use cases, road environments...

This document lists regulatory texts and studies or projects that provide some assessments of road safety gains, considering the potential reduction of accident casualties,

4.1 The Commission's Delegated Regulation (EU) 886/2013

Commission Delegated Regulation (EU) 886/2013 of 15 May 2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to data and procedures for the provision, as far as possible, of free minimum universal road safety-related traffic information for users (action c).

Action c concerns the following information:

- Temporarily slippery road.
- Animal, people, obstacle, debris on the road.
- Unprotected accident area.
- Short-term road works.
- Reduced visibility.
- Wrong way driver.
- Unmanaged blockage of a road.
- Exceptional weather conditions.

SCOOP should make it possible to collect and disseminate this information relating to action c of the ITS Directive. It is therefore interesting to take note of this estimate given in the explanatory memorandum of the text:

“The overall effect of road safety-related traffic information is estimated to be an average reduction of 2.7% in fatalities and 1.8% in injuries, relative to all road accidents*. These figures vary depending on the road types and safety events to be covered by the service (although in the absence of a road accident database, including information about the causes of the accident, it is difficult to produce precise estimates).

* Based on an extensive literature review including CODIA, eIMPACT, PROSPER, Easyway, road operator reports and the CARE database".

4.2 The Easyway project

Easyway is a project about intelligent traffic information systems and dynamic traffic management deployment, without the use of cooperative systems.

Assessments indicate that travel information and early warning systems reduce by 11% the number of accidents with injuries in poor weather conditions.

A working group on cooperative systems selected seven priority services yielding the greatest benefits from the point of view of road authorities and operators:

- Hazardous location notification.
- Traffic Jam Ahead warning.
- Road Works warning.
- Decentralized collection of Floating Car data.
- Traffic information and recommended routes.
- In-vehicle signage (including speed management).
- Automatic access control and parking management (including intelligent areas for HGVs).

This group produced the deliverable "Business case and benefit-cost assessment of EasyWay priority cooperative services, April 2012" presenting a cost-benefit analysis by 2030 (100% vehicle penetration rate). This study attempts to assess the monetized benefits in terms of the impact on three criteria: safety, congestion and environment.

- In all cases, the benefit-cost ratio is greater than 1; specifically, it is 1.5 for V2V services and 1.8 for V2I services.
- The ratio of the V2V group of services is close to the European rate for the countries analyzed except for those where road safety is the best (United Kingdom and Germany where it is 1.1).
- In all countries, the advantage in terms of improved traffic and reduced environmental impact prevails over road safety.

4.3 The iMobility Effects Database

This database http://www.imobility-effects-database.org/ lists the effects on safety and the environment of different use cases. The results are reported in tabular form for each use case.

- Dynamic traffic management (variable message signs).
- Emergency braking.
- Local danger warnings.

- Obstacle and collision warning
- Real-time traffic information.
- Speed alert.

4.4 DRIVE C2X

The DRIVE C2X final report (Deliverable_D11 6_Final report, conclusion of paragraph 4.2.2, safety) indicates:

"The safety impacts of DRIVE C2X functions are clearly positive. Drivers react to information and warning signals.

- IVS Speed limit and Weather warning showed most potential to decrease fatalities:
  - Assuming a 100% penetration rate, IVS speed limit that provides continuous information would reduce on average 23% in fatalities and 13% in injuries. Weather Warning would lead to 6% less fatalities and 5% less injuries
  - It is assumed that the penetration rates would be in 2020 highest 12% and 76% in 2030. For IVS speed limit, this would lead to the reduction in fatalities up to 3% in 2020 and up to 16% in 2030
- Assuming a 100% penetration rate, Road works warning would decrease fatalities by 3%, Emergency brake light warning and Traffic jam ahead warning by 2%. These functions would decrease injuries by 2% assuming all vehicles are equipped

The DRIVE C2X project successfully measured and analyzed direct and short-term effects of drivers' use of the DRIVE C2X functions. The safety impacts of the DRIVE C2X functions were found to be positive even for functions aimed at relatively infrequent events."

4.5 SAFESPOT

The SAFESPOT final evaluation report (Deliverable 5.6.5-Final evaluation report) reports the following evaluation for the "danger warning" use case, including the speed warning:

"The safety impact will depend on the level of deployment of the SAFESPOT systems. This was taken into account – with regard to the penetration rate of SAFESPOT-equipped vehicles - for an H&IW Use Case by means of a microscopic traffic simulation. For a 15% penetration rate, the simulation indicated an increase in safety for the H&IW congestion warning, indicated by a decrease in the smallest TTC. The TTC "time to collision" in seconds is used as an indicator for accident risk, e.g. TTC < 3 sec indicates a high risk of not being able to stop in time. A reduced level of a low TTC is therefore equivalent to a reduced risk of accidents and hence an improvement in safety. Using this assumption, penetration rates of 15-50% with 100% compliance increased road safety by 11% (i.e. 11% less TTC < 5 sec than without H&IW). A higher penetration rate reduced the results to 6% due to a saturation effect."

4.6 CVIS

CVIS applications include urban, inter-urban services (incident warnings, weather, traffic conditions, speed limits, vehicles in reverse direction) and freight and vehicle fleet services.

It is indicated in the deliverable D.CVIS.1.3 - CVIS objective 6: Impact on Driving Behavior:

"During the development of the Validation Plan, it was concluded that this objective could not be achieved during the CVIS project lifetime since it requires a large number of vehicles driven in a realistic context over a long period of time using applications that are product ready. This objective is one of the main points for forthcoming FOTs".

4.7 SCORE@F

Use cases processed:

- Road Works warning
- Alert stationary vehicle / breakdown warning
- Obstacle on Road warning (the driver receives a warning)
- Obstacle on Road notification (the driver sends a warning)
- Pedestrian warning Weather information: reduced visibility (heavy rain, fog)
- Weather information: reduced stability (slipper road, heavy rain)
- Emergency Electronic Brake lights
- Approaching Vehicle

The report on the impact on road safety and road traffic, (Deliverable L531 of 01/03/2014, paragraph 10.1), concludes by stating:

"This preliminary work on the evaluation of the SCORE@F use cases, however, returned insufficient results allowing to make the right decisions. Their accuracy is often limited because of the lack of variables in accident databases but also because it was impossible to take into account all the factors enabling us to define their efficiency. For example, when considering accidents with obstacles on the road, we need to have a precise definition of the use case to know if the obstacles encountered in those accidents correspond to the use case. Moreover, the notion of temporality is fundamental; the conflict situation must be detected early enough to be able to process the data, send a message to the driver and allow the driver time to react appropriately. We would therefore need to go into more detail in the specification of use cases and in the analysis of accidents in order to refine their implications. The purpose is to be able to define indicators that will be used to define the overall performance / efficiency of use cases.

This project also serves as a starting point to explore the methods to be used to estimate the real effectiveness of these use cases by creating a link between accidentology and behavior. However, we were unable to complete the method because of a sample set:

- Often too small in terms of the number of testers.
- Biased by display systems and displays inside the cockpit of the car that differed fairly significantly.
- Constituted from heterogeneous experimental methods and measurements.

We were not able to identify an efficiency gain for each road safety use case and estimate its reduction in terms of fatalities, serious injuries or accidents."

4.8 simTD

Deliverables are in German, including a summary in English.

Extract of the summary in English of the Deliverable 5.5, Part B-1A "Project result: Analysis of the Efficiency of Selected simTD Systems on the Basis of Real Accident Data from the GIDAS - German In-Depth Accident Study – Database":

"To accurately assess the benefit of a simTD system, the new probability of being seriously injured (MAIS2+?) is calculated for each person involved in an accident by the Injury Risk function.

In 61% of the 447 simulated accidents, the vehicle in front is outside the area of action of the electronic brake light. In accordance with the trigger conditions, no information or alert is activated for these cases. Thanks to the electronic brake light, 7.3% of simulated accidents can be avoided”.

		Electronic brake light **- Comparison to the original course of the accident**	-
Number of simulated accidents		447	
Avoided Accidents	Min. value	2.2%	
	Expected Value	7.3%	
	Max. value	10.7%	
Reduction of MAIS2+ injuries	Min. value	39.64%	
	Expected Value	43.2%	
	Max. value	45%	

5 Driver Distraction

5.1 Approach to designing an ADAS

5.1.1 Introduction: Definition of an ADAS

ADAS (Advanced Driving Assistance Systems) or Driving Aids are designed to help the driver with the task of driving his vehicle.

The goal may be to enhance comfort by relieving the driver in a particular task. For example:

- The automatic switching on of the dipped-beam headlamps saves the driver from having to develop the reflex of switching them on as darkness falls.

The aim may also be to improve road safety.

- For example, the Collision Risk Warning alerts the driver if there is a risk of his car hitting the vehicle in front.

Quite often, behind the search for comfort is also the search for safety.

- For example, it can be seen that, thanks to the automatic activation of the dipped-beam headlamps, the headlamps are switched on much more often than when this task is handled by the driver; thus, automatic activation means that the driver sees better and is seen better.

In addition, a distinction is to be made between **informational ADAS** where information is "simply" pushed to the driver, with the onus then on the driver to react or not and **active ADAS** which can act directly on the vehicle (e.g., cruise control).

In all cases, the connection with the driver takes place via a **HMI (Human Machine Interface)**: this can be a pictogram displayed on a screen, a button that the driver presses, etc.

At PSA and Renault, safety ADAS are often classified into several levels, as shown in the table below:

Levels	Informational and preventive ADAS	Informational and Safety ADAS	Active and Safety ADAS
Example	"Inter-vehicle time display"	"Collision risk warning"	"Automatic braking in case of collision risk"

Frequency of activation of the function	Quite frequent (very frequent in heavy traffic)	Occasional	Very rare
Vehicle behavior	**Discreet beep** when the inter-vehicle time (safety margin with the vehicle in front) becomes too short	**Strong and intrusive beep** when the inter-vehicle time becomes so short that the driver must absolutely react	**The vehicle brakes** in place of the driver, to avoid a collision, or, at least, to give the driver some time to react
Behavior expected of the driver	Increased vigilance, or even he slows down the vehicle to return to the recommended safety distance	Heavy braking or avoidance	At any time, the driver can take over control of the situation to avoid a collision

NB: From the point of view of C-ITS standards, preventive informational ADAS are in the category of Road Hazard Signalizing (RHS) applications, and safety informational ADAS are in the category of Collision Risk Warning (LCRW and ICRW) applications.

5.1.2 Design approach

When designing an ADAS, we need to define:

- **The objective for the client** (the client must be at the center of everything).
- **The conditions of use** (town, high speed, heavy traffic...).
- **Possible sources of information, as well as their reliability/availability** (are they reliable? accurate? available in all weather conditions? able to manage all types of situations and/or obstacles?

This analysis makes it possible to design the appropriate functional ADAS and HMI, and to define the components involved.

Throughout the design and validation (see LAB deliverable), we need to verify the impacts of the ADAS on:

- **The driver's behavior** (whether negative or positive: better respect for driving rules, familiarization with the function, feeling of insecurity...)
- **Safety** (driver, passengers, and/or other road users)

5.1.3 Prototyping on a Road demonstrator

In order to define the above precepts under representative conditions, the ADAS function must be accurately prototyped.

This demonstrator is operated by manufacturer's experts (ADAS, HMI, safety, etc.) under representative conditions, i.e. on open roads.

5.1.4 External Functional Analysis (EFA)

External Functional Analysis is a method for comprehensively expressing, from the beginning of the design stage, the functions expected of a product to meet the needs of users and the requirements of the environment.

This method makes it possible to identify:

- Real-life situations associated with the system,
- The service functions expected from a system (the What) without taking the organic architecture into account (the How),
- The constraint functions associated with the system,
- The system-state diagram (different nominal and degraded states of the system and transition conditions between the different states).

The EFA is the first document produced when designing a driving aid.

5.1.5 Preliminary Risk Analysis (PRA)

The design process for a vehicle component or function is carried out in accordance with ISO 26262.

ISO 26262 is an international standard for the design and validation of on-board electronic functions in vehicles. It was published in November 2011.

ISO 26262 is applied to define the state-of-the-art in the design and verification/validation of such functions.

ISO 26262 applies in particular to the design of driving aids.

The Preliminary Risk Analysis makes it possible to define the risks incurred by road users (driver, passengers, pedestrians, other vehicles...) in a given situation.

The general principle of the PRA is as follows:

For each service function identified in the EFA, the following cases are considered:

- "No function" or "loss of function": e. g. no alert when there should have been one
- "Unwanted operation": ex: alert when there should not have been one
- "Incorrect operation": e.g.: alert too early, too late, beep too loud, wrong icon displayed....

Then we analyze the consequences:

- Driver dissatisfaction
- Loss of trust in the function (which may lead to the driver disabling the function)
- Risk of personal injury to the driver himself or any other road user.

In the latter case, the rigorous implementation of a Safety Concept, in accordance with ISO 26262, is required in order to implement all the necessary means to avoid risks.

If the consequence can be to cause physical injury to a road user (called a Level 4 Feared Event or FE4), we move to a specific design mode. A function may be abandoned if the Safety Concept is not successful.

5.2 ESoP criteria

ESoP: European Statement of HMI Principles for safe and efficient in-vehicle information and communication system

These requirements are formalized in the document “Communication multimedia system compliance with HMI design standard” to ensure that ESoP requirements are taken into operational account. They mainly concern:

- The position of the screen.
- Distractive images.
- Text and iconography.
- The layout of the screen.
- The homogeneity of the displays.
- Tasks prohibited while driving.

5.2.1 SCOOP@F wave 1

The use cases selected for SCOOP@F wave 1 are those described in the following table:

Use cases	Name
B1	Alert closure of part of a lane, whole lane or several lanes (fixed, mobile, and salting area)
B2	Alert operator vehicle approaching Alert operator vehicle in intervention
B3	Winter maintenance – Alert vehicle moving
D1	Alert temporary slippery road
D2	D2a: Alert animal on the road D2b: Alert people on the road

D3	Alert obstacle on the road
D4	Alert stationary vehicle / breakdown D4a: vehicle stationary D4b: vehicle breakdown
D5	Alert accident area
D6	Alert reduced visibility
D8	Alert unmanaged blockage of a road
D10	Alert emergency brake
D11	Alert end of queue
E6	Alert extreme weather conditions

For each use case, the vehicle equipped with the SCOOP system may be at the origin of the event or may be the one receiving the information. The SCOOP system then decides whether or not to deliver it to the driver based on its relevance.

5.2.2 Implementation of use cases

5.2.2.1 PSA

Delivering information

When a vehicle receives “SCOOP” information, the vehicle firstly checks the relevance of this information for the driver.

If the information is relevant, it will be displayed either:

- As an icon with text in the navigation screen:

- As an icon with text in a “pop-up”, if the current screen is not the navigation screen.

The icon must be displayed early enough so that the driver has enough time to adjust speed, and late enough to make sense and be properly understood by the driver.

The information's quality will be displayed (if present in the received SCOOP message) via asterisks.

If present in the received SCOOP message, the legal speed limit will also be displayed.

This display principle must comply with the usual design rules (prioritisation, ergonomics, graphics, etc.) for PSA series vehicles.

They will be validated on the Road demonstrator by PSA's experts.

Information Feedback done by the driver.
The driver will be able to report an event "manually" via his touch screen, by:

- Displaying the dedicated menu (selected by pressing the dedicated icon)
- Choosing the type of event.

The dedicated menu will be as follows (temporary version):

Once again, this mechanism will be validated on prototype by HMI experts.

RENAULT

Three interaction sequences are identified and presented below, from the shortest to the longest.

Séquence 1	Séquence 2	Séquence 3
Pop up	Changement d'affichage dans le widget	Accès à l'application pour la déclaration d'évènement
		
1 clic pour fermer 1 clic pour accéder à l'application, onglet view	1 clic pour accéder à l'application, onglet view	Au moins 2 clic pour déclarer un évènement Au moins 2 clic pour paramétrer le service

Sequence 1	Sequence 2	Sequence 3
Pop-up	Change display in the widget	Access the application to declare the event
1 click to close 1 click to open the application, View tab	1 click to open the application, View tab	At least 2 clicks to declare an event At least 2 clicks to chose service's settings

Sequence 1: Display an alert via a pop-up over the navigation map
Sequence 2: Display an alert in the widget
Sequence 3: Report an event, requiring to use the application

5.3 SCOOP External Functional Analysis

About ten main functions have been identified, most of which already exist at both PSA and Renault.

The "new" service functions are:

- Inform the driver of the presence of an operator vehicle behind him
- Inform the driver of the presence of a danger (right or left)
- Allow the driver (or passenger) to report an event

5.4 SCOOP Preliminary Risk Analysis

SCOOP mainly takes over existing PRAs.

The SCOOP PRA for the above new functions, which do not reveal any FE4 (i.e. Level 4 Feared Event that could cause bodily harm to a user), will be consolidated throughout

the design and validation phases, particularly on a road prototype.
No function leading to an FE4 will be implemented in SCOOP@F.

5.5 Comparison with ESoP criteria

5.5.1 Screen layout

ESoP 4.3.2.4 Rule "Visual displays should be positioned as close as practicable to the driver's normal line of sight. Within 30°downward viewing angle of the driver's normal forward view" is respected.

This criterion depends on the layout of the screen in the series vehicles (manufacturer's technical policy) and not on the SCOOP application.

5.5.2 Distractive images

ESoP 4.3.1.3 Rule "The system does not distract or visually entertain the driver. Visual entertainment may occur by displaying images which are attractive because of their form or content" taken into account by:

- The monitoring of the visual animation is interruptible at any time: the driver can return to the driving screen at any time and return later without having lost any information.
- They add value to the driving: Dynamic value and graphical representation (for "distance to the event")

5.5.3 Text and Iconography

ESoP 4.3.3.1.3 taken into account as follows:

- ISO 15008 application for text sizing
- No scrollable text

ESoP 4.3.3.1 Rule "Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough to not adversely affect driving" taken into account as follows:

- Pop-up with a maximum of 2 lines
- Use sans serif fonts for all texts OK
- ISO 15008 application for icon recommendations
- Limit the use of text abbreviations and check their intelligibility
- Limit the use of text truncations and check their intelligibility

5.5.4 Screen structure

ESoP 4.3.1.5 Rule "Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible" taken into account as follows:

- Use the same template for each function of the system to allow minimizing memorization effort, bringing consistency and contributing to an easy experience of use.
- Apply prioritization rules to screen contents.
- Provide prioritization rules to features themselves by proposing main functionalities only with a direct access and providing others behind optional menus or suggestions.

5.5.5 Homogeneity of displays

ESoP 4.3.3.1.5 taken into account as follows:

- The graphical codes are consistent with internal guidelines.
- The audio matrix is defined and gathers all features prioritization of a system.
- Reference main prioritization criteria used; suitability with internal guidelines.

5.5.6 Tasks prohibited while driving

ESOP 4.3.3.1.3 taken into account as follows:

Any functions prohibited while driving (e.g. video) are not made available to the driver.

6 Organizational impact study for roadworkers

Road operation is defined as all actions designed to improve or facilitate the use of an existing road network. There are three areas of road operation that are described in the road operation master plan:

- Maintenance of viability: maintaining or restoring the conditions of use of the roadway (network monitoring and alerting, emergency response, winter service, organization of foreseeable interventions and equipment maintenance),
- Traffic management: distributing and controlling traffic flows over time and space,
- Travel assistance: provide forecast information on traffic conditions.

All the field of studies are public road departments (Ile-de-France and Atlantic Road Department). They are geographically organized in districts and functionally structured as follows:

- Traffic information and management center (CIGT) monitor traffic, coordinate field interventions and organize road information.
- Maintenance and intervention center (CEI) maintains viability and manages traffic in coordination with the CIGT, monitors the network, intervenes in the event of an incident or accident, and helps road users.

6.1 Methodology

The study is focused on agents of CEI (maintenance and intervention centers) and operators of CIGT (traffic information and management centers). The hierarchic line of these two jobs has also been considered. These two jobs are those which should be the most impacted by the implementation of the SCOOP system, as highlighted from questionnaires and interviews with local project pilots in the summer 2015. Each job was studied on a different site for reasons of ease of access to the field: Ile-de-France Road Department (DIRIF) for the agents of the maintenance and intervention center and Atlantic Road Department (DIRA) for the operators of traffic information and management center.

In both cases, we observed the working activity without modifying it. The observed activities aimed for an exhaustive overview of the activities carried out. After the observations, we conducted informal interviews with workers and managers. We chose not to conduct formal interviews that the agents/operators might have experienced badly.

6.2 Experimental Framework

6.2.1 Areas of study

DIRIF has chosen 2 pilot sites that have been equipped with roadside units and vehicle units: Jouy-en-Josas and Champigny-sur-Marne. The Jouy site has 12 agents who work in teams of two and use the same van. There is one response manager by day and another by night. This site has already been involved in the testing of a digital register. The Champigny site has 25 employees, 6 response managers and 4 technicians. An intervention manager generally supervises a team of 3 agents. Most often, the agents go on the same intervention but each with a vehicle. The digital register has not been a success in Champigny but we did not focus on this subject.

DIRA has only one traffic information and management center which is located in Lormont. It has 9 operators, supervised by a head of unit. They cover 630 km of road network (equipped with, among others, 72 VMS, 78 cameras, 22 automatic incident detection cameras) and 12 maintenance and intervention centers.

6.2.2 Method

We observed the activity and took notes. Some activities were filmed or photographed for further analysis with the authorization of the concerned agents/operators. We asked questions to clarify the observations. We also considered different kinds of documents: general procedural guides or specific field tools filled by the agents.

6.2.3 Participants

The agents/operators and managers were volunteers and were solicited by their chiefs following our recommendations: vary the experience and the interest for new technologies. 4 agents (between 1.5 and more than 10 years of experience), 3 operators (between 7 and 12 years of experience) and 3 managers (between 10 and 20 years of experience) were included in the study. All of them were men. All the operators have previous experience as team leader in maintenance and intervention center.

6.2.4 Procedure

For the CEI, the study consisted in 5 sessions between May, 25th 2016 and July, 26th 2016, organized as follows:

- Patrol observation in the morning
- Intervention observation during mornings and afternoons (pedestrian on the roadway, accident with an injured driver, picking up an object on the roadway, driver stopped on the shoulder, broken down vehicles)
- Beaconing at night

For the CIGT, we opted for a two-days presence by choosing the two busiest days (Monday and Tuesday) on June 12 and 13, 2017 from 6 AM to 6 PM.

6.3 Results

6.3.1 Working organization

All DiRIF CEI are organized on 4 shifts: morning (1:00 AM to 12:30PM), afternoon (12:30 PM to 1:00 AM), day (7:45 AM to 4:45 PM), night (9 PM to 6:30 AM). Morning and afternoon shifts include an on-call duty at home at the beginning (1:00 AM to 5 AM) or at the end (8:30 PM to 1:00 AM) to ensure rapid mobilization of personnel in case of an unplanned intervention or for general availability. In general, the work is organized in such a way that the teams formed and the people in charge vary over time. There is no stable team. The work of agents also changes with the seasons. In winter, each agent can be called upon to ensure winter viability (salting, snow removal). In the spring, the work is more related to winter-damaged road repairs and vegetation control.

The DIRA CIGT operate on 4 shifts: morning (6:00 AM to 13:00 PM), afternoon (1:00 PM to 9:00 PM), day and night (9:00 PM to 6:15 AM). Two operators work together at certain times of the day. The shift operator is the main operator. The two operators constantly exchange information about current events especially because the existing professional software is not updated in real-time. The shift between morning and afternoon takes 15 min and deals with ongoing events.

6.3.2 Functioning of the information flow

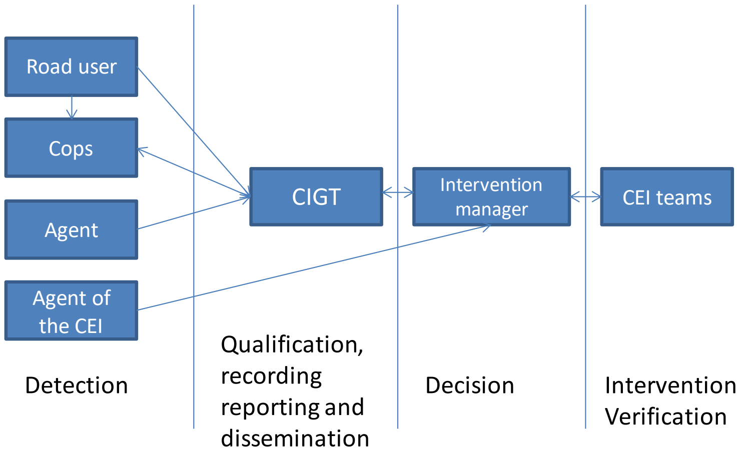

Figure 4: From the detection to the intervention

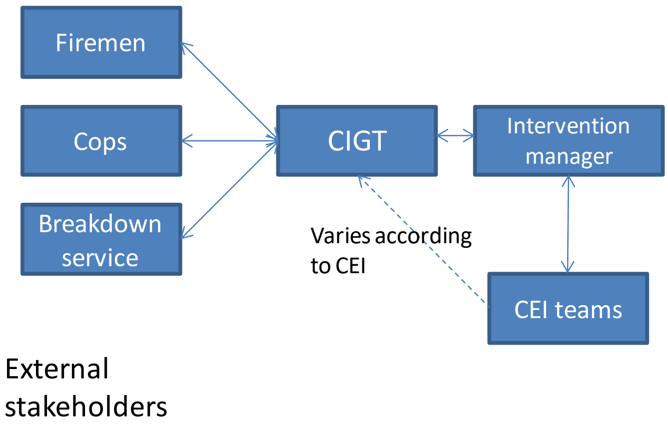

Figure 5: Information flow between DIR entities and external stakeholders

During the intervention depending of the CEI and of the personnel, manager included, agents and managers may call the CIGT. Jouy's agents systematically call the CIGT.

We have also seen this at the DIRA. The CIGT always call the intervention manager. But direct communications take place between the teams of agents and the operator to prevent their arrival on site or the end of the event in some CEI. In other CEI, this task is assigned to the intervention manager.

6.3.3 Tools

CEI agents use vans equipped with the following equipment: topometer, radio (less used than mobile phone), hand-free kit for mobile phone, an interface for managing lights and sirens, a touch screen for managing signaling equipment. Some of the vans are specifically equipped after a recent project. They carry all the equipment needed to cope with all kind of interventions.

To ensure traceability, agents have to report information on paper (patrol sheets, intervention sheets, patrol reports, patrol notebooks, pocket-sized notebooks...). Practices vary from center to center, these papers are not filled in by the same persons (agents themselves or intervention managers), have not the same content (names of the agents who filled in the form and of the manager, origin of the call) and are not filled in at the same times (during or just after the intervention or after the return to the center).
CIGT operators use a large number of digital tools that evolve constantly. The main tool is TIPI, which is used as a register of all the events. Sagase is used to disseminate information, especially on variable message signs. It proposes partially automated scenarios. Operators also use cameras to search or to supervise events, automatic incident detection to be warned, trafficolor from magnetic loops to visualize the traffic, prisms to change the recommended route, VMS to inform road users, lane allocation and closure system on the Aquitaine Bridge, and a telephone.

6.3.4 Main activities of the CEI agents

Patrolling activity (observed in Jouy): patrolling consists of examining the network along a defined route (sent on paper). Agents trace all the points through which they have passed. The patrol is intended to be able to be interrupted at any time in the event of an intervention to be carried out. On the way, agents may identify problems to be solved. Whenever possible or urgent, they do it immediately. If not, problems are recorded in the patrol report and scheduled for future interventions.

Intervention (observed in both sites): Interventions are always urgent but road departments vans are not considered as priority vehicles. The chronological steps of interventions are mostly as follows:

- Awareness of an event (call or direct identification).
- Access to the site with flashing light and siren if necessary.
- Arrival on site: diagnosis, securing (some agents use Waze to find accurately an intervention place).
- Call to report the arrival and transmit information (to the CIGT or the manager, for Champigny).

- Waiting until all the vehicles are gone.
- Clean the area if necessary.
- Remove the security elements.
- Call to signal the end of the intervention.
- Complete an intervention report on site or later, by the agents or by the manager.

Small works on the roadway: an intervention report is completed. On high traffic roads, the road users (especially van drivers) are aggressive toward the agents when a track is neutralized.

Beaconing (observed in Champigny): This activity is carried out by night and planned in advance. Two teams of 3 agents are managed by one manager. The departure takes place in the same time. The activity involves many phone communications for the manager: with the CIGT to inform of closures, with the intervening companies, with the team and with neighbor centers to coordinate closures.

Winter viability (unobserved): We limited ourselves to observing the equipment and questioning the organization of this activity. We saw that the cabin is already crowded by the control devices.

6.3.5 Main activities of the CIGT operators

NB: The pace of activity is sometimes steady and the phone rings a lot before the operator has time to treat the first call.

Processing an event reported by phone: There are 7 major steps in processing an event after a call:

- Receive the information (from the Police officer, from the CEI...): the operator takes notes on a sheet of paper, asks some questions to have all the needed information. Sometimes he asks to be called back to have more information when the agents are on site. Sometimes information is partial (the origin of the signaling) or inaccurate (the localization).
- Call to the appropriate CEI (the intervention manager): the information provided often varies. The operator says if he is not able to see the event on the camera.
- Carrying out management actions to close a lane on the Aquitaine Bridge or to redirect the traffic flow.
- Entering information on TIPI with all the requested information about the event and the actions made. Some boxes can stay empty or imprecise, waiting for more information. When entering the information, the operator thinks about the consequences in terms of transmission to users.
- Validation or modification of the VMS scenario proposed by Sagase.
- Following up the event to adapt the information provided to road users and to close the event at the right time. The operators use the camera or the phone for this task.
- Close the event: information about the end of an event does not always arrive on time. Sometimes the operator has to give a call to know it.

Processing an event reported by the republican security company

The republican security company are part of the national police. One of their missions is to ensure safety on free motorways.

Some of the events are communicated directly by the republican security company agent present in the room. In those cases, the operator looks at it through cameras. The activity is then the same as for an event reported by phone but with more exchanges between the operator and the agents of the republican security company.

Processing a lane closure for roadwork (most of the activity)

The operator receives information by phone from the concerned CEI to fill in the register TIPI to inform road users at the beginning of the roadwork, when there is a change or at the end.

6.3.6 Acceptability

We have seen during our observations and interviews that CEI agents are not characterized by a strong technical culture. New technologies do not have a place in their professional activity. The core activity is field intervention to help road users. Technologies will only be accepted if they help them to achieve this professional goal.

In order to anticipate the acceptability of the SCOOP system, we asked the agents about a technical system they had recently tested: an embedded register application. Reactions vary between centers but also between agents (age, familiarity with the technologies). The younger ones have positive opinions. However, many disadvantages were mentioned by both agents and managers:

- Inadequacy of the tablet to the professional activity.
- Technical problems.
- Double work in keeping paper version in addition to digital version.
- Users' negative reaction to the photos taken.

In definitive, Champigny agents think that ensuring the traceability of the activity is not part of the work of field agents (managers do this currently) while not time efficient and effortless. The success of SCOOP system will depend on its ability to provide added value to the staff, becoming a useful tool in their work.

Observations and interviews show the variability of work organization depending of the center. The proposed tool should cope with this variability and allow local adaptations.

We also interviewed agents and managers about their ideas about the system:

- It should also function inside tunnels.
- All vehicles should be equipped because some are used in replacement.
- Issues about geolocation concern exclusively personal trips.

- There are issues about distraction of the driver when agents are alone in the van or when they become pedestrian during an intervention.
- Without repression, announcing the presence of agents on the road will not be sufficient to ensure the safety of agents.
- They think it is not a part of their job to use this kind of system.
- There are doubts about the adoption of the system by road users because some existing apps like Waze offer a good service, because there are concerns about privacy and there is an overload of information
- They see some advantages about the automation and the precision of the information displayed to them and to road users.
- No one mentioned the health risk associated with exposure to the Wi-Fi or Bluetooth waves.

For each observed activity, we identified some actual or potential (in the future evolutions of the system) utilities.

Activity	Actual utility	Potential utility
Patrol	Trace the patrol without any action of the agents Identify the closest agent for an intervention	Indicate the itinerary to be followed
Intervention	Warn drivers to facilitate the access to an intervention Secure the agents on the road Find precisely the location of the intervention Know the source of the report	Find the quickest route to reach the place of intervention
Day work	Calm the aggressiveness of road users Warn drivers to avoid accidents	
Night work	Rapid diffusion of information about closed road, limitation of the phone calls	
Winter viability	Secure agents (isolated worker) Inform users in real time	

Agents have no clear vision of what will the system look like. This led to the generation of an imaginary that may be unfavorable to future implementation. They are waiting to know what the system will be used for and how it works in practice. Factual presentations based on use case situations will be a good way to present the project

to them.
As for the CEI agents, the CIGT operators are attached to their mission of informing road users and are opened to all improvement in that way. During our observations we have seen that the circulation of information and the difficulties that this entails are at the heart of the activity of CIGT operators. They think that SCOOP will facilitate their work through a better flow of information which is going to be more rapid and more accurate. It could help to localize efficiently the place of an event, to know when CEI agents are gone, signifying the end of an event. The SCOOP system could also prevent multiple reports of the same event from being considered as several events.

Compared to CEI agents, CIGT operators are marked by a strong technological culture. The idea of a new system does not seem to frighten them. They still have some reservations. In particular, the system must be fully integrated with existing systems without adding a specific task.

Some utilities of the system are emphasized by agents:

- More systematic transmission of information
- Limited number of calls (suppression of calls at the beginning and at the end of the intervention)
- Precise location of the events
- Automation of the register entries, checked by the operators

6.3.7 Recommendations

1. Maximize the flexibility of the system to adapt it to different organizations which may vary in size and number of centers.
2. Make the system a work tool by integrating it in existing tools and procedures and by involving agents/operators in the evolutions of the system: facilitate the flow of information and communication, securing agents, ease administrative tasks, improve the quality of service for road users, calming road drivers.
3. Communicate quickly in a concrete and applied way to agents/operators, provide training, insist on the improvement of the quality of service for the road users
4. Limit technical problems that could be used as a good reason not to use the system
5. Pay attention to the tasks of the intervention managers who will have to cope with the increase of information.
6. Maintain the current way of communicating between agents and manager but initiate a reflection on the usefulness of some communications between agents and CIGT operators. Define what should be retained and how.
7. Think globally about the communication between DIR agents and external actors like Police officers or republican security company agents.
8. Leaving out of the SCOOP system certain tasks requiring initiative from CIGT operators.
9. Take into account, in the specification of the system, the way of which certain information is disseminated by the operators. For example, for an obstacle that could be mobile, increase the warning area on both directions.

These recommendations have been taken into account.

7 Organizational Impact Study for Traffic Managers

This document provides a summary of work undertaken and results collected by the organizational impact study1 for Project Scoop as part of activity 2.3. This study was started as part of a French Master's degree and then completed during a doctoral thesis in social psychology. It uses a research framework that is grounded in the field of psychosocial engineering (Baillé, Py, & Somat, 1998; Py & Somat, 2007).

Scoop is a pilot project for the deployment of cooperative intelligent transport systems (C-ITS), i.e., systems based on the exchange of information between connected vehicles and roads. In practice, the deployment and use of C-ITS assumes that traffic managers are able to receive and process the information received in order to benefit from it and to send users information on traffic conditions collected via traditional channels (patrol vehicles, cameras, etc.) as well as the new C-ITS channels. As part of Scoop, traffic managers were required to equip operating agents' vehicles with on-board systems with which they could interact using a human–machine interface (HMI; tablet), and also to equip traffic management centers with a computer interface to manage events.

C-ITS devices were intended to complement the tools already used by operating agents as part of their work. It was therefore necessary to facilitate the integration of these new tools into an environment made up of other devices and related practices. For this reason, this study centered on three questions: (1) What is the impact on traffic managers of the deployment of C-ITS? (2) How can traffic managers be supported in this deployment process? (3) What support tools can be used? These questions led us to (1) identify the changes likely to affect traffic managers following the deployment of C-ITS, (2) to participate in supporting the design and deployment of C-ITS by taking into account factors relating to individuals, organizations, and technology, and (3) to formulate some key principles relating to the professional users, the technology, and the organization hosting the deployment in order to support the introduction of technological devices.

7.1 Key Issues and Literature Review

7.1.1 Difficulties related to the deployment of innovations

The systems deployed under Scoop can be considered technological innovations. However, a number of studies indicate that the success of a technological innovation is not guaranteed simply because it was introduced in the best possible manner, and/or was a priori positively evaluated by users. For example, Andréani (2001) writes that 95% of new technologies that enter the market fail. This pessimistic estimate is somewhat attenuated by a study conducted by IBM. According to this study, only 45%

[1] All works and results, in particular the recommendations and the documents created as part of the support process framework, can be consulted in the final report on the action research summarized here.

of organizations believe they have below average results. Additionally, 35% feel that they have been moderately successful in their projects and 20% feel that they have been successful with their innovations. Although we can identify a number of explanations of a technological nature (difficulty in changing systems or processes, lack of data required, lack of know-how or insufficient resources, insurmountable technological obstacles), it remains the case that failure is most often due to the human factor. Indeed, two of the main obstacles cited concern organizational culture (44%) and the fact that the complexity of the project was underestimated (40%) (Jørgensen, Bruehl, & Neele, 2014). As a result, we may conclude that the success or failure of a project is not systematically related to the actual characteristics of the technological innovation, but to the context of its implementation and deployment (Jørgensen et al., 2014).

In light of the difficulties related to the deployment of innovations, we wanted to support the implementation of C-ITS in a way that would promote their success. We also designed this process of support to enable us to learn lessons for future deployments.

7.1.2 Literature review

There are many theories and models in the scientific literature that deal with the adoption of new technologies or individual and organizational change. Acceptance theory is one of the scientific approaches most often applied to the adoption of new technologies. This area of theory has been used to help understand and predict individuals' behavior toward innovations, especially technological ones (for a review see Pasquier, 2012). However, analysis using these models drew our attention to a lack of consideration of the social dimension and a tendency to focus on the study of the relationship between the individual and the technology. Moreover, these models also demonstrate a limited consideration of the dynamic aspect of the deployment of technological systems, although some authors have tried to introduce a longitudinal dimension into their work by distinguishing between a priori acceptability (acceptance before deployment of the device), acceptance (acceptance when first experiencing the device), and appropriation (acceptance after several months of use) (Terrade, Pasquier, Reerinck-Boulanger, Guingouain, & Somat, 2009).[2]

In view of these limitations and also the specific context of Scoop (i.e., the numerous individuals involved [operating agents and traffic management operators] within different departments [Maintenance and Intervention Centers (Centres d'Entretien et d'Intervention, CEIs) and Traffic Management and Engineering Centers (Centres d'Ingénierie et de Gestion du Trafic, CIGTs)]; use of new tools [touchpads and management interfaces] that allow operating agents and traffic management operators to interact with each other), we decided not to rely only on acceptance theory but to employ more systemic models for understanding change. Field theory, as proposed by Lewin (1951), seems particularly relevant to our study. According to this theory, the introduction of a new device disrupts a complex social system (the social field), which

[2] The original terms in French used by Terrade et al. (2009) are *acceptabilité* a priori, *acceptabilité*, and *appropriation.*

in turn is restructured. Considering the difficulties related to the successful deployment of innovations, it seems essential to create a context of support for this disruption in order to achieve a new balance in the system, in which the technology would be fully integrated. Although conceptually rich, this approach has remained at the theoretical stage.
By comparison, other systemic models seem more transferable to specific issues, such as the human-technology-organization (HTO) model and the instrumental approach (also called the anthropocentric instrumental approach). These two approaches both indicate that technology should be seen as part of a three-dimensional system: (1) technology and its features, (2) the organizational context in which technology is deployed, and (3) users of the technology in a professional context (Baron, Bruillard, & Lévy, 2000; Brangier, 2002). The HTO model describes both a goal to be achieved and a process. It describes what the dimensions studied (human, technology, and organization) should aim for, namely a balance in which each partner benefits from the others (= goal), but also the nature of the interactions between these dimensions, i.e., the fact that they evolve simultaneously (= process). The instrumental approach also considers the individual as part of a system, but the central tenet of this theory is the differentiation between artifact (tool or technology) and instrument. When an artifact is embedded in an activity (meaning that it is used and appropriated), it becomes an instrument. It is this process of instrumentalization and its repercussions on other individual activities, but also on the organization and on the technology itself, that interests us. In order to understand these interactions, we need to consider the concepts of activity and scheme. The scheme can be understood as “the structure or organization of actions as they are transferred or generalized when this action is repeated under similar or identical circumstances” (Piaget & Inhelder, 2008). The scheme is thus a set of behaviors and thoughts that facilitate the implementation of more or less contextualized activities. In addition, the scheme of an activity is defined as “whatever is implemented by the subject in order to perform the task” (Leplat & Montmollin, 2004).

According to Vergnaud (1990), human activity can be broken down into several distinct but interdependent components. “Expectations” are the expectations that individuals have about their activity; “rules of action” are the specific means put in place by the individual in order to carry out the activity; “operational invariants” are the knowledge and beliefs that this individual mobilizes with regard to the task, and finally “inference potentials” represent a set of parameters against which the individual measures the importance of adapting in order to achieve the activity. Additionally, Coulet (2011) highlights the presence of feedback loops that help us understand how an activity can evolve (see Figure 6). Several authors have also shown that an activity is not only possible at the human level, but also exists and can be analyzed from the point of view of a group or organization (Bonjour, 2008; Bonjour, Dulmet, & Lhote, 2004; Coulet et al., 2009; Dufour, 2010) or of a technology (Pichot, Quiguer, & Somat, 2018; Quiguer, 2013). It would therefore seem possible to compare these activities to study interactions in the HTO system.

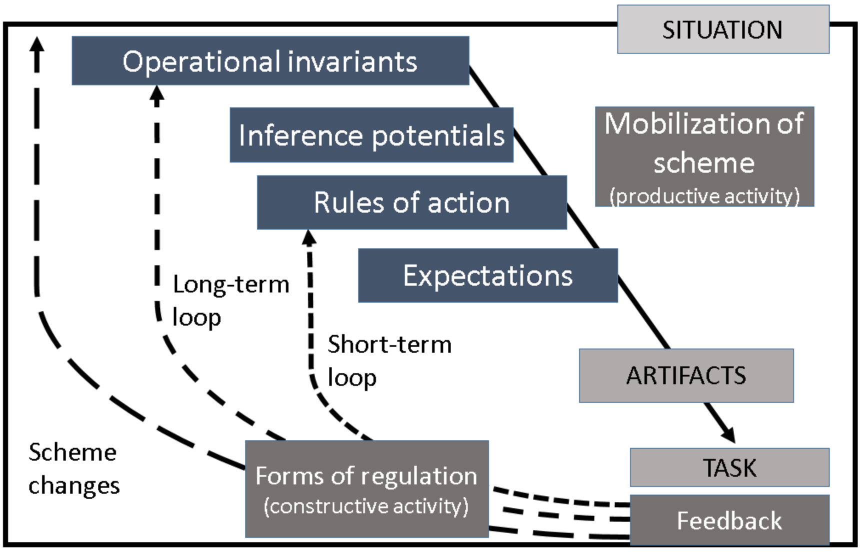

Figure 6: Model of Dynamic Analysis to Describe and Assess Competencies (MADDEC [Modèle d'Analyse Dynamique de Description et d'Évaluation des Compétences], Coulet, 2011)

7.2 Methodology: Designing and Testing an Action Model

7.2.1 Designing an action model

The literature review above indicates that the introduction of a new technology disrupts a system of individuals within an organization. This disruption is dynamic, meaning that its study and support should be viewed in the context of a longitudinal and iterative logic. It is essential to provide support for this period of disruption if we want to ensure the creation of an environment conducive to the use of new technology and avoid its partial or total rejection. In an attempt to encompass these different theories and models, we proposed a model of support that takes into account the strengths and weaknesses of each.

To do this, we have identified three main phases of analysis: a pre-use phase (A), a phase of initial use (B), and a phase of established use of the system (after several months of use) (C). In addition to these key periods, other phases can be considered if necessary (technological or organizational change, etc.). At each phase and in parallel, the technological (1), human (2), and organizational (3) dimensions, as well as their interactions (4), require analysis. This should lead to the proposal of a set of recommendations (5) and to a support process for some or all of these recommandations (6) (see Figure 7 [3]). With the above in mind, the analysis phases (points 1 to 4) can be distinguished from the action phases (points 5 and 6). This distinction between analysis and action phases is artificial and has been created for

[3] This model presents the three phases of analysis that we consider essential for examining the human, technological, and organizational dimensions and their interactions. The interactions between these three dimensions are shown by black arrows. In the first phase, these black arrows are slightly wavy, indicating some disruption because the introduction of new technology has affected the system. In the second phase, the introduction of new technology significantly disrupts the system, as shown by the very wavy arrows. Finally, in the third phase, the arrows have stabilized, denoting that the system has also. The use of arrows is based on the 3-step model of change proposed by Lewin (1947a, 1947b).

the purpose of understanding the process. In practice, this distinction is not this formal, since the tasks are carried out continuously and in parallel throughout the project.

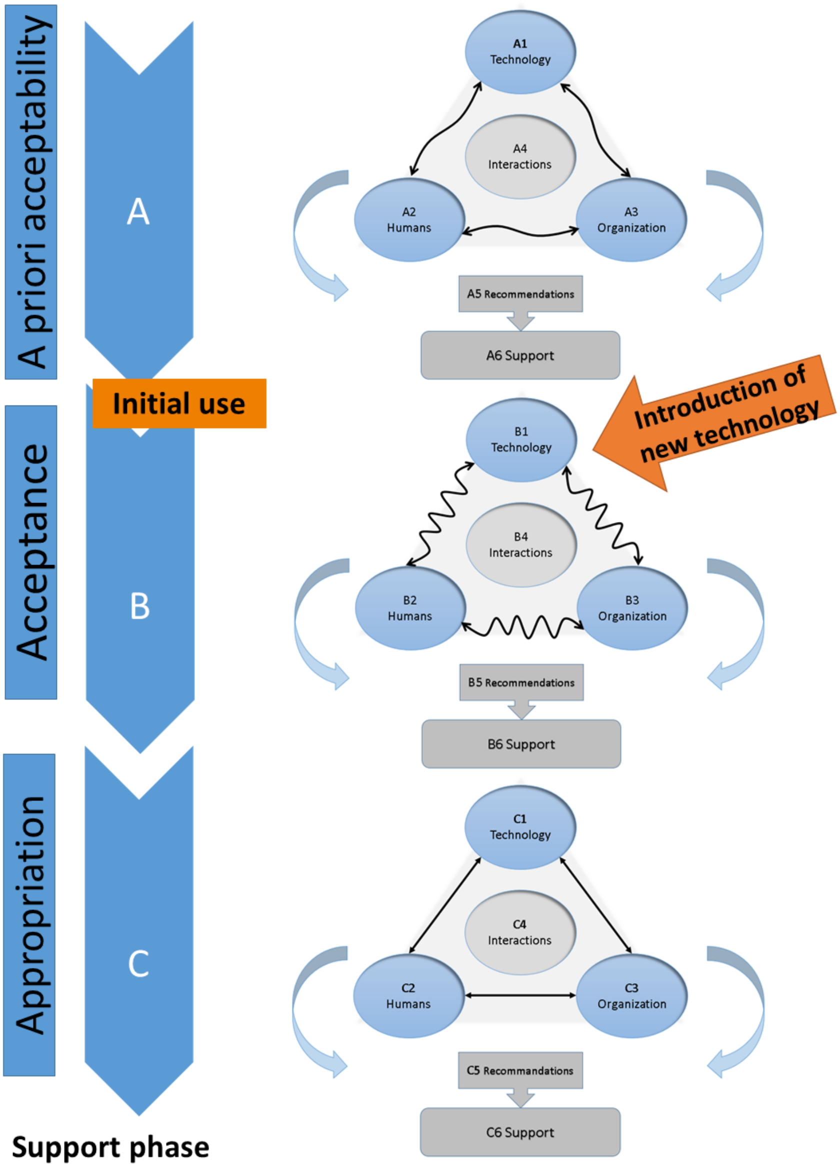

Figure 7: Proposed support model for the deployment of C-ITS

7.2.2 Action research: Testing the support model

Based on a first phase consisting of a context analysis and a literature review, we proposed a support model that is generic yet adapted for the deployment of C-ITS by traffic managers. We decided to test this support model in the West of France and more specifically at the Interdepartmental Directorate of Roads in the West of France (the Direction Interdépartementale des Routes Ouest, hereafter DIR Ouest). Action research seemed the best way to achieve this. Action research is distinguished by its dual aim: (1) it seeks to produce social change in order to achieve a practical goal, and (2) at the same time, it strives to produce new scientific knowledge (Van Trier, 1980). Action research, then, is the development of science in and through action (Rhéaume, 1982). This type of approach makes it possible to compare the theoretical models used with reality and thus to re-examine them. This approach is attributed to (Lewin, 1946).

From a scientific point of view, this action research was intended to:

1. Check that the model has the capacity to be operationalized;
2. Evaluate the relevance and potential side effects (positive or negative) generated by the implementation of the model; and
3. Produce general scientific knowledge on the psycho-social determinants of behavior and more specifically behavior in relation to scientific innovation.

From a practical point of view, this action research should also make it possible to:

1. Check the adequacy of the model for the context studied;
2. Identify impacts that may be caused by the deployment of C-ITS;
3. Establish recommendations to optimize this deployment;
4. Provide support for some of these recommendations; and
5. Gain feedback on the entire process with the aim of identifying some essential principles for supporting the deployment of technological devices to be used by traffic managers.

7.3 Results of the Action Research

Three main studies, based on the methodology described, were conducted. They will be presented in the order in which they were carried out. These studies enabled us to identify various findings and propose recommendations. These findings and recommendations were shared as each study was completed. We have retained this information without making too many changes because our results illustrate a state of affairs at a given moment. This information should give any new traffic manager intending to deploy C-ITS a clear understanding of the problems that may be encountered. A number of the recommendations had already been applied or considered at the time that this document was created. Lastly, a general and updated summary table of **all recommendations for traffic managers new to deploying C-ITS is available at the end of this document**.

7.3.1 Study of the impacts of C-ITS on the roles of operating agent and traffic management operator

7.3.1.1 Methodology

The first study, which we conducted prior to the deployment, focused on the impacts of C-ITS on the roles of operating agents in CEIs and of traffic management operators in CIGTs, or in other words those roles that are the most affected by the deployment of Scoop.

The study was conducted in two stages. The first stage consisted of gaining an understanding of the way the HTO system functions. To this end, we first studied (1) the way in which C-ITS should operate at DIR Ouest as part of Scoop, and then (2) analyzed how the organization worked as a whole so that we could finally (3) analyze the activity of operating agents and traffic management operators (N = 17 or ~ 51 hours of analysis) (of site activity, patrols, interventions, and winter viability). In the second stage, we sought to identify the interactions between these three dimensions. For this purpose, we (1) compared the activities against each other using a matrix, (2) introduced DIR employees and line managers to Scoop during interviews (N = 17), (3) introduced DIR employees and line managers to the project during focus groups (N = 23), and (4) interviewed them via a questionnaire about a priori acceptability (N = 34).

7.3.1.2 Findings and recommendations

This first study of the HTO system presented various findings that led us to propose a set of recommendations to promote the deployment of C-ITS. The table below presents the various findings and associated recommendations.

Table 2: Findings and recommendations from the study of the impacts of C-ITS on the roles of operating agents and traffic management center operators

<table>
<tr><th>Findings</th><th>Recommendations</th></tr>
<tr><td colspan="2">Reaction to C-ITS</td></tr>
<tr><td>Concerns of some employees about the complexity of C-ITS.</td><td rowspan="3">DIR Ouest (Direction Interdépartementale des Routes Ouest [Interdepartmental Directorate of Roads in the West of France]) (1) Provide information about C-ITS and associated projects (Scoop, C-Roads, etc.). (2) Strengthen communications about the usefulness and especially the added value of C-ITS compared to similar systems already in existence internally or externally. This is a crucial factor for acceptance and appropriation. (3) Continue meetings with the ambassadors of the different services and ensure the distribution of information.

DIT (Direction des Infrastructures de Transport [Directorate of Transport Infrastructure]). Build an information strategy internally and externally around C-ITS and related projects.</td></tr>
<tr><td>Correspondence between the purpose of C-ITS and the professional role of employees: enhancement of road safety, improvement of traffic management, management of real-time events and of services for users.</td></tr>
<tr><td>Employees' questions about the added value for the government of deploying C-ITS (compared to similar services already in existence, e.g., Waze).</td></tr>
<tr><td>Concerns about misuse, especially relating to geolocation and monitoring.</td><td>DIR Ouest. (1) Set up additional safeguards (user mode, regulation, non-transferable authentication, voluntary action, etc.). (2) Communicate that the aim is not to geolocate operating agents and that safeguards exist and will be reinforced (e.g., via data security such as CNIL, PKI, etc.).

DIT. Support DIRs on this issue, which may present an obstacle to deployments.</td></tr>
<tr><td>Concerns about work overload and distraction during driving caused by the presence of an additional device in operating agents' cabs - CEI.</td><td rowspan="2">DIR Ouest. (1) Communicate results of studies evaluating the HMI in traffic management vehicle (TMV) OBUs and driver distraction. (2) Involve operating agents in co-designing more ergonomic driving cabs to enhance the usability of C-ITS and thus improve acceptance and appropriation. Emphasize the interconnection between devices and the automation of certain actions. (3) Launch</td></tr>
<tr><td>Concerns about work overload caused by the presence of an additional device in CIGTs.</td></tr>
</table>

	a program to optimize devices incorporating C-ITS. **DIT.** (1) Communicate the results of impact studies. (2) Initiate reflections on the ergonomics of cabs across all DIRs. Potentially pool developments and/or devices. (3) Build a forward-looking approach to the development of devices used by the DIRs.
Employees' questions about consultation and integration of trade unions' views on C-ITS.	**DIR Ouest**. Organize regular and transparent progress meetings with the trade unions to communicate and avoid potential obstacles. This helps to "demystify" the process and to take into account concerns expressed. **DIT.** Propose points of communication to the DIRs and support the process of taking into account the concerns expressed by the trade unions.
Concerns about the reliability of information received.	**DIT.** Verify the reliability of information in the systems.
C-ITS and the development of professional roles	
Initial co-design activities (rolled out for this study) were highly appreciated by employees.	**DIR Ouest**. (1) Communicate about follow-up action on co-design work to encourage participation. (2) Communicate reasons why some views were not taken into account, where necessary. **DIT.** Present and promote the methodology to other managers.
Employees' concerns about whether their views were really taken into account.	
Employees' concerns about modification or discontinuation of activities. The deployment of C-ITS raises questions about some modes of operation. **Points of context.** DIR Ouest collects, processes, and distributes traffic information using relatively vertical procedures whereby information is passed upwards from those working on the ground toward line management and the CIGTs. The CIGTs are responsible for distributing this information to users. Line managers and the CIGTs are also responsible for directing interventions by operating agents. **1. A new way of collecting traffic information: workload, relationship to external actors, and level of service.** With C-ITS, information feedback is live and does not use an intermediary as is currently the case with the police forces. Should DIR Ouest inform the police of events that have been reported to ensure they have been alerted? Moreover, without this filter, and with a large number of users, C-ITS could lead to an increase in the volume of information that DIR Ouest has to deal with on a daily basis. This could lead to an increase in the workload of CIGT operators. This also raises questions about the level of service: does more information imply more operations to	**DIR Ouest.** **Co-designing to facilitate the integration of C-ITS**. Deploying C-ITS without addressing the various findings presented here would lead to disparate practices and internal tensions. We recommend initiating a process of reflection on new ways of working with C-ITS. To aid acceptance and appropriation, these ways of working should reflect actual activity of employees (Coulet, 2011). Co-design is the best solution (Bernoux & Gagnon, 2008). **Moving toward new procedures.** We supported DIR Ouest in defining new work procedures. We formed a working group of about twenty people with very different profiles: operating agents (CEI), team leaders (CEI), traffic management center operators (CIGT), heads of management centers (CIGT), and district and branch operating agents. With this group, we co-designed new ways that operating agents and traffic management operators can work with C-ITS. An evaluation will be undertaken to take into account these changes in practices and to adapt the procedures as necessary. **Employee training.** Based on the analysis of work activities and the new co-designed ways of

be undertaken by operating agents? DIR Ouest is planning an evaluation and possible changes. **2. Means of communication and the CEI/CIGT relationship.** The introduction of C-ITS could change the relationship between operating agents and traffic operators (also the case for other types of on-board systems). Operators use the telephone to pass information to the CIGT. As an addition to the telephone, passing on information via the TMV OBUs may be perceived by operating agents as a form of duplication. In practice, this could lead them to abandon using the phone in favor of the TMV OBU. For the purposes of the trial, DIR Ouest wanted to maintain use of the telephone. DIR Ouest is planning an evaluation and possible changes in means of communication. **3. A new information circuit: new tasks and responsibilities?** C-ITS mean that operating agents distribute and receive live traffic information. This task does not currently fall to them. In addition, this information could give them the ability to manage their interventions in full (detection of events, route management, resolution, communication). C-ITS therefore raise questions about the tasks and responsibilities of CEIs and, by implication, those of the CIGTs. The process of answering these various questions will help define new procedures that will lead to changes in the activities of future users.	working, training programs have been developed. These are based on MADIC (Modèle d'Aide au Développement Individuel des Compétences [Model to Help Individuals to Develop their Competencies] proposed by Coulet, 2011). They are intended to (1) deconstruct existing activity, and (2) develop the skills of individuals receiving training. **DIT.** (1) Follow up on feedback from DIR Ouest about the changes in work roles and their interactions in order to consider national developments where relevant. (2) Present and promote the support process to other managers to ensure a minimum level of performance.
The deployment of C-ITS will cause unexpected changes in the activities of employees and services.	**DIR Ouest**. A follow-up on developments in activity appears essential to implement adaptations and ensure that objectives are met. **DIT.** Follow up on feedback from DIR Ouest and other managers.

Following these recommendations, DIR Ouest initiated a number of action points. Among the most significant were two projects that were launched to facilitate the operating agents' work and optimize the integration of the new device. The aim of SAGACITE was to create a Traffic Management Support System (Système d'Aide à la Gestion de Trafic, SAGT) that would serve as a single interface for recording and managing events. The objective of the Fourgon 2020 project was to design the traffic management vans of the future with intelligent and interconnected equipment.

The first study indicates that C-ITS seem to have significant impacts on operating agents' and network monitors' roles. These systems represent a new vector of information (feedback and emissions) that should gradually encourage traffic managers using the equipment to examine their current organization and potentially to adapt their operational methods.

7.3.2 Study of the impacts of C-ITS at organizational level

7.3.2.1 Methodology

Following the results and recommendations from the first study, we wanted to study the more general impact of C-ITS on the organization of a traffic management directorate, namely DIR Ouest. This study, conducted prior to deployment, was also intended to allow us to identify other job roles that could be affected by the deployment of C-ITS. To carry out this study, we had to take into account (1) the use of C-ITS at DIR Ouest as part of Scoop and (2) the nature of DIR Ouest's activity. For the first point, we endeavored to refine the analysis that was carried out in the first study. For the second point, we conducted interviews with all department heads of DIR Ouest services (N = 14 / ~ 24 hours of interviews). We then studied the interactions between these two dimensions. We focused on (1) the interaction between the activities, as well as on (2) the exchanges that took place during the interviews.

7.3.2.2 Results and recommendations

The results of this study highlighted the fact that all DIR Ouest services were impacted by the deployment and exploitation of C-ITS. In total, 47 of the 69 "rules of action" (or actions) implemented by DIR Ouest services were likely to be, have been, or will be impacted by C-ITS. Most of the impacts identified were grouped according to seven themes. These are shown in the table below (see Table 2).

Table 3: Findings and recommendations from the study of the impacts of C-ITS on the organization of DIR Ouest

Findings	Recommendations
Strategy for dynamic equipment	
C-ITS could eventually do the job of other equipment used in traffic management: variable message signs (VMSs), inductive counting loops, etc.	**DIR Ouest and DIT.** Initiate a process of reflection on strategies for managing existing and future equipment to avoid duplication of information, to rationalize costs, and to ensure equipment is compatible.
Managing on-board systems	
The deployment of TMV OBUs highlighted the need to monitor and construct developments across the entire vehicle fleet and installed equipment. There are many OBUs and they come in many different models (or brands). Moreover, no tool existed to control them collectively. Various local and national projects providing tools for operating agents coexist: OBUs, on-board transaction logs, intelligent wildlife warning systems, etc.	**DIR Ouest.** Structure DIR Ouest policy: organize the monitoring and development of on-board systems and vehicles, optimize the coordination of different on-board systems, streamline on-board systems in operating vehicles by developing interconnectivity and device pooling; reflect on the deployment of on-board transaction logs within DIR Ouest's area; develop a prototype van to create a strategy to ensure compatibility of devices. This approach aims to improve the ergonomics of cabs and operating agent safety in order to promote acceptance and appropriation, and in turn efficiency. **DIT.** (1) Educate managers on vehicle and on-board systems management processes. (2)

	Initiate a process of reflection about a national equipment pilot project (on-board transaction logs, intelligent wildlife warning systems, etc.) to encourage streamlining of equipment and to meet individual needs and specificities. (3) Initiate a process of reflection on the structure of inter-DIR strategy for on-board systems in order to organize the issuing of instructions, command strategy (i.e., the possibility of using command groups such as the SAGT SAGACITE), the maintenance of on-board equipment, and to create budgets for these various activities. It may be useful to involve equipment suppliers in these processes of reflection.
Exploiting and benefiting from recorded C-ITS data	
C-ITS could in the long term produce large quantities of recorded data that will be useful to traffic managers.	**DIR Ouest**. Reflection on the management of C-ITS data internally. It is in the interest of various services that C-ITS traffic data should feed into a range of activities: knowledge of the network, provision of additional road information to users, operational diagnosis, development of maintenance and modernization policies, identification of gray areas, definition of operational processes, evaluation of highway projects (e.g., traffic flow, incidents, etc.) and so on. **DIT.** (1) Initiate reflections on the extraction, backup, and use of C-ITS data: what infrastructure and what skills are required? (2) Ensure the coherence and integration of C-ITS with other systems or processes that facilitate the use and sharing of data (e.g., integration of roadside units [R-ITS-Ss] in Geographic Information Systems [GISs]) (3) Streamline and avoid initiating other projects (related to road safety) based on the collection of data similar to those resulting from C-ITS (e.g., driver data). Anticipate the installation of additional equipment (e.g., accelerometers) to optimize data collection and facilitate data use.
Creating a favorable environment for the development of C-ITS-related skills through career development and career management	
Activities related to dynamic road signs and C-ITS require specific skills (managing the development, integration, and maintenance of the electronic infrastructure; organizing tests, installing R-ITS-Ss, installing OBUs, reading documents, etc.) which has led to the formation of an extended team equipped with these skills. In comparison to other activities, C-ITS projects involved a small number of employees.	**DIR Ouest**. (1) Organize project ownership: recruit an assistant project manager (APM), form a number of inter-service working groups (R-ITS-Ss, OBUs, and information systems), set up a COTECH (technical committee) and COPIL (steering committee), set up meetings of representatives. These actions are part of the acculturation and skills enhancement of DIR Ouest's partners and services. (2) Organize contract management: provide support framework for the Highways Engineering Service (HES), engage specialists to support the development process (doctoral study, external

	academic expertise, Cerema, and private service providers). **DIT.** (1) Need to promote intelligent transport systems (ITS) and C-ITS to attract skilled employees. (2) Need to develop a career management policy to include the skills needed to work with ITS and C-ITS (initial and ongoing training, both internally and externally and for new and existing employees; specialist working groups, etc.). (3) Initiate reflections on the role of APMs to strengthen teams. If this solution is used, there will need to be review of public procurement and of the optimization of coordination between actors.
Integrating C-ITS into working methods and into training for future users	
The initial C-ITS training was planned as a module that introduced various new elements to core activities. In general, modular training can carry the risk of confusing operating agents and even conveying conflicting messages. In addition, this format could give the impression that traffic information is not an essential component of operating agents' role. It should be noted that training does not amount simply to giving guidelines. The real nature of operating agents' activities must be taken into account in order to ensure proper appropriation (MADIC, Coulet, 2011).	**DIR Ouest.** In the short term, DIR Ouest planned specific training events to help launch the trials. In the medium term, DIR Ouest plans to integrate a module on C-ITS into operating agents' initial and refresher training. **DIT.** In the long term, it is desirable to integrate C-ITS training and other additional/modular training into core training programs.
The development of traffic information and related roles (CEI/CIGT)	
Lack of regulation	
Because they are such a recent development, C-ITS do not feature in national guidelines on traffic information provision.	**DIT.** Update reference documents (Section 9 of the French governmental memo IISR on traffic signalization and technical notes on traffic information) and create a technical corpus and updated working standards ready for future deployments.
Coordination of traffic information	
The increase in the number of modes of communication has given rise to a need to set up a centralized review on the meaning and nature of the messages transmitted to users by these various modes (VMSs, Tipi, C-ITS, etc.). Need to develop use reflections to ensure that traffic messages can be clearly understood by users.	**DIR Ouest**. A process to structure information policies has been initiated at DIR Ouest (with DIT assistance). Coordination is underway and communication events (particularly on the highways information circuit) and training are planned for employees. A road information guidance document (DOIR) will be drafted to coordinate DIR Ouest's highways information policy, just as the winter viability guidance document (DOVH) coordinates a number of operational activities. **DIT.** Initiate reflection on the structure of traffic information at national level. This could potentially lead to the creation of a DOIR by all managers.
CEI-CIGT relationship	

The relationship between CEIs and CIGTs is organized around the telephone. CEIs inform CIGTs by this means. The TMV OBU presents a new mode of information. There are two possible outcome scenarios: (1) operating agent interaction with traffic information is improved thanks to the visuals on the tablet and their new functionalities - the outcome would be an improvement in the production of traffic information; (2) operating agents perceive either the phone or tablet as a pointless duplicate and abandon one of the two means of communication - the outcome would be a loss of efficiency in the production of traffic information and/or an organizational change in communication methods.	**DIR Ouest**. Carry out an evaluation following the trial and, if necessary, identify areas for development. **DIT and DIR Ouest**. (1) Remain attentive and carry out an evaluation of future transformations in the relationship between CEIs and CIGTs to ensure awareness of the real consequences of the deployment. (2) Initiate reflection on the compatibility of information transmission devices (C-ITS, telephone, radio) to encourage appropriation.
Traffic information circuit	
C-ITS will lead to greater and faster availability of information about events via new channels. In the future, will DIRs have to alert the police? More generally, what will be the link between the DIRs and the police?	**DIR Ouest**. The “Grand Ouest” trial envisaged cooperation with the French police with the aim of enabling reflection on inter-service relations. An evaluation will be undertaken. **DIT.** (1) Need to re-examine the traditional traffic information circuit and relationships with other stakeholders and other government ministries. (2) Initiate interministerial reflection on the deployment of C-ITS technologies in police vehicles.
Processing user information	
The deployment of C-ITS has raised many questions about the information generated by users. Can user information be trusted? How should user information from C-ITS be processed? If this information merits being used, should we also retrieve information from other existing cooperative/collaborative systems?	**DIR Ouest**. Closely monitor the impact on employees’ workload to avoid overload and tension within and between services. **DIT.** Test the reliability and frequency of events reported by users. Evaluate the contribution of user data via C-ITS and its compatibility with other modes of data collection.
Public-private relationship	
There is frequent internal questioning about the role of the government in these projects. Are C-ITS viable in a context where the government has to make its information available to the private sector? Other information systems will have access to government information AND user information (shared by the mass of users). These systems can alert the police (which is of high value for the user). In this context, what is the added value of C-ITS for users? Can C-ITS prevail in this context? Are C-ITS “condemned” to be systems used only by traffic managers? What means can be deployed to democratize C-ITS? Is it the role of the government to provide this service? If the government withdrew, what possibility would there be to create added value via other existing systems (e.g., specific rerouting) or through user data?	**DIR Ouest**. Communicate to teams about specific contributions of C-ITS (multimodality, autonomous vehicles, etc.) and their compatibility with private systems. **DIT.** (1) Undertake an evaluation of compatibility between public and private systems (number of users, services offered, safety improvements, etc.). (2) Initiate strategic reflection on the place of C-ITS and public and private highway managers in the traffic information context, and subsequently on measures to be put in place. (3) Examine interactions that will be necessary with private systems (rerouting policies, HMI standardization, etc.). (4) Communicate about both internal and external factors (users, partners, etc.).

<table>
<tr><th colspan="2">Evolution of the relationship between traffic managers and users</th></tr>
<tr><th colspan="2">A new link to the user</th></tr>
<tr><td>C-ITS are new modes of communication compared to existing modes. C-ITS communicate live (V2V, I2V & V2I) and create a new proximity with users and therefore a new relationship.</td><td>DIR Ouest and DIT. Following C-ITS projects, evaluate new relationships and their impacts on traffic managers.</td></tr>
<tr><th colspan="2">Evolving from a service for users to a service for each user</th></tr>
<tr><td>Potential to improve the current service AND to generate new services. C-ITS assist users from the beginning to the end of their journeys. The systems make it possible to personalize information to the user, which was not previously possible.

The user has access to various networks and not just the national highways network (réseau routier national, RRN). C-ITS transcend networks. This presents a real opportunity to create partnerships (with traffic managers and transport networks) to improve mobility.</td><td>DIR Ouest. Partnerships initiated with local authorities as part of Scoop and on an ongoing basis. C-ITS have created opportunities to offer new mobility services to users.

DIT. (1) Produce an evaluation following the trial. (2) Use C-ITS to support all DIRs in creating more partnership services (in accordance with French law on mobility, LOM 17/09/19).</td></tr>
<tr><th colspan="2">The user as both beneficiary and partner?</th></tr>
<tr><td>The user benefits from the information transmitted by traffic managers but also becomes a partner in the creation of traffic information and potentially later in the creation of other services.</td><td>DIR Ouest and DIT. A trial has been initiated to create user committees to evaluate services currently offered and to co-design the services of tomorrow.</td></tr>
<tr><th colspan="2">Involvement at all levels</th></tr>
<tr><td>Integrating C-ITS into the activities of DIR Ouest is not a neutral event but has purpose. It involves motivating employees and supporting changes in practice and organizational innovations brought about by C-ITS.</td><td>DIR Ouest. Continue integrating C-ITS into the next project.

DIT. Integrate C-ITS into the strategic objectives of DIRs. The entire work hierarchy must be involved as well as all the managers across services, from operational to maintenance.</td></tr>
<tr><th colspan="2">General recommendations for the DIT</th></tr>
<tr><td colspan="2">Simply asking traffic managers to deploy C-ITS is not in itself enough to make them a success. There is a need for ongoing practical reflection on the real objectives of the Ministry of Ecological and Solidarity Transition (Ministère de la Transition Écologique et Solidaire, MTES) in relation to the deployment (area? level of service? route and/or mobility? place of users?) and in the context of the actual impacts of C-ITS.

Deploying C-ITS entails a direct examination of the activity (or service project) carried out as part of the structure (i.e., objectives, aims, etc.), and thus of the meaning of employees’ work (from road maintenance, to providing services to users, to developing mobility). In addition, these systems cause us to review the interactions between DIRs, their beneficiaries, and their partners. One area of such review is the proximity with the user (C-ITS could strengthen the link between operating agents and users); another is the place of the user in the structure (i.e., their transition from beneficiary to partner). These systems also cause us to re-examine existing interactions with public partners such as local authorities. C-ITS offer the potential to develop new services within an area, which implies shared governance and reflection.

Carrying out this in-depth process of reflection will facilitate better communication and, especially, support for the managers affected by the deployment of C-ITS so that they are able to appropriate them and deploy them in an optimal manner (i.e., communicate, motivate employees, support</td></tr>
</table>

changes in practice, and facilitate structural evolution). Time must be set aside to carry out these different steps.

It can be concluded that the deployment of C-ITS may have a significant impact on traffic management organizations. These systems must therefore be deployed in accordance with specific objectives that must be anticipated in order to guarantee success. This makes it important to take into account not only direct impacts but also first and foremost the indirect impacts that we believe are shown, at least in part, in the results of this impact study. In addition, a number of considerations have emerged that will help develop the organization of traffic managers as well as the roles they carry out and tools they use, thus facilitating the smooth integration of C-ITS.

7.3.3 Study of the impacts of C-ITS on the roles of system and network administrators and maintainers of roadside equipment

7.3.3.1 Methodology

The study of the impact of C-ITS at organizational level identified two roles that seemed highly likely to be affected. These are system and network administrators and maintainers of roadside equipment. The activities carried out by these employees are essential for the deployment and efficient operation of C-ITS. We therefore wanted to further examine the nature of the impacts of C-ITS on these two roles prior to deployment. During this study, as during the study of the impacts of C-ITS on operations and monitoring, we proceeded in two stages. The first stage was to understand the functioning of the HTO system. To this end, we first studied (1) the way in which C-ITS were designed to work at DIR Ouest as part of Scoop, then (2) we analyzed, by means of interviews (N = 2), the way the activities pertaining to these roles were organized, and finally (3) we examined the initial activity of the administrators and maintainers, again using interviews (N = 5). In the second stage, we sought to identify the interactions between these three dimensions. To this end, we (1) compared the roles against one another and (2) introduced administrators, maintainers, and their managers to Scoop during interviews (N = 7).

7.3.3.2 Results and recommendations

During this study, we identified findings and recommendations, split across three phases (see Table 3). The first phase relates to the design of the C-ITS. The second phase is the installation (or integration) of these systems into the existing framework. The third phase corresponds to the operational period, incorporating network administration and equipment maintenance. These three phases are of course interdependent because if the design or installation phase is incomplete, it will be more complex to manage the operation of the systems.

Table 4: Findings and recommendations from the study of the impacts of C-ITS on the roles of system and network administrators and maintainers of roadside equipment

Findings	Recommendations

Phase 1: Systems design	
Initially, the teams were introduced to C-ITS. They had the opportunity to see their complexity: innovative technologies, interactive equipment, numerous partners and service providers with various degrees of familiarity with the system. The real nature of roles related to administration and maintenance is not well known. There is an existing risk that organizations may not call upon teams at the ideal point in time. In this context, teams may be forced to focus on a narrow segment of the system and not have a global vision. There is a risk of not understanding the usefulness of C-ITS or the complexity of the design of the full chain of computer systems and C-ITS equipment within the chain of existing tools	**DIR Ouest**. (1) Involve administrators and maintenance engineers by creating a project team to focus on the computer system, its administration, and its maintenance. (2) Communicate to create a global vision and to validate the project and the current and future role of these employees. This will contribute to better understanding and motivation. **DIT**. (1) Promote involvement and communication with the teams in charge of IT structures, administration, and maintenance in DIRs. Anticipate and plan a period of learning for those working with ITS because there is inevitably a need to invest time and energy to achieve an increase in competence. (2) Take advantage of work done at DIR Ouest on team cooperation procedures.
Phase 2: Systems Installation	
Informing administrators and maintenance engineers about the importance of anticipating the installation of equipment. For example, decisions related to the installation of R-ITS-Ss have significant impacts on team activities (administration, maintenance, and operation of highways). These decisions must be considered carefully (i.e., areas of poor signal, secure access, groupings etc.).	**DIR Ouest and DIT**. Involve teams in the installation of equipment to avoid subsequent technical problems or problems during use.
Phase 3: Systems operation	
Following the design and installation phases, it became clear that we need to integrate these systems into administration and maintenance strategies. Methods for integration were discussed: in-house, partial or total, or using outsourcing.	**DIR Ouest**. (1) Initiate reflection on strategy and procedures for administration and maintenance during the trial. Undertake a review to capitalize on feedback and adapt strategy for the operational phase. (2) Train these employees accordingly. **DIT**. (1) Make use of feedback on the strategy and procedures employed by DIR Ouest to manage the administration and maintenance of C-ITS. (2) Following Scoop: plan for the possibility of purchasing new equipment (R-ITS-Ss, OBUs, etc.) and plan a budget for the administration and maintenance of systems and equipment. (3) Initiate reflection on the sharing of certain tasks at DIR level.
Administrators and maintenance engineers already had tools to manage the systems and equipment they supported. C-ITS management equipment and tools have been developed alongside existing systems within teams. The question of integration has therefore arisen. As a minimum requirement, administrators recommend the creation of a central supervisory system that integrates all information from C-	**DIR Ouest and DIT**. (1) Initiate reflection on the integration of C-ITS into the existing IT framework. (2) Initiate reflection on the integration of equipment into the CMMS and on the creation of an on-board module dedicated to administration and maintenance.

ITS servers. Maintenance engineers recommend the integration of R-ITS-Ss into their computerized maintenance management system (CMMS) software. In addition, an on-board module would provide live information on equipment. This module could also facilitate exchanges with partners (administrators, CEIs, and CIGTs) during interventions (information relating to broken equipment, alerts about interventions, etc.).	**DIT**. (1) Initiate reflection on the development and/or evolution of administration and maintenance management tools (e.g., SAGT connection modules, server supervision tool, on-board maintenance module, etc.) at national level for DIRs. (2) Initiate reflection on how C-ITS would help develop existing communications and relationships among managers to improve efficiency.
The deployment of C-ITS has introduced new equipment and new action points for the administration and maintenance teams. DIR Ouest has planned appropriate training sessions.	**DIR Ouest**. Provide training that caters for the actual employee activity (Coulet, 2011). **DIT**. (1) Provide technical guides for the installation, administration, maintenance, and upkeep of C-ITS. (2) Define tasks and tools provided and/or managed at national level and those managed at local level. Share feedback from the DIRs.
These employees are sometimes victims of abusive behavior by users. Could C-ITS help improve the image of those who work on the highways (carrying out operational and maintenance activities)?	**DIR Ouest and DIT.** Initiate reflection on how to communicate with users through C-ITS. What kind of messages is it possible to send? Subject to what conditions?

We emphasized the fact that the roles of network and system administrators and equipment maintainers would be greatly impacted by the deployment of C-ITS. The appropriation of these new systems and new modes of working necessarily involves (1) involvement of teams to ensure that the reality of their work can be taken into account when devising solutions, and (2) their training.

7.3.4 Quantitative assessment

After undertaking the work presented above, we sought to assess the overall support process. We created and distributed a questionnaire to operating agents and traffic management center operators (63 items) as well as a questionnaire to their line managers (73 items). These questionnaires were distributed to DIR Ouest (where the support process was implemented) as well as to two other DIRs who participated in Scoop. Our intention was to compare the results obtained at DIR Ouest with a control group. A total of 390 people (40.9% of survey recipients) responded (NDIR OUEST = 254, NOTHER = 136).

The key results show that the overall support process at DIR Ouest seems to have had positive impacts. For example, employees are more familiar with Scoop and C-ITS and feel they are in a better position to use them. In addition, they feel their managers have a better awareness of them. Lastly, DIR Ouest employees are more positive about the deployment of these new technologies.
More specifically, employees who were directly involved in the process are more familiar with the project and C-ITS and feel more able to use them. Their intention to use these systems is very high, as well as their intention to recommend their use. These employees are very positive about the deployment process that has taken place. Moreover, the support process seems to have had the effect of reinforcing the general

feeling of participants that their job matters.

Although the results at DIR Ouest are more favorable toward C-ITS, we could not find any statistically significant differences in understandings of these systems (ease of use, attitude, etc.). It is likely that, at the time of the survey, DIR Ouest employees had not had feedback on all measures intended to facilitate their appropriation. After further communication, a subsequent assessment could help to refine the results.

7.3.5 Qualitative assessment

Alongside the quantitative results presented above, this support had some qualitative results that were achieved throughout the process but could not be formally measured in any way.

One of the main results was DIR Ouest's and the DIT's implementation of the recommendations put forward. For example, DIR Ouest employees voiced their concerns about the potential problems that could result from real-time vehicle geolocation. DIR Ouest has therefore undertaken not to use these systems to track operating agents as they travel, and has instead proposed various practical solutions. Our recommendations also led to the launch of new projects at DIR Ouest with specific support from the Ministry of Ecological and Solidarity Transition with a view to national deployment. One example is the creation of a new SAGT to provide CIGT operators with a single interface for event and equipment management. In addition, the launch of the Fourgon 2020 project aimed to create vehicles in which the control interfaces of the tools available to operating agents would be shared and/or interconnected. Ultimately, these projects aimed to improve the working conditions of operating agents and traffic management operators. Beyond the launch of these new projects, it is interesting to note that other projects have been inspired by the support method (e.g., the approach to structuring road information).

Lastly, it seems important to us to mention the relationship between DIR Ouest and the trade unions. Throughout the deployment process, milestone points were reached with trade unions. Transparency and the approach taken have reassured them overall. During meetings, the trade unions even thanked DIR Ouest for consulting stakeholders and genuinely taking employees' views and concerns into account. C-ITS were on the whole well received because they enable DIRs to regain their place as a state and public service in the road information chain. The trade unions have even asked that the project be able to complete its work but also that it be able to go further (offering new services, new functionalities, etc.).

7.4 Conclusion and Insights

During the course of this impact study, we discovered that C-ITS are a form of innovation that is fully in line with the formal objectives of traffic managers. Moreover, these systems are in tune with what operating agents and traffic management operators want to see in their work: more real-time information, greater and better network visibility, easier interventions, more services including new services for users across the network and beyond, improved understanding of the network and the uses that are made of it, and more. This is an important result: in many cases of technological innovation, the projects or innovations planned by organizations are not perceived as being in line with the way the professionals concerned view their work, a fact that poses a major obstacle to their appropriation. In fact, innovation can be seen as disruptive and can cause negative impacts or even psychosocial risks. The fact that Scoop is perceived as being in line with professional objectives and roles is an important lever in the movement toward acceptance.

In addition, the traffic managers we met realized that C-ITS offered them new opportunities. For example, live connectivity with vehicles will allow them, as government employees, to work more closely with vehicle users. This connectivity was previously only available to private operators, and came with potential risks (use and sale of user data, unreliable algorithms for working out routes, etc.). The arrival on the scene of these private operators and their services has caused upheaval in users' relationship with the highways network. Previously, highway users only had access to information provided by traffic management centers, but this is no longer the case. However, traffic managers are best placed to qualify road information and intervene if necessary. C-ITS has therefore allowed managers to resume their place in this ecosystem, which would not have been possible without these new technologies. Similarly, the employees we met realized that the context of the highway and the way it is used has undergone a period of great change in recent years. They viewed the arrival of C-ITS as an appropriate means of bringing greater added value to their work, as well as possibly the benefit of greater social recognition. It is indeed a mark of success that employees and line management seem to agree on the potential of C-ITS.

The support process presented in this document was highly valued by participants, however closely they were involved. In addition, the process has created many results that meet the initial objectives. Firstly, the three studies presented here have highlighted the fact that the deployment of C-ITS inevitably leads to a reappraisal of the organization of traffic managers and their main activities. The most impacted roles have been shown to include those of operating agents, traffic management operators, system and network administrators, and equipment maintainers. More generally, all services are impacted. The number of activities impacted indicates that the developments brought about by C-ITS can be anticipated and support provided to promote their success. This process should be carried out by each traffic manager. On the other hand, certain action points or studies (e.g., study of the use of C-ITS by users) should be carried out at national level since all DIRs are directly concerned.

Following the process described above, a number of specific recommendations have been formulated to enable a new traffic manager to successfully deploy C-ITS. These recommendations have been summarized in table form (seeTable 5). In applying these recommendations, it is essential to prioritize two key principles: the actual nature of work should be taken into account, and line management should receive training. Indeed, understanding the actual nature of work is the main factor in the success of C-ITS deployment. Ultimately, this is what ensures good appropriation by future users. This understanding must be based on the reality of their work activity and not on the way that their work is perceived by their superiors or by the developers of the technology. Although this point may seem trivial, this understanding is far from being the norm within organizations (Leplat & Montmollin, 2004). For this reason, simply having access to the recommendations proposed below or having access to support is not enough to guarantee the successful deployment of C-ITS. This is why we believe it is essential to raise awareness among line management and to involve and train them in this mode of understanding the appropriation of new technologies. Vertical management has some advantages, but it is not a suitable solution for the successful deployment and use of innovations. It is important to view the deployment of technology not as a goal in itself but as a tool for the benefit of employees and the organization. This inevitably entails the development of work roles, the organization, and the technological systems used in order to create a context conducive to the use of C-ITS.

Table 5: General recommendations for managers deploying C-ITS

General recommendations for managers deploying C-ITS
Managerial attitude
Understand the real nature of working activity
Understanding the working reality of highways employees (future users) is the main success factor for priation of the technology and therefore successful deployment. This understanding must be based on nature of their work activity and not on the way that their work is perceived by their superiors or by the of the technology. This therefore involves a phase of gaining understanding of the real work of the and of cooperating with the teams involved, as well as the creation of the climate of trust that is essential elopment of a peaceful and constructive dialogue.
Raise awareness and train line management
Taking into account the reality of work, as described above, is far from being the norm within organizations (Leplat & Montmollin, 2004). For the best implementation of the results of this impact study and the recommendations presented below, we recommend that a paradigm shift in practices is needed. We believe it is essential to raise awareness among line management and to involve and train them in this mode of understanding the appropriation of new technologies. It is important to view the technology not as a goal in itself but as a tool for the benefit of employees and the organization. It will therefore be necessary to facilitate development in working roles, in the organization, and in the technological systems used in order to create a context favorable to the use of C-ITS.
Concrete action points
Involve line management
Senior management must be fully involved so that they can in turn involve all line managers and employees. C-ITS must be treated as a major issue and time must be given to teams to build skills and achieve their goals.
Create a multidisciplinary project team
The project must be coordinated by a person with a global vision of C-ITS but must then be based on various pilots of particular activities relating to IT structures, R-ITS-Ss, OBUs, communication and support. The deployment of C-ITS requires multiple skills.
Meet with the trade unions
Organize regular and transparent progress meetings with the trade unions to communicate and avoid potential obstacles. This helps to “demystify” C-ITS and promotes an understanding of concerns expressed.
Communicate at all levels across the organization
Develop communications intended for all employees. Highlight the principles of C-ITS operations, data protection, services offered, and added value compared to other systems (internal and external).

These communications are intended to inform collaborators of ongoing projects (Colquitt, 2001) but also and above all to promote systems whose value may be less obvious at first glance.
Communicate with employees directly affected by C-ITS
Develop communications specific to the most affected roles: operating agents, traffic management operators, system and network administrators, and equipment maintainers. The purpose of these communications is to inform employees about the specific changes that will be inevitable or that will be introduced during co-design phases. This makes it possible to maintain the relationship of trust needed for these new systems to be accepted and appropriated.
Create or strengthen relationships with external partners
C-ITS offer the opportunity to develop new services with partners for users. This should contribute to the management of mobility throughout the country, which makes it possible to develop the added value of DIRs and to meet national expectations. However, these partnerships need to be built or consolidated, for existing ones. They may require the creation and implementation of common operating and information strategies.
Integrate C-ITS in current operations (1/4): Promote team cooperation
C-ITS are, at the outset, innovations. Once installed, they are intended to form part of current management operations. In order to succeed in this, the tools deployed and the new modes of working must take into account the way in which the professionals involved perceive their work. If the new systems improve working conditions and are clearly consistent with the objectives of work tasks, and if the professionals are aware of this, then there should be fewer issues related to acceptance. To successfully implement this recommendation, it is useful to actually examine the way tasks are performed in working scenarios. Co-design is a very effective method if it is properly conducted, i.e., in line with the previously stated objectives. The results of these methods correlate to the fact that (1) the views of those involved are taken into account (Thibaut & Walker, 1975), (2) participation of teams engages them in the process of change (Joule & Beauvois, 1987; Kiesler, 1971), and (3) those involved are given the power to make decisions, which contributes to the improvement of conditions of use of these systems (Quiguer, 2013).
Integrate C-ITS in current operations (2/4): Improve working conditions
Co-design should clearly generate proposals for changes in existing work procedures but also to tools and cabs. These proposals must be taken into account in order to simplify the work of future users and thus ensure smooth deployment and use. These points are supported by feedback from Scoop and the C-Roads project. DIR Ouest, with the support of the DIT, has set up a number of projects with this goal. These include, for example, SAGACITE, Fourgon 2020, and a project on the structure of road information.
Integrate C-ITS in current operations (3/4): Train teams
Once tools have been configured and new working methods have been defined (updating or creating procedures and making new tools available), a training phase is essential. This phase will need to include further communication about C-ITS, their added value, and the importance of data protection. This should be followed by training about the development of working practices. This phase should be largely facilitated by the previous phase of co-design. The partial deconstruction of employee activities is an essential part of the process of enabling them to adopt new ways of working. The Model to Help Individuals to Develop their Competencies (MADIC, Coulet, 2011) suggests that this deconstruction enables better management of work processes and skills deployment. This training can initially be modular in format. This will allow the new training to complement the training that the majority of employees have received. However, modular training can carry the risk of confusing employees and even conveying conflicting messages. In addition, maintaining that format in the long term could suggest that these are “secondary” activities. Therefore, in the medium-term C-ITS should be incorporated into initial employee training and these procedures should be presented in a general, systemic way.
Integrate C-ITS into current operations (4/4): Monitor developments generated by C-ITS
Once employees are trained, the process is not finished. Indeed, the relationship of individuals with technologies evolves in line with experience gained through use. In addition, some aspects may have

been overlooked during the co-design and/or training phase, or the context may have changed. For these reasons, it will be important to remain attentive and put in place processes for identifying problems that could affect the use of these systems or the working conditions of users. These processes should be implemented by line management because it is not necessarily the case that problems will be communicated by users. For example, for CEIs, DIR Ouest will provide feedback forms in display boxes to allow employees to draw attention to problems that arise. For urgent issues, a dedicated phone number can be provided to users. In addition, an online platform has been planned. Information gathered by these means will facilitate changes at individual, organizational and/or technological level in order to ensure the efficiency of the traffic managers.

Work to date has generated many useful findings. In view of all the questions that have been raised in the course of the various studies, it is important to us to follow up on the reflections about organizational impact studies and thus to benefit from new feedback. Moreover, since the support process and associated principles used have been proven to successfully support C-ITS, the process can also be employed to support other organizational changes brought about by innovations.

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8 Acceptability assessment

From drivers' point of view, SCOOP system displays road safety messages such as "Road works" or "adverse weather conditions" on the dash board of the car when approaching the event. It also includes messages about very near events such as "hard braking ahead". This first C-ITS deployment is an opportunity to evaluate the system in particular to assess its real impact on driving.

Taking user experience into account for acceptability evaluation was a challenge as it has four specificities at this stage of development:

A few vehicles in circulation with a few probability to cross the path of a R-ITS-S and then a few probability of receiving a message can lead the driver to consider the system as silent most of the time and acceptability evaluation would be biased.

SCOOP is part of an environment of services which is already well developed (Waze, Navigation systems, Coyote, TomTom). Drivers experience of a innovation may thus be hard to catch.

SCOOP's objective added value is sophisticated: efficient filtering of messages, increased validity when messages are displayed, mixing drivers notifications with institutional notifications etc. Drivers may not be able to notice these items.

The system is integrated in the on-board navigation system which could bring potential limitations: differentiation between C-ITS notifications and the car multimedia system could be hard. Negative opinions about the navigation system's HMI could also have an impact on the evaluation of SCOOP@F system.

8.1 Methodology

Acceptability of a technical system is a concept accounting for all determining dimensions when introducing a new tool into personal practice. If a system failed at demonstrating reliability, utility, usability, and efficiency, it may be not properly used, or rejected. First experience with the new technology is thus a critical step in user's acceptance. On one hand, the system must match with user's expectations to show its benefits. On the other hand, the system must be easy to use to avoid reluctance (Nielsen, 1993).

Given the small diffusion of SCOOP@F, this acceptability study was focused on the practical dimension of acceptability, which was split into 4 different phases along time (Figure 8):

- Expectations ("A priori" acceptability) before any contact with the service. This step is directly linked with expectations derived from the naive representation of the system and the user's current uses.
- First experience, corresponding to the grip (system discovery step). It includes feelings associated with the first transmissions and receptions of

messages, when the user does not have the feeling of having a global and stable view of the system.

- Acceptability-in-the-use includes a first phase – the bounded experience of the system - corresponding to the early stages of stabilization of the driver's feelings towards the system. It is synchronized with the moment when the user feels having a rough overview of the system.
- Reconsidered acceptability refers to experiences in the longer time, including experience review loops spontaneously generated by the cohabitation of the service with other available systems (on board navigation, Coyote, WAZE etc.)

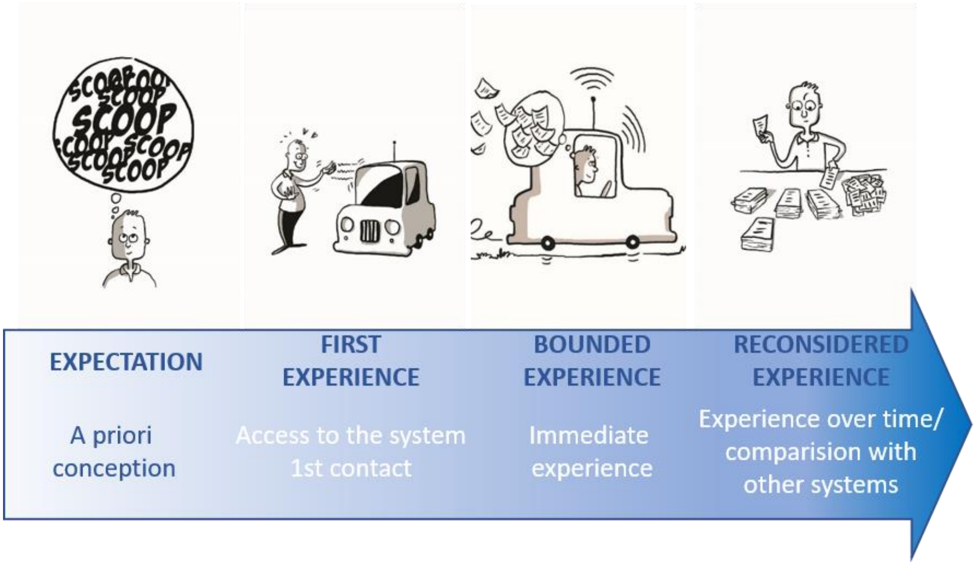

Figure 8:Acceptability steps along time

8.2 Experimental Framework

There are four ways to look at data. The research approach that was applied consists in connecting several methodologies to combine benefits as well as addressing limitations of each one. The aim was on the one hand to keep “ecological validity” from the user experience point of view by maintaining the goal and habits of the travel. The protocol needed to be integrated into daily use of the vehicle. On the other hand, the drivers should be exposed to enough messages to ensure a minimal experience and to be able to compare drivers in an experimental process (controlled and comparable data). Five types of data collection were therefore defined to take advantage of the organizational and geographical characteristics of the project (a multi-partners involvement in 5 areas of France) and to frame its essential constraint (the low message flow transmitted at this step of development) (L.Guyonvarc’h, 2019). Figure 9 shows an overview of the acceptability study protocol.

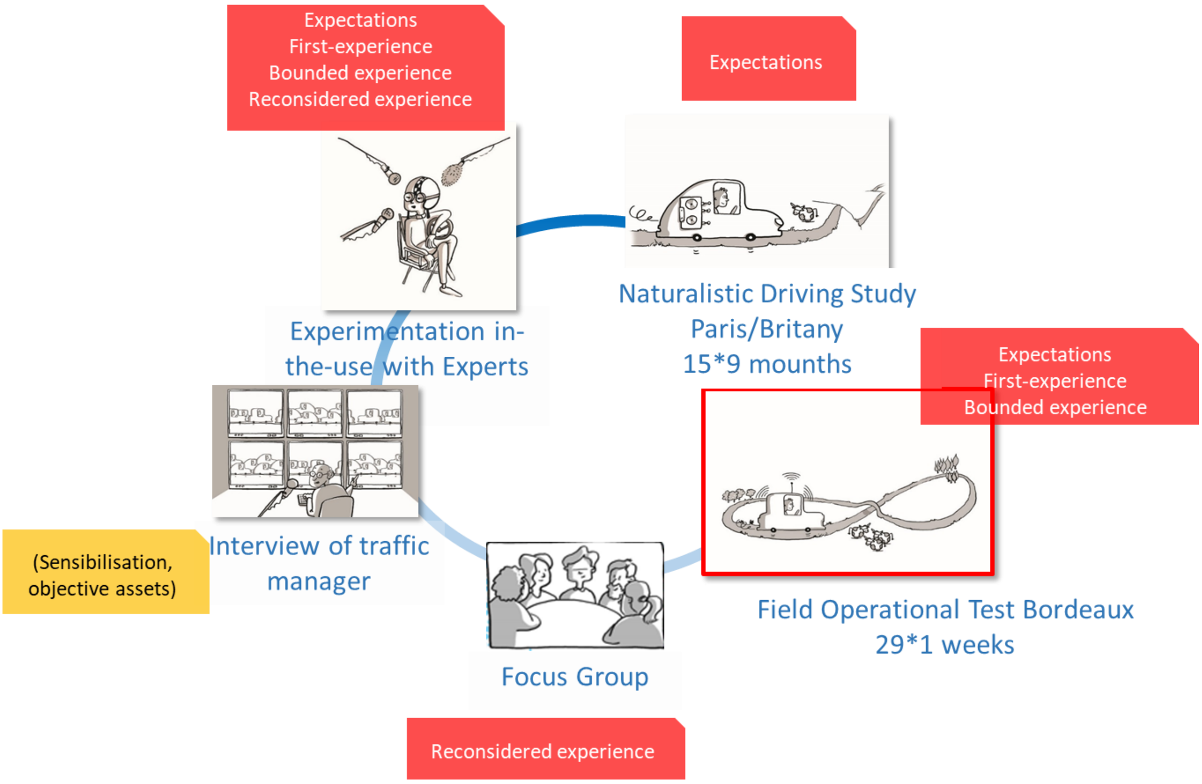

Figure 9: The four different data collection process for acceptability study in SCOOP@F

8.2.1 Naturalistic driving studies (NDS) in Brittany and Ile de France

The experimentation of a system integrated within the participant's personal vehicle, in his/her personal frame of use during his/her spontaneous trips, leads to the collection of more ecological data, purified of experimental biases. This Naturalistic Driving Studies (NDS) is very popular among the various stakeholders because it is representative of future uses (Eenik, 2014) (Antin, 2011) (Neale, 2006). Nevertheless, it has the disadvantage of relying on the natural facts of the road ecosystem. It is penalizing as we know that I2C and even more C2C communication is likely to be infrequent at this SCOOP's stage of development. Therefore, NDS in SCOOP includes the risk of a very weak constitution of experience among the involved participants. To control this risk in terms of budget, the NDS was launched over a limited period to cover the different stages of acceptability. The number of participants was also limited to guarantee reasonable cost. Fifteen volunteers' vehicles were ultimately equipped and participated in data collection. Participants drove in Ile de France and Brittany over a period of 9 months.

8.2.2 FOT in Bordeaux

NDS was completed by a Field Operational Test (FOT) in Bordeaux (Figure 10). The strategy is complementary: it is also a matter of collecting data in an ecological context (open roads, without pre-set trip) but from a wider panel of participants (30) in a restricted geographical area to maximize the occurrence of messages (C2C, I2C). The objective was to increase the amount of data from the first stage of acceptability - the "take-over" or "discovery" phase - by including more participants into indirectly controlled conditions to provide more objective experience of the system (Guyonvarch, 2016). For practical reasons (cost of vehicle equipment, staffing of participants), equipment of personal vehicle was replaced by loaning car (PSA C4 and RENAULT Megane) for a shorter period (1 week). However, the time window of the test will not make it possible to study the "bounded experience phase" and the "reconsidered experience phase".

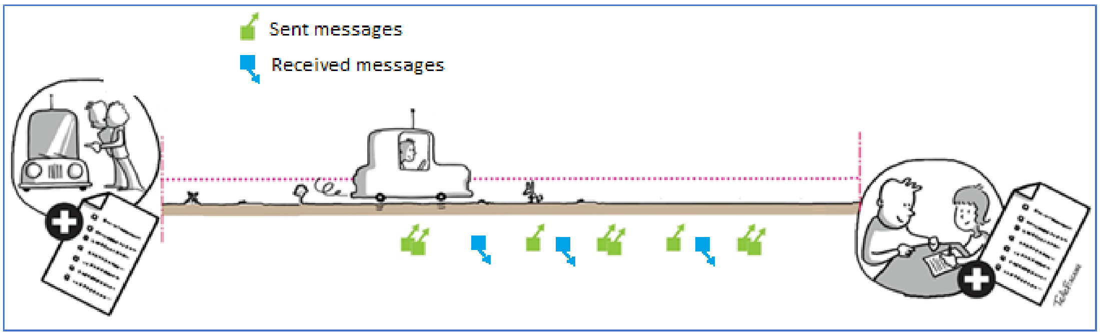

Figure 10. FOT experimental design

The FOT in Bordeaux consisted in collecting both objective and subjective data for one week. The cars were equipped with measurement instruments. Objective data (e.g. speed, acceleration, location) were recorded by sensors. Before the drive, users were interviewed to give their current use of C-ITS, their expectations and their knowledge about SCOOP (scope and goal). When driving, users could record their feelings and live experiences thanks to a vocal logbook. After a week, acceptability was assessed in a debriefing session (Barbier, 2018). Vocal recordings, sent and received messages were presented to users to reinforce recall of encountered situations.

8.2.3 Focus group

From the FOT participants, 8 drivers were selected to participate in a focus group (Figure 11). The objective was to allow participants who had used SCOOP to imagine possible future uses and make proposals to improve the acceptability of the system. The information so collected was used to document the Reconsidered Acceptability and to make recommendations.

Figure 11. Focus group flyer

8.2.4 Experts judgement data collection

Parallel to naive participants data collection, expert's judgement, which is very popular for car manufacturers was included into the protocol. This consists in supplementing empirical data by collecting them from experts using the system. They express their point of view without considering users data, but using their expertise and knowledge gathered over time from users' behaviors. Their analytic point of view is collected after a first experience of the system to raise relevant reference situations. This type of study complements partly the lack of data from bounded and reconsidered experience, experts being considered as representing the user's point of view along time. Eight experts were part of this protocol: HMI experts (automotive/ non-automotive), ADAS experts, UX designers. For practical reasons, most of experts (six) were interviewed after experiencing the system for 30 minutes. The others (2) had experienced the system in the FOT condition (ie. during 1 week). After an elaboration about the experience, interview continued with open-ended questions, the target being to gather items spontaneously raised by the expert. Examples of SCOOP as well as other ITS HMI were shown to experts to allow elaboration in comparison with competitive systems (Waze, Googles Maps…).

8.2.5 Interview with traffic experts

Finally, data collection included an interview with a traffic expert from a road management center. This expert is in charge with displaying messages to drivers through variable message panels (on the roads). The interview was focused on elaborations of corrections applied by the operator to the system to provide efficient data to the road users. The idea was to map the type of messages where the added value due to expert intervention is highest to observe, in the field, if such effect is perceived by drivers. In case it is not perceived, the map of advantages of an information system corrected by human operator becomes a target for the design of the C-ITS and its global visibility.

8.3 Results

As regards the intermediate deliverable, the results were completed with:

- NDS participants taken out of the study (for whom no messages were received): the interview and questionnaires were used to provide drivers with details about SCOOP and how it works. The results were used mainly to determine the level of initial acceptability and drivers' opinion about the Use Cases.
- PSA expert opinions: The experts' experience with the system and interviews were used to determine the acceptability of the HMI and the functionality of SCOOP. The results were to make recommendations to improve the acceptability of SCOOP.
- The focus group: The discussion with a group of FOT Bordeaux users served to enhance the initial acceptability of SCOOP and to get the point of view of these Bordeaux users as to possible evolutions of the system. The results were used to make recommendations and to determine which Use Cases should be taken into account (and which should be excluded), as well as extensions of SCOOP functionalities.

The intermediate deliverable presented intermediate results specific to two of the five studies carried out during the project. To facilitate the reading and understanding of the overall results, they were summarized in relation to the different stages of acceptability. The results presented in the intermediate deliverable are thus integrated with the results of the other studies.

8.3.1 Expectations

8.3.1.1 Current use of ITS

Currently, drivers use C-ITS mainly to optimize their trip (time and trip planning, arrival time, re-routing, signaling risk areas). However, no system seems to cover all drivers' needs. Reliability of information, the ability of systems to provide real-time information, ease of guidance and the use of remote devices are the limitations most often mentioned. Although users are satisfied with the systems currently available to them, the majority do not show any particular resistance to change.

Figure 12 shows how participants interact with existing systems.

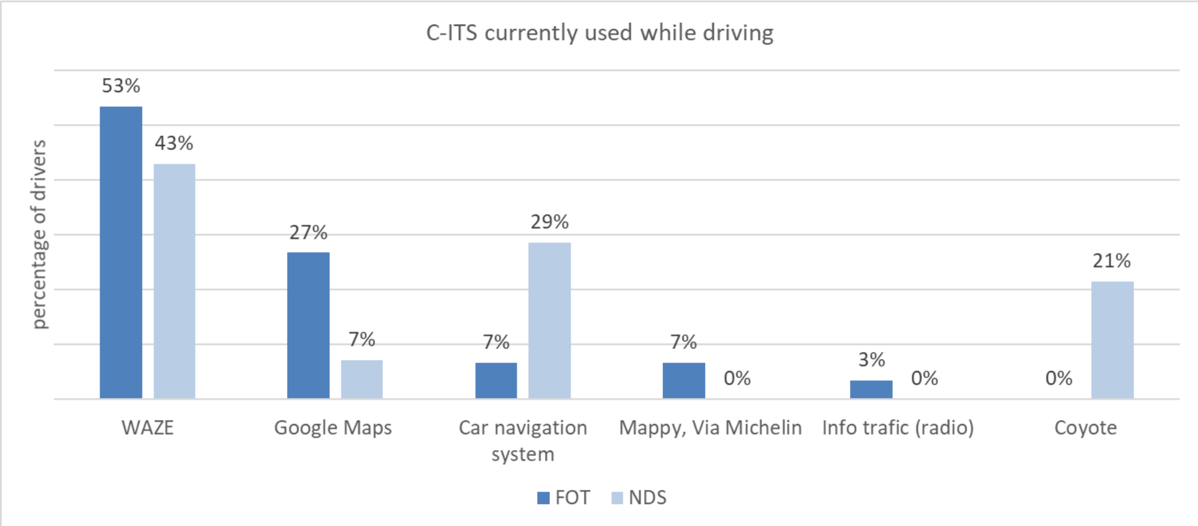

Figure 12: SCOOP's psychologically competitive environment

To be acceptable compared to other C-ITS, SCOOP would have to demonstrate its advantages over other C-ITS in terms of reliability, relevance of information, ability to inform drivers in real time, simplicity and integration on vehicle navigation.

8.3.1.2 Specific expectations from SCOOP

The users were rather neutral towards SCOOP, with neither negative nor positive expectations (Figure 13). Few complaints were noted about the quality of the data provided by the current systems (false negatives and false positives information), and this can be considered one of the advantages of SCOOP information. The potential advantages of the system is real. However, most of respondents “lacked imagination” as to what the “ideal system” might be. It was very often seen as just an extension of current systems, and the discussions were striking by the highly realistic nature of the ideas evoked. To resume therefore, SCOOP is expected to be an improved navigation system able to optimize journeys (planning and journey time, re-routing, etc.).

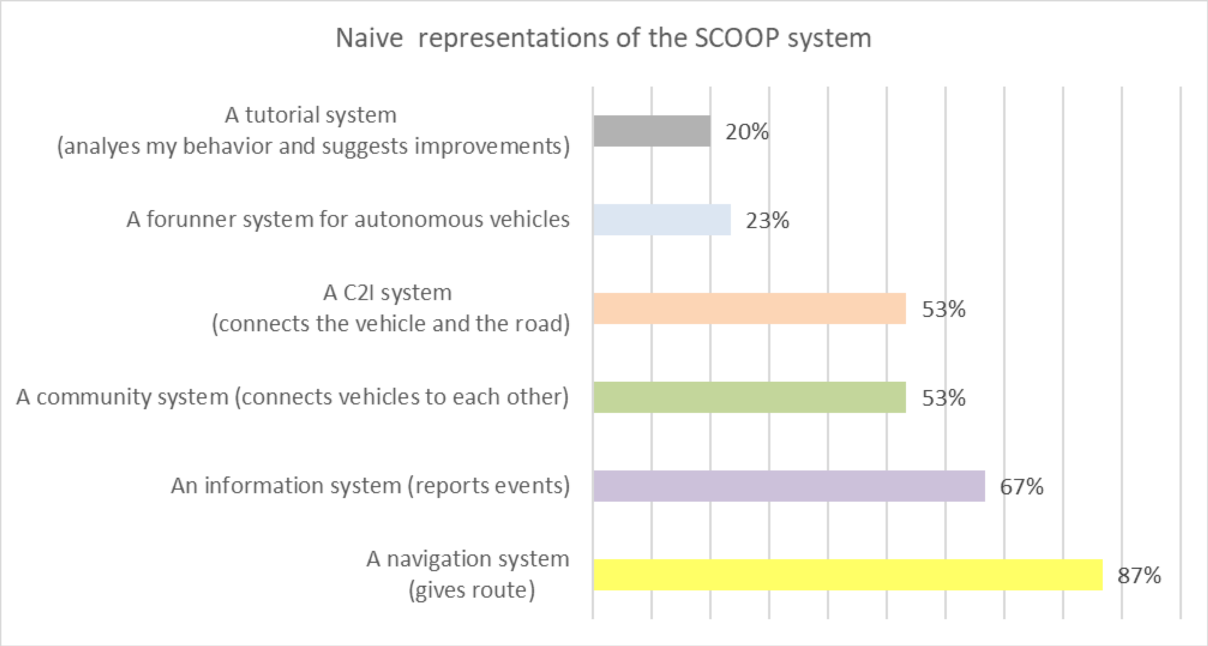

Figure 13: Initial perception of SCOOP.

8.3.2 « First experience »

Initial acceptability (i.e., prior to any actual contact with SCOOP) can be summarized in three points: **firstly**, drivers see SCOOP as a navigation system. Thus, there is a risk of SCOOP disappointing drivers when compared with specialized driving apps such as Waze or Google Maps: underperformance in terms of navigation (because this is not the purpose of SCOOP) and driver blindness as to the benefits of SCOOP (because users received few messages during the tests). Similarly, the benefits of safety-centric information are not immediately perceived, especially the benefits of getting road operators involved. Nevertheless, the advantages (compared with other systems) of this source of information do start to become clearer at the end of the first week of use.

Second, although users are not waiting for a system such as SCOOP, it could carve out a place for itself in the market, especially since drivers are not attached to their current system. Moreover, most of the drivers express concern about road safety and support ways to improve it. Finally, SCOOP's most visible assets are the screen comfort, provided by its integration into the navigator, and the potential functional synthesis of all in-vehicle information systems. However, this latter asset would require an evolution of the philosophy of SCOOP, currently designed as an independent info-alert system.

Lastly, SCOOP benefits from a facilitating social factor: the increasing willingness of users to change systems, and their openness to new experiences. Participants involved in the trial are part of a service culture that focuses on creating new needs rather than meeting existing needs.

No major defects were reported when using SCOOP but there is room for improvement. Nevertheless, the overall design lacks a visual break from prevailing designs (expectation of visual innovation, “modernity”). There is confusion between SCOOP functions and the functions delivered by the vehicle's navigator, and this leads to false attributions and expectations of perspective between the reported incidents and the current route.

8.3.3 « Bounded experience »

Projections regarding the prolonged use of SCOOP confirm that integration into vehicle navigation is one of the main levers for the acceptability of the system. The displaying of events about the current route is perceived as useful and relevant for optimizing the journey. However, drivers did not consider all information sent and received to be relevant. For example, information on weather conditions and priority vehicles was not perceived as useful (Figure 14).

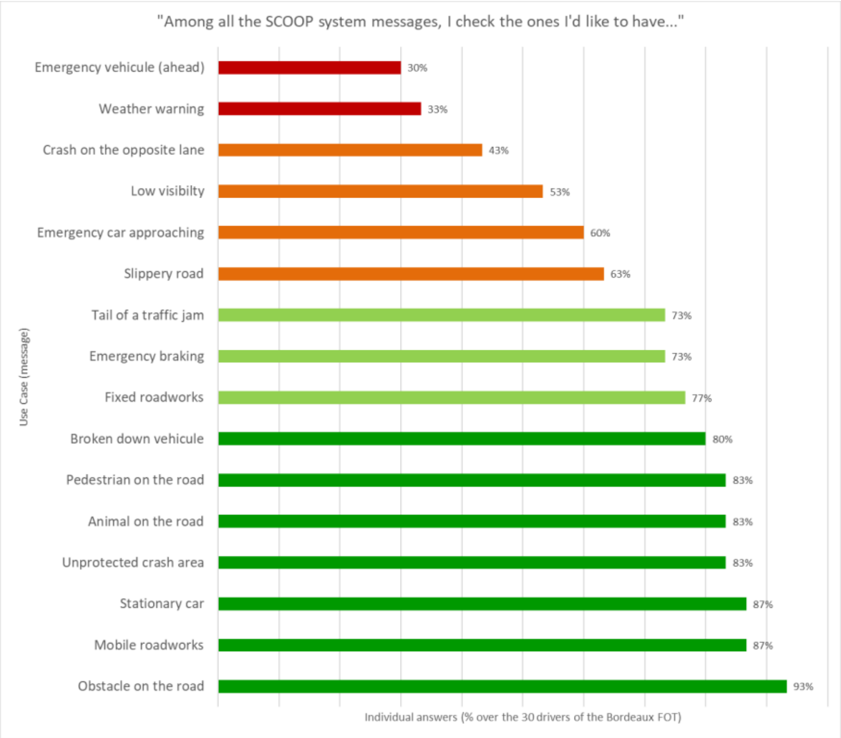

Figure 14: Usefulness of Use Cases.

The choice of events that can be notified by the driver also received many comments. In general, experts and users recommend allowing frequent events to be reported and not including rare events (e.g., blocked roads). In particular, the possibility of receiving and transmitting information on traffic jams and risk areas were seen as elements that could increase the usefulness and acceptability of SCOOP (Figure 15).

Experts and drivers suggested several proposals to increase the usability of SCOOP. For example, alerts could be displayed on the dashboard rather than on the navigation screen since they concern safety rather than navigation. The possibility of interacting with the system by voice was also seen as an important lever of acceptability. The filtering of information that could lead to display false information (false positives) could also be preferable to filtering that would result in not displaying true information (false negatives).

Lastly, it would be imperative that the information delivered by the navigation and SCOOP (e.g. type and location of events) be fully consistent.

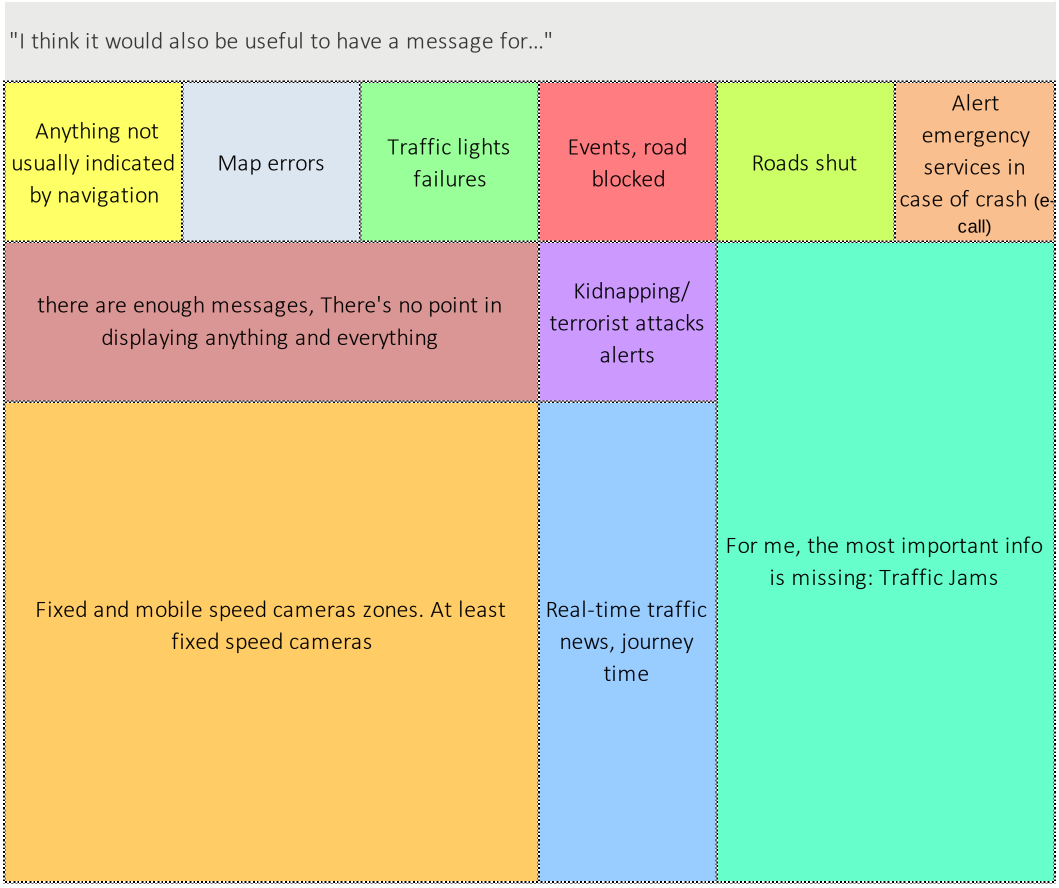

Figure 15: Use Cases required by FOT users

8.3.4 Reconsidered experience

Firstly, the acceptability of SCOOP is limited by the expectations of a system that optimizes driving (i.e., the route taken by the vehicle) rather than increasing safety. Secondly, the safety benefits, with the involvement of road operators, are not so clear. Its functions are therefore perceived as limited compared to existing systems.
Thus, the recommendations made by experts and drivers have to do with adding navigational functions and/or integrating SCOOP with other services. For example, the sending of automatic messages (e.g. emergency braking) is not perceived as an added value compared to current systems (the usefulness and timing of this function could not be tested). Nevertheless, some drivers perceived a strong interest in the system's ability to provide feedback on their driving (e.g. the driver's driving is scored as “rough” to “smooth” based on the analysis of vehicle data). Focus group participants also found interesting that SCOOP would enable them to obtain information from other public institutions or local authorities. They envisage, for example, that the system could enable them to take into account traffic disruptions related to temporary and mobile events (e.g. presence of a garbage truck, movement of an event). The connection with

other information systems (e.g. GLOSA) would also be an added value for the system.

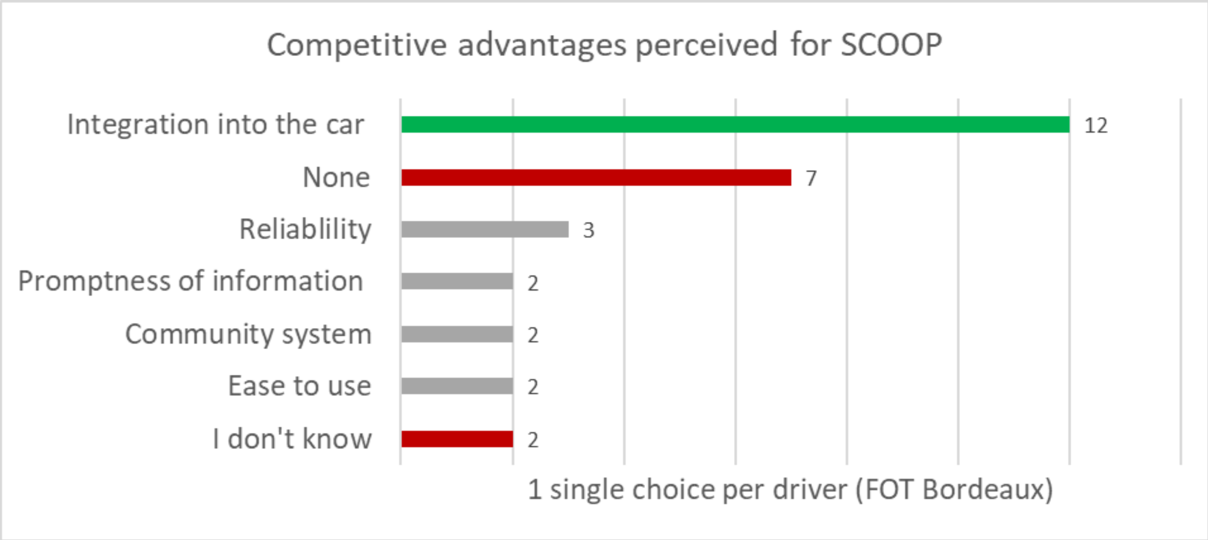

Figure 16: Perceived competitive advantages for SCOOP over existing systems

8.4 Conclusion

At the current stage of the deployment of SCOOP, not all the functions of the system could be experienced by users. In particular, participants were not able to test C2C and were exposed only to a few messages. However, the investigations did not show any major impediment to acceptance of the system; users recognize the potential of the system to improve safety. SCOOP has no major flaws and is simple to use. The system's integration with navigation and its ability to feedback information from the vehicle are the main advantages for users.

The evaluations carried out with users and experts lead to several recommendations to improve the acceptability of SCOOP in relation to its overall design, HMI and Use Cases.
Thus, SCOOP or the systems/services with which it is associated should include signaling traffic jams and risk areas, as these Use Cases are eagerly awaited.

Another determining factor for the acceptability of SCOOP is its assimilation as a system for safety rather than route optimization. The discrepancy between expected functions and actual functions was a source of disappointment for users. Likewise, the benefits of the involvement of road operators only became apparent after the system had been used. This aspect should be further emphasized to demonstrate the benefits in terms of reliability, relevance of information and ability to inform drivers in real time. Another solution would be to integrate SCOOP information with other systems and/or add new sources of information. This would respectively compensate for currently missing information and/or provide information that is not provided by any other system.

8.5 Bibliography

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9 Benefit analysis on road safety (accident analysis evaluation) – Gains for drivers

SCOOP system displays alert messages to inform the drivers about potential dangerous situations such as works on the road, bad weather conditions/temporary slippery road, random hazardous situation (i.e. pedestrian, obstacle, stopped vehicle on the road) amongst other evaluated use cases.

This ex-post study, which follows up the study of the road safety stakes (see deliverable 2.3.4.1 related to the ex-ante study: “accidents analysis stakes of SCOOP use cases [1]), deals with a first evaluation of SCOOP system impact on road safety, characterized by the benefits/gains in terms of injured accidents/fatal accidents reduction and accidents severity reduction in the context of the rolled out uses cases. The use cases considered for this impact study are listed in the annex part. The methodology and experimental conditions are partially described in the deliverable 2.3.4.1 bis: “Tools specifications and methods for analysis and evaluation (behavior/acceptability)” [2]

9.1 Methodology

To determine the benefits of each use case considered in this study, we need to know the SCOOP system efficiency and the accident analysis stake for those use cases respectively.

The benefits (use case i) = [Stakes(use case i) x Efficiency(use case i)].

Before mentioning the main accident analysis stakes determined in the deliverable 2.3.4.1, and determining the efficiencies and then the benefits, there is a description of the experimental conditions in which the SCOOP system efficiencies have been evaluated.

9.1.1 Experimental conditions

9.1.1.1 Experimental fleet

The Table 6 describes the experimental fleet of SCOOP passenger cars driving on open road, equipped with specific sensors and recorders:

Table 6: experimental fleet of passenger cars (PC)

Location	Number of participants (Number of vehicles)	Driving period of time
Ile-de-France	15 (15 PC)	February 2018 => July 2019
Western area (~ Rennes)		
Bordeaux city	30 (2 PC)	November 2018 => MaY 2019

The evaluation of the SCOOP system impact on the road safety was mainly carried out in Bordeaux city, based on the methodology described in the deliverable 2.3.4.1 bis, with some exceptions regarding the baseline.

At the very beginning of the study, an experimentation (Natural Driving Study (NDS)) was worked out in Ile-de-France and in the Western area over one year to get a lot of messages and to record a lot of behaviors consequently. However, few vehicles were involved. The likelihood to drive close to road side units was low and to get an alert message when crossing a road side unit was low as well.

In Bordeaux city, two vehicles (PC) were involved: one Citroen C4 and one Renault Megane, both equipped with SCOOP system. The display of the messages was different between the two cars. This study does not allow to evaluate the effect of the differences on the real impact on driving. Thirty participants drove one car for one week, as two a week. The road side units are concentrated on the ring road of Bordeaux. The drivers committed to drive on it, daily. Such an experimentation is rather a Field Operational test than a NDS. No baseline (see deliverable 2.3.4.1 bis) could be implemented due to resources' reason. An alternative protocol was developed consequently.

The cars were equipped with different instruments to measure and record objective synchronized data like speed, acceleration, location, inter-distances, traffic signs, obstacles, … The

Figure 17 represents the main equipment of the SCOOP passenger cars (PC) of the experimental fleet.

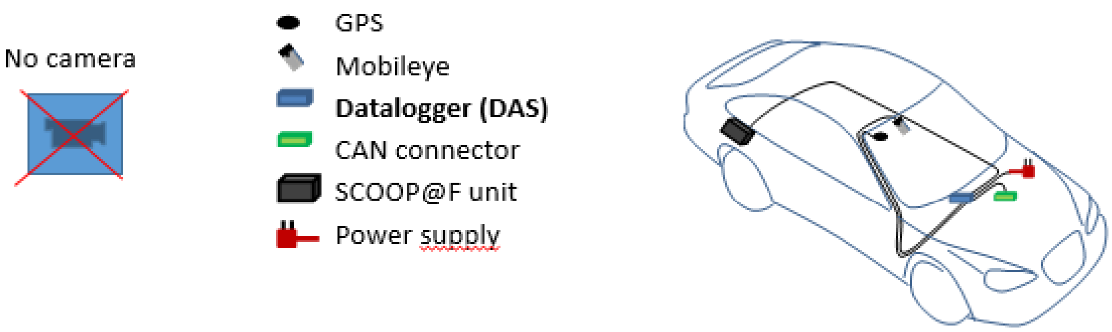

Figure 17: specific equipment of PC

The recorded data were sent continuously and synchronized, via the DAS (Data Analysis System), to a database for preprocessing and analysis.

9.1.1.2 SCOOP messages: treatment of displayed messages

The messages received and displayed on vehicles HMI correspond to 14 use cases of the French catalog [3]. Some of them were grouped as describing similar accident configurations when it comes to the accident analysis. The table 2 shows the 14 use cases and the grouping.

Table 7: list of use cases/alert messages displayed during the experimentation and the grouping for accident analysis purpose.

SCOOP messages	Simplified messages
Alert stationary vehicle	Stopped vehicle
Alert breakdown	Stopped vehicle
Alert Accident area	Accident
Alert Animal on the road	Animal
Alert Animal on the road - herd	Animal
Alert people on the road	People
Alert obstacle on the road	Obstacle
Alert operator vehicle in intervention. Operator vehicle stopped for protection	Road working
Alert planned road works. Fixed road works	Road working
Alert unmanaged blockage of a road	Obstacle
Alert extreme weather conditions	Weather
Alert extreme weather conditions - Strong winds	Weather
Temporary slippery road alert	Ice
Temporary slippery road alert – persistent ice	Ice

NB: the deliverable 2.3.5.5 on Acceptability evaluation, mentions that experts recommend to limit the details level of the displayed messages of use cases. For instance: drivers do not care to distinguish “breakdown vehicle » and « stopped vehicle ».

Then, there was a need to treat all raw received messages, sent to the database via the DAS: approximatively 600 messages. Only displayed messages have an interest and amongst them, only certain driving situations and distances to the events have the final and relevant interest. The treatment consists in elimination of redundant messages; messages issued from pretests; messages displayed when PC is stopped or driving at very low speed; etc …. (see the deliverable 2.3.4.5 for the detail). At the end of this analysis, 12 messages/driving situations are selected to perform the determination of the efficiency of SCOOP system. The
Figure 18 shows the apportionment of the displayed messages as per the use cases.

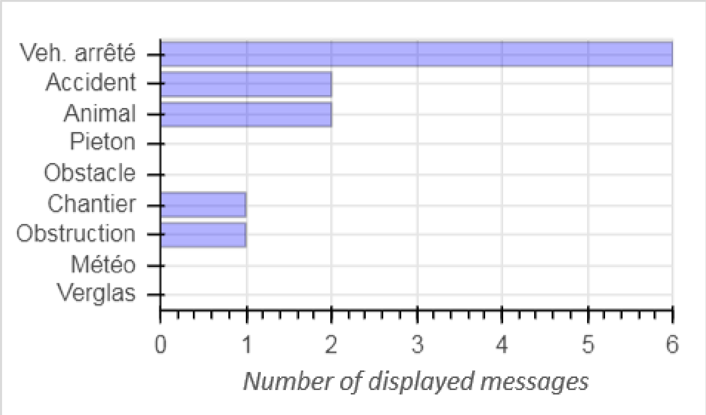

Figure 18: apportionment of the displayed messages as per the simplified use cases names

9.1.2 Reminder - Accident analysis stakes: criteria

See the deliverable 2.3.4.1: the stakes results related to the passenger cars only (as the experimentation was performed with PC).

NB: the deliverable also presents the stakes results for all vehicle categories (PC, light duty vehicles, heavy duty vehicles, motorcycles).

The Figure 19 summarizes those criteria:

- Frequency = number of accident
  - Injured accident
  - Fatal accident
- Severity = number of seriously injured and dead

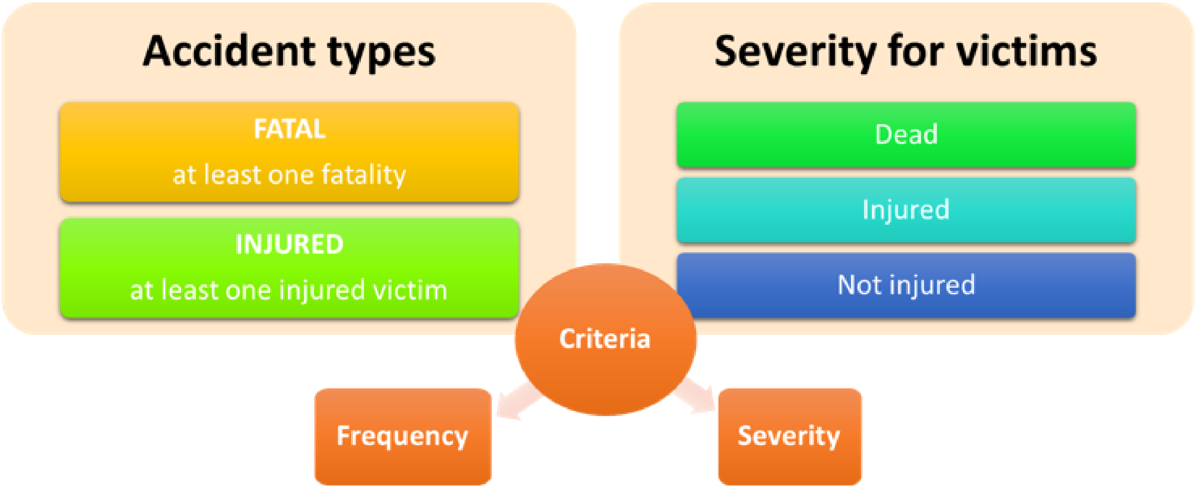

Figure 19: the two main criteria for accident analysis stakes evaluation

The main results presented at the first SCOOP@F seminar are:

- Frequency (based on the VOIESUR database [4]).

The Figure 20 shows the distribution of the accident analysis stakes in frequency, for each of the 14 use cases: % of injured accidents at the left and % of fatal accidents at the right (compared to all accidents in France, in 2011).

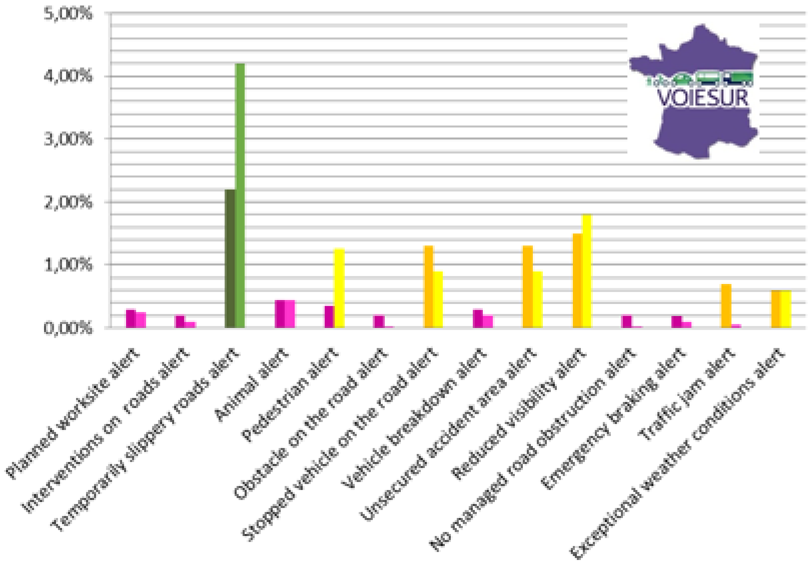

Figure 20: Distribution of the accident analysis stakes in frequency

- Severity (based on the VOIESUR database [4])

The Figure 21 shows the distribution of accident analysis stakes in severity, for each of the 14 use cases: % of dead + seriously injured (compared to all dead + seriously injured in France, in 2011).

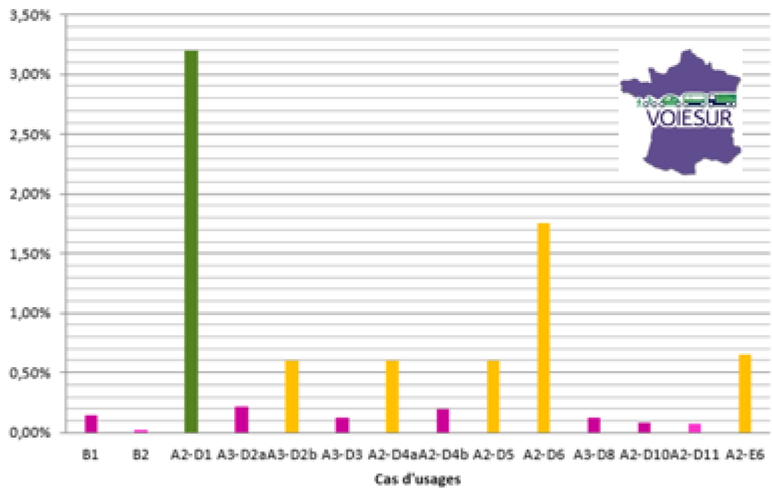

Figure 21: Distribution of accident analysis stakes in severity, for each of the 14 use cases

The use cases “temporary slippery road” (A2-D1) and “reduced visibility” (A2-D6) are the most dangerous.

9.1.3 SCOOP system efficiency determination

In theory, the efficiency of road safety equipment, as SCOOP system, is determined from objective data vehicle recording (i.e. driving speed, acceleration, deceleration, braking, …) without and with the equipment/system in order to evaluate the efficiency with regard the accident risk reduction and the injuries severity reduction if an accident occurs.

Efficiency = 1 $-(Risk\ with \div Risk\ without)$

Driving speed is a key criterium during an accident [5]. As the baselines are not established, the methodology (see deliverables 2.3.4.1 bis) is adapted consequently. The driving speed, recorded continuously, is the criterium retained to describe the potential effect of the displayed message on the driver behavior. The assumption is that the risk of accident and the risk of serious injuries are expressed as a function of the driving speed when the message is displayed. Practically, to consider the driving speed mean over the 10 seconds before the displayed message and over the 10 seconds after, to make the delta. A positive effect is a reduction of the driving speed. The Figure 22 illustrates the principle.

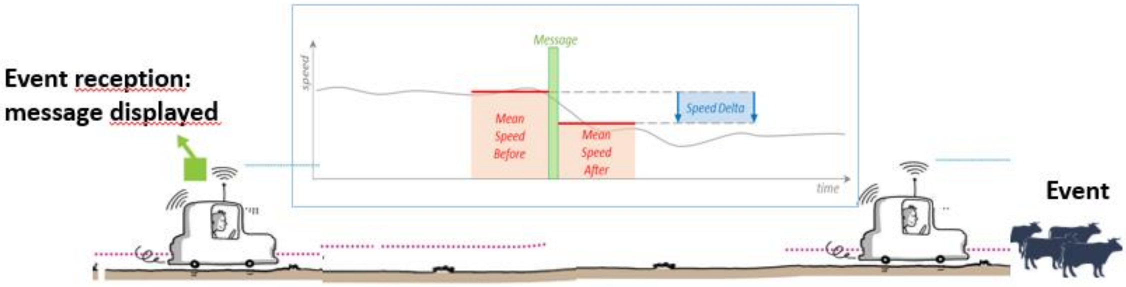

Figure 22: Principle of efficiency determination

Efficiency related to the reduction of the accidents frequency:
The assumption considered is that the risk "without" is the risk before displaying a message, linked to a certain driving speed, and the risk "with" is the risk after displaying the message, linked to a certain driving speed, expected lower. The Figure 23 represents the distribution of the speed delta (km/h) observed for the 12 messages.

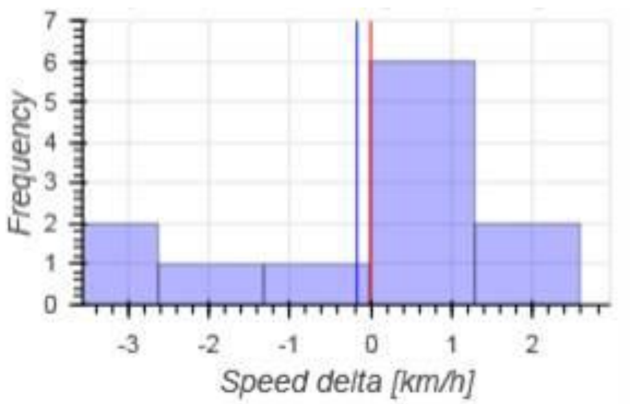

Figure 23: speed delta (km/h) distribution

In 8 cases out of 12, we observe an increase of the driving speed (risk "with"), so 66% of the cases. The efficiency is set at 33%. However, the sample is so low (12 cases), the confidence interval is calculated via bootstrap [6]: the 95% confidence interval is

[8%; 58%] which is large and insignificant.

Efficiency related to the reduction of the accidents severity:
A first step is to establish the risk curves from VOIESUR database. Two types of accidents are considered based on the 14 use cases: pedestrian/passenger car collision and passenger car/all vehicles or obstacle collision (assumption: the 13 use cases considered in this study, except pedestrian on the road (A3-D2b), could lead to a front impact, the most frequent). In case of pedestrian/passenger car impact, the risk of injuries concerns the pedestrian.

The Figure 24 corresponds to the risk curve related to the passenger car/all vehicle or obstacle collision: it gives the risk of injuries from an initial driving speed.

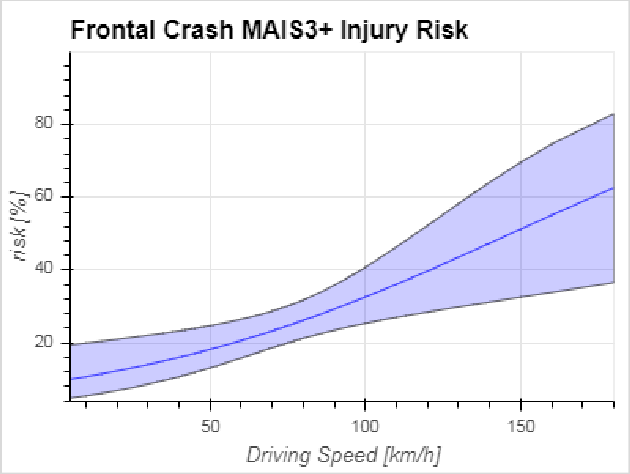

Figure 24: risk curve for passenger car/all vehicle or obstacle collision.

The Figure 25 corresponds to the risk curve related to the pedestrian/passenger car collision: it gives the risk of pedestrian injuries from an initial driving speed.

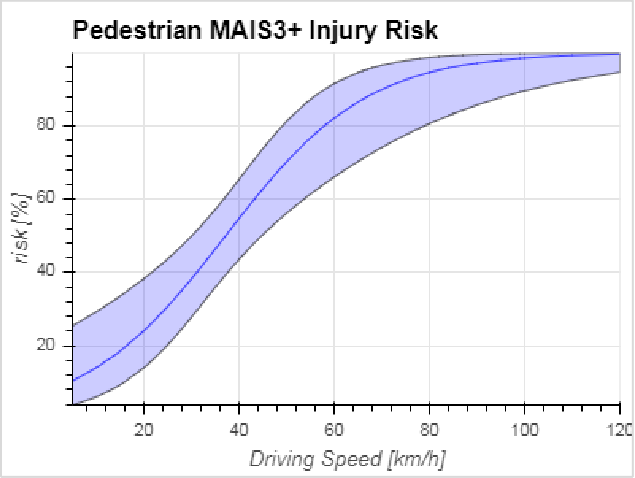

Figure 25: risk curve for pedestrian/passenger car collision.

For each of the 12 messages: the risk of injuries before the displayed message compared to the risk of injuries after the displayed message, as a function of the driving speed

Efficiency = 1- (Risk $_{After}$ / Risk $_{before}$)

The mean efficiency is calculated for the two types of collisions. The confidence interval is also calculated via bootstrap. The table 3 gives the respective efficiencies and the confidence intervals associated.

Table 8: mean efficiency related to severity of accidents and confidence intervals

Collision types	Mean efficiency	Confidence interval
Pedestrian	-0.34%	[-1.63% ; 0.51%]
Vehicle or obstacle	0.13%	[-0.99% ; 1.43%]

The respective efficiencies are insignificant due to the very small size of the sample (12 messages): no effect observed.

9.1.4 SCOOP system benefits/gains determination

The Figure 26 illustrates the formula to determine the benefits/gains.

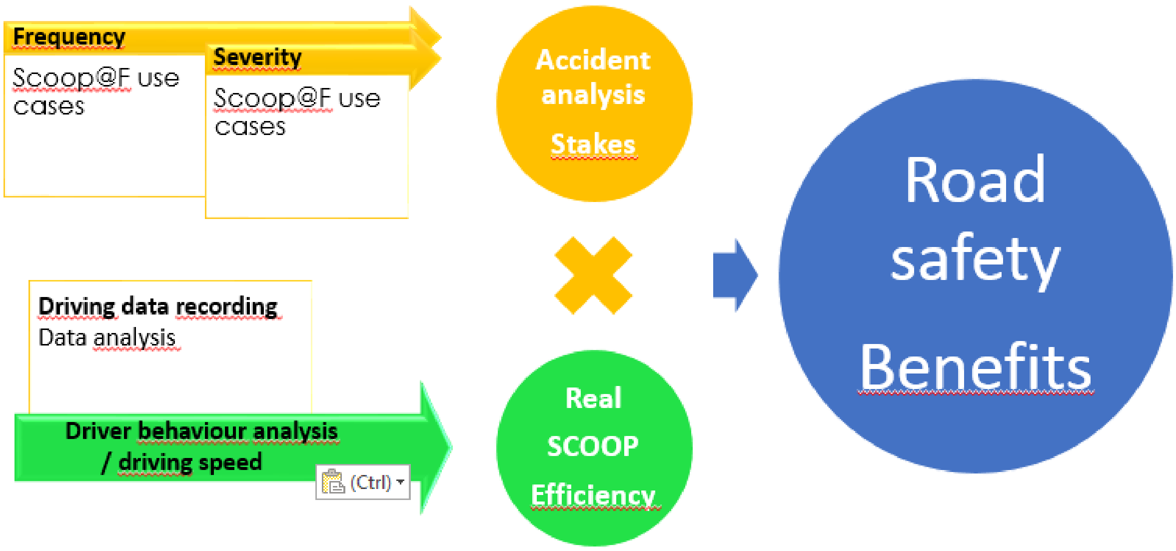

Figure 26: benefits/gains determination from use cases stakes and SCOOP system efficiency.

9.2 Results

Benefits related to the frequency: reduction of injury accidents and fatal accidents:
For each use case, the benefits are calculated with an efficiency of 0,33.

The benefit values are low, mainly < 1%. The highest benefit concerns the use case A2-D1 (temporary slippery road): 1,4% of fatal accidents reduction.
If we add the 14 uses case stakes, the respective potential benefits of the all are: 3% of injured accidents reduction and 4% of fatal accidents reduction. To get an idea of absolute accidents number reduction, we consider the latest report 2018 of the French road safety Observatory (ONISR) where we apply the 3% and the 4% respectively:

1296 injured accidents and 84 fatal accidents could be avoided potentially thanks to SCOOP. These results have to be checked with a further impact study as the sample of this study is too small and the efficiency insignificant.

To get an order of magnitude of the SCOOP system benefits in terms of injured and fatal accidents reduction, there is a rule in accident analysis when stakes are low, around 1%: the maximum benefits can be compared to the stakes. The cumulative stake of the 14 use cases is equal to 10% (for injured accidents and fatal accidents). So, the maximum potential cumulative benefits is equal to 10% if 100% of the vehicles fleet is equipped. Based on ONISR 2018 results, it would mean a reduction of 4320 injured accidents and 230 fatal accidents, if 100% of the vehicles fleet is equipped. The **Erreur ! Source du renvoi introuvable.** summarizes the results.

Table 9:Benefits estimation for injured and fatal accidents reduction

Estimation	Benefits / accidents reduction
For each use case	**From 0 to 1,4% (fatal and injured)**
Global: all use cases	**From 3% (injured) to 4% (fatal)**
Accidents reduction, if 100% of the fleet is equipped (cf. ONISR 2018)	**1296 (injured) ; 84 (fatal)**
Maximum reduction of injured accidents, if 100% of the fleet is equipped (cf. ONISR 2018) = the global stake of all use cases	**Benefit max = 10% (global stake)**
	4320 injured accidents / 230 fatal accidents

Benefits are related to the severity: reduction of severity of accidents (dead + seriously injured).
As the study cannot allow to evaluate the efficiency (~0%) due to the size of the sample, we use the rule of accident analysis exposed above to give an order of magnitude of such benefit/gain with regard severity. The cumulative stakes of the 14 use cases considered in the study is 8,4% (dead + seriously injured). So, the maximum potential cumulative benefit is equal to 8,4% if 100% of the vehicles fleet is equipped. Based on ONISR 2018 results, it would mean a reduction of 1567 dead + seriously injured, if 100% of the vehicles fleet is equipped. The table 4 summarizes the results.

Table 10: benefits estimation for severity accidents reduction.

	Benefits/severity reduction
Per use case	**Not highlighted ˜ 0**
Global : all use cases	**Not highlighted ˜ 0**
maximum reduction in the number of fatalities and serious injuries, if the fleet is 100% equipped (see ONISR 2018) = The global stake of all use cases	**Benefit max= 8,4% (global stake)**
	1567 fatalities + serious injuries

9.3 Conclusion & Recommendation

This impact study evaluation is a key learning lesson with a multi-approaches protocol in order to adapt the analysis to the available data.

The study gives some tendencies in terms of potential maximum benefits based on stakes and assumptions, since the efficiencies estimated in this study are insignificant.

There is a need to perform a further impact study evaluation to check such tendencies, ensuring a suitable size of messages sample.

In terms of recommendation, it appears necessary to carry out an experimentation with cameras installed into the vehicles in order to get more objective information inside (real driver behavior) and outside the vehicles (real events crossed; competition with other events; …) and to reduce the number of assumptions.

9.4 REFERENCES

[1] Chauvel C. (2017) Enjeux accidentologiques des cas d'usage, SCOOP@F.

[2] Bigi L, Chauvel C., Guyonvarch L., Koustanaï A. (2018), Spécifications des outils et méthodes pour l'analyse et l'évaluation (comportement / acceptabilité), SCOOP@F.

[3] Ministry for an Ecological and Solidary Transition – Directorate (2019), C-ITS French Use Cases Catalog – Functional descriptions.

[4] Projet VOIESUR, Site web : http://voiesur.esy.es/index.html /Projet VOIESUR, Livrable L3 - Méthodologie redressement et extrapolation, avril 2015, Emmanuelle Amoros, Audrey Lardy, Jean-Louis Martin, http://voiesur.esy.es.

[5] G.Coley, A.Wesley, N.Reed, I.Parry (2008), Driver reaction times to familiar but unexpected events., TRL published Project Report PPR313.

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10 Benefit analysis on congestion

10.1 Context and content of the deliverable

The Scoop@F project implements and aims to perform assessment of information systems that enable and promote communication at infrastructure technology level in transportation systems. This communication protocol is designed to interact, broadcast and collect messages between participants of a network supported by information technologies. In particular, this platform enables vehicle to vehicle (V2V) communication and infrastructure to vehicle (V2I – I2V) or vice versa. The main functionality of this system is to broadcast specific messages towards drivers currently using in a traffic network about emerging situations that could have potential impact on the traffic condition. Messages of this nature aim to inform about risky situations such as accidents, weather conditions, road conditions or specific behaviors existing in the network like current works, events. The information is propagated upstream from the location of a specific situation (accident, road works, slippery road…) with the support of technology infrastructure.

To this aim, a study on the traffic conditions was carried out in simulation. This approach allows to make projections with different penetration rates of the system and proposes a vision on current challenges and ambitions for the future implementation and deployment phases. The present synthesis recalls the scenarios for the selected simulation studies, particularly the software tools used, chosen hypotheses and assumptions, and the parameters applied for each test case. The following document extracts the main ideas for creation of the simulation and summarizes main findings.

The results of this study and their effects intend to characterize the effective impact produced on traffic conditions under the presence of vehicles equipped with the communicating system (designed within Scoop@F) in combination with flow of regular vehicles immersed in traffic for which there are no communication capabilities equipped.

For more details on the methodology, specific results and the way the study is built, we propose the reader to look up deliverables 2.3.7.1 to 2.3.7.4.

10.2 Simulation driven study

10.2.1 Reasons to go virtual

While the system users were driving on public roads, we have collected data, which necessarily relates to these vehicles only. On public roads and even with a considerable implementation effort, the expected penetration rate for this type of experimentation represents a very small part of road traffic. Regular traffic grows in proportion to the current deployment. An example of this situation can be verified within hourly traffic data observed on two one-way lanes towards Paris on the South R 118 where the average flow varies between 2000 and 3000 vehicles per hour, which is the maximum implementation ambition this project can have.

The use of simulation responds to the necessity of taking into account the traffic around Scoop vehicles. It is crucial to fully grasp the impact of the system not only on the equipped vehicle but on the flow, globally. Thanks to the simulation environment, it is possible to know the trajectory of non-Scoop vehicles and to vary the penetration rate of Scoop vehicles. Since all the trajectories are known they make it possible to produce road traffic indicators characterizing the modifications created by Scoop on the flow. These gains are expressed in terms of total spent time over network and speed distributions.

10.2.2 From use cases to trajectories parameters

The Scoop project covers a considerable amount of use cases corresponding to events of different nature. It was not possible to evaluate distinctly each of these use cases in this project. By building the model, we reached the conclusion that in fact, they all share the same constraints of infrastructure and other vehicles. When such an event occurs, the actions available for the driver are:

- Acceleration: adopting a higher or lower vehicle speed
- Lane change: as insertion or lane reduction
- Road change: by a traffic easing route

Our study excludes the route change that implies a strong variability in the results and an even more important model complexity. We keep the acceleration and lane change parameters, which are easier to build to estimate the profits of the Scoop system while being more reliable (less variance and phenomena complexity). For these two acceleration parameters and lane change, we introduce two dependent parameters:

- The anticipation: it is specific to the project, allowing an upstream action executed by connected vehicles.
- The acceleration power: it is also function of anticipation

So that our study can be part of a specific use case, we selected the roadworks use case corresponding to the closing down of a lane with upstream markings ordering to slow down (here from 90 km/h to 70 km/h) over 1 km.

10.2.3 Scoop project specificities for modeling

10.2.3.1 Main tools

As mentioned in deliverable 2.3.7.4 dedicated to methodology, we use Symuvia1, a traffic dynamic micro simulation tool that estimates the position of each vehicle at every second on the network. A puR-ITS-Sit law makes this estimation possible for each time step. It takes into account the regulation on the travelled network as well as the presence of other vehicles close by in order to reproduce realistic trajectories. Since the LICIT is not qualified to study the behavioral aspects of driving, we analyze their translation in trajectories to estimate anticipation, acceleration, lane and direction change phenomena.

For the Scoop project, a specific complementary module named SymuCat has been developed in order to include the specificities linked to the information drivers expect. This system, developed in Python language, allows to reproduce trajectories profiles, noticeably different between connected and non-connected vehicles. Then two categories of vehicles are available, with divergent strategies and that produce trajectories with a significantly distinct quality and anticipation degree.

Reproducing in a realistic way this strategy divergence is the most critical aspect of this study. If the aim is reached, then it is possible to estimate properly the effects on the trajectories of the other vehicles. The propagation of behaviors anticipated by the connected vehicles on the other vehicles is a key aspect of this study. The physical constraint of a leading vehicle on a following one allows to change the flow thanks to more anticipation with no need of a high penetration rate. Following this hypothesis, the virtuous effects of Scoop System can be expected at low penetration rate.

10.2.3.2 Specific tools

For this application it is considered the simulation of microscopic traffic models where longitudinal position follows a specified behavior defined by two main components. The car following behavior describes the behavior of the vehicle in its longitudinal dynamics while the lane change behavior describes the behavior in the lateral position. In order to modify traffic behavior for a condition, the system is modeled via traffic model where V2I messages modify vehicle speed or lateral position.
For the sake of clarity, the following corresponds to the notations for variable description in the model. It is considered the vehicle position of a vehicle as xn and the headway space between a vehicle and its leader as $s_n = x_{n-1} - x_n$. The vehicle's speed and acceleration are defined as a_n, v_n respectively. For a determined vehicle in the network the longitudinal dynamics are determined by the acceleration behavior. In this case it is considered Tampere's Law (Brackstone & McDonald, 1999).

$$a_{n(t+T_n)} = min\left(c_{1,n-1}\Delta v_{n,n-1} + c_2\left(\Delta x_{n,n-1} - \left(s_0 + \tau v_n(t)\right)\right), c_3\left(v^{\star}(t) - v_n(t)\right)\right)$$

One of the main features of this model is the adaptability to a specific speed condition, while preserving properties of the traffic such as the car following behavior in congestion situation. This feature makes it possible to trace features in the fundamental diagram. *To implement the model a class object called Tampere has been implemented. The class intends to describe the full behavior of the vehicle.* So far parameters in the model have been fixed although random scenarios can be also considered.

Parameter	Value	Units
c_1, c_2, c_3	0.5	
τ	$\frac{1}{wk_x}$	[s]
w	6.25	[m/s]
k_x	0.16	[veh/km]
u_i	25	[m/s]

Figure 27 : model parameters

The inputs for simulation are:

- **Flow**: Vehicles are tested up to maximum capacity in free flow condition
- **Market Penetration Rate (MPR)**: Penetration rate for connected vehicles
- **Speed Drop**: Final speed limit for connected vehicles

10.3 Scenarios and tests

10.3.1 Network and traffic rules specifications

In order to determine the behavior of traffic under the influence of messages a particular scenario is selected. Generally, lane reductions and road works constitute a big source of congestion. The scenario under consideration takes into account one single link of two lanes (2900 vehicles / hour) headed at the same direction (90 km/h) with a lane reduction and speed drop (70 km/h). Non connected vehicles start adapting speed 1km before, to comply with virtual road signs placed as described in next figure. Scoop vehicles anticipates from 5 to 10 kilometers upstream. Vehicles of two types will enter the traffic network in a uniform flow configuration. At 14 km starts the road works signage and at 15km the lane reduction over 1 km. It creates a congestion, the propagation of the congestion follows the behavior of the well-known Lighting William Richards model, via the fundamental diagram. The Shockwave congestion propagation move upward at 22.5Km/h.

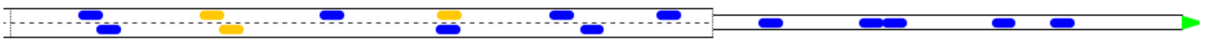


Figure 28 : Symuvia map extraction of network used

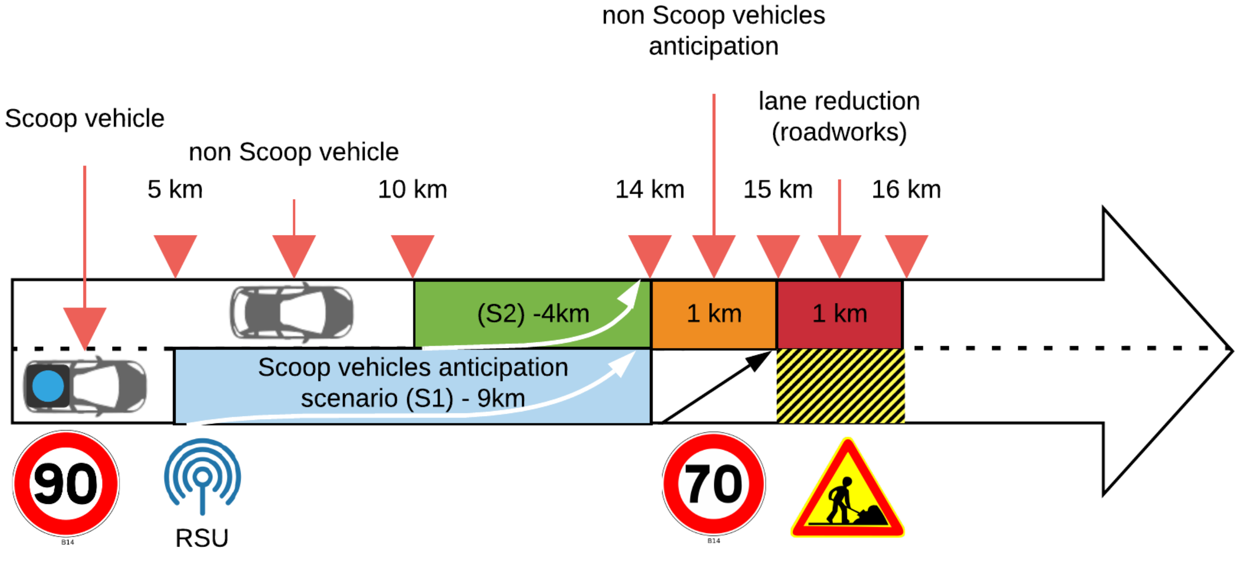


Figure 29 : simulated network with parameters

10.3.2 Scoop vehicles anticipation probability

10.3.2.1 Scoop - R-ITS-S range and message probability

We simplify broadcast frequency and transmission failures as this study is not a technology validation process. As our scenario implies minimum 1km (or 40 seconds) anticipation we consider no effects of these parameters. The R-ITS-S is localized upstream, 10km before roadworks and broadcast in a range of 500 meters.

We also simplify this behavior by considering the hypothesis that drivers are more likely to change their behavior when they approach to the event. In such case it is possible to model the probability distribution of compliance as a function of the distance to the emitter (exponential law for draw). Two scenarios are considered:

- 10 km to 1 km: means driver has received message at 10km from roadworks and is speed reduction (to 70 km/h) is dawned between this point and last kilometer before roadworks. There is no lane change anticipation (this is Scoop wave 1 use case version of roadworks).
- 5 km to 1 km: same but closer from roadworks.

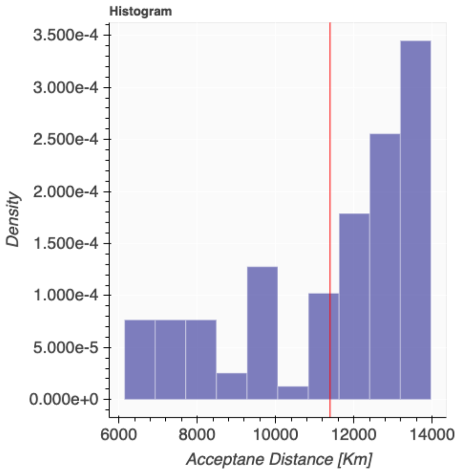


Figure 30 : acceptance distribution 10 km

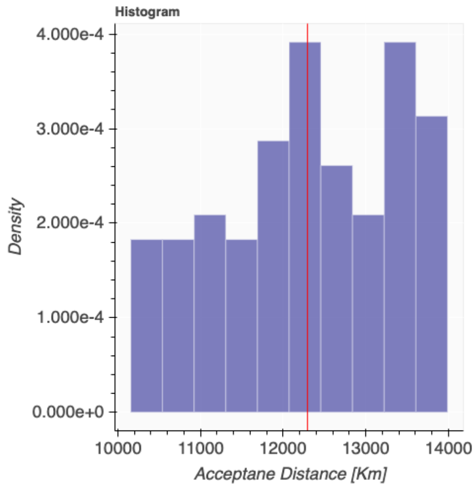


Figure 31 : acceptance distribution 5 km

Example of space probability distribution for messages transmitted to SCOOP vehicles. The probability to send a message increases when approaching to congestion, left case distribution when the message is broadcasted at 5Km on the right when the message is broadcasted at 10Km

10.3.2.2 Non-Scoop – parametric behavior

For these vehicles we consider speed drop start at 1 km from roadworks, where signage and downstream congestion is at view.

10.3.3 Vehicles acceleration profile

10.3.3.1 Common behavior to all vehicles

Acceleration constraints. Inspired by (Bokare & Maurya, 2017) boundaries on acceleration where fixed to emulate similar traffic behavior, mean acceleration is around 1 m/s^2 while maximum accelerations where constrained to 3m/s^2. In a scenario of congestion, the profiles of acceleration can be easily transformed to policies in space and time.

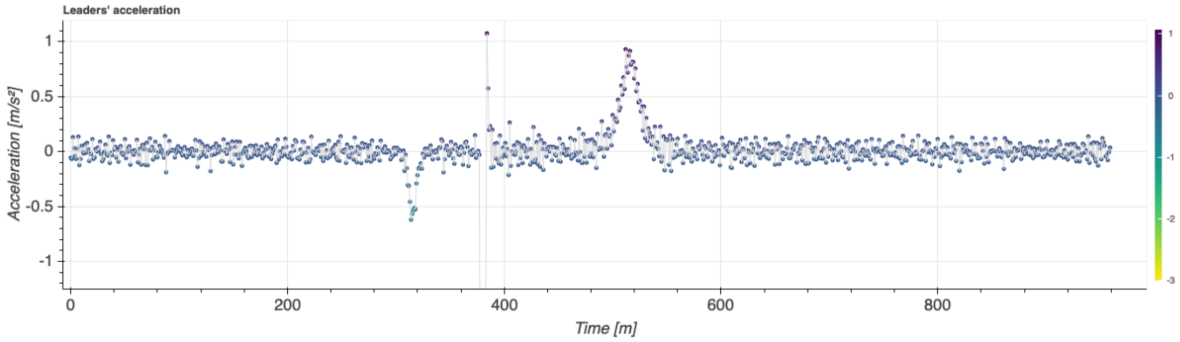


Figure 32 : acceleration profile of a vehicle with stochastic speed setting

10.3.3.2 Main leader profile for congestion

At the beginning of every scenario tested the first trajectory (main leader) is simulated:

- by maximum speed (25 m/s, 90 km/h) at beginning,
- then dropping speed (5 m/s, 18 km/h) along the roadworks,
- then back to maximum speed (25 m/s, 90 km/h)

This speed drop lasts for 1 kilometer (roadworks length) and is sufficient to initiate speed shockwave that results in initial congestion. It represents previous congestion generated by non-Scoop vehicles at lane closure. Therefore, it also allows us to evaluate scoop system capacity to resolve congestion. the corresponding speed an acceleration profiles illustrate these behaviors.

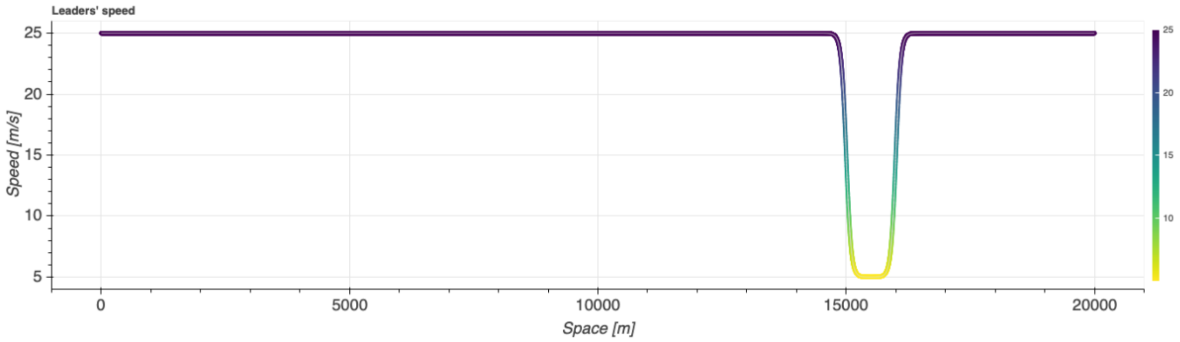


Figure 33 : Speed in space. Drop due to special main leader trajectory

10.3.3.3 Scoop vehicles acceleration profile when message received

In order to setup the message transmission of a speed suggestion is created as a function of space. For the current vehicle control the variable indicated to the driver corresponds to the *vehicle* speed.

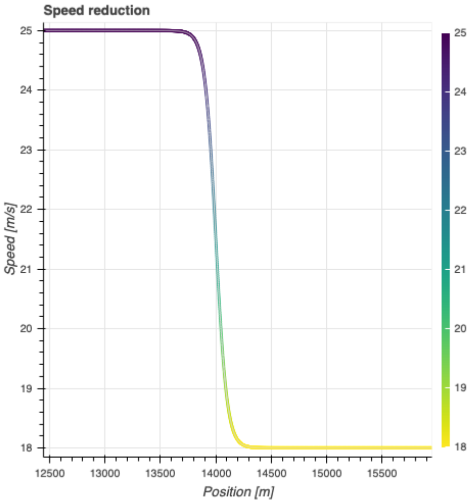


Figure 34 : Example of a message transmitted to a vehicle. The speed is selected to be reduced from 25m/s [90Km/h] to [65Km/h]

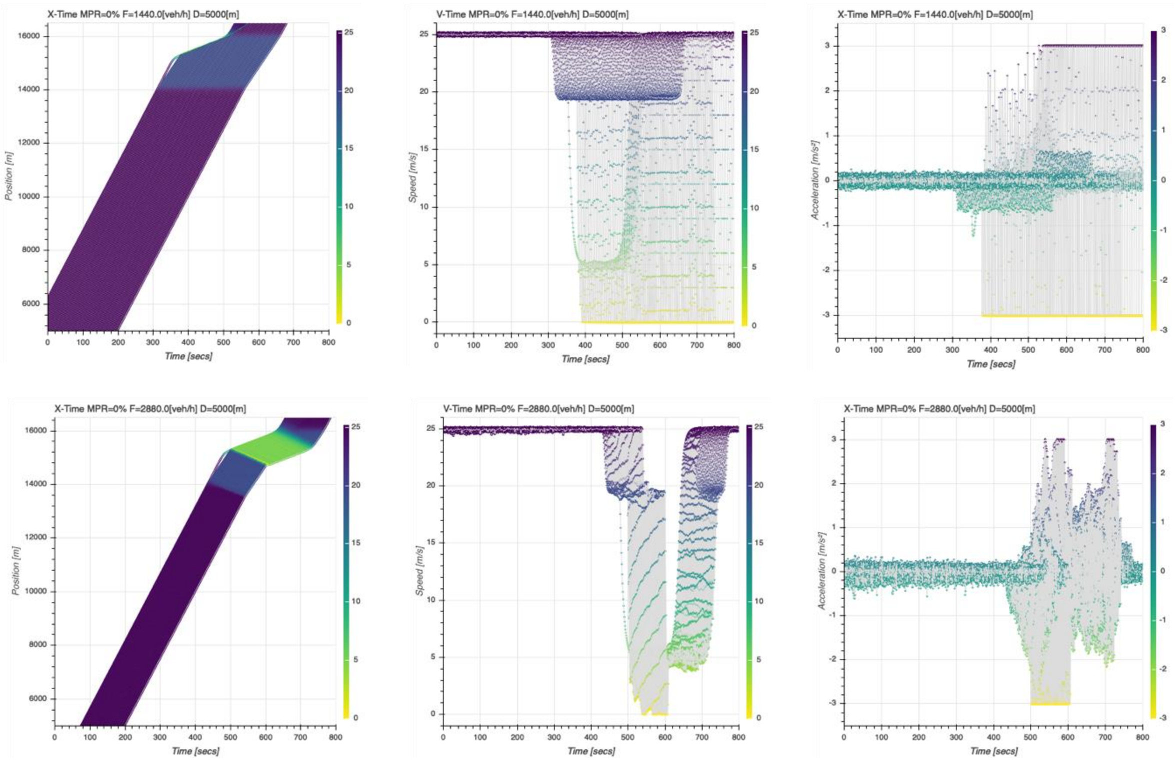
10.4 Main results

10.4.1 Selected scenarios

All parameters values combination hereafter:

- Penetration rate: 10, 20, 30 % of traffic demand
- Capacity (traffic demand), 2900, 1450 vehicles per hour
- Anticipation boundary for Scoop vehicle: 5000 and 10 000 meters from start.

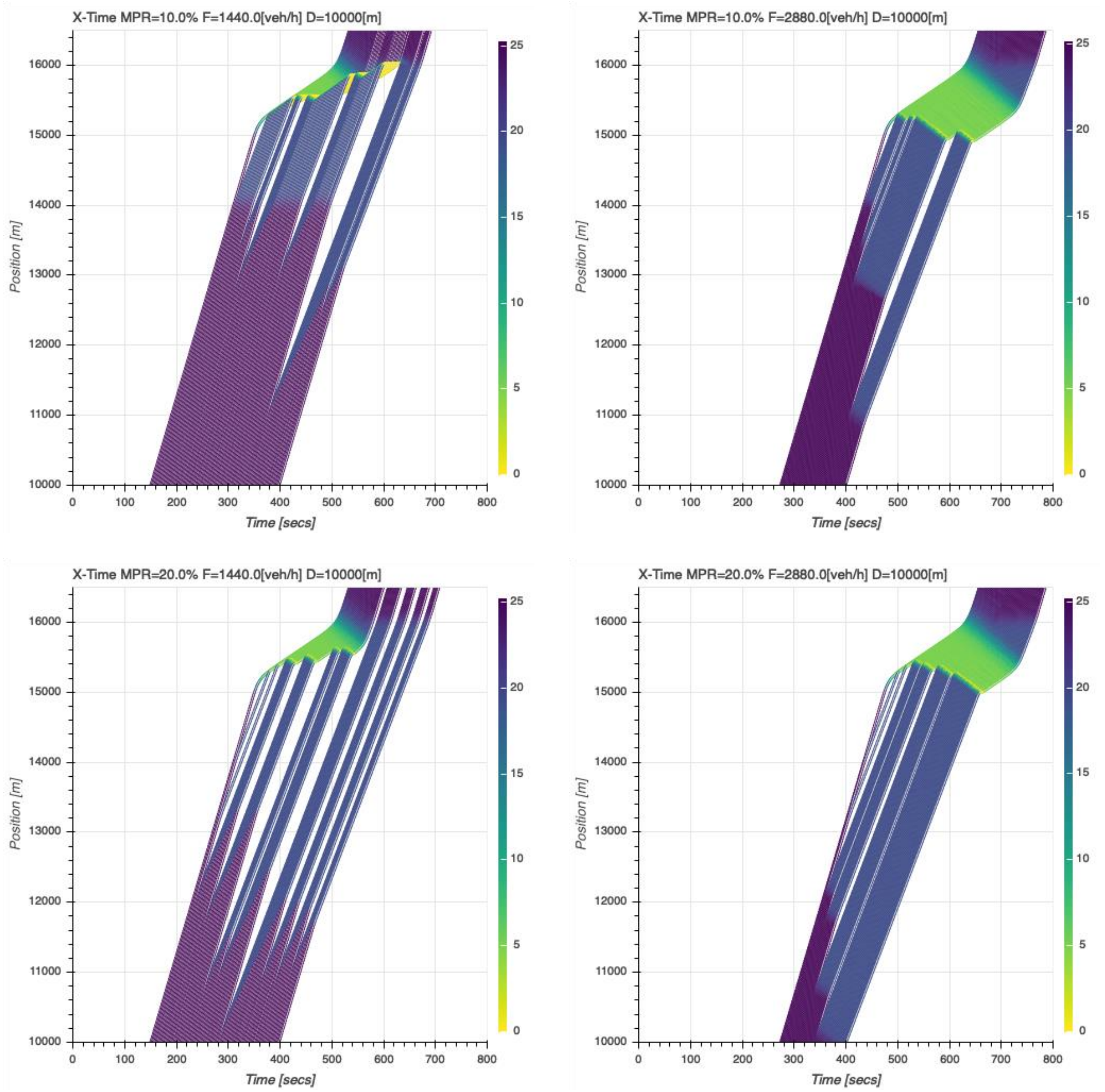
10.4.2 Reference situation

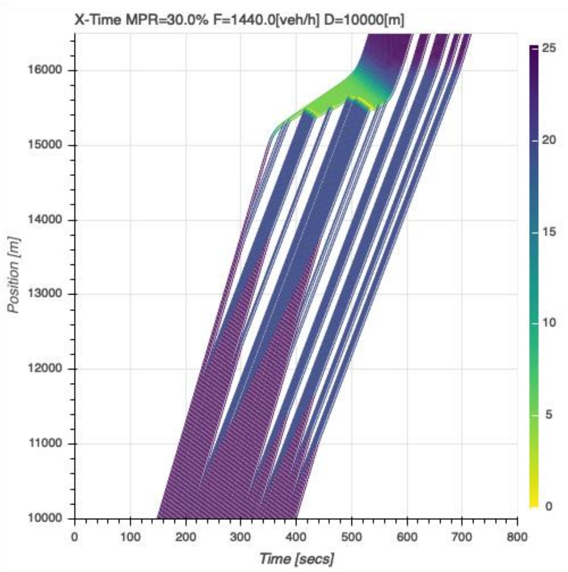


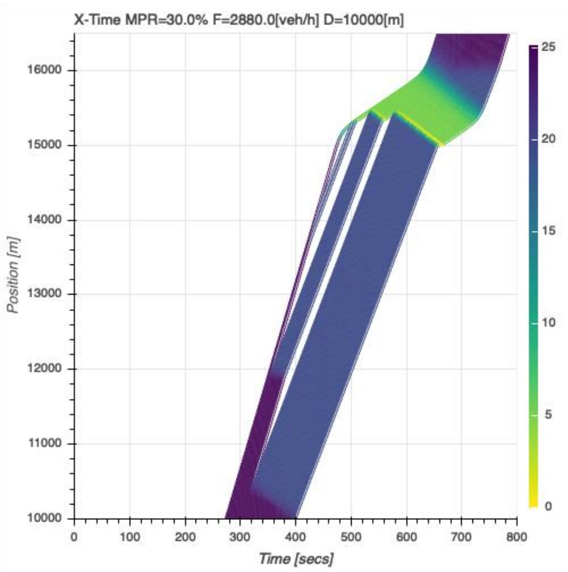
We consider the case where penetration rate is 0%. The only parameter changing is the capacity (traffic demand), as penetration rate and anticipation distance for Scoop vehicles are not relevant. On the space & time figures we can see clearly the speed drop at roadworks position. While authorized speed drops from 90 km/h to 70 km/h vehicles goes to 18 km /h as congestion happened. The speed profile figure shows the same phenomena viewed from speed angle. Acceleration is distributed widely at this point of the network. Congestion is created by main leader and with no Scoop system deployed it grows indefinitely.

N.B.: next figures titles: MPR: market penetration rate, F: capacity /1 (2800), D: Distance from link start.

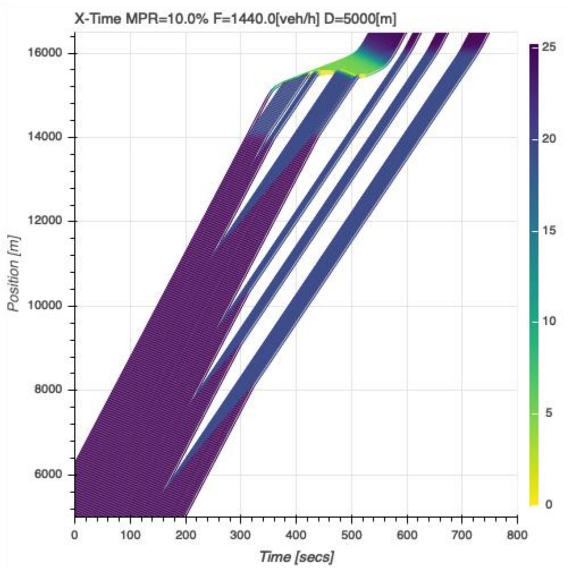
10.4.3 10 km anticipation from roadworks scenarios

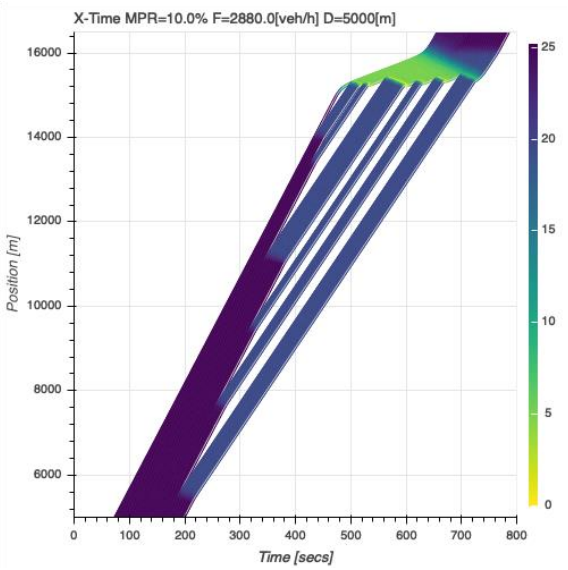


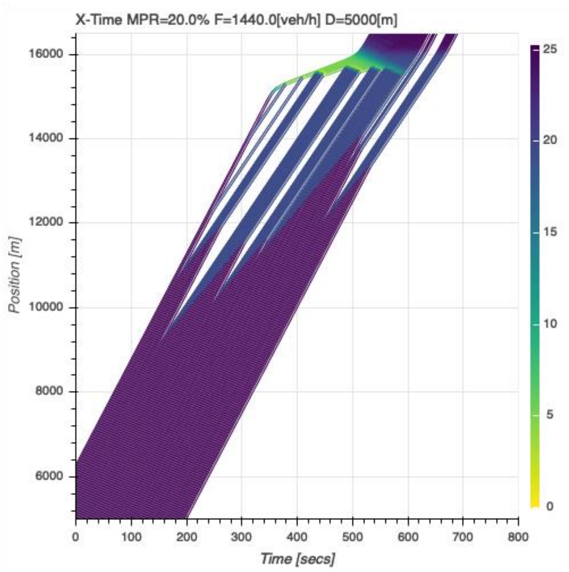


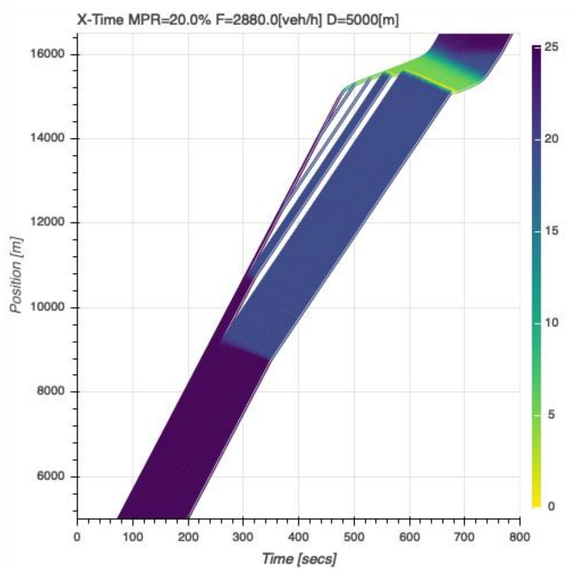


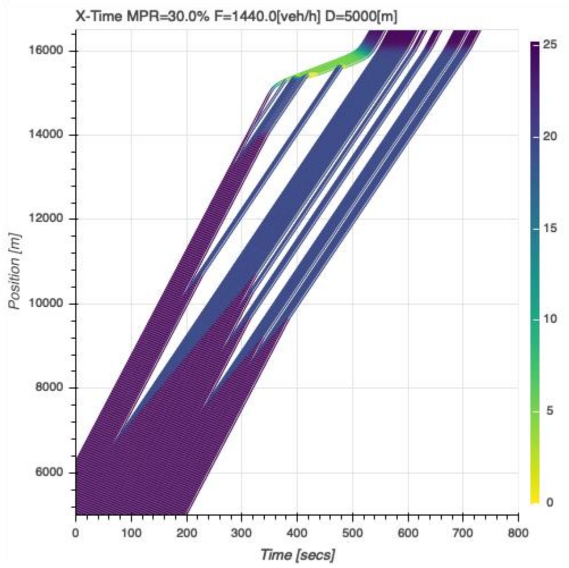
At 1400 vehicles per hour (left column, previous figures) and 10% of penetration rate reduces strongly congestion and from 20 % it resolves shortly. This allowing half vehicles to avoid speed drop stronger than regulation. At capacity (2800 vehicles), gains are significant from 10 to 30 % of penetration rate but yet not sufficient to resolve. This is nearly penetration rate independent phenomena. It mainly depends on anticipation distance being too close to roadworks (10 000 from start = 4 000 from roadworks).

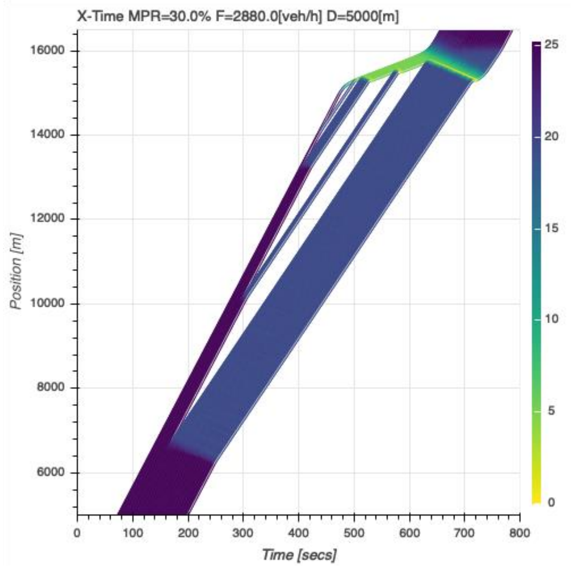




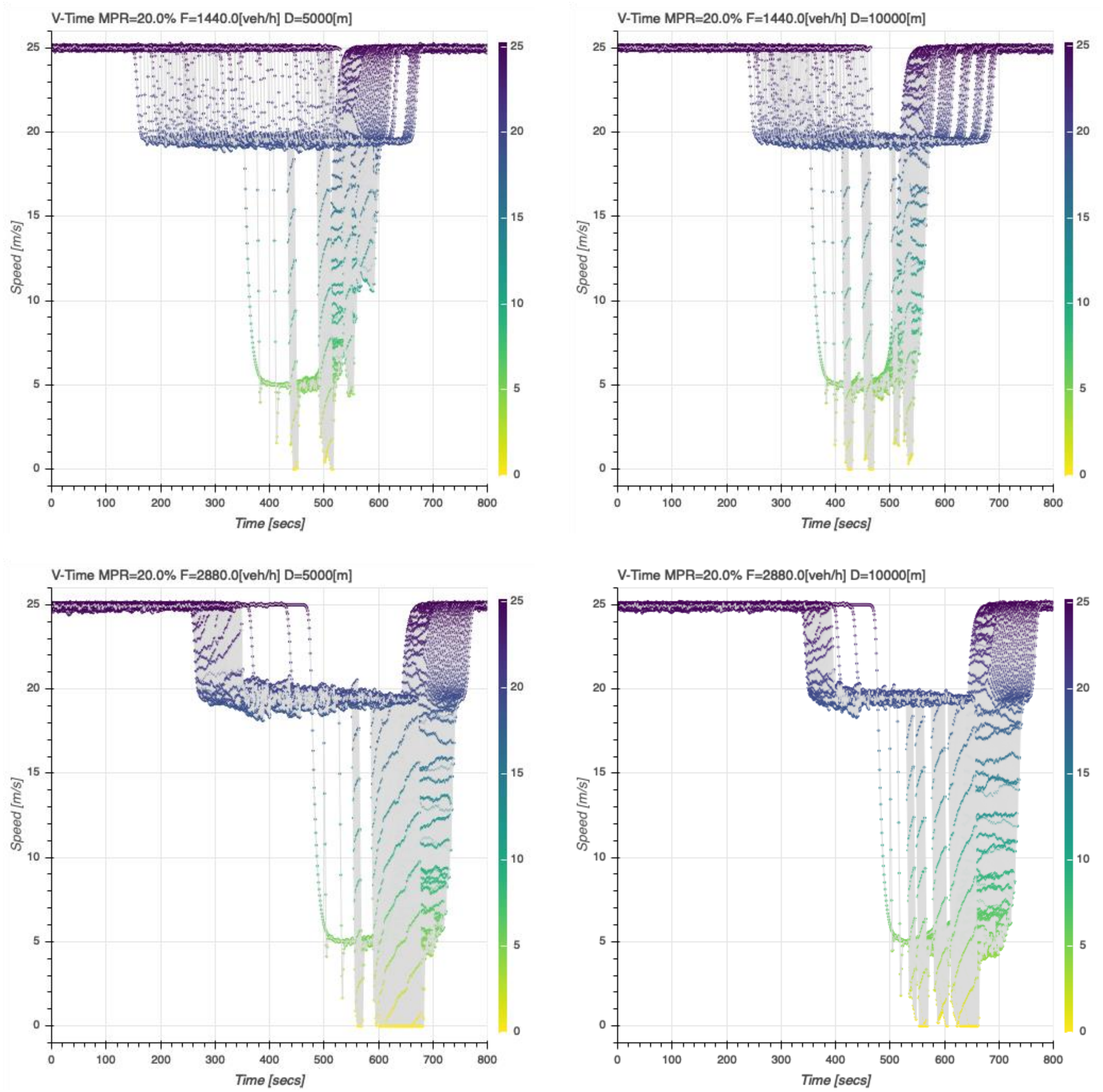








With 5 000 meters anticipation (10 000 from roadworks) space between vehicles tense to be larger, which impacts is to reduce the road capacity. As it comes with more time for action, we avoid speed shockwave in most cases while as a consequence it will increase the average travel time. Due to this anticipation policy, the speed at the moment of the roadworks tense to be more uniform. At mid capacity (1400 veh/h) the congestion solved even at 10% of penetration rate. At capacity (2800 veh/ hours) congestion is resolved at 30 % of penetration rate. This increased anticipation from 5000 to 10000 is the major factor to that change in traffic behavior.



These four figures show the speed performance of the group of vehicles traveling along the network. In all cases the penetration rate corresponds to 20% and it can be effectively seen the earlier broadcast towards scoop vehicles.

10.5 Conclusions on global gains from system over traffic

10.5.1 Neutral situations

On any given road if traffic congestion is strong there is no local regulation being efficient. As long as vehicles trajectories are locked between stopped or very slow vehicles one can only drive to avoid collision and keep moving. In this context no advice can be followed, apart from rerouting which we excluded from this survey.

On any given road, if traffic runs in free flow, far from congestion, one can only expect individual gains from scoop System. Anticipating will allow lower speed decrease and probably less consumption (non-significant).

10.5.2 Optimal situations

When the traffic runs in significant packs or at capacity (near congestion) context the capacity drop induced by road works generates congestion. As half our third of capacity is lost and lane change is required speed will decrease. The congestion can keep growing, find equilibrium or resolve. Scoop system can solve congestion that otherwise would keep growing. As speed decrease is anticipated it decrease flow equally. The congestion can be released and avoid waves to happened.

10.5.3 Impact on traffic indicators: Travel time

The following scenario illustrates a study of sensitivity when varying multiple parameters in the network. We have analyzed the behavior of the mean travel time for all vehicles in the network when influenced by the change of behavior of SCOOP vehicles.

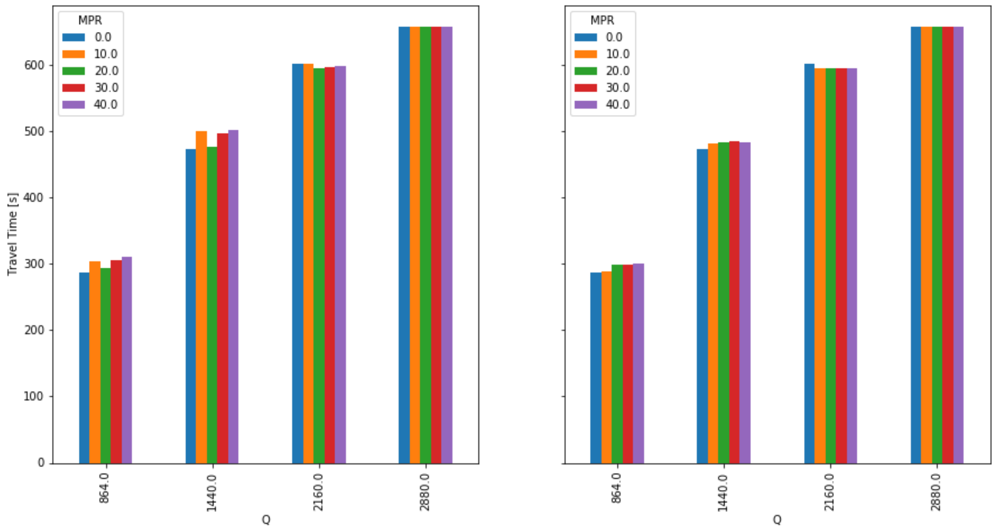


Figure 35: Average travel time of all vehicles in the network. The case on the left side illustrates the phenomena when the message is broadcasted at Km 5 and the case on the right side when the vehicle is broadcasted at Km 10.

In fact, the first result we can observe is the very low impact effect that penetration rate may have in the average travel time tested in this scenario. One of the main reasons why this could be the reason is the fact that once vehicles tend to receive the message the speed keeps uniform, during the full trip. Another reason is the fact that the scoop vehicle that adopts the suggested policy may impose a boundary conditions for vehicles upstream. However, the story is very different if we analyze the distribution of travel times of vehicles in the network. As it can be seen in the following figure the penetration rate has a strong influence in the travel time reliability; allowing to increase the stability and the homogeneity of the traffic at higher rates. This can be explained also by the fact that penetration rate has a lot impact in spatial distribution of SCOOP vehicles.

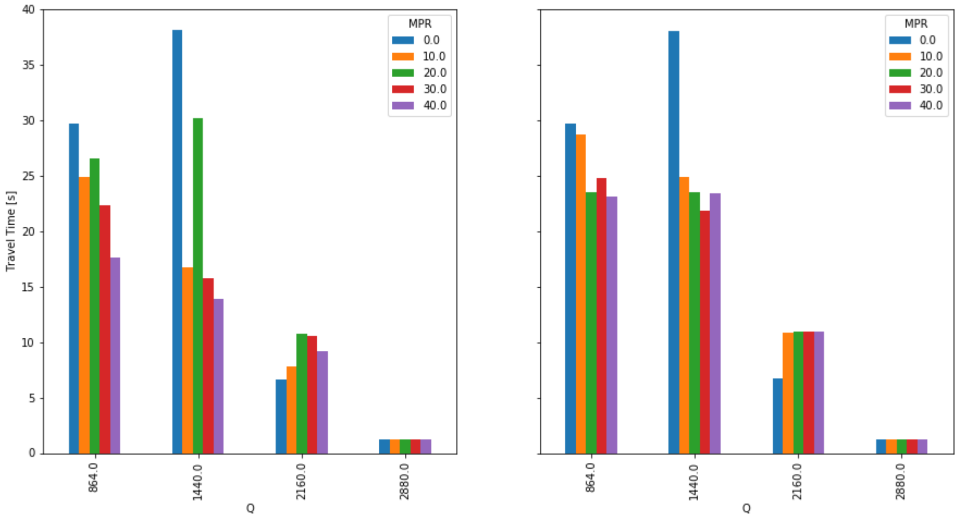


Figure 36: Standard deviation travel time of all vehicles in the network. The case on the left side illustrates the phenomena when the message is broadcasted at Km 5 and the case on the right side when the vehicle is broadcasted at Km 10.

On the other hand, it can be also seen that; the effect of broadcasting the message earlier in the network does not necessarily has an impact on the reliability of travel time.

10.5.4 Limitations of our study

To achieve these performances, we had to increase up to 10 km the anticipation boundary of Scoop speed drop vehicles. Also, as our study is considering 100% compliance within a spatial distribution. This is more likely to be expected from autonomous vehicles as behavior. There is a significant variety of patterns while traffic runs as stacks that would require more iterations to produce gains.

10.6 References

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11 Economic impacts - Socio-economic evaluation

11.1 Introduction

Connected vehicles provide users with new services and significantly improve road safety. However, the implementation of these services requires a dedicated equipment in the vehicles and/or on the infrastructure. This equipment is expensive and, at the current time, we cannot be sure that vehicle manufacturers and road operators will implement it.

This note presents the results of the socio-economic assessment carried out in the framework of the SCOOP and C-Roads projects, this evaluation being a more general assessment of a large-scale deployment of a communications system between vehicles and with the infrastructure, as experimented in the SCOOP and C-Roads projects.

A Socio-economic assessment is a method of gauging the potential interest of a project for the community as a whole. The assessment is broader than a typical cost-benefits analysis in that it takes into account all the concerned members of society, including third parties who are impacted by transport-related environmental nuisances (pollution, noise, greenhouse effect), insecurity (road accidents) and traffic congestion. This analysis is monetarized, i.e., the main advantages or disadvantages of the project are expressed in monetary form through collective values. For example, one collective value defines how much a person is willing to spend, on average, to save travel time, another collective value gives the cost to the community of averting loss of life (e.g., by equipping the road network to make it safer), and a third collective value gives the value of the greenhouse gas emissions saved.

These collective values have been defined and are regularly updated through discussions between experts in several working groups. The values currently used are mostly taken from the taskforce chaired by Émile Quinet for the Commissariat Général à la Stratégie et à la Prospective (French Commission on Strategy and Perspective) in the report L'évaluation socio-économique des investissements publics (Socio-economic evaluation of public investments) published in September 2013. The collective value of carbon emissions was recently updated by the Commission chaired by Alain Quinet for France Stratégie in the report La valeur de l'action pour le climat (The Value of Climate Action) published in February 2019. Each of these collective values and methods for socio-economic assessment are detailed in the Transport Projects Assessment Handbook, under the auspices of the French Ministry of Transport, which has served as a reference for the assessment of all transport projects financed by the State of France since the 1960s.
Lastly, it should be noted that this socio-economic assessment is an updated assessment; in other words, we determined the NPV (net present value) of expected future gains or benefits by applying a discount rate. The NPV reflects society's preference for the present time. Thus, just as a private investor will attempt to gauge expected future benefits before launching an investment project, a socio-economic analysis weighs up all the benefits expected from a project by asking for a certain collective profitability.

A socio-economic assessment is therefore a decision-making tool used to weigh up the main advantages, costs and disadvantages of the principal investment choices that public stakeholders face.

11.2 Technology scenarios

The main purpose of this study is to evaluate the potential interest in undertaking a large-scale deployment of a SCOOP and C-Roads system from 2020 onwards. This system, as currently being tested, is based on the ITS-G5 standard and allows short-range communications between two vehicles (V2V) and between a vehicle and the infrastructure (V2I and I2V). The implementation of this standard requires a double investment:

- First, the vehicles themselves have to be equipped with antennas and a system to transmit and receive messages, as well as a man-machine interface to display the collected information on the driver's dashboard.
- Second, the infrastructure has to be equipped with road side units (R-ITS-S) capable of transmitting, relaying or receiving messages from vehicles.

The ITS-G5 standard is not the only technology that enables communications of type V2V and V2I. It is therefore important to consider, as part of the assessment, different technology options in order to demonstrate the rationality of investing in a particular technology. Without going into the details of all the technological developments concerning connected vehicles, it is nevertheless worthwhile looking at the other major options that could be enforced by public authorities:

- The LTE-V2X standard promises to deliver the same services as the ITS-G5 standard, but unlike ITS-G5, it is not immediately operational (i.e., as of the current time). The standard could be deployed as of 2022 instead of 2020.
- The arrival of 5G should make it possible, going forward (approx. 2024) to set up short-distance communications offering the same services as the ITS-G5 standard.

In addition, more and more vehicles are equipped with telephone chips able to handle communications from the 4G network. These chips are being integrated by the manufacturers to offer on-board driver assistance services similar to some of the services envisaged under the SCOOP and C-Roads projects. Lastly, more and more drivers have GPS driving apps (e.g., Waze, Here, TomTom, Coyote) running either on their smartphones or on a separate device. It is therefore necessary to take into account, in the analysis, the distribution of these services at a reduced cost but without an on-board interface.

The working group focused on seven technology scenarios, including potential hybridizations between cellular technologies and short-range communications:

0. **Smartphone Scenario**: this is the baseline option, and it assumes an absence of investment in connected vehicles. This scenario consists in the expanded use, by drivers, of driving apps already available for

smartphones, with the constraint however that events must be reported manually. This scenario can also concern Apple Carplay or Android Auto type devices when they do not have access to the vehicle's on-board data (said data enabling the automatic transmission of events).

1. **4G On-board Scenario**: vehicles are equipped with 4G and then 5G (long range) chips communicating with the telephone network to offer on-board navigation services. With this scenario, V2V communication is not possible and there are no R-ITS-Ss installed.

2. **ITS-G5 Scenario**: vehicles are equipped with antennas and receivers for short distance message sharing using the ITS-G5 standard. This scenario has V2V communication as well as V2I communication, even in the absence of a telephone network. The vehicle cannot however communicate with the 4G telephone network.

3. **ITS-G5 + 4G Scenario**: identical to the previous scenario but the antennas/receivers are equipped with hybrid technology allowing them also to receive and transmit messages with a server via the 4G telephone network in the covered areas.

4. **LTE-V2X Scenario**: identical to the ITS-G5 scenario but with a different communications protocol (deployment delayed to 2022).

5. **LTE-V2X + 4G Scenario**: identical to the ITS-G5 hybrid scenario but with a different communications protocol (deployment delayed to 2022).

6. **5G short range Scenario**: in which vehicles are equipped with 5G chips (deployment scheduled to start in 2024). In addition to communication with the telephone network in the covered areas, these chips enable V2V communications with a sufficiently low latency to offer most of the services of a connected vehicle (provided that these vehicles are located inside a covered area). However, this scenario does not correspond to the first generations of 5G technology and the start date for deployment in this scenario takes this into account. Moreover, the feasibility of this solution has not been demonstrated by real-world tests.

For the *Smartphone* scenario, it was assumed that the usage rate of driving apps was 40%. This rate comes from a survey conducted among drivers in 2017 as part of the 13th Axa accident-prevention study (“baromètre Axa prévention”). In 2016, only 26% of drivers reported using their smartphone's GPS while driving; thus, it is possible that this proportion will rise to over 40% in the future. However, the AXA survey does not give any information on the duration of GPS use and it is likely that some of these drivers use driving apps only for a part of their trip (i.e., not for the entire trip). Thus, a driving apps usage time of 40% of driving time seems a reasonable assumption in the absence of additional information.

It is important to note however that driving apps also come with disadvantages, in terms of road safety. The Axa study considered driving apps as distracting drivers, with the potential to cause road accidents. In addition, people who make use of their smartphone's GPS (as a driving app) can be tempted to also use their phones to make phone calls while driving, and this behavior is known to significantly increase road safety risk. However, this distraction effect could not be measured nor incorporated into the socio-economic calculations of this assessment.

Finally, driving apps do not provide an equivalent level of service to the on-board applications considered in the other scenarios. Switching on a smartphone, connecting it to a charging socket and providing route information requires an effort on the part of the user that is avoided in other cases. For this reason, and also because of the apparent maturity of these solutions, we did not assume that their use would be more widespread than it is today. In addition, the smartphone can have other uses in the car besides driving assistance, for example by offering multimedia services (music streaming). These services are not affected by vehicle connectivity.

Table 11 summarizes, for each scenario, the types of communications allowed. Communications can be vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) or infrastructure-to-vehicle (I2V). For V2I and I2V communications, communications can be made directly between a vehicle and a R-ITS-S in the case of ITS-G5 and LTE-V2X technologies or via the Internet in the case of 4G. In the latter case, the road operator has a centralized server connected to the Internet.

Table 11: Available communication modes per scenario

N°	Scenario	Technologies	Operating conditions	Modes of operation
0	Smartphone	4G/5G	Smartphone use (40% of users) + network	V2I, I2V
1	4G onboard	4G/5G (long range)	Network	V2I, I2V
2	ITS-G5	ITS-G5	Road side units	V2I, I2V
		ITS-G5	-	V2V
		4G/5G	Smartphone + network	V2I, I2V
3	ITS-G5 + 4G	ITS-G5	Road side units	V2I, I2V
		ITS-G5	-	V2V
		4G/5G	Network	V2I, I2V
4	LTE-V2X	LTE-V2X	Road side units	V2I, I2V
		LTE-V2X	-	V2V
		4G/5G	Smartphone + network	V2I, I2V
5	LTE-V2X + 4G	LTE-V2X	Road side units	V2I, I2V
		LTE-V2X	-	V2V

		4G/5G	Network	V2I, I2V
6	5G short range	4G/5G	Network	V2I, I2V
		5G	5G Network	V2V

In all of these scenarios, services are deployed on national roads, on the secondary road network as well as in major urban areas. The infrastructure required for the scenarios studied consists of relay antennas for the telephone network and road side units to be deployed every two to five kilometers for V2I and I2V communication modes. Three deployment scenarios were considered for these road side units (Table 1).

Table 12: Infrastructure Deployment Scenarios

Deployment speeds	Slow	Average	Fast
4G coverage of road networks - in 2020 - every year thereafter	 75% 2.5%	 75% 2.5%	 75% 2.5%
R-ITS-S coverage of the national network - in 2020 - every year thereafter	15% 3.5%	30% 7%	30% 7%
R-ITS-S coverage of the secondary road network - in 2020 - every year thereafter	2.5% 0.25%	5% 0.5%	5% 2.5%
R-ITS-S coverage of the major urban areas - in 2020 - every year thereafter	7.5% 2.75%	15% 5.5%	15% 8.5%
5G Coverage	Same as R-ITS-Ss, operational from 2024.		

The deployment of road side units on the national road network and on the secondary road network is supposed to follow a principle of efficiency by targeting the most accident-prone sections as a priority. In this study, traffic modeled from a traffic model was used as a proxy variable to measure the accident frequency rate of a road section. For example, it was determined that 30% of the equipment fitted on the national road network, if properly distributed, can cover 56% of traffic and thus a similar proportion of accidents. Similarly, 5% of equipment on the secondary road network can cover about 43% of accidents. In particular, traffic and accidents on the secondary road network are very unevenly distributed, so that the equipment required for just a small percent of this network can be enough to cover almost all such traffic and accidents.

Concerning the deployment of the 5G network, the tender call launched by Arcep foresees a complete coverage of motorways in 2025 and main roads in 2027. Nevertheless, in this present study, we made the same deployment assumptions as for the scenarios with road side units; by so doing, we can compare the different technological options. In addition, the Arcep tender call requires that vertical services (*network slicing*) be available before the end of 2023. It was therefore assumed that V2V Use Cases will be available for 5G technology from 2024 onwards.

In addition, three scenarios were also defined for the deployment of services in vehicles (Table 13). These scenarios entail equipping new vehicles and retrofitting older vehicles. They are therefore expressed as a proportion of the equipped vehicle fleet.

Table 13: Fleet deployment scenarios

	Slow	Average	Fast
Annual speed of deployment in the fleet	1%	3%	5%

Expressed in terms of the equipment rate of new vehicles, these scenarios correspond to the following shares of connected vehicles in sales:

- **Low scenario**: around 13% of new vehicles between 2020 and 2025, then an increase to 17% in 2030, 27% in 2040 and 37% around 2050.
- **Average scenario**: around 40% of new vehicles between 2020 and 2025, then an increase to 50% in 2030, 80% in 2040 and 100% around 2045 (bearing in mind that part of the equipment can be retrofitted).
- **High scenario 2030**: around 66% of new vehicles between 2020 and 2025, then an increase to 80% in 2030 and more than 100% in 2040, given that older vehicles are retrofitted.

Beyond the deployment of vehicle connectivity in the fleet, we need to look at how this equipment will be perceived by drivers. Depending on the conditions of use that will be requested and the requirements of the CNIL (i.e., the French data protection agency), it is possible that some drivers will refuse to participate in the system. In such cases, the vehicles concerned would neither transmit nor receive any information and the road safety benefits would be diminished. In this study, we assumed, for the sake of simplicity, that the number of unwilling drivers will be low and of no impact on the results.

11.3 Use Cases

The quantitative assessment of the effects of a connected vehicle is largely taken from the final report of Ricardo's *Study on the Deployment of C-ITS in Europe* for the European Commission (February 2016), which was updated in December 2018 (*Support study for Impact Assessment of Cooperative Intelligent Transport Systems*). The list of services offered by connected vehicles, also called Use Cases, therefore corresponds to those set out in this report. A number of Use Cases were ignored in the Socio-Economic Assessment, either because the services were not easily monetarized or because it was not clear that they were relevant from a socio-economic point of view. The list of Use Cases retained for the socio-economic assessment, as well as the possible modes of communication for the operation of these services, is given in Table 14, and the list of Use Cases ignored are given in Table 15.

Table 14: Use Cases selected for the socio-economic assessment

Use Cases	Acronym	Modes of operation	Compatibility 4G network
Emergency Electronic Brake Light	EBL	V2V	No
Emergency vehicle approaching	EVA	V2V	No
Hazardous location notification	HLN	V2I2V, V2V	Partial
Slow or stationary vehicle	SSV	V2I2V, V2V	Partial
Traffic Jam Ahead Warning	TJW	V2I2V, V2V	Partial
In-vehicle signage	VSGN	I2V	Yes
Road Works Warning	RWW	I2V	Partial
Weather conditions	WTC	I2V	Yes
Green light optimal speed advisory	GLOSA	I2V	Partial
Signal violation	SigV	V2I2V	No
Vulnerable road user protection	VRU	V2X	Partial
Wrong-way driving	WWD	I2V	Yes

The Use Cases *Emergency Electronic Brake Light* and *Emergency Vehicle Approaching* operate only in V2V mode and therefore require short range communication technology (ITS-G5, LTE-V2X or 5G short range).

The Use Cases *Hazardous Location Notification, Slow or Stationary Vehicle* and *Traffic Jam Ahead Warning* can work in both V2V and V2I2V mode. In the latter case, the vehicle concerned by the event sends the information back to the network via a road side unit or the telephone network, and the information is then distributed to the connected vehicles. This mode of operation was not possible for the Use Case *Emergency Vehicle Approaching* where the validity time of the information, less than one minute, did not allow alerts to be reported via the 4G network.

The Use Cases *In-vehicle Signage, Road Works Warning, Weather Conditions, Wrong-way Driving* and *Green Light Optimal Speed Advisory* require only top-down information between the infrastructure and the vehicle. This information can be provided with a certain latency and these Use Cases can therefore be integrated into a driver assistance service operating via the 4G network.

The Use Case *Signal Violation* warns all users that a driver has run a red light. This Use Case requires that both of the vehicles involved in a potential collision be equipped along with the traffic light where the (potential) collision could occur. This Use Case requires very low latency and is therefore not compatible with driver assistance systems connected to the 4G network.

The Use *Case Vulnerable Road User Protection* involves direct communication between the vehicle and a pedestrian (here, a person working on the road who is assumed to be connected at all times).

For a number of Use Cases, latency requirements mean that the 4G network cannot provide the service with the same level of quality. In a number of cases, messages arrive too late to be of any real use to the recipient. The studies carried out in the NordicWay project, and included in the update of the Ricardo study (*Support study for Impact Assessment of Cooperative Intelligent Transport Systems*), show a decrease in impacts on road safety of around 30% when the information is transmitted via the 4G network for Use Cases *Hazardous Location Notification* and *Road Works Warning*. This result will be used unchanged in this study and extended to the Use Cases *Slow or Stationary Vehicle, Traffic Jam Ahead Warning, Green Light Optimal Speed Advisory* and *Vulnerable Road User Protection*.

Table 15: Connected vehicle Use Cases not included in the socio-economic assessment

Use Cases	Acronym	Reason
In-vehicle speed limits	VSPD	The literature shows that in these cases the loss of user time outweighs the gains in road safety. The baseline scenario is therefore sub-optimal.
Probe vehicle data	PVD	Service not intended for the end user, significant risk of double counting.
Shockwave damping	SWD	We considered it too difficult to impose adaptive cruise control until 100% of vehicles are equipped.
Traffic Signal Priority request	TSP	The effect only concerns buses and emergency vehicles.
Information on fuelling/charging stations	iFuel	Service available via smartphone under the same conditions.
On/Off street parking information	Pinfo	Service available via smartphone under the same conditions.
Traffic information & Smart Routing	SmartR	Service available via smartphone under the same conditions.

Park & Ride information	P&Ride	Service available via smartphone under the same conditions.

11.4 Baseline scenario

The main parameter of the baseline scenario to be defined is the trend in road accidents. In a declaration made in Valletta in 2017, the ministers of the European Union member states declared their intention to halve the number of seriously injured road traffic casualties in 2030 compared to 2020 and promised to put in place policies to achieve this goal. Therefore, we considered it necessary to factor this statement into the baseline scenario of our Socio-Economic Assessment.

The main challenge is that vehicle connectivity plays a major role in achieving this goal. An analysis of Ricardo's study (*Study on the Deployment of C-ITS in Europe*, February 2016) shows that if all vehicles and the entire infrastructure were equipped, the gains in terms of road safety would be around 20%. Thus, in the absence of the prospective analyses that led to the formalization of this objective, we considered a 30% decrease in the accident rate in the absence of vehicle connectivity to be a reasonable assumption, reflecting the scope of the Valletta declaration. This corresponds to an annual decrease in road accidents of 3.5% between 2020 and 2030. The accident rate was assumed to remain constant after 2030.

This trend in accident rates reflects the other measures envisaged by the Member States of the European Union to reduce road accidents: active safety technologies (tightening of seatbelts in the event of an imminent accident, raising the front bonnet in the event of a pedestrian impact), improvement of infrastructure, etc.

In addition, the potential arrival of completely self-driving vehicles is a possibility to take into account in the assessment. Whilst experts are of the opinion that 100% driverless vehicles will not be arriving on the market in the coming years (despite announcements made by some players), this possibility does argue in favor of tightening the assessment horizon, traditionally set at 2070 in the context of road projects. Thus, we considered that the benefits of vehicle connectivity are too uncertain from 2050 onwards owing to the possible widespread deployment of self-driving vehicles around that date. Thus, **we set the assessment horizon at 2050.**

However, it is necessary to add an important clarification, namely that the investments envisaged are often seen as a first step towards a switch to driverless vehicles. In the opinion of many experts, V2V communication will be essential if completely self-driving vehicles are to become a market reality. Indeed, V2V communication is often seen as an essential redundancy to ensure the safety of driverless vehicles.

11.5 Costs

The cost assumptions for vehicle equipment have been reworked based on the results of the Ricardo study (*Support study for Impact Assessment of Cooperative Intelligent Transport Systems*, December 2018). These assumptions are detailed in Table 16. An additional cost of €10 per vehicle was added for 5G equipment on vehicles compared to the same equipment with 4G technology. Assumptions for the deployment of connectivity in the vehicle fleet were refined using a fleet model to represent the rate of vehicle turnover.

The costs relating to the purchase of smartphones for scenario 0 (the baseline option) were not taken into account because the decision to purchase a smartphone is rarely motivated by the sole prospect of using a driving aid. The development costs of smartphone applications were not taken into account, as they are much more widely distributed, which means that the app development costs are easier to recoup than for software that has to be adapted for each vehicle model.

The cost elements to install new road side units, for scenarios 2 to 5, are given in Table 16. In the absence of available data, these costs have been extrapolated for 5G network equipment along roads.

Table 16: Vehicle equipment costs (based on Ricardo's study)

Category	Costs	Amount	Technologies	Scenarios
Investments	DSRC transmitter/receiver (for 1)	€80.02	All	1 to 6
	DSRC antenna (for 2)	€12.31	ITS-G5, LTE-V2X	2 to 5
	Electronic Control Unit	€55.40	All	1 to 6
	Wiring	€11.08		
	Cellular on-board equipment	€12.31	4G, 5G	1, 3, 5, 6
	5G SIM card surcharge	€10	5G	6
	Installation	€8.47	All	1 to 6
	Development & Integration	€28.48		
	Vehicle software development	€2.85		
	Total	**€198.61**	**4G, ITS-G5, LTE-V2X**	**1, 2, 4**
		€210.92	**ITS-G5+4G, LTE-V2X+4G**	**3, 5**
		€208.61	**5G**	**6**
Operating costs (per year)	Maintenance	5%	All	1 to 6
	Secure communications	€2.56		

	Vehicle software (updates)	€3.02		
	Cellular data	€3.94		0 to 6

Table 17: Costs of road side units (based on Ricardo's study)

Category	Costs	Amount
Investments	Equipment/hardware	€6619.79
	Installation/mounting	€7500
Operating costs (per year)	Regular maintenance	5%
	Power consumption	€42.05
	Data	€200.56
	Secure communications	€37.91

The life time of a road side unit was assumed to be 10 years. Beyond this period, road side units have to be replaced; this requires the same investment costs except for the *installation/mounting* expenditure item, recorded at the reduced amount of €1500 since the initial set-up work does not have to be redone. Road side units are installed every two kilometers along national and secondary roads, with deployment targeting high-traffic areas and the most accident-prone areas as a priority. Urban areas are covered according to a logic of complete coverage of the urban area: a model of circle packing in a plan shows that the 15,700 km² of urban areas in France can be covered using 6050 road side units.

The costs of installing and operating a centralized system for the management of road side units and traffic control (a few million euro), given in detail in the Ricardo study, were not taken into account in this study because not significant compared to other items of expenditure. Likewise, we did not include the cost of deploying relay antennas for 4G coverage for the territory because it was considered that this deployment was based on an economic logic independent of the issues facing connected vehicles.

11.6 Effects on road safety

The assessment of the effects on road safety is based, with a few variations, on the results of the Ricardo study (*Study on the Deployment of C-ITS in Europe*, February 2016). Contrary to Ricardo's study, the Use Case “Vulnerable Road User Protection” was only considered for the case of motorways, since it was considered that a widespread deployment of equipment for pedestrians and cyclists in urban areas was unlikely. In Ricardo's study, equipping all pedestrians and cyclists in urban areas resulted in a 1.8% reduction in the number of deaths and a 1.9% reduction in the number of injuries. By equipping all motorway personnel with transponders enabling V2X communication, the eight deaths that took place over the last ten years could have been avoided; hence, our assumption of a 0.1% reduction in the number of deaths and injuries on motorways. We assumed that this Use Case would not be operational before 2025. The effects on road fatalities per Use Case are given in Table 18.

Table 18: Effects of vehicle connectivity on road deaths (assuming 100% equipment rate for vehicles and for the infrastructure), adapted from Ricardo's study.

Use Cases	Acronym	National road network	Secondary road network	Major urban areas
Emergency Electronic Brake Light	EBL	-2.7%	-2.7%	-2.7%
Emergency vehicle approaching	EVA	-0.8%	-0.8%	-0.8%
Hazardous location notification	HLN	-5.2%	-5.3%	-1.7%
Slow or stationary vehicle	SSV	-1.1%	-1.1%	-1.1%
Traffic Jam Ahead Warning	TJW	-2.4%	-2.0%	-1.2%
In-vehicle signage	VSGN	-1.0%	-1.3%	-1.3%
Road Works Warning	RWW	-1.9%	-1.9%	-1.9%
Weather conditions	WTC	-3.4%	-3.4%	-3.4%
Green light optimal speed advisory	GLOSA	0%	0%	-0.1%
Signal violation	SigV	0%	-3.8%	-3.8%
Vulnerable road user protection	VRU	-0.1%	-1.8%*	-1.8%*
Wrong-way driving	WWD	-0.4%	0%	0%

* The benefits related to the Use Case “Vulnerable road user protection” in urban areas and on the secondary road network were not taken into account in the rest of this study, since to glean these benefits would require a high equipment rate for pedestrians and cyclists and we were of the opinion that, in the medium term, this high rate is only feasible for personnel working on the national road network.

In total, and after removing double counting between Use Cases as reported in the Ricardo study (see below), vehicle connectivity would be expected to lead to a reduction in road mortality of 15.8% on the national road network, 18.9% on the secondary road network and 14.8% in the major urban areas. The number of injured persons would fall by 15.9% on the national network, 22.0% on the secondary road network and 17.4% in the major urban areas. This of course would require a 100% equipment rate for vehicles and for the infrastructure.
If only some of the vehicles and/or some of infrastructure are equipped, these benefits

on road safety must be reassessed to take account of the equipment rates:

- For Use Cases requiring the V2V communication mode, the effects are proportional to the square of the vehicle equipment rate;
- For Use Cases using V2I or I2V communication modes, the effects are proportional to the rate of vehicle equipment multiplied by the proportion of the network equipped (in road side units for ITS-G5 and LTE-V2X technologies or in relay antennas for 4G technology);
- For V2I2V Use Cases, the effects are proportional to the square of the vehicle equipment rate multiplied by the proportion of the network equipped. As regards the Use Case *Signal violation*, this could be transformed into an I2V Use Case, assuming that the traffic lights are equipped with sensors to identify vehicles running red lights.

There are, however, some exceptions to this rule. In order to maximize benefits, it will be assumed that all emergency vehicles and pedestrians on the road will be connected in the short term (emergency vehicles can be retrofitted). For the Use Case *Traffic Jam Ahead Warning*, we assumed that the information will be systematically disseminated since only a few connected vehicles in the traffic jam are needed to transmit the information.

For Use Cases involving multiple modes of communication, we assumed that the equipment of the road side units was independent of the 4G network coverage, and that the equipment of the vehicles was independent of the road network.

Since a number of Use Cases have similar functionality, it is possible that several services may overlap and apply to identical driving situations. In practice, when two or more services are deployed, the resulting impact on road safety is not necessarily equal to the sum of the impacts for each service. The difference, corresponding to the driving situations covered by the two services, constitutes double counting. These double counts were therefore deducted from the calculation in accordance with the service-overlap assumptions made in the Ricardo study:

- 25% of the impacts of the Use Case *Traffic Jam Ahead Warning* are covered by the Use Case *Emergency Electronic Brake Light*,
- 25% of the impacts of the Use Case *Road Works Warning* are covered by the Use Case *Emergency Electronic Brake Light* and an additional 25% by the Use Case *Traffic Jam Ahead Warning*,
- 50% of the impacts of the Use Case *Weather Conditions* are covered by the Use Case *Hazardous Location Notification*.

The results of the study in terms of road fatalities are represented in Table 19 for each of the seven technology scenarios and for the central scenarios in terms of vehicle equipment and infrastructure equipment. These results are given with respect to a situation with zero vehicle connectivity. Thus, with Technology Option 3, which provides for the deployment of hybrid equipment compatible with ITS-G5 and 4G network, only 3346 fatalities would be avoided compared to the baseline option of scenario 0 (the baseline option).

Table 19 : Number of fatalities averted for the central scenarios in terms of vehicle equipment and infrastructure equipment (2020-2050)

Scenario	0	1	2	3	4	5	6
Fatalities averted on the national road network	316	636	802	807	728	778	754
Fatalities averted in urban areas	551	955	1372	1408	1248	1331	1262
Fatalities averted in rural areas	1113	2289	2778	3112	2495	2967	2668
Total Fatalities averted	**1981**	**3880**	**4952**	**5327**	**4471**	**5076**	**4684**
Fatalities averted over the period 2020-2030	743	955	928	1052	827	1007	974
Fatalities averted over the period 2031-2040	619	1228	1499	1625	1343	1546	1424
Fatalities averted over the period 2041-2050	619	1697	2525	2650	2302	2523	2285

By way of comparison, the baseline scenario predicts 72,100 deaths over the period 2020-2050, of which 28,703 from 2020 to 2030, and 21,698 from 2031 to 2040, and 21,698 also from 2041 to 2050. These victims are distributed as follows: 10,748 on the national road network, 20,534 in urban areas and 40,817 in interurban areas. Table 20 gives the number of fatalities averted according to the scenario considered for the speed of deployment of infrastructure and vehicle equipment.

Table 20: Number of fatalities averted thanks to vehicle connectivity for each of the scenarios considered (comparison with the "smartphone" reference scenario)

Infrastructure deployment	Vehicle equipment	1	2	3	4	5	6
Slow	Slow	570	460	**796**	372	759	677
Slow	Average	1899	2643	**3212**	2204	2986	2516
Slow	Fast	2949	4708	**5378**	4181	5103	4245
Average	Slow	570	590	**817**	489	776	711
Average	Average	1899	2971	**3346**	2490	3095	2703
Average	Fast	2949	5213	**5649**	4629	5337	4656
Fast	Slow	570	659	**827**	552	784	725
Fast	Average	1899	3134	**3406**	2629	3142	2782
Fast	Fast	2949	5462	**5774**	4843	5439	4832

11.7 Other effects

While most of the benefits of connected vehicles relate to gains expected in terms of road safety, other effects can also be seen. This is particularly true for the Use Case *Green light optimal speed advisory*, which, in addition to some very slight gains in road safety, brings about a reduction in fuel consumption of around 0.7% in urban areas (according to the Ricardo report), a reduction in greenhouse gas emissions as well as a reduction in emissions of atmospheric pollutants.

11.8 Socio-economic calculation

The socio-economic calculation consists of a monetarized cost-benefit analysis to assess the relevance of vehicle connectivity to the community. This is presented as a classic financial calculation by summing the costs and benefits over the life of the project using a discount rate that corresponds to the natural preference for the present. The result is the net present value (NPV) of the vehicle connectivity project.

$$VAN = \sum_{n=2020}^{2050} \frac{Benefits_n - Costs_n}{(1+a)^{n-2020}}$$

where:

$$Benefits = Num._{\ fatalities\ averted}\ x\ Cost_{\ fatality} + Num._{\ injuries\ averted}\ \ x\ Cost_{\ injury}$$

$$Cost = Num._{\ vehicles\ fitted}\ \ x\ Cost_{\ vehicle\ equipment} + NB_{RSUs\ installed}\ x\ Cost_{RSU}$$

The discount rate a of this study is the rate used for the evaluation of transport projects, i.e. 4.5%. It is in line with the recommendations of France Stratégie for the socio-economic assessment of all public investments. It was assumed that the C-ITS services of this study would be deployed from 2020 onwards; thus, the costs and benefits have been discounted to 2020. The study horizon is 2050.

The main benefits of vehicle connectivity are related to road safety. Since these benefits do not correspond to direct economic spin-offs, they have be expressed in monetarized form using collective values. These values represent the costs of investments that the community is willing to make to improve road safety, such as infrastructure improvement projects. The collective values used, taken from the Transport Projects Assessment Handbook, which itself complies with the recommendations of France Stratégie, are specified for 2015 in Table 21 (they change over time in proportion to GDP per capita).

Table 21: Collective values for road accidents in 2015

Collective values	Amount (€uro)
Killed	3,200,000

Serious injuries (hospital)	400,000
Minor injuries	16,000

The other effects (i.e., benefits in terms of fuel savings, reduction of greenhouse gas emissions and pollutants) were also assessed in accordance with the Transport Projects Assessment Handbook. Nevertheless, these benefits, once monetarized, account for only 1% of the road safety gains.

The results of the socio-economic calculation, for the median scenarios of deployment of the infrastructures and equipment of the park, are shown in Table 22.

Table 22: Net present values in relation to the reference situation, according to the scenario considered (median assumptions for deployment of vehicle equipment and infrastructure), in millions of euro

Scenario	1	2	3	4	5	6
EBL	0	1660	1660	1328	1328	812
EVA	0	932	932	771	771	497
HLN	2310	2858	3067	2331	2914	2646
SSV	528	657	700	537	665	611
TJW	1139	1367	1983	969	1824	1564
VSGN	661	469	666	401	662	662
RWW	821	1020	1251	874	1187	1135
WTC	2355	1721	2372	1473	2361	2358
GLOSA	171	226	265	192	251	238
SigV	0	2232	2232	1807	1807	1438
VRU	6	11	11	10	11	10
WWD	29	29	30	24	29	29
Double counts	-1210	-2147	-2580	-1746	-2331	-1933
Total benefits	**6810**	**11,036**	**12,589**	**8971**	**11,479**	**10,067**
of which SCOOP Use Cases	*6633*	*7635*	*9149*	*6191*	*8640*	*7884*
Vehicle + data costs	-7077	-7077	-7432	-6049	-7381	-7546
R-ITS-S costs	0	-980	-980	-980	-980	0
NPV (M€)	**-266**	**2978**	**4177**	**1942**	**3118**	**2521**

The net present value is positive in all scenarios except Scenario 1, which shows the profitability of the services offered by connected vehicles. Scenario 1 (4G on-board) is less cost-effective than the baseline scenario because few new Use Cases emerge, while the costs of integration into vehicles are equivalent to those of the other scenarios. This result is linked to the high proportion of users using a smartphone-type application in the baseline scenario. Scenarios 3 (ITS-G5 + 4G) and 5 (LTE-V2X + 4G) are more cost effective than their unhybridized versions (Scenarios 2 and 4) because the service coverage extends to networks without road side units at a similar cost. Scenario 6 (5G short range) appears less profitable due to a later deployment. Table 23 shows that the results are impacted by the speed of equipment deployment in the fleet. In particular, the baseline scenario becomes preferable if deployment is too slow.

Table 23: Net present values of vehicle connectivity for all scenarios considered for this study (millions of €uro compared to the baseline scenario)

Infrastructure deployment	Vehicle equipment	1	2	3	4	5	6
Slow	Slow	-274	-1568	-87	-1612	-232	-18
Slow	Average	-266	1748	**3836**	955	2934	1684
Slow	Fast	419	6653	**8997**	5409	7425	4492
Average	Slow	-274	-1327	-389	-1434	-558	**131**
Average	Average	-266	2978	**4177**	1942	3118	2521
Average	Fast	419	8935	**10,216**	7315	8370	6388
Fast	Slow	-274	-1767	-1106	-1906	-1285	**182**
Fast	Average	-266	2932	**3691**	1778	2562	2806
Fast	Fast	419	9319	**10,070**	7495	8079	7036

11.9 Summary of effects not taken into account

The main effects not taken into account in the socio-economic calculation and which were raised in this study are:

- the removal of a potential source of distraction for users who stop using their smartphone as a driving aid,
- the possibility of achieving, over time, fully driverless vehicles, whose safety would be improved by the redundancy of information made possible through V2V communications.

Lastly, it is possible to extend connectivity to all pedestrians and cyclists in urban or rural areas, which would enable activation of the Use Case *Vulnerable Road User Protection* outside the national road network. This scenario would involve the participation of all road users, and not just motorized users; this would generate additional equipment costs. This scenario was not studied because of its many specific characteristics.

11.10 Sensitivity tests

The socio-economic assessment carried out in this study required that a number of assumptions be made and a sensitivity study was required to estimate the contribution of each of these parameters to the final outcome. After analysis, it appears that the parameters with the greatest number of uncertainties (weakness of the available documentation) are as follows:

- the proportion of journeys that use a driving app such as Waze, Here, TomTom or Coyote,
- the road accident reduction trend in the baseline scenario,
- the expected lifetime of the service, e.g., the potential date of mass deployment of driverless vehicles, which would have the effect of rendering the equipment for a connected vehicle obsolete,
- the proportion of drivers who will refuse to contribute to the system and who will not agree to provide nor receive road safety information, all of which has the effect of changing vehicle equipment rates as in Table 13.

The use of the smartphone as a driving assistance tool in the baseline scenario has little impact on ranking the various project scenarios (Table 24). Thus, even very high levels of smartphone usage would not have the effect of invalidating the benefits of vehicle connectivity.

Table 24: Net present values of vehicle connectivity based on the percent of journeys made using driver assistance applications in the baseline option (millions of €uro, median scenarios for fleet and infrastructure deployment)

Scenario	1	2	3	4	5	6
Smartphone share of 0%	2336	5667	**6780**	4325	5721	5120
Smartphone share of 20%	1035	4323	**5479**	3133	4420	3820
Smartphone share of 40%	-266	2978	**4177**	1942	3118	2521
Smartphone share of 60%	-1568	1634	**2876**	751	1817	1222

Scenario 3, which maximizes road safety benefits, naturally becomes all the more interesting compared to the other scenarios if the expected trend reduction in road accidents does not materialize (Table 25).

Table 25: Net present values of vehicle connectivity according to the decrease trend in road accidents over the period 2020-2030 (millions of €uro, median scenarios for deployment in the fleet and on infrastructure)

Scenario	1	2	3	4	5	6

No change	3470	9294	**11,186**	7201	9541	8136
-1%/year	2240	7210	**8877**	5463	7425	6286
-2%/year	1147	5362	**6827**	3,924	5545	4643
-3.5%/year	-266	2978	**4177**	1942	3118	2521

The longer the lifetime of the service, the greater the expected benefits of vehicle connectivity. By contrast, investments in connected vehicles are not justified if connected vehicles become obsolete in 2030 due to new modes of travel (Table 26).

Table 26: Net present values of vehicle connectivity according to the time horizon considered for the calculation (millions of €uro, median scenarios for fleet and infrastructure deployment)

Scenario	1	2	3	4	5	6
2030	-781	-1405	-714	-1454	-957	-760
2040	-837	-371	**653**	-852	39	-20
2050	-266	2978	**4177**	1942	3118	2521
2060	885	7672	**8966**	6369	7651	6518
2070	1901	11,367	**12,724**	10,068	11,388	10,057

In the event that some drivers refuse to contribute to the system and do not provide nor wish to receive road safety information, the effective connectivity rate of the vehicle fleet decreases. The effect of such a refusal on the evaluation results can be inferred from Table 23.

11.11 Conclusion

This study shows that the services rendered by connected vehicles are very cost-effective due to the road safety gains they are likely to bring. The provision of in-vehicle services maximizes road safety gains and is relevant in most scenarios. The provision of these on-board services can be made available through the cellular network alone (4G) or through the integration of ITS-G5 or LTE-V2X short-range communication systems. In the latter case, it seems relevant to ensure a hybridization of the system with the cellular network in order to maximize the benefits. Road safety gains and socio-economic benefit are then maximized.

11.12 Glossary

This glossary provides definitions of a list of technical terms related to Socio-Economic

Assessment. The definitions are taken from the *Guide de l'évaluation socioéconomique des investissements publics* (Guide to a Socio-Economic Assessment of Public Investments) published by France Stratégie in December 2017.

Discounting: method of estimating the present value of a future cost or benefit by applying a discount rate, i.e. by multiplying the future values by a specific coefficient.

Cost-benefits analysis: A quantitative approach to determine whether, or to what extent, an investment is appropriate from a socio-economic perspective. A cost-benefits analysis differs from a financial analysis in that it considers all the gains and losses of an investment. A cost-benefits analysis leads to the calculation of a socio-economic net present value.

Socio-economic costs and benefits: social costs or benefits to the economy as a whole. They may differ from private costs to the extent that they may include externalities (social cost = private cost + external cost).

Capital cost: Capital expenditure incurred for the implementation of the project or program.

Operating cost: expenses incurred for the operation of an investment, including maintenance costs but not depreciation costs or capital expenditure.

Opportunity cost: marginal cost expressing the loss of earnings due to a choice (of investment, production, distribution...). For example, the cost of storing raw materials may represent an opportunity cost.

Externalities: effects of the project that are observed outside the project itself, and therefore are not included in the financial analysis. An externality arises when the production or consumption of goods or services by one economic unit has a direct effect on the welfare of other units of production or consumption, without there being any financial compensation between these units. Externalities can be positive or negative.

Investment avoided: investment that would have been made in the baseline option but which is not made in the investment option.

Monetarization: process which consists in assigning a monetary value to assessment criteria whose unit of measurement or account is not monetary.

Baseline option and investment option: the baseline option is the project owner's choice of intervention corresponding to the most likely optimized action in the absence of project implementation on the considered horizon. This baseline option is not a "do nothing" decision; it must include the operations (investment, operating or other) that may be necessary if the project is not carried out (the "do minimum" option). The operating conditions of the option must be optimized. An economic analysis of an investment option involves a comparison of its effects compared to those of the baseline option. This analysis informs us as to whether it is better to implement the investment option rather than the baseline option, but it does not give any insight as to whether another investment option might have been better. This is why it is important to choose the baseline option carefully, and to make several comparisons of possible variants to the investment.

Constant prices: base year prices adopted to exclude inflation. They are different from current prices.

Current prices (or nominal prices): prices actually observed over a given period. They include the effects of general inflation and are opposed to constant prices.

Project: operation consisting of a series of works, activities or services with clearly established objectives. In other words, it is an investment activity in which resources are spent (the costs) to create assets that produce benefits over an extended period of time.

Baseline scenario: set of variables external to the project. It therefore represents the framework within which the project is assessed, and is thus by definition common to the baseline option and the investment options. The baseline scenario includes assumptions on the evolution of GDP, population, fuel costs, etc.

Discount rate: rate at which future values are discounted.

Net present value (NPV): sum obtained when the present value of future costs is deducted from the present value of expected future benefits.

Socio-economic net present value: sum of positive and negative benefits resulting from a project, discounted to a reference year using the socio-economic discount rate, evaluated in a cost-benefits analysis.

Collective value: value given to a non-market good, defined by the public authority, representing its value (or cost) to the community and intended to be used in socio-economic calculations.

11.13 Bibliography

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12 Economic impacts – Business models

Two frames are used to describe C-ITS Business model: The Value Network Model (Chanal, IAE Grenoble) and the Value Chain Model (Frame specifically designed for C-ITS and used by the WG "Horizontal Issue" in the framework of the European C-ITS Platform phase 2).

12.1 Business Model Design

The following definition can somewhat be considered as a consensus:

A Business Model describes the way an organization produces and delivers value to its customers/consumers.

« Organization » label is rather a large concept here. It refers to whether a private company, a public institution, an association or a NGO (non-governmental organization). This means any entity made of one or several people who build value for third parties on the basis of:

- Resources (human, materials, tools, finance, patents…).
- Processes using those resources.

This concept means that an organization is not necessarily profit-centered.

According to previous definition of what is an organization here, it can be either:

- A whole entity as defined by its juridical status.
- A business unit inside a company.
- Or even an ecosystem of several entities/companies operating together, according to the concept of extended enterprise.

The « business » specificity of business models refers to financial considerations. This means that the purpose of a business model approach is to embrace financial aspects.

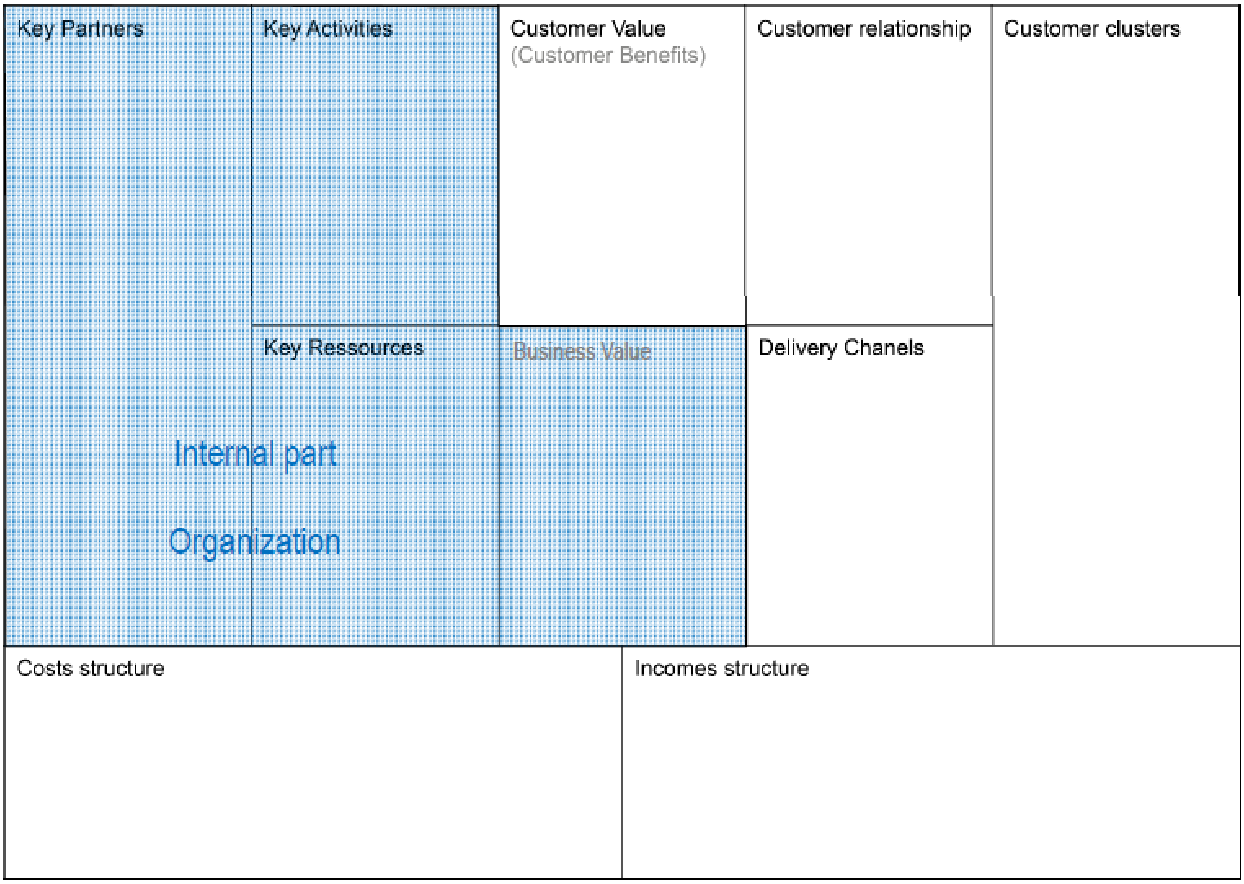
There is no consensus yet between academics about the number of components to be described to expose a Business Model. Financial considerations are part of the polemic.

One considers here that the Business Model approach does not include financial considerations: the description of the business model will only consist in a qualitative description.

This means that we consider that the project finance approach (or cost/benefit analysis) comes after when designing the business plan, and more especially when embracing socioeconomic impact studies in the case of C-ITS.

There are two macro-components to be described in a Business Model:

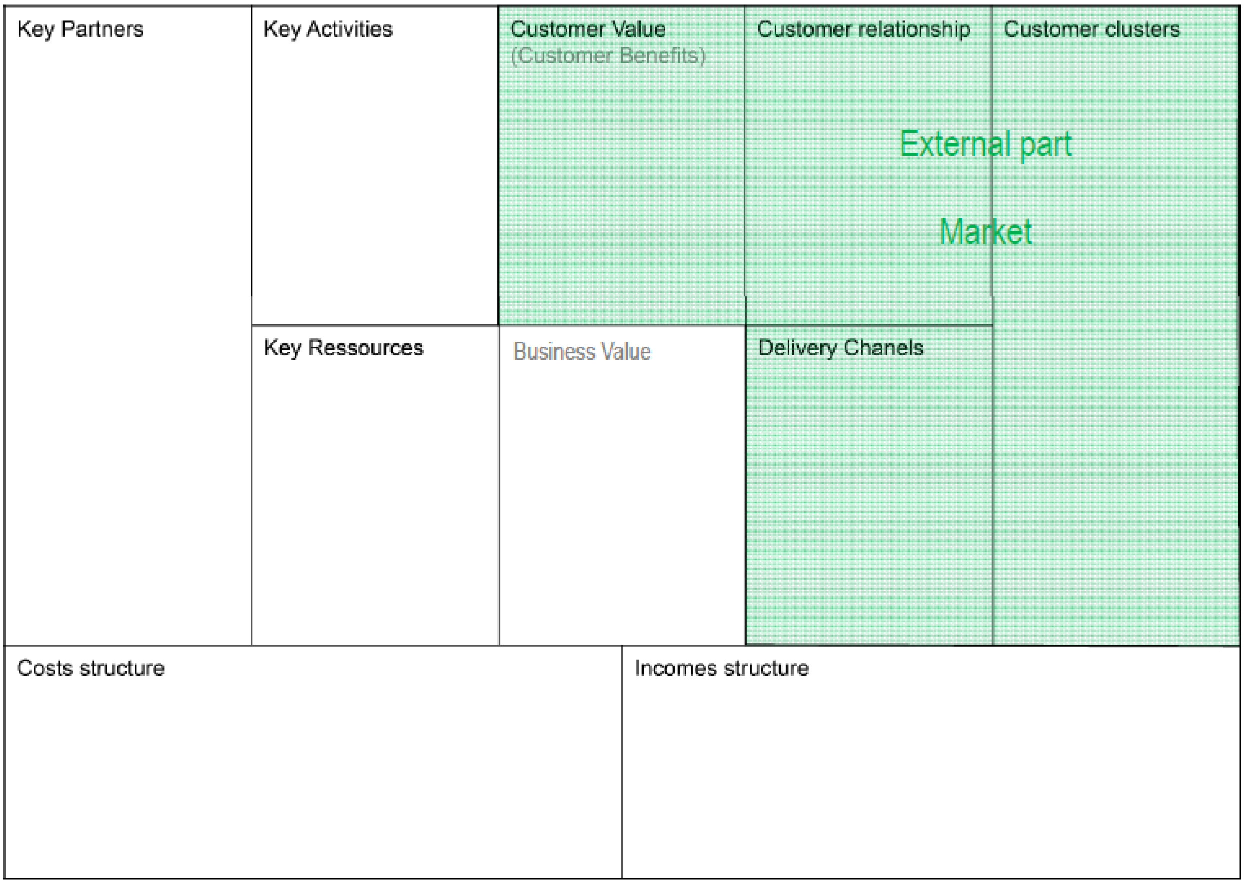
- The internal part ("produces") which corresponds to the organization, i.e. the partners involved, the activities to be driven and resources supporting these activities



Business Model CANVAS, Osterwalder & Pigneur, HEC Lausanne, 2011

Figure 37: Internal part / Organization

- The external part ("delivers") which corresponds to the marketing mix in the case of a business



Business Model CANVAS, Osterwalder & Pigneur, HEC Lausanne, 2011

Figure 38: External part / Market

12.2 C-ITS Business Model(s)

12.2.1 VALUE NETWOK Model

The following representations of SCOOP@F Business Model focus on the organization between stakeholders and flows between all of them. They don't present flows between two units/entities/assets owned by a single stakeholder.

This kind of representation mainly focuses on the way the value is delivered, and not so much on the way it is produced: it doesn't expose all activities and resources supporting these activities. Such a description will be done:

- First, through macroscopic representations using VALUE CHAIN Model frame (see section C at the end of this annex),
- Second, more precisely by each stakeholder to lead C-ITS socioeconomic impact studies.

Since a value network can fastly become difficult to read due to all flows represented on it, several graphics have been done. Main graphics are presented in this synthesis.

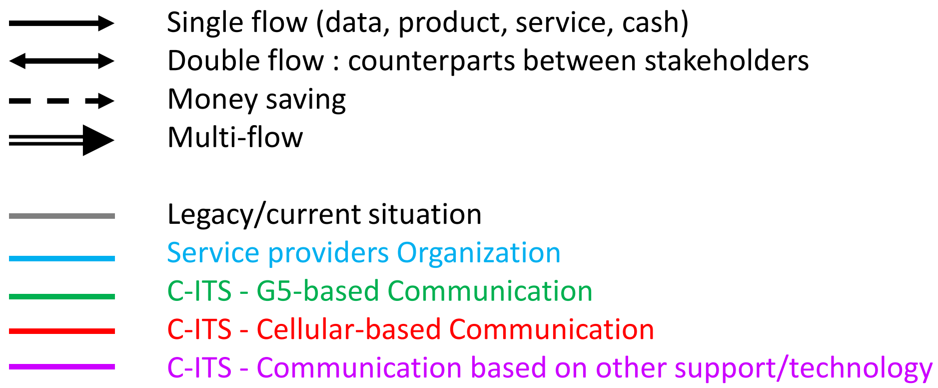
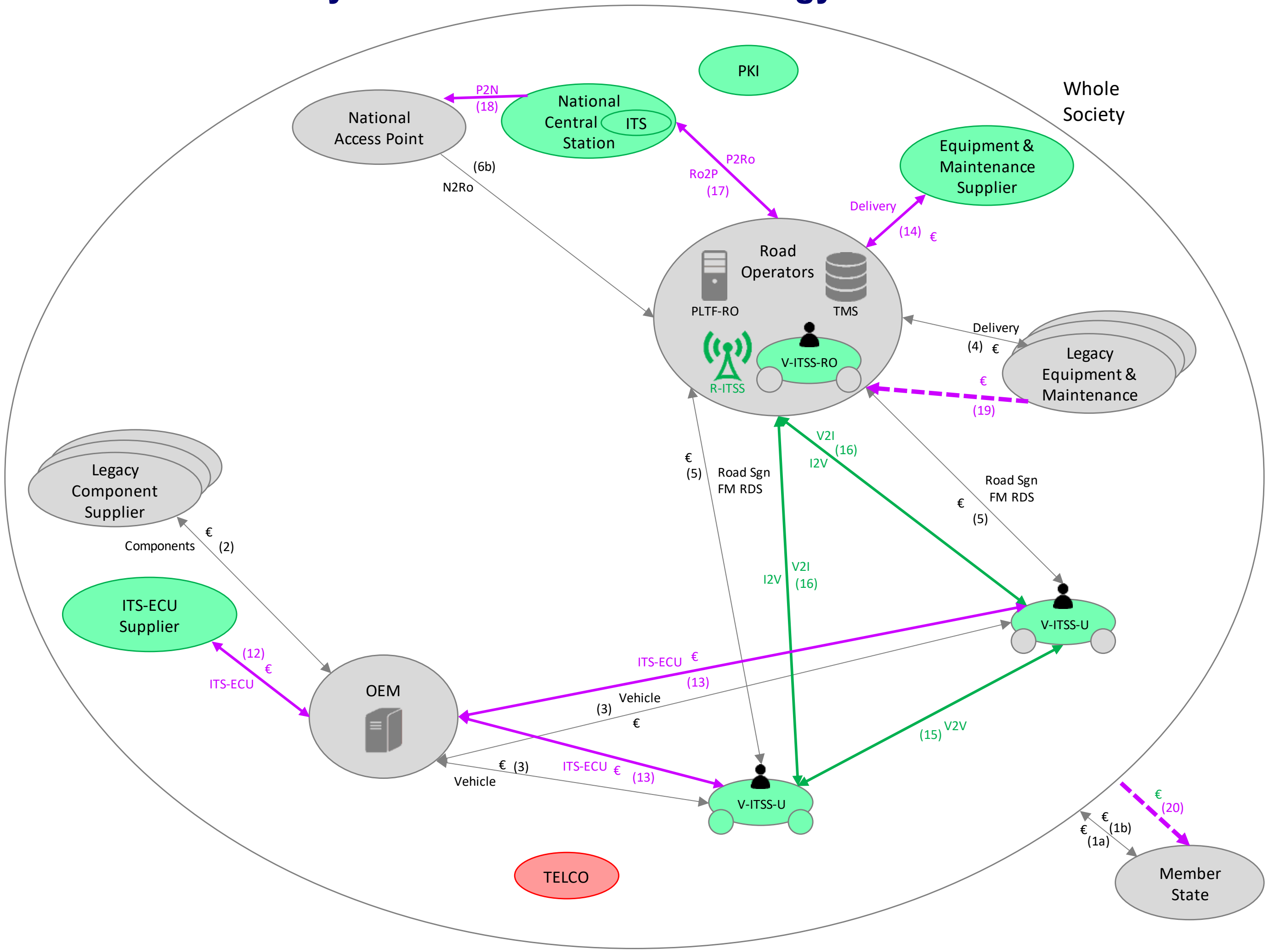


Figure 39: VALUE NETWOK Model Index

12.2.1.1 Organization of the ecosystem based on G5 technology

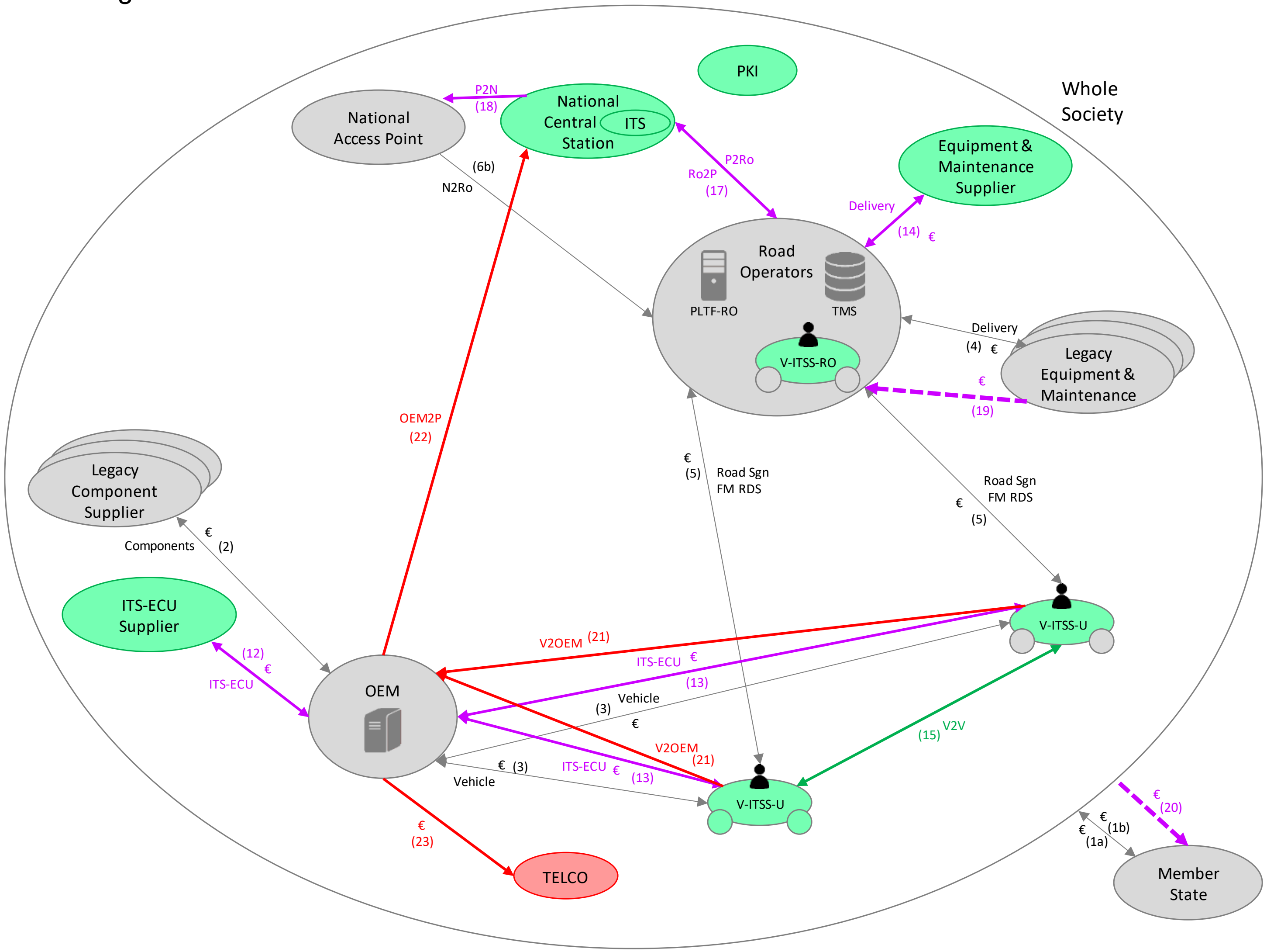


13	Price of the ITS ECU bought by the OEM to the supplier. It won't be exposed since only "14" is important.
14	Price the customer will pay for ITS functionality. It includes "13" but also its integration into the vehicle (screws, electric cables). At this step of the project, no one knows if the vehicle price could be adjusted due to C-ITS services, whether in correlation with OEM costs or not. But, safety being considered by customers as a condition when using the vehicle, he may not accept to pay more than today.
15	Road side units and maintenance services bought by the road operators to suppliers.
16	Messages exchanged between user vehicles (CAM, DENM, according to use cases and ETSI standards).
17	Messages exchanged between road operators (R-ITS-S, OBU-RO) and user vehicles (CAM, DENM, according to use cases and ETSI standards).
18	Reduction of equipment cost compared to the actual situation. For instance: • In the short/mid-term: ○ Sensor under the road to detect vehicles speed and traffic conditions, ○ Video camera along the road side. • In the long term: ○ Since Road signage will become vehicle in-signage, thanks to ITS technology.
19	Reduction of "1b" costs, thanks to C-ITS.

12.2.1.2 Organization of the ecosystem based on hybrid [G5 + Cellular] technology

The SCOOP@F communication is supported by a hybrid solution based on G5 and LTE/3G. On roads not equipped with R-ITS-S (no R-ITS-S is detected by vehicles), the ITS-TCU (Telecommunication Control Unit) of the vehicle will send the data using Cellular network. In such a situation, two cases can be considered according to each OEM policy.

"LTE/G5" Hybrid based Organization: Case 1

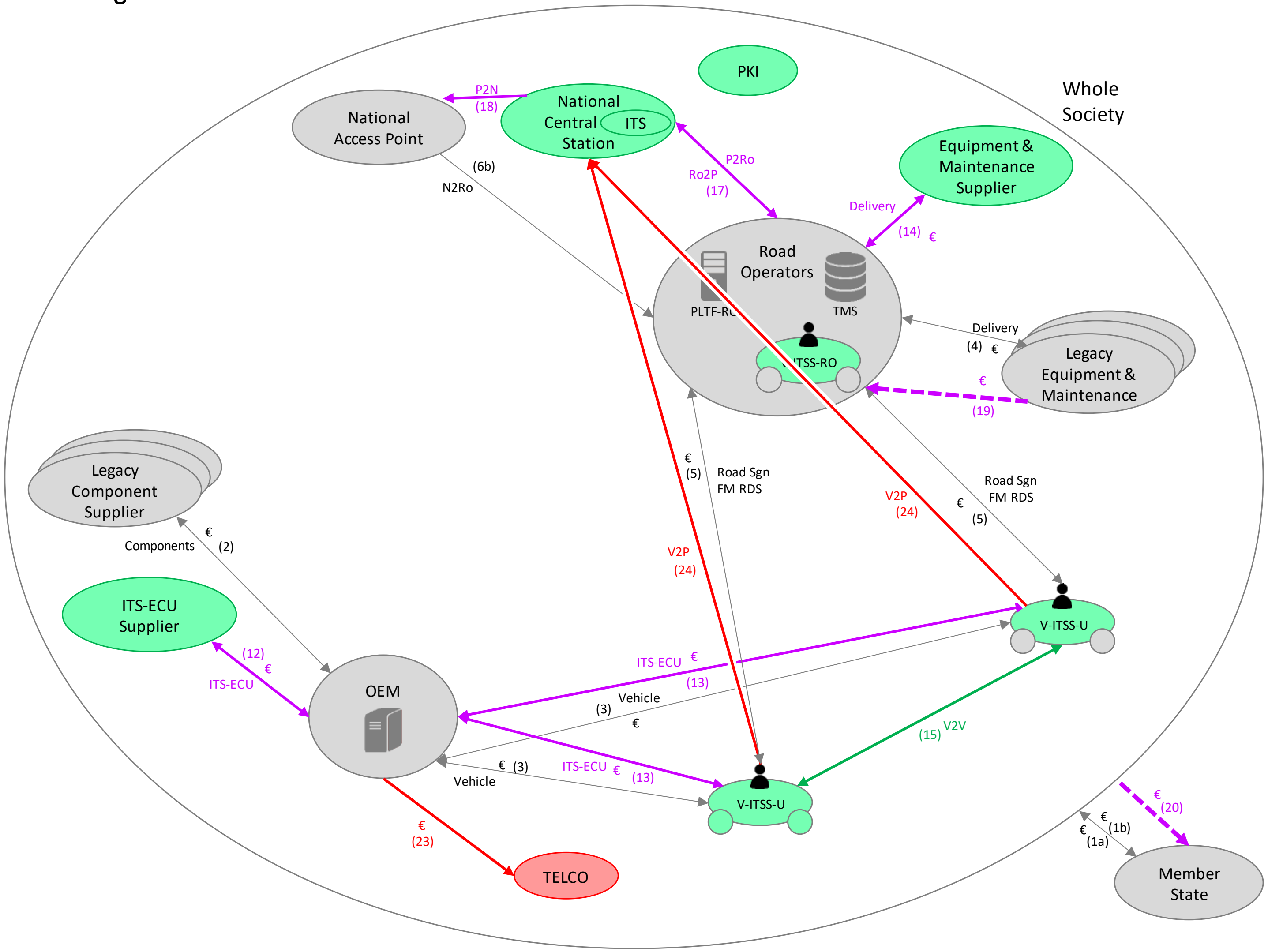


13	Price of the ITS ECU bought by the OEM to the supplier. It won't be exposed since only "14" is important.
14	Price the customer will pay for ITS functionality. It includes "13" but also its integration into the vehicle (screws, electric cables). At this step of the project, no one knows if the vehicle price could be adjusted due to C-ITS services, whether in correlation with OEM costs or not. But, safety being considered by customers as a condition when using the vehicle, he may not accept to pay more than today.
15	Road side units and maintenance services bought by the road operators to suppliers.
16	Messages exchanged between user vehicles (CAM, DENM, according to use cases and ETSI standards).

18	Reduction of equipment cost compared to the actual situation. For instance:
	• In the short/mid-term:
	  ○ Sensor under the road to detect vehicles speed and traffic conditions,
	  ○ Video camera along the road side.
	• In the long term:
	Since Road signage will become vehicle in-signage, thanks to ITS technology.

19	Reduction of "1b" costs, thanks to C-ITS.
20	DENM messages and aggregated information from CAM sent to the National Central Station.
21	Information sent to the national access point, in compliance with [b] and [c] delegated acts of ITS European directive.
22	V2OEM (Vehicle-to-OEM): the vehicle sends information to the OEM back-end server, using the SIM card included in the TCU.
23	OEM2P (OEM-to-Platform): the OEM sends aggregated data to the National Central Station since the road operator can't do it.
24	It corresponds to LTE/3G fees payed by OEM to TELCO to send vehicle data to the OEM server (22).

“LTE/G5” Hybrid based Organization: Case 2



13	Price of the ITS ECU bought by the OEM to the supplier. It won't be exposed since only "14" is important.
14	Price the customer will pay for ITS functionality. It includes "13" but also its integration into the vehicle (screws, electric cables). At this step of the project, no one knows if the vehicle price could be adjusted due to C-ITS services, whether in correlation with OEM costs or not. But, safety being considered by customers as a condition when using the vehicle, he may not accept to pay more than today.
15	Road side units and maintenance services bought by the road operators to suppliers.
16	Messages exchanged between user vehicles (CAM, DENM, according to use cases and ETSI standards).

18	Reduction of equipment cost compared to the actual situation. For instance:
	
	• In the short/mid-term:
	  ○ Sensor under the road to detect vehicles speed and traffic conditions,
	  ○ Video camera along the road side.
	• In the long term:
	
	Since Road signage will become vehicle in-signage, thanks to ITS technology.

19	Reduction of "1b" costs, thanks to C-ITS.
20	DENM messages and aggregated information from CAM sent to the National Central Station.
21	Information sent to the national access point, in compliance with [b] and [c] delegated acts of ITS European directive.
25	The vehicle sends information directly to the National Central Station, using the SIM card included in the TCU.
26	LTE/3G fees payed by OEM to TELCO to send vehicle data to the National Central Station (25).

12.2.2 VALUE CHAIN Model

Since G5 technology is not operated by any stakeholder, G5-based communications won't be positioned in the frame on the Communication Provider line. They will be positioned on two lines:

- For one part, on the line of the stakeholder who emits,
- For a second part, on the line of the stakeholder who receives the communication.

12.2.2.1 Road works warning triggered from the Traffic Control Center-France-ITS G5 (I2V)

Generic value chain for traffic information incl. detailed process steps			Content provision												Service provision												End User
			Content Collection						Content Processing						Service Provision						Service Presentation						
Road Works Warning triggered from the TCC - ETSI ITS G5			Detection	Data delivery	Data reception	Data pre-processing	Data delivery	Commu-nication	Data reception	Content fusion	Data processing	Quality check	Content delivery	Commu-nication	Content reception	Content fusion	Service generation	Pre-formatting	Service delivery	Commu-nication	Service reception	Service decoding	Info fusion	Service rendering	Service presentation		
Roles		Example Actors																									
R-ITS-S (RSU)	Operator	DIR Ouest, SANEF...							X	X	X	X	X	(1)	X	X	X	X	X	G5							
C-ITS-S (SCOOP platform)	Operator	DIR Ouest, SANEF...			X	X	X																				
Communication	Provider	Telecom operator, Unity Media, fixed cable						Cellular, Fiber or Cable																			
Service Application	Provider	TomTom, INRIX, Here																									
V-ITS-S 1	Operator	Renault, PSA...																		G5	X	X	X	X	X		
V-ITS-S 2																				G5	X	X	X	X	X		
TCC (SAGT)	Operator	DIR Ouest, SANEF...	X	X																							
Road Infrastructure (V-ITS-S-RO)	Operator	DIR Ouest, SANEF...																									
Infrastructure PKI	Operator	IDNOMIC									X											X					

(1): The communication is internal to the Road Side Unit.

12.2.2.2 Hazardous location notification V2V-France ITS G5

Generic value chain for traffic information incl. detailed process steps			Content provision												Service provision												End User
			Content Collection						Content Processing						Service Provision						Service Presentation						
Road Works Warning triggered from the TCC - ETSI ITS G5			Detection	Data delivery	Data reception	Data pre-processing	Data delivery	Commu-nication	Data reception	Content fusion	Data processing	Quality check	Content delivery	Commu-nication	Content reception	Content fusion	Service generation	Pre-formatting	Service delivery	Commu-nication	Service reception	Service decoding	Info fusion	Service rendering	Service presentation		
Roles		Example Actors																									
R-ITS-S (RSU)	Operator	DIR Ouest, SANEF…																									
C-ITS-S (SCOOP platform)	Operator	DIR Ouest, SANEF…																									
Communication	Provider	Telecom operator, Unity Media, fixed cable																									
Service Application	Provider	TomTom, INRIX, Here																									
V-ITS-S 1	Operator	Renault, PSA…	X	X	X	X	X	G5						(2)													
V-ITS-S 2	Operator	Renault, PSA…																		G5	X	X	X	X	X		
TCC (SAGT)	Operator	DIR Ouest, SANEF…																									
Road Infrastructure (V-ITS-S-RO)	Operator	DIR Ouest, SANEF…																		G5	X	X	X	X	X		
Infrastructure PKI	Operator	IDNOMIC				X																X					

(2): V2V are time-critical use cases. The communication channel is shorter: the “Content Processing” and “Service Provision” blocks are supposed not to be used.

12.2.2.3 Hazardous location notification I2V-France ITS G5

Generic value chain for traffic information incl. detailed process steps			Content provision											Service provision													End User
			Content Collection						Content Processing					Service Provision						Service Presentation							End User
Road Works Warning triggered from the TCC - ETSI ITS G5			Detection	Data delivery	Data reception	Data pre-processing	Data delivery	Commu-nication	Data reception	Content fusion	Data processing	Quality check	Content delivery	Commu-nication	Content reception	Content fusion	Service generation	Pre-formatting	Service delivery	Commu-nication	Service reception	Service decoding	Info fusion	Service rendering	Service presentation		
Roles		Example Actors																									
R-ITS-S (RSU)	Operator	DIR Ouest, SANEF…							X	X	X	X	X	(1)	X	X	X	X	X	G5							
C-ITS-S (SCOOP platform)	Operator	DIR Ouest, SANEF…			X	X	X																				
Communication	Provider	Telecom operator, Unity Media, fixed cable						Cellular, Fiber or Cable																			
Service Application	Provider	TomTom, INRIX, Here																									
V-ITS-S 1	Operator	Renault, PSA…																		G5	X	X	X	X	X		
V-ITS-S 2																				G5	X	X	X	X	X		
TCC (SAGT)	Operator	DIR Ouest, SANEF…	X	X																							
Road Infrastructure (V-ITS-S-RO)	Operator	DIR Ouest, SANEF…																		G5	X	X	X	X	X		
Infrastructure PKI	Operator	IDNOMIC									X											X					

(1): The communication is internal to the Road Side Unit

13 Legal and regulatory impact studies

13.1 Legal assessment: Connected vehicles, protection of personal data and users' privacy

13.1.1 Context elements

Among the evaluations planned for the project, an impact study was commissioned to IFSTTAR to implement compliance measures for the protection of drivers' personal data and privacy. Indeed, personal data were collected, first, to enable the system to operate and, second, to carry out technical[4] and non-technical[5] evaluations. This study was presented to the CNIL (the French Data Privacy Agency) in 2016 (*Guilbot et al., 2016, deliverable 2381*). The **conditions for implementing pre-deployment and, where applicable, deviations from the initial provisions relating to the protection of the rights of the drivers involved, were described by the SCOOP partners.**

Given the evolution of the law since the conception of the SCOOP project, the legal context described below also includes legal elements that will have to be taken into account for the deployment of the systems.

1. Legislative and regulatory context

SCOOP is part of the process of implementing Directive 2010/40/EU of 7 July 2010, which establishes a framework to support the deployment and coordinated use of C-ITS in the European Union (ITS Directive, art. 1). Their deployment is also dependent on its compliance with the personal data protection legislation and the application of legal and technical rules on cybersecurity.

(a) The C-ITS context

The 2010 Directive is complemented by Commission Delegated Regulations (DR)[6] and by a recent resolution adopted by the European Parliament encouraging the adoption of a "*European strategy for cooperative intelligent transport systems*".
This resolution contains recommendations on 4 major points: protection of personal data and drivers' privacy; cybersecurity; communications technologies and frequencies; the development of a common European strategy.

Another draft delegated act based on the ITS Directive was adopted by the European Commission on 13 March 2019[7] (hereinafter referred to as DR 2019). The text calls for respect for the fundamental rights of physical persons (point 2.3). Among the

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[4] Mainly monitoring of the technical functioning in the pre-deployment phase, calculating statistics on system performance.

[5] Impacts on driver behaviour, acceptability, accident reduction, traffic impacts, supervision.

[6] See appendix for references to the main applicable legal texts, whether or not cited in this summary text.

[7] C(2019) 1789 final. Discussions not completed at the time of writing this synthesis.

elements highlighted by the WP29, who was consulted during the preparatory works phase, it is observed that this Regulation alone cannot constitute the legal basis for data processing because it only covers the exchange of messages between C-ITS stations. This implies various consequences listed in the draft as it stands, including a prohibition on the reuse of data for commercial or law enforcement purposes, the strict application of the principle of data minimization and a data retention period in line with the principle of necessity.

These provisions seem insufficient to us. In particular, we consider it necessary to categorize C-ITS services which, in our opinion, are similar to a value-added optional service of the same nature as TPS-eCall as described in the European legislation for this service, also based on ITS Directive 2010/40. Such a categorization would make it possible to define more precisely the legal framework applicable to the data collected8.

On the basis of the 2010 Directive, a definition for Intelligent Transport Systems has been transposed to France9.

"Intelligent transport systems are devices using digital and electronic communications technologies, implemented in the road transport sector and its interfaces with other transport modes, in order to improve traffic management, enhance road transport safety, increase its efficiency in terms of energy saving and reduce its environmental impact, and enable safer, better coordinated and more efficient use of transport networks. A decree shall define the priority areas and actions for which intelligent transport systems and the services they provide must comply with specifications to ensure the compatibility, interoperability and continuity of these services."

Table 27: Definition of Intelligent Transport Systems in the French Transport Code, Art. L.1513-1 (verified on 28.05.2019)

The priority areas and actions referred to in paragraph 2 of Article 1513-1 of the Transport Code must be implemented in accordance with the specifications adopted by the Commission under the delegated acts. **The implementation of services is not mandatory, but when the decision is made to deploy them, certain obligations must be respected**. This concerns, inter alia, security (in the cyber sense) and the protection of personal data (ITS Directive, Art. 10). Some standards are made mandatory. For example, service providers must provide the data in Datex II format, updated in accordance with the requirements of EU's legislation, in a readable and interoperable format with this format (DR 2015(962)).

To date, France has adopted 4 regulatory texts for the implementation of the ITS Directive (see list of texts in the annex). The draft Mobilities Framework Bill (LOM – Loi d'orientation des mobilités), still under discussion, incorporates the provisions of RD(EU) 2017/1926, which concerns the provision of services, in a section entitled "*Opening up the data necessary for the development of digital mobility services*" (Mobilities Framework Bill, art. 9)10. These provisions are not discussed here. In the

[8] It would appear that consultations are underway with the regulatory authorities (EDPS, CNIL, etc.). Status of non-public discussions as at 27 May 2019.

[9] Version resulting from the ITS Ordinance of 13 June 2012, based on the authorisation granted by Bill 2012-260 of 22 February 2012 (art. 6). The Ordinance was ratified by Bill 2013-619 of 16 July 2013 (art. 36), which gives it legislative force.

[10] Mobilities Framework Bill references as they stood at the time of delivery of this synthesis (28 May 2019).

event of a final vote of approval by the French Parliament, it would be useful if they were included in the final SCOOP report since they would be applicable to the deployment of C-ITS.

(b) The context concerning the protection of personal data

SCOOP was initiated under the laws in force in 2016, namely Directive 95/46/EC of 24 October 1995 and Law 78-17 of 6 January 1978 as amended. The deployment of C-ITS will be subject to the provisions of the General Data Protection Regulation (GDPR) which came into force on 25 May 2018 and the French Data Protection Act in a version amended by a 2018 ordinance11.

The deployment may also be subject to the provisions of Directive 2002/58 on *electronic privacy and communication* and, where applicable, to any Regulation that might replace it12.

A reiteration of compliance with these texts can be found in the recitals of the above-mentioned draft DR 2019 (recitals 23 to 26). The need to clarify the legal basis for C-ITS services, in accordance with Article 6 of the GDPR, is also recalled in this draft DR.

(c) The cybersecurity context

We must also analyze the impact of the implementing legislation for Directive 2016/1148/EU of 6 July 2016 concerning the measures for a high common level of security of network and information systems across the European Union (*NIS Directive*). The application of this Directive is specifically referred to in the draft DR 2019 (recital 6). Under French law, Decree 2018-384 of 23 May 2018 on the security of networks and information systems of essential service operators and digital service providers applies to ITS operators for the following services: centralized management of a vehicle fleet, traffic management assistance, passenger information, operational assistance. These texts are applicable to public authorities.

Deployment modalities should be examined and developed in a coordinated manner for personal data protection and cybersecurity. In both cases, technical and organizational measures, of the same nature, will lead to risk prevention.

2. Organizational context

SCOOP is led by the Ministry for the Ecological and Inclusive Transition of France (MTES/DIT/MEDDE).

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[11] For the deployment, we need to consider the applicable text following the revision of the 1978 Bill by the Ordinance of 12 December 2018 adopted puR-ITS-Sant to Article 32 of the Bill of 20 June 2018 on the protection of personal data. The ordinance came into force on 1 June 2019. Decree 2019-536 of 29 May 2019 implementing the amended 1978 Bill was published on 30 May 2019 in the JORF.

[12] Directive 2002/58/EC of 12 July 2002 on the processing of personal data and the protection of privacy in the electronic communications sector. Proposal for a Regulation of 10 January 2017 (COM/2017/010 final) which will complement the GDPR for personal electronic communications data (*still under discussion during the meetings of 24 May 2019*).

The role and aims puR-ITS-Sed by the main stakeholders are described in a deliverable presented to the CNIL in 2016 (Guilbot et al. deliverable 2381 p.12-20, July 2016). SCOOP is underpinned by two general end-purposes:

- The **provision of services**, referred to as use cases by the partners (for example, alert obstacle on the road, alert planed road works, etc.). These services are provided to improve road safety and optimize traffic. This end-purpose is the main end-purpose of the deployment.
- **System evaluation** through **impact studies**. This is a research end-purpose that should not occur in the context of deployment. This end-purpose only concerns the project.

Two other end-purposes are inseparable from a C-ITS project: the supervision and maintenance of systems and the “professional” objective of road operators. An additional end-purpose, namely, “calculation of travel times” for equipped vehicles, has also been determined. These calculations are performed by road operators.

Reaching these objectives involves many partners: SCOOP's direct partners, most of whom process project’s data; their service providers and subcontractors (for example, to develop system components such as V-ITS-S or R-ITS-S, or for supervision). In addition, many vehicles were supposed to be fleet vehicles managed either by the road operators involved in the project or by private companies for Renault vehicles and part of the PSA vehicles. The pre-deployment phase also involves public research and study institutions as well as subcontractors of these entities.

For the pre-deployment phase, it was planned to equip, on 5 pilot sites, 3000 vehicles, including 1000 vehicles sold to individuals or companies for their fleet by PSA, 1000 vehicles sold to companies for their fleet by Renault and, in the long term, 1000 vehicles for road operators.

This situation could have had an impact on drivers' rights, mainly because of the risks of re-identification and traceability of their journeys linked to the small number of devices, particularly equipped vehicles. This fact concerns in particular the risks related to the data collected for the evaluation. It does not impact the reasoning regarding legal impacts concerning the deployment of C-ITS.
Nevertheless, measures for the protection of the personal data of first, drivers of private vehicles, and second, road operators' agents, on the other hand, have been taken.

These measures are mandatory regardless of the driver’s category:

- For **private drivers** because they were not professional drivers, but persons participating in a pre-deployment, doing so in the context of their daily lives, in their private capacity or during their professional activity and their daily commutes. The voluntary nature of participation does not exclude the obligation of protection and confidentiality;
- For the **agents of road operators'**, the enhanced obligations are linked to the existence of a vertical relationship between agents and their employers, who are, moreover, partners in the project. In addition, for some of these agents, data collection, particularly geolocation, was not necessary for the

exercise of their activity but only for the performance of pre-deployment and evaluations.

These measures will have to be maintained in the event of a large-scale deployment, subject, for some of them, to changes in the regulations on C-ITS 13.

13.1.2 Protecting the personal data of drivers

The purpose of the impact study on drivers' personal data and privacy was to draw up a list of applicable texts, to help identify risks, to recommend the implementation of organizational and technical measures to remedy them14 and to coordinate a presentation file to the CNIL, initially for the purpose of an authorization request15. The study also aimed to raise awareness of this issue among partners.

We will only mention here the major points of vigilance identified, associating them in particular with the remarks made by the CNIL during exchanges with partners and in the letter sent to the DGTIM by the President of the CNIL16.

13.1.2.1 The major risks identified

We will focus here exclusively on the risks that we consider to be the most important: security breaches, possible re-identification and traceability, disclosure of a traffic violation.

(a) Security breach

One of the major risks of cooperative systems is the risks inherent in a **security breach** in one of the elements of the system, from vehicle ITS stations (V-ITS-S) to Traffic Management Services (TMS), including the various roadside equipment (R-ITS-S) and the networks used.

The partners' commitments, in particular through the elements presented in the file submitted to the CNIL and the implementation of a PKI managed by a trusted third party, offer guarantees as to the confidentiality and security of data. The contribution to the construction of a body of standards, in particular to ETSI, the definition of a technical and organizational environment to prevent the risks of damage to drivers' personal data are all measures that can be taken into account as part of the due diligence performed by project members during an analysis of liabilities in the event of

[13] Example: the collection of consent may not be necessary if there was a legal obligation imposing data collection without consent needed, which is however unlikely to happen for the provision of value-added services but could happen for services that provide a convincing guarantee of safety (see eCall Regulation distinguishing between public service of general interest and optional value-added services).

[14] in addition to and in coordination with the safety study conducted under the supervision of the Mines Télécom Institute

[15] The CNIL subsequently re-categorized the “Request” as a “Declaration” (letter of 18 May 2017).

[16] ditto

post-deployment failure (violation of personal data, breaches of system security).

In concrete terms, protection measures from the design stage of the project (privacy by design) tend to prevent intrusions at all levels of the process (data collection via V-ITS-S and R-ITS-S, communication networks, servers, SCOOP platforms). <u>These technical measures and their evaluations are discussed in another part of this synthesis report.</u>

(b) Re-identification and traceability

The identification or risk of re-identification of a physical person is the central criterion for the qualification of personal data. The presence of a single potentially identifying data, if only by cross-referencing with other available information, implies the personalization of most of the data processed with it and the obligation to comply with the GDPR and the French Data Protection Act. Only <u>irreversible anonymization</u> allows the data to be processed freely in accordance with the legislation on the protection of personal data.

The data contained in the CAMs alone present an increased risk due to the **duration of the pseudonymous certificate** and the simultaneous collection of the vehicle's geolocation. The **risk of traceability and re-identification** of drivers cannot be excluded, in particular by cross-referencing with other data, for example by analyzing origin-destination data in non-urban areas. This duration, set at one hour, was requested by road operators to optimize traffic management by calculating the travel times of equipped vehicles.

The CNIL, in its letter to the MEDDE, reiterated that the CAM and DENM files must be “deleted as soon as they expire, after a few minutes or a few seconds depending on the services, and at each contact break”. This concerns the “Services” purpose. As regards the “Calculating Travel Time” purpose, the Commission has “drawn the attention of road operators to the obligation to delete data as soon as they have calculated travel time or issued alerts”.

(c) Disclosure of a traffic violation

A third risk, also related to <u>geolocation</u>, is the association of this data with <u>speed at a given time</u>: combined, these two data items can be used to reveal speed violation. However, data on offences are only accessible to public authorities responsible for control/sanction tasks, as well as (under certain circumstances) to bodies referred to in the law or regulation (e.g. insurers for compensation of road accident victims).

Nevertheless, the need to collect and process this data for the <u>purpose of accidentology research</u> has been demonstrated on several occasions by the IFSTTAR, for the SCOOP project as well as for other projects. The difficulty was overcome for scientific research by calling on the authority of the 1995 Directive and of the French

Data Protection Act in its version in force at the time the dossier was prepared17. However, following the amendments to texts on the protection of personal data, the legal basis identified above is no longer operational. The search for a new legal basis is currently being examined to enable researchers to comply with the GDPR and with the French Data Protection Act as amended in 2018.

(d) Some additional difficulties

In any event, other difficulties may arise during deployment:

- The precautions taken in advance do not exclude the risk of data capture by a third party or the use of the equipment for purposes other than those intended. On this point, the contractual conditions for deployment, especially with subcontractors, must be very precise and mandatory, both for the design of equipment and for the management of devices;
- The risk of data being used to prove that a legal violation took place could also arise in the event of a judicial requisition of the data, especially following a traffic accident;
- The latter point should also be examined in the light of the aforementioned Mobility Framework Bill, once it has been finally voted on and implemented.

13.1.2.2 Personal Data Controllers in SCOOP

For the pre-deployment phase, each of the activities involving data collection was analyzed in order to measure data needs and to categorize these needs (identifying data or not? personal data or not?). Each controller has been entrusted, according to the “sub-purposes”, with responsibility for the processing being assigned to the partner primarily responsible for the execution of the purpose.

The “evaluation” purposes (consisting of a scientific research activity) have been distinguished from the “operational” purposes (service delivery, safety and supervision).

The following bodies have been designated as data controllers:

- for technical impact studies: IFSTTAR
- for non-technical evaluations, according to the studies carried out: the LAB (accidentology laboratory common to French car manufacturers), IFSTTAR, Cerema
- for supervision: road operators for their equipment (R-ITS-S, Vro-ITS-S); car manufacturers for vehicle equipment

Other data-controlling responsibilities have been identified, including:

- car manufacturers for the collection and processing of data until they reach an ITS station or a partner's server (e.g. IFSTTAR for the evaluation part);

[17] This possibility for scientific research was subsequently developed in the "Connected Vehicles Compliance Package" published by the CNIL after consultation with professionals in the sector and also with IFSTTAR (CNIL, October 2017).

- trusted third party in the event of failure of the PKI;
- operators of the communication network used in the event of data transmission by cellular means (3G or 4G). This responsibility was identified during the course of the project, the use of the cellular communication was not initially planned.

In the event of a data breach or security attack, two elements must be analyzed at all stages of the deployment process, i.e. from the design of the various modules used:

- Responsibilities related to a failure of technical measures concerning the prevention of security breaches and confidentiality breaches;
- Responsibilities related to insufficient organizational measures to protect the rights of drivers with regard to their personal data and privacy.

Each party involved in the deployment, at their level of responsibility, should endeavor to verify that these technical and organizational measures are operational. More generally, each party involved in a phase of the process to deliver a service is potentially responsible for data processing or a subcontractor. It is observed that under the GDPR, subcontractors are responsible in the same way as data controllers and no longer only through their contractual relations with the latter.
It should be noted that in penal cases, each partner organization18 remains liable for any errors. In the field of personal data breach, negligence may be an element of the qualification of the offence. The agents of the partners involved may also be implicated in penal proceedings on a personal basis.

Different categories of actors may thus be responsible for data breaches, depending on their activity(ies):

- design and operation of technical and technological systems,
- operation of the connected equipment,
- management of data transmission networks, the conditions of their hosting and storage and compliance with storage periods if the data are not irreversibly anonymized,
- supervision,
- and for the pre-deployment phase, each of the organizations involved in evaluations and impact studies, bearing in mind that the IFSTTAR is responsible for processing the technical evaluation component.

One of the difficulties encountered during the pre-deployment phase in accurately analyzing the legal situation of each partner concerns contractual tools. The project was indeed backed by a research agreement, and some aspects were not contractualized between the partners but only between a partner and its subcontractor(s). Most contracts were not accessible for analysis.

This difficulty will have to be resolved for deployment. This aspect is important when determining responsibilities in the event of a breach of data security and the rights of

[18] with the exception of the State and public authorities if the activity in question cannot be the subject of a public service delegation.

the data subjects. In addition, “GDPR” clauses will have to be introduced in contracts, in particular subcontracts and public procurement. It will be necessary to be more vigilant during the pre-contractual negotiation phases.

13.1.2.3 Principles to be respected for the protection of personal data

Partners were reminded of the essential principles of personal data protection and various measures put in place for pre-deployment to ensure compliance. Only the most important ones will be listed here, which will obviously also have to be respected for deployment, depending on specific legislative developments that could be incorporated into Community regulations and/or national law.

The **end-purposes** are at the heart of the protection of the rights of personal data. They must be determined, explicit and legitimate. The purpose of ITS is to provide on-demand services to improve road safety and optimize traffic. For the evaluations, the scientific research end-purpose was assumed to be the prevalent one.

The **legal basis**. Different legal bases can legitimize the collection and processing of personal data (GDPR, art. 6):

- the legal obligation (e.g. eCall to make a first-responder call);
- the performance of a contract (which nevertheless requires consent under the conditions required by civil and consumer law);
- the performance of a mission in the public interest or the exercise of its mission by a public authority;
- the vital interest of a physical person (the simple prevention of road risk, in general, does not constitute this interest);
- the legitimate interest of the controller or a third party. In this case, a proportionality analysis must be carried out to verify whether or not there is a prevalence of the interests or fundamental rights and freedoms of the person concerned.

If none of these bases are present, the person’s consent is imperatively required. It must be free, enlightened, specific and unambiguous.

It is noted that whatever the legal basis, the protection rules are applicable.

SCOOP being a pre-deployment project, consent was required for any end-purpose. The following clarifications should be made:

- full and accurate information on the project should be provided to potential drivers to meet the Informed Consent requirement (provided by car manufacturers for passenger vehicles, provided by road operators for their agents and representatives);
- the participation was contingent on the person expressing his free will in writing;

- the opinion of employee representatives should be obtained for fleets, including road operators, since consent is not considered as given “freely” in the presence of a hierarchical subordinate relationship;
- the CNIL has accepted, in view of the “experimental” nature of the project, a default activation of the systems. Nevertheless, the driver must retain his freedom of consent and have the possibility to deactivate the system at any time, without having to give any reasons. Only operating agents for whom data are necessary for the performance of their activity do not have this possibility of deactivation during working hours (e. g. agents in charge of winter maintenance or road works). In its letter to the MEDDE, the CNIL expressly states that the system must be disabled by default in the event of deployment.

In the context of deployment, the legal basis could take the form of:

- a legal obligation, for all or part of the services, or another of the above bases (which will probably be determined by the European legislation);
- a contract that could be signed at the time of purchase of the vehicle for certain services or on other terms. Consent to be geolocated will require specific consent;
- a consent at the time of purchase may be accompanied by a consent to access one or more service categories, at the choice of the drivers, for example via the vehicle dashboard.

One of the difficulties, in the case of a contract or consent, is the development of a process to obtain consent from drivers who are not the buyers of the vehicle (usually the holders of the registration certificate). This difficulty already exists for driver services, whatever the technical modalities of their implementation (with the exception of eCall first-responder call). The solution involves informing people and setting up a **default deactivation system with activation at the driver's choice after providing clear and accessible information about the system for collecting and processing personal data**.

Other measures adopted for pre-deployment, which should be developed during deployment, include those that ensure compliance with the following principles:

- data minimization. Only relevant, adequate and necessary data for the fulfilment of the stated purposes may be collected. This also implies respect for the proportionality of the amount of data to be used. They must also be accurate and up-to-date;
- security and confidentiality. This requires the implementation of technical and organizational measures (restricted access to data according to the needs of each party according to the purpose they are puR-ITS-Sing, appropriate technical measures);
- anonymization at short notice, irreversibly, and failing that, pseudonymization. In the meantime, a storage period for personal data for the strictly necessary period, determined or determinable, must be set.

Given that the risks of intrusion and violations of personal and private data can be particularly high in the field of geolocated mobility, an impact study on the risks of violations of drivers' personal data and their private lives must be carried out. This type of study was carried out for SCOOP19. It is likely that regulatory authorities may develop standards to complement regulation, especially if it proves insufficient, as is still the case with the draft Delegated Regulation 2019, as mentioned above.

Finally, the GDPR lays down 3 basic principles that are essential for data controllers and sub-contractors:

- the principle of ***accountability***, whereby responsibility is placed on those parties in charge of ensuring the full respect of the measures to be taken to protect the rights of the persons concerned by the data collected
- the principles of **protection from the design stage (privacy by design)** of projects, systems (through appropriate technical measures) and **by default** (e.g., the default deactivation provided for in the design unless the device is a strict safety device20).

In general, personal data must be: "processed lawfully, fairly and in a transparent manner in relation to the data subject (lawfulness, fairness and transparency)"; (GDPR, art. 5a).

[20] in which case it will most likely be made mandatory by automotive technical regulations

13.2 Legal evaluation: Connected vehicles, impact on legal responsibilities for the public authorities

13.2.1 Introduction. The SCOOP project, contextual elements useful for a reflection on liabilities

The evaluations conducted for the SCOOP project were intended to test and validate the system before a broader deployment could be launched. This work is essential from the point of view of analyzing liability in the event of an accident during the deployment phase: it makes it possible to measure the level of consideration by stakeholders of foreseeable risks and the search for ways to remedy them.

Considering the small number of pre-deployed vehicles, it seems to us that additional evaluations should be carried out, particularly with regard to the use of the system by ordinary drivers. Indeed, the understanding of the system, the confusion that can be caused by the multiplication of in-vehicle information devices, the distraction that they can generate, an insufficient assessment of the quality of the information provided and the ability of drivers to understand the information provided to them, are all elements that suggest we reflect on the responsibilities of the stakeholders.

However, it is possible to explore, hypothetically, the legal impacts of ITS deployment to establish the applicable theoretical framework.

In a dispute, the analysis of the responsibilities involved in the event of damage suffered by physical persons due to a malfunction of the system or violations of their rights in connection with the violation of their personal data, will require a precise mapping of the stakeholders involved in the deployment and their subcontractors, taking into account the missions entrusted to each stakeholder. This implies a very clear definition of these missions, as of the design of the systems, on the basis of the regulations in force and the contractual relations between the parties.

C-ITS are based on 3 modes of interaction: vehicle/vehicle, vehicle/infrastructure and infrastructure/vehicle. After feedback in an equipped vehicle, the action to be taken to respond to the reported situation is managed by the driver. At this stage of development, no automated response by the vehicle is planned.

Malfunctions liable to generate liabilities may be related to CAM and DENM messages, equipment (Vru-ITS-S, Vro-ITS-S, R-ITS-S, platforms, etc.), network, security systems (including PKI). Security breaches are one of the major risks to be considered. Any breach is favorable to the intrusion of a third party into the system, accompanied by the unlawful collection and use of drivers' personal data or a modification of the information provided, and may contribute to the occurrence of an accident. In order to attribute responsibility, we need to determine the origin and nature of the fault.

IFSTTAR's mission in the SCOOP project was to provide food for thought for public action. This report will therefore **focus on the potential liabilities incurred by public authorities and their agents**. The study does not address the responsibilities of the private legal entities involved, i.e. car manufacturers and their partners. However, they may be mentioned if their action or inaction is likely to have an impact on the responsibility of public partners.

The report on responsibilities is organized in 2 parts:

- a theoretical analysis of legal liabilities,
- case law illustrations of the responsibility of the administration and its agents.

13.2.2 Legal responsibilities

Community law promulgated in 2008 (ITS Action Plan) and 2010 (Directive 2010/40, art. 11) reminds us of the need to consider the question of liability in the deployment of Intelligent Transport Systems.

This accountability report is a prospective study. Three points are discussed after some general information:

- The theoretical framework of legal liability in the event of damage to physical persons (accidental injury or manslaughter; infringement of their rights to personal data protection and privacy).
- A particular development on the responsibility of public officers and their functional protection.
- The responsibilities of the State and local authorities towards their public servants.

The study was based on positive law (texts, case law21). A thorough analysis of the foreseeable situation for C-ITS would also require access to contractual documents between stakeholders, including subcontractors and other partners. This first part therefore exclusively sets out the theoretical framework applicable in France.

13.2.2.1 General information

Generally speaking, several categories of persons are likely to be involved in an accountability mechanism and, for this type of mechanism:

- legal entities governed by public law (State, public institutions, local authorities involved in the design and deployment of a cooperative intelligent transport system),
- physical persons (road management service agents, public or private sector employees involved in the SCOOP project and subsequently, during the deployment, drivers of equipped vehicles, whether they are public or private agents),
- legal persons governed by private law (car manufacturers; communication network operators; designers, developers and other subcontractors).

Among the public employees concerned are various categories, in particular:

[21] Mainly studied until the end of 2018.

- central administration officers involved in the design, management and implementation of the pre-deployment, and ultimately, the deployment itself;
- the road operators of the State services (DIR) and local authorities;
- the operating agents (main users of Vro-ITS-S);
- road traffic operators who validate events: they receive, process and communicate information;
- agents in charge of supervising and maintaining equipment, both tangible and intangible.

Several clarifications can be made at the outset.

- The State can never be held criminally liable, nor may local authorities and their groupings, if the activity in question cannot be the subject of a public-service delegation.
- Public and similar officials and employees of partner companies act within the framework of their professional activity. Whilst they may incur penal liability (including for negligence in the exercise of this activity), they should never incur civil liability to compensate victims. Only deliberate error or gross negligence, both of which have the effect of removing their protection status as public employees, could lead to them incurring liability.

The aim is to understand each other's responsibilities through a **prospective analysis of positive law**, in a context of pre-deployment that has not yet been the subject of contentious application.

So, we are forced:

- to call on the authority of texts that are not always appropriate to these innovations,
- to imagine what the position of a judge, particularly an administrative judge, might be. We do so by looking at legal disputes that we consider transposable to the matter, since administrative case law is basically in the hands of the courts.

In penal matters, legal risks seem to us to be easier to understand.

- The risk, for agents, of incurring penal liability as a result of bodily injury or death occurring while carrying out their professional activity does not seem to be any greater than is already the case in the context of their “traditional” professional activity;
- but this risk could take on a new dimension in the event of failure to respect the rights of individuals in the field of personal data protection or negligence in terms of system security, assuming these failures contributed to the occurrence of an accident.

Amongst the possible legal risks to be studied is the prevention of risks related to the health impact of the propagation and multiplication of electromagnetic waves. These risks are not proved and not exclusively related to the implementation of ITS, but public services must take them into account for the future, in a comprehensive way. This subject is not analyzed in this report, but we consider that the State should prepare an epidemiological study taking into account all the connected systems likely to broadcast waves at the same time in the public space in order to measure the real global risk incurred by the populations.

In this synthesis, we present the main lines that have been or should be addressed.

13.2.2.2 Liability regimes

The implementation of responsibilities in the event of damage to physical persons has two purposes:

- compensate victims (civil liability, administrative liability)22;
- punish misconduct, including recklessness or negligence, committed by a stakeholder, legal or physical person (mainly by penal prosecution23).

Compensation for road accident victims

The application of the specific provisions on compensation for victims of road traffic accidents24 does not exclude the charging of the financial burden to parties other than drivers or guardians of land motor vehicles.

The idea of calling the different liability regimes into play in the event of a traffic accident related to an infrastructure problem is not new. But we must take into account the unprecedented situation generated by ITS in the road traffic system. In particular, we would need to consider the impact of novelty; the categorization of equipment (public work or not?); the new functions of vehicles acting both as receivers and senders of information which could contribute to the occurrence of an accident (through the dissemination of erroneous information, for example); and lastly, the categorization of computer architectures (tangible or intangible, public work or not).

In addition, if a vehicle belonging to a legal person governed by public law, or circulating for the purpose of performing a public-service mission, were involved in an accident, the courts have jurisdiction to hear the harmful consequences of the accident and the substantive rules of private law will apply25, provided that the damage is caused by the fact that the vehicle was circulating. If, however, the determining cause of the damage was a public work, then the administrative judge is, beyond contest, competent to rule on compensation.

The following points will now be successively examined:

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[22] In the report, we reason in terms of responsibilities - the question of insurers' coverage is not studied. This does not alter the reasoning on the allocation of responsibilities which is a central consideration, particularly for the final allocation of the financial burden.

[23] Administrative sanctions may be imposed, in particular by regulatory authorities such as the CNIL, in the event of non-compliance with the rules relating to the protection of personal data, which is applicable in the case of ITS-C.

[24] In particular, the application of Bill 85-677 of 5 July 1985 on improving the situation of victims of road accidents and speeding up compensation procedures.

[25] Art. 1 of Bill 57-1424 of 31 December 1957 conferring jurisdiction on the courts to rule on actions for liability for damage caused by any vehicle

- the impact of the involvement of an C-ITS equipped vehicle in an accident,
- the categorization of C-ITS equipment and the applicable liability regime,
- the allocation of responsibility for final compensation.

The impact of the involvement of an C-ITS vehicle

The reasoning implies questioning the application of the criteria of the notion of involvement of a C-ITS equipped vehicle, as a result of sending or receiving incorrect information or as a result of failing to send the information.

The next step is to determine the jurisdiction in the event of the involvement of an administration vehicle equipped with the system. We focused on the specific situation of C-ITS, namely a traffic accident resulting from the incorrect delivery of information by an equipped vehicle owned or used on behalf of the road operator, regardless of whether the information was sent by the system or was manually sent by an operating public officer on duty. To this end, the main criteria studied were the categorization of the event that contributed to the occurrence of the accident: “traffic event” or “vehicle action” (jurisdiction of the judicial judge); “operating event” (jurisdiction of the administrative judge) as well as the status of the victim (public officer or not)26.

Categorization of the C-ITS Equipment and the applicable liability regime

In the event that the applicable regime falls under the law of administrative liability, the equipment must be categorized to determine the basis of the administration's liability. This requires, first of all, determining whether those criteria conditioning categorization as a “public work” are applicable to C-ITS equipment. If the equipment is considered a “public work”, we can then study the compensation of victims by applying the theory of the lack of normal maintenance by taking into account, as is usually done, the status of the victim with regard to the public work (user, third party or participant).

The categorization of the IT architecture developed for the operation of the system should also be examined (*analysis still in progress given its complexity*)

Finally, in the event that the damage affected a user, we will examine under which conditions the Administration can provide proof of normality and thus not incur any liability for compensation.

Allocation of responsibility for final compensation

In the event of litigation, the Administration, if sentenced to compensate victims, may implicate other parties in order to have them pay some or all of the compensation.

We looked at two aspects, both from a highly theoretical perspective: first, a third party under a public contract was rendering a service; second, the possibility for the Administration to allege liability for defective products. Both of these aspects would have to be consolidated by practitioners with actual contractual elements in place for the deployment of systems.

[26] Case law has evolved since 2009 for the case where the victim is a public officer.

Sanctioning faults

Two situations are considered in the report.

- A road accident due to a malfunction of an element of the C-ITS system.
- Violations of drivers' rights due to non-compliance with personal data protection regulations or a security breach that enabled an illegitimate intrusion into the computer system.

Penal liability in the event of a fatal or physical traffic accident involving an element of the C-ITS system.

The possibilities of penal prosecution for manslaughter or accidental injury may apply to:

- a public officer or similar (operating agent, operator, physical person involved in the design, supervision or maintenance of equipment);
- a legal entity involved with the device; either a legal person governed by private law in a contractual relationship with legal persons governed by public law, or a public authority in the event that the activity giving rise to the problem is likely to be the subject of a public service delegation27.

The general principles for the implementation of penal liability are restated, as are the penalties incurred in the event of manslaughter or accidental injury following an accident, taking into account in particular the criteria developed by Article 121-3 of the Penal Code and its judicial applications.

Two points were specifically studied: first, the nature of the causal link between the alleged facts and the damage (direct or indirect); second, the nature of the fault. The two concepts are linked by penal law as constituting grounds for physical persons to incur liability: the court is petitioned to hand down a charge of “aggravated fault” against them if the causal link is indirect. This fault is analyzed under two approaches that we believe are applicable to ITS: deliberate fault with regard to the concept of the “standard” and fault characterized with regard to the concept of awareness of the risk, as applied by the penal judge.

Lastly, the criteria developed by the judge to determine if the accused persons did, or did not, perform the “normal due diligence” required of them in the performance of their duties, in accordance with the conditions set out in the Penal Code (art. 121-3 above), are analyzed.

Liability related to IT security and the protection of drivers' personal data

The precautions taken, as described in another part of this general summary report, do not exclude the occurrence of a risk. The types of liability potentially incurred can be linked to two types of problems:

[27] Of note is that first, the study of the penal liability of legal persons in connection with the motor vehicle industry did not fall within the scope of IFTTAR's mission and, second, although the State does not incur criminal liability, each agent may be found personally liable.

- a failure of technical measures concerning the prevention of security breaches and the risks of breaches of confidentiality;
- insufficient organizational measures to protect the rights of drivers with regard to their personal data and privacy.

The fault that is identified can be considered as “intentional” but also “negligent” (case of non-compliance with personal data protection rules).

The legal risk is examined from two angles: the penal liability of the concerned parties and the administrative sanctions that may be imposed by a regulatory authority (CNIL in France), bearing in mind that these sanctions can be upheld or overruled by an administrative judge.

Further reflection on the legal risks, beyond the theoretical description of positive law, should be puR-ITS-Sed at a later stage by the stakeholders in charge of the design and development of IT systems. In addition, generally speaking, in the current context of the deployment of automated and/or connected vehicles, many texts are emerging or are under discussion at different levels (international, European, national law). The articulation between these texts will have to be done gradually under the aegis of the authorities responsible for regulating vehicles and road traffic.

13.2.2.3 The liability of civil servants and their functional protection

The amended Bill of 13 July 1983 on the rights and obligations of civil servants establishes the principle of the right to be protected by the Administration when the acts alleged in penal proceedings do not have the character of a personal fault separable from the public officer’s performance of his duties. In matters of compensation, a third party cannot seek, within the context of legal proceedings, to have a judicial court rule that a public servant incurred civil liability for a fault committed by that public servant in the performance of his duties28.

The Administration may exempt themselves from their obligations only for reasons of general interest or if the harmful acts were unrelated to the service or if the harmless acts are the consequence of a personal fault of the public servant, separable from the service itself. The concept of “fault in connection with a service rendered” is widely understood by the administrative courts.

The penal indictment of a public officer

In the context of C-ITS, public servants may be held liable for acts that contributed to the occurrence of damage or injury suffered by victims in the event of an accident and/or violations of drivers’ personal data.

[28] Art. 11-II of the Bill of 13 July 1983 amended by Bill 2018-727 of 10 August 2018, art. 73. In the past, the public authority had to cover the civil servant against any civil sentences handed down against him. In addition, in the event of compensation, Case Law considered that this should be paid by the concerned public authority to the victims.

A concrete outline of events can be drawn:

- Operating agent or an operator (or a person under their supervision) sends incorrect information;
- Insufficient material maintenance of an R-ITS-S or of the platform which would hinder the sending of significant and accident-prone event,
- Absence, on the part of a subcontractor, of verification of software updates necessary for the operation of the system and security,
- Failure to comply with the most recent best practice or standardization, subject to a statement of the reasons for such deviation from the standard in view of the unconsolidated nature of cooperative systems,
- Failure, by any public officer involved in C-ITS to comply with the security and confidentiality measures taken to protect the personal data and privacy of drivers29,
- Failure to intervene on an event in order to remedy it within a reasonable time could also become a major cause of litigation. In this type of configuration, both operating agents and TMS operators may be involved.

Awareness of the risk may be an important element in assessing penal liability.

The prosecution of civil servants in penal matters is relatively rare in the field of unintentional offences, as shown in particular by research carried out in the 2000s by INRETS (Ferrant, 2004; Guilbot et al. 2006; Guilbot, 2008).

Functional protection and its limitations

Since protection is directly linked to the categorization of the public officer's fault, the criteria of the latter are studied in order to infer this categorization. We then analyze the conditions under which the Administration can take recourse action against its own public officer.

Fault committed by a Public Officer

Among the categorizations envisaged by administrative law (strictly personal fault; personal fault committed during the service but considered separable from it; personal fault committed outside the service but not unrelated to it; fault of service), only the latter two fall within the scope of protection. The analysis of Case law makes it possible to determine the criteria of the 3rd category to enter the scope of protection. These points should be supplemented by the experience of litigation usually borne by road operators.

The Administration's recourse action against a civil servant

The compensation process can follow two steps: the payment obligation (by which the victim can be compensated) and the contribution to the final damages paid out. Like any party that is “liable” to settle a debt, the Administration, initially obliged to compensate the victim for damages caused by a fault caused by its own civil servant in the rendering of his public service, may, if the Administration believes that this fault

[29] However, we exclude the possibility of illegitimate use of data by a public officer, or any other intentional harmful act of a malicious nature.

is attributable to the personal actions (or inactions) of the public officer, turn against the public officer to have him pay some or all of the damages.

We investigated whether or not this possibility was applied by Administration. Once again, it will be the practices of those public bodies and services involved in C-ITS that will enable them to assess the risk with regards to deployment. The previous work carried out by the IFSTTAR (INRETS) on the subject, mentioned above, showed that Administration has almost never engaged such recourse action, and this has had the effect of calming concerns as to the potentially excessive risk of litigation in relation with the professional activity of public officials.

Protection does not however include paying penal fines.

13.2.2.4 Responsibilities of public authorities as regards public officers

Depending on the tasks assigned to them, public officers themselves may suffer damage related to the deployment of C-ITS. We considered 4 types of impacts:

- the geolocation of agents,
- risks related to distraction due to manual handling of Vro-ITS-S,
- overwork, for agents and for TMS operators,
- the impact of waves on the health of agents (a situation not analyzed as mentioned above but which we would like to highlight).

Finally, an analysis of the legal risk related to distraction or overwork should be carried out in conjunction with the project's psychologists and sociologists in order to be relevant.

13.2.3 Case law illustrations of the liability of Administration and its public officers

This chapter concerns case law highlighting the various criteria used to consider whether or not liability was incurred. We have classified these criteria by considering two categories of situations: risk management by the Administration and its public officers (1); Information provided to the user (2).

In order not to have too much information in the summary, only the points we analyzed are outlined here.

13.2.3.1 Risk management by the Administration and its public officers

We are developing three criteria that may have an impact on liability incurred:

- Level of awareness of the risk on the part of the Administration
- Providing, at the appropriate time, information to equipped vehicles circulating on the network
- Response time of operating agents, on-site.

13.2.4 Awareness, on the part of the Administration, of road risk and ITS

Case law addresses three situations: actual awareness of the risk; predictability of the risk; unpredictability of the risk. It has also been shown that the administrative judge and the penal judge sometimes take into account the resources made available to civil servants to determine the risk.

The case law opinions were then compared with innovations related to ITS that provide new elements of knowledge of road risk. A concrete analysis would involve the contribution of road operators in order to determine:

- what is the contribution made by a C-ITS system to their knowledge of road risk?
- which situations seem new to them, in relation to the knowledge of road events or in relation to the risk of malfunctioning of the system itself (failure prevention, software malfunction etc.): for example, how is this risk anticipated? for R-ITS-S? for Vro-ITS-S?

13.2.5 Timely delivery of information

Here, the goal for the road operator is to assess the proper distance, both in time and in space: not so long that the driver forgets, and not so short that the driver is unpleasantly surprised.

Not much case law is available on this subject. That said, two decisions did catch our attention in cases where, both times, the Administration was held liable: firstly, a warning sign placed too far away from the area concerned (i.e., the information was provided to the driver too early) and two work zones, the second of which was not signaled.

We asked road operators to bring to our attention any litigation that might provide insight for our legal counsel, as well as to provide information regarding elements that are part of the SCOOP project, so as to determine the best time to provide drivers with salient information. To date, the information we have obtained is incomplete.

13.2.6 The response time of operating agents

V/V and V/I communication will allow road operators to be aware of, more quickly, what is happening on the road network. These events could therefore be managed more quickly and more appropriately, and should enable operating agents to arrive on the scene faster. We would also need to take into account the time required for the TMS to check the events reported via users' vehicles.

We consider two possible causes of impact on liabilities in the event of an intervention that would be considered as having taken place late: first, a reduction in the time required for operators to become aware of the risk; second, precise knowledge of the location of the event.

Here, the two criteria that seemed relevant to us were: priorization of the responses;

response time itself (i.e., the time that elapses between the moment when the operating agents/operator receives information and the time when he actually arrives on the scene). Once again, we use the information provided to us by SCOOP partners as the basis to carry out a legal risk analysis. Some examples were taken from the available deliverables.

13.2.7 Information provided to the user

In the SCOOP project, in the pre-deployment phase, the reliability of the information provided would not be expected to have any impact on liabilities (content/communication) given that the system is intended to be used for evaluation purposes, and potential drivers must be informed beforehand of this fact. By contrast, any accident that might take place during the deployment phase as a result of incorrect information, or as a result of a lack of information or a problem with the readability of information, could give rise to litigation.

The impact on the liability incurred by the road operator and its agents will also depend on the technical methods used to send and receive information, as well as on the methods of reception in terms of readability as seen by the user.

13.2.8 Delivery of information to the user

With this scenario, the information was not delivered at the right time. There could be a number of reasons for this: equipment failure, unavailability of the communication network, security breach that prevented the sending of information by hacking into the system, etc.
In order to analyze liabilities, we need to consider the cases of equipment malfunction (V-ITS-S, Vro-ITS-S, R-ITS-S, platform, TMS, communication network) and the origin of the failure, that could have led to the failure to deliver information. In the absence of relevant case law that can be transposed to C-ITS situations, the analysis in this case must be based on the measures taken by the consortium.

13.2.9 The information is incorrect, unsuitable or inappropriate

We considered here the case where the information is reported by the TMS and verified by the road operators.

We excluded the following cases from our reasoning:

- The information is transmitted from vehicle to vehicle (Vru-ITS-S)
- The information was misappropriated and replaced following a malicious intrusion (this scenario is considered part of the 'Security breach' occurrence)

We called on the authority of case law pertaining to the dissemination of erroneous information following the disruption of an automatic signaling system, and we adopted the methods provided for in the project (namely, this system using asterisks to indicate the quality of the information displayed).

13.2.10 Readability of the information

We understood this concept in the sense of “Readability of the road”: understand the message/no information overload, clarity of the message.

Three specific situations were considered:

- Readability of the information in relation to the methods used to issue the alert,
- Consistency of the information with regulations pertaining to signaling and signage,
- Case of contradiction with information provided by another source.

As it stands, we did not find any case law of a nature to enable us to properly analyze the legal risk. A relevant analysis could be carried out with road-signage specialists to determine what measures are being taken for these new modes of information (regulatory changes, standardization, etc.). In addition, there should be taken into account the recommendations made by the SCOOP studies in the fields of ergonomics and psycho-sociology.

13.2.11 The message or system prompts the user to make a wrong decision

This aspect should also be studied in coherence with the work on acceptability and usage. We considered two scenarios:

- the message is not consistent with the predictable reaction of a normal driver (e. g. the driver does not adapt his behavior whereas the agent expected an adaptation, such as a decrease in speed as he approaches a road works site);
- the system or message generates a distraction for drivers. One of the concerns is that this distraction is caused by a device introduced and approved by Administration, or even by the regulations, and not by a device introduced by the user himself.

Regarding these scenarios, case law did not provide us with any substantive rulings of a nature to enable a prospective analysis. That said, some non-legal work does exist as regards the development of automated vehicles, including texts of a nature to inform discussions on potential regulations. Such texts could be referenced here.

14 Health impact assessment

Health impact assessment in terms of exposure to radiofrequency electromagnetic waves is performed in the framework of the Scoop project. Over the last few years, there has been increasing concern about the possibility of adverse health effects resulting from exposure to radiofrequency electromagnetic fields, such as those emitted wireless communication devices. Moreover, IARC has classified, in 2011, radiofrequency electromagnetic fields as possibly carcinogenic.

Since the ongoing deployment of Scoop wireless communication system (base stations and mobile platforms) induces additional sources of electromagnetic waves, an EM exposure assessment will be proposed. The two general objectives in of this assessment are first to ensure compliance to current regulations and second, to inform the public and workers on their level of exposure and how it compares to the maximum levels recommended (for risk perception management).

The first deliverable intended for the stakeholders of the Scoop project gave a description of the state of the art on regulations, recommendations and available standards for the problem of human exposure to radiofrequency electromagnetic waves. It also provided a short description of the scenarios for which specific EM exposure assessment will be performed in the last phase of the project. These scenarios have been previously discussed and selected with the partners of the project. This assessment should eventually provide relevant and representative data to be used as a communication support both to the general public and workers.

The deliverable was organized as follows. After a short descriptive analysis of the Scoop communication system specifications and their integration context, the regulatory framework of EM exposure assessment is defined. Then a short literature review providing an appreciation of exposure levels with respect to prescribed limits is proposed. Finally based on the requirements of the project, three scenarios will be defined where field exposure assessment will be conducted where necessary.

14.1 Analysis and description of Scoop wireless communication system in terms of electromagnetic radiation

As depicted in Figure 40, the different radiofrequency electromagnetic sources to be considered are: the roadside 802.11p units, onboard 802.11p units and Scoop YoGoKo Wi-Fi box and tablet.

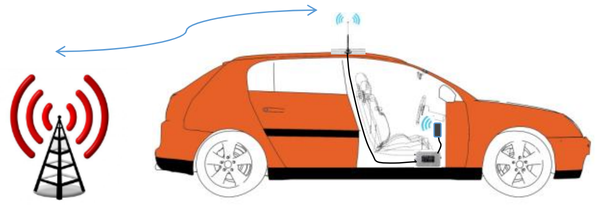


Figure 40: Scoop wireless communication systems

Several exposure assessments have been published on electromagnetic exposure due to cellular systems and to Wi-Fi systems; typical exposure levels can be extracted from these studies. However, Wi-Fi 802.11n systems and 802.11 p systems for C-ITS present a few differences such as the effective radiated power: the maximum authorized power is 23 dBm (200 mW) in indoor environments (and 1 W outdoor) for Wi-Fi 802.11n systems while the outdoor ERP is 10 dB higher or 33 dBm (2W) in outdoor environments for 802.11 p systems.

There is thus a need for EM exposure assessment due to C-ITS deployment of 802.11p in road environments. Two important parameters need to be accounted for to evaluate the exposure levels to electromagnetic fields, namely:

- Parameter 1: The radiofrequency specifications of the systems deployed
- Parameter 2: The integration constraints and propagation and wave confinement which can influence the level of exposure

If the first parameter can be defined from the wireless communication protocol specified, the second one is harder to control and evaluate but it can also constitute a tuning parameter to limit the level of exposure if required. For example, a rooftop antenna will contribute much less to the exposure of a driver and an antenna placed inside the car body. Table 1 gives an overview of the different systems to be deployed by the project stakeholders and their integration context and constraints.

	Wireless communication system deployed in Scoop	Integration context and constrainsts
Renault vehicles[30]	Bluetooth Cellular systems ITS G5 (802.11p)	Rooftop ITS G5 antenna
Peugeot vehicles[31]	Cellular systems	ITS G5 antenna on the front and back windscreen

[30] Extrait du livrable SCOOP-2.4.2.3-R-OBUforRenault-v1.0-fr.pdf

[31] *Extrait du livrable* SCOOP-2.4.2.3-P-OBUforPSA-v1.0-fr.pdf (Juin 2015)

	Wireless communication system deployed in Scoop	Integration context and constrainsts
	ITS G5 (802.11p)	
Road infrastructure operator vehicles	Cellular systems ITS G5 (802.11p) Wi-Fi link inside the vehicle	Rooftop ITS G5 antenna
Infrastructure	ITS G5 (802.11p)	Rural environment, semi-rural, …

14.2 Regulatory framework

14.2.1 Definition of electromagnetic exposure limits

Human exposure to electromagnetic waves is determined as a function of the radiated power density, the electric and magnetic fields. These parameters are measurable quantities and can be easily measured unlike other exposure metrics such as the SAR (Specific Absorption Rate) which represents the power absorbed in a given volume of the human body.

The SAR is a metric giving the power absorbed per unit mass averaged over a period of 6 minutes to account for the thermal relaxation of human tissues. The EN 50383 standard provides the basics for evaluating human exposure levels by calculation and measurement. It is generally simpler to calculate or to measure the fields rather than to evaluate the SAR. There might exists cases when a measurement of the SAR is compulsory such as when there is a strong coupling due to short distances between a source and the human body.

The population considered for exposure assessment can be divided in two categories: workers and the general public. The first category consists of adults a priori in good health, conscious and trained on the risks they are exposed to during their working hours. The general public consists in a higher dispersion and include vulnerable people such as young children, elderly people… with possible exposure over as much as 24 hours a day and 7 days a week (people living close to R-ITS-Ss). The exposure of the second category will be obviously more restrictive.

14.2.2 French regulations

In order to protect the public from potential adverse health effects of radiofrequency electromagnetic waves, limits have been established by different authorities. The European Council has ratified a recommendation (1999/519/UE) on the limitation of exposure levels. These limits are based on the recommendations of ICNIRP. European countries have been either partly or totally adopted the recommendation by law. In France, the decree « Décret 2002-775” of 3rd May 2002.

There is another directive relative to exposure to human exposure particularly for occupational health (directive 2013/35/UE of the European parliament). This European directive has been adopted in France as from beginning of 2017. This directive stipulates that every employer should evaluate the level of exposure of their workers to EM fields and they should take preventive measures if the levels are higher than the maximum prescribed levels [Staebler, 2016].

Generally, the limits (in terms of electric fields) recommended by ICNIRP depend on the operation frequency band; they are shown in Figure 41 with a particular highlight on the GSM, Wi-Fi et ITS-G5 systems.

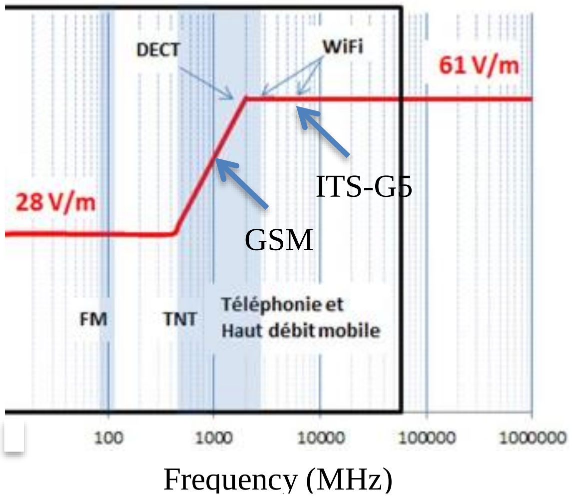


Figure 41 : Limits for the electric field for the general with respect to the operating frequency band (for GSM, Wi-Fi et ITS-G5 systems)

Table 28 and Table 29 show the values of the exposure limits for the two categories for a GSM system and Wi-Fi or ITS-G5 system (for frequencies up to 6 GHz) respectively.

Table 28: Maximum level of exposure to GSM systems (general public and occupational exposure)

		Public	Occupational
Electric field exposure limits		41 V/m	94 V/m
SAR[32] averaged over 6 minutes (W/kg)	Whole body	0.08 W/kg	0.4 W/kg
	Local (Head/trunk)	2 W/kg	10 W/kg
	Members	4 W/kg	20 W/kg

Table 29: Maximum level of exposure to Wi-Fi systems and for frequencies up to 6 GHz (general public and occupational)

[32] Specific absorption rate

Electric field exposure limits		61 V/m	137 V/m
SAR averaged over 6 minutes (W/kg)	Whole body	0.08 W/kg	0.4 W/kg
	Local (head/trunk)	2 W/kg	10 W/kg
	Members	4 W/kg	20 W/kg

In the context of the Scoop project, to guarantee a level of exposure under the prescribed limits, one can note that several controlled or certified evaluations can be done, namely:

- Within vehicles, this evaluation is the responsibility of the car manufacturers; they attest that the maximum exposure limit is respected.
- Outdoor, after deploying the R-ITS-S, a neutral body (e.g. a certified laboratory) in agreement with the ANFR (Agence nationale des fréquences) performs measurements and these can be made available to the general population.

14.3 Short Summary of literature review on measured/calculated exposure levels

In the scientific literature several papers [Foster, Joseph et al., Khalid et al, Kuhn, Peyman et al.] dealt with the problem of exposure due to Wi-Fi systems both inside a car body and in a free-space environment. A brief summary is given thereafter.

In the case when a Wi-Fi source is studied in an indoor environment, the level of exposure has been shown to be lower than the prescribed limits. Indeed, for example, at a distance of 15 cm, the exposure level is 10 V/m which is much lower than the prescribed limit of 61 V/m. The SAR of a car passenger has also been shown to be of the order of 0.25 W/kg for a restricted limit of 2W/kg for the case of exposure to a connected tablet via a GSM system [Ansaldi et al.].
Although these case studies tend to show that the exposure levels are generally lower than prescribed limits, the systems and integration constraints considered in the Scoop project are slightly different and there are concerns about adverse health effects both from workers and the general public. Risk perception management goes through exposure assessment campaigns to be conducted during the second stage of the project.

14.4 Overview of the exposure assessment methodology

The exposure assessment methodology has been defined based on (i) a thorough knowledge of the specifications of the system to be deployed (and the related hardware) as well as (ii) the ability to distinguish the signals emitted by the system in the environment. Accounting for the integration and mobility constraints, the approach we have considered here for exposure assessment is based on measurements. To determine the relevant parameters for the test campaigns such as use of an amplifier, optimal sampling required…, a two-step approach was proposed. It consisted in performing laboratory tests before a general "site survey" to ensure that the signal detection parameters are adequate. The main steps are depicted in the flowchart below.

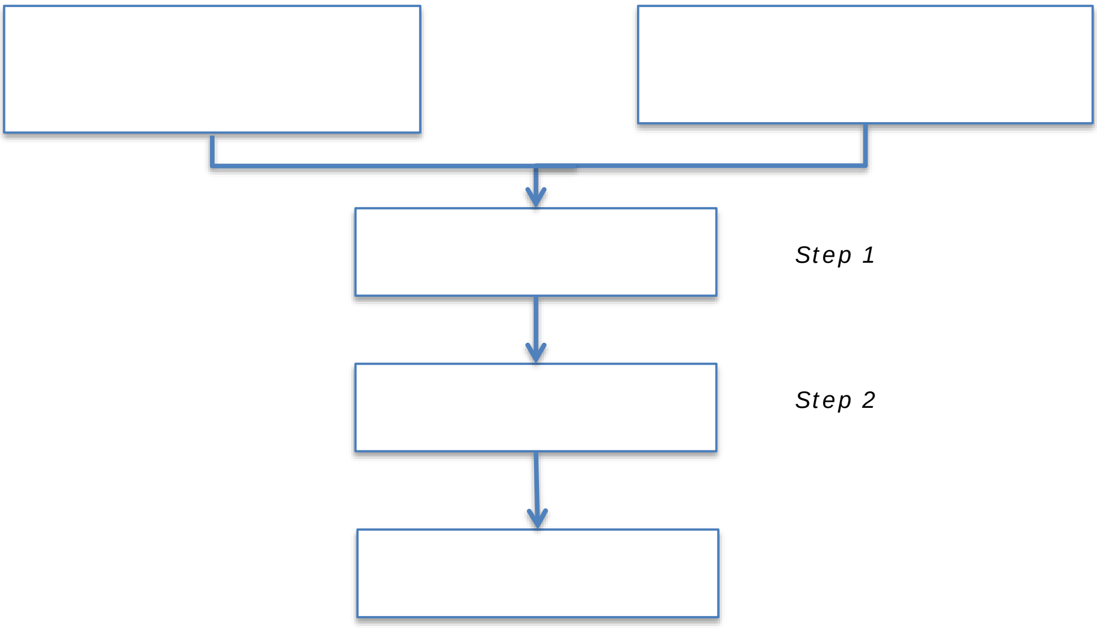


Figure 42: Flowchart of the methodology for EM exposure assessment

14.5 Key hardware components considered

Table 30 provides an overview on the key components of the Scoop@F system which have been considered to set up the methodology.

Table 30: Overview of key components considered for defining the outdoor exposure evaluation methodology

Key component	Description	Annex reference
ITS G-5 Onboard Box	Cohda Wireless ITS-G5 (LTM 501) – ETSI Mask C	Annex A, § 5.1
Roadside antenna	PN18-5900 Series Antenna	Annex A, § 5.2
Multiband antenna	LTM501 Series (vehicular) on board antenna	Annex A, § 5.1
Tablet	Samsung Galaxy Tab with Wi-Fi antenna	Annex A, § 5.3

YoGoKo Box	Wi-Fi frequencies: 802.11 b/g	Annex A, § 5.3
Antenna	Wi-Fi frequencies: 802.11 b/g	Annex A, § 5.3

14.6 Overview of the measurement set-up

The measurement set-up is composed of a spectrum analyzer, a sensing antenna, a GPS antenna, and a computer is used both for *parametrising* and *data acquisition* (Figure 43). The data acquired at each experiment are all the set-up parameters, the power level measured as well as the GPS coordinate corresponding to each measurement point.

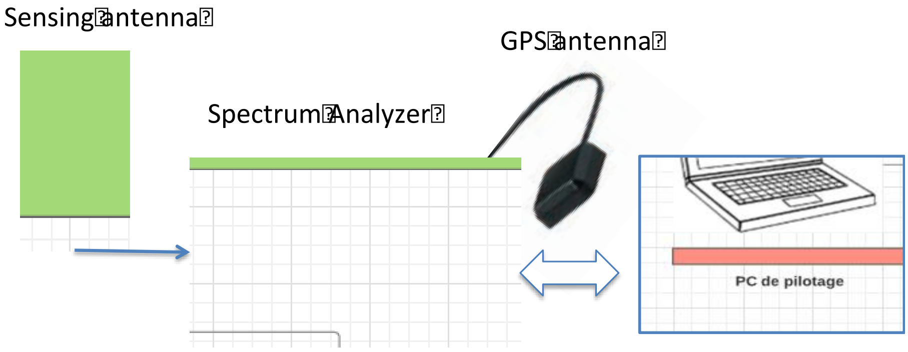


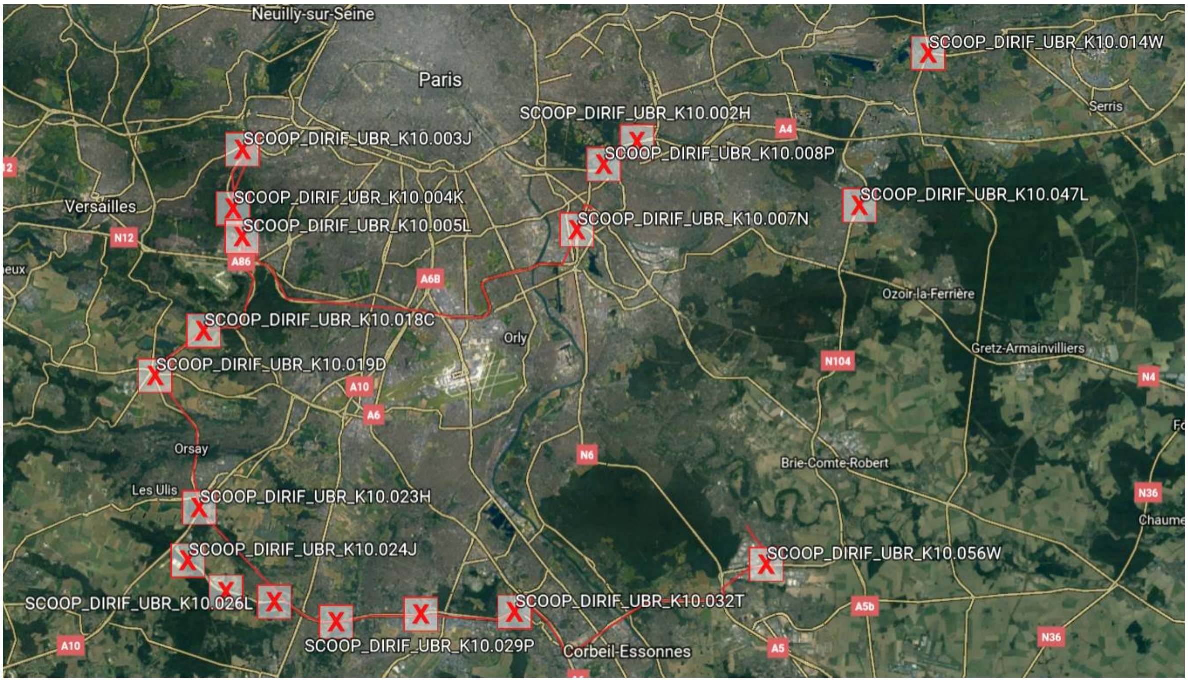
Figure 43: Measurement set-up for human exposure to EM fields

Several measurement campaigns have been done along highways and roads where Scoop R-ITS-Ss have been deployed in vehicles equipped by Scoop OBU. The partners involved and who have provided their equipped vehicles in the measuring campaigns are PSA, DIRIF and SANEF.

The measurement results presented in this report have been done along three different itineraries presented in section 14.7. The scenarios as well as the measurement setup on board are detailed.

14.7 Measurement itinerary

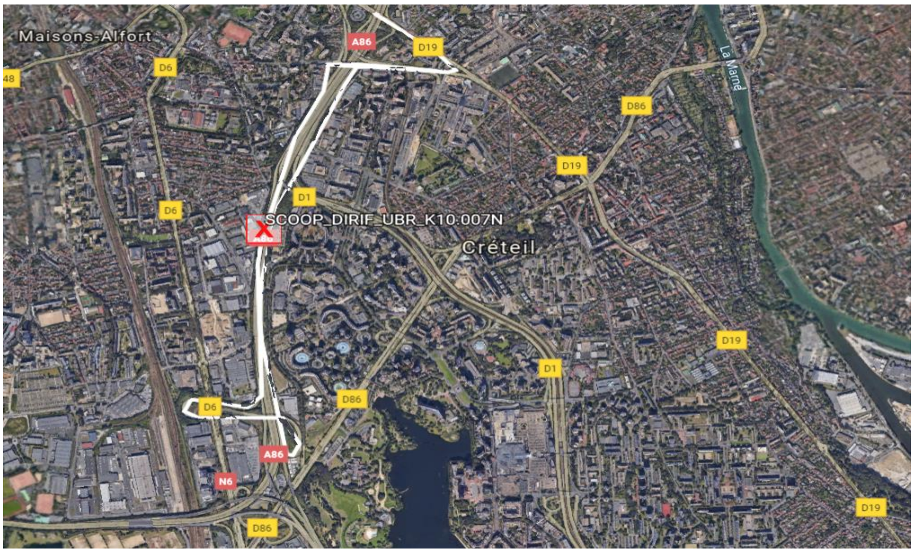
The first measurement itinerary (i) the A86 highway between Pont de Sèvres and Marne-la-Vallée, as well as the N104 and N106 national roads. Figure 44 shows the itinerary followed in a SCOOP-system equipped car along the roadsR-ITS-Ss managed by DiRIF highlighted.



Deployed SCOOP R-ITS-Ss

Figure 44 : Itinerary followed between Pont de Sèvres and Marne-la-vallée, N104 and N106 national roads. The red crosses indicate the R-ITS-Ss managed by DIRIF present along the itinerary.

The second itinerary is a short part of the A86 where measurements have been done inside the vehicle. It is shown on Figure 45. The R-ITS-S is indicated by a red cross and is managed by DIRIF.



Deployed SCOOP R-ITS-Ss

Figure 45: Itinerary along A86 for measurement inside vehicles. The red cross indicates the R-ITS-S managed by DIRIF present along the itinerary

The third itinerary followed was along the A4 between Paris and Reims, as well as the closed section formed by A4, A34 and A344 around the city of Reims.

The R-ITS-S deployment consists in 8 SCOOP R-ITS-Ss (indicated by red crosses) and 4 C-ROADS R-ITS-Ss (indicated by blue crosses) managed by SANEF as shown in Figure 46.

Deployed SCOOP R-ITS-Ss   Deployed C-ROADS R-

Figure 46: Itinerary along A4 between Paris and Reims, and A34, A344 around the City of Reims for measurement inside vehicles. The red cross indicates the Scoop R-ITS-S and blue crosses the C-Roads R-ITS-Ss managed by SANEF present along the itinerary.

14.8 On-board measurement set-up

14.8.1 Vehicular configuration

During the measurements, the sensing antenna as well as a GPS antenna were placed on the roof of the vehicle. The only aim of the GPS antenna is to provide the location of each measurement acquired during the measurement campaign such that they can be plotted on a map. The sensing or measuring antenna is then connected to the spectrum analyzer which is controlled by a personal computer PC for parametrising and for automatic data acquisition and storage as detailed in Figure 47.

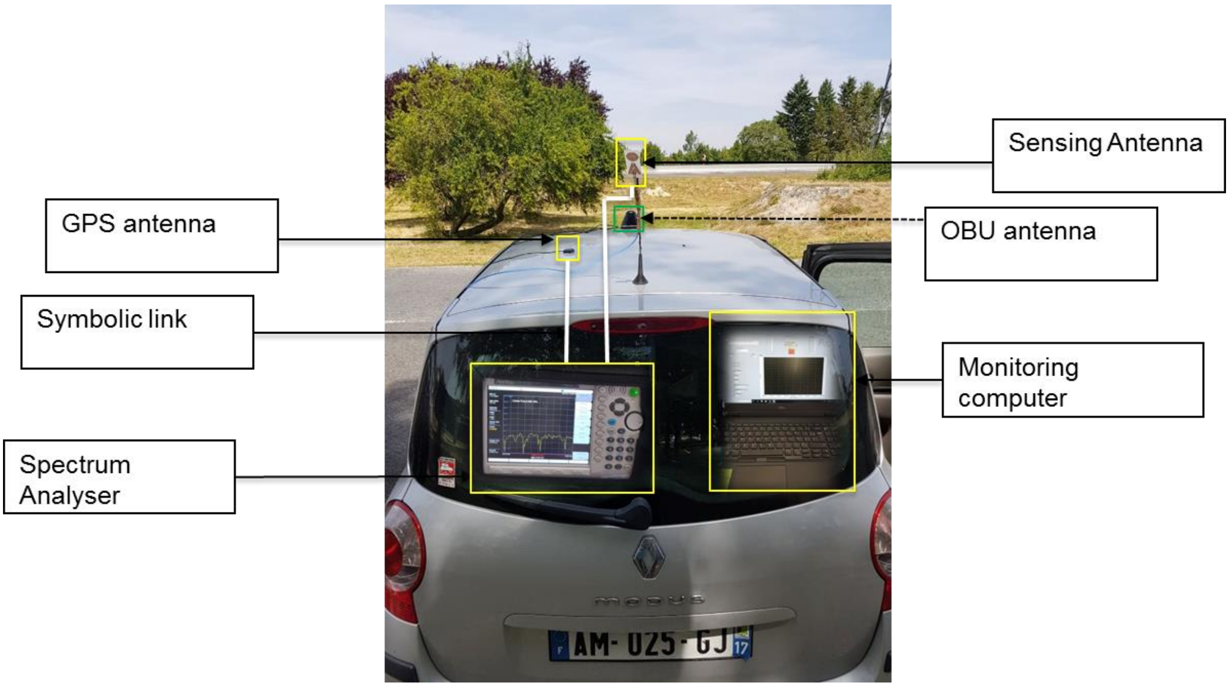


Figure 47: Equipment set-up inside and outside the vehicle.

The measuring or sensing antenna as well as the GPS antenna are on the roof. They are both connected to the spectrum analyzer which is in turn connected to a laptop for parametrising and automatic data acquisition.

14.8.2 Personal exposimeter setup

For intra-vehicular exposure measurement mainly due to the Wi-Fi link between the ITS-G5 router and the tablet, a personal exposimeter. The main properties of the exposimeter are:

- It integrates the fields measured over all frequencies and only provides a single value for exposure due to all wireless systems emitting at frequencies between 300 kHz and 8 GHz. Indeed, the exposure due to the specific Wi-Fi system and/or ITS-G5 system can thus not be distinguished.
- It is worn close to the human body such that the field measured is the one really close to the body unlike the measurements done by the antenna described in figure 7.

Figure 48 depicts the exposimeter used and the way it is worn by the driver during experiments.

Figure 48 : Personal exposimeter worn by the driver during the experiments

14.9 Assessment results

The assessment results for the itineraries presented in section 14.7 and each of the scenarios described in §3.3 are presented in this section. For each case two types of measurements are presented, instantaneous electric fields in V/m as well as average E-field (V/m) as per ICNIRP requirements.

14.9.1 Scenario 1

Scenario deals with exposure measurements around Paris with R-ITS-Ss managed by DIRIF.

ICNIRP recommends a max electric field level of 61 V/m. An EM exposure field level normalized to this value of 61 V/m map is thus shown in Figure 49 such that one can appreciate to which extent the E-field is lower than the recommended value of 61 V/m.

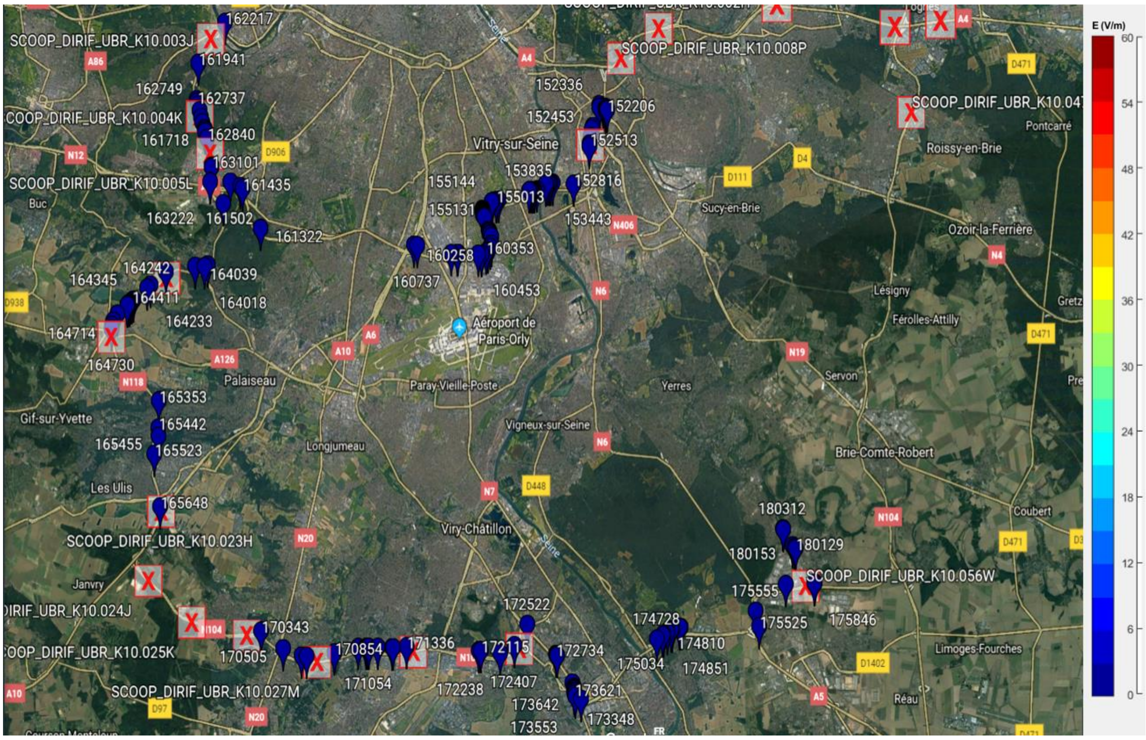


Figure 49: Scenario 1 - Magnitude of electric field measured normalized to the reference value of 61 V/m recommended by ICNIRP

Figure 50 provides the averaged E-field cumulated over the whole ITS-G5 frequency band and averaged over a period of 6 minutes.

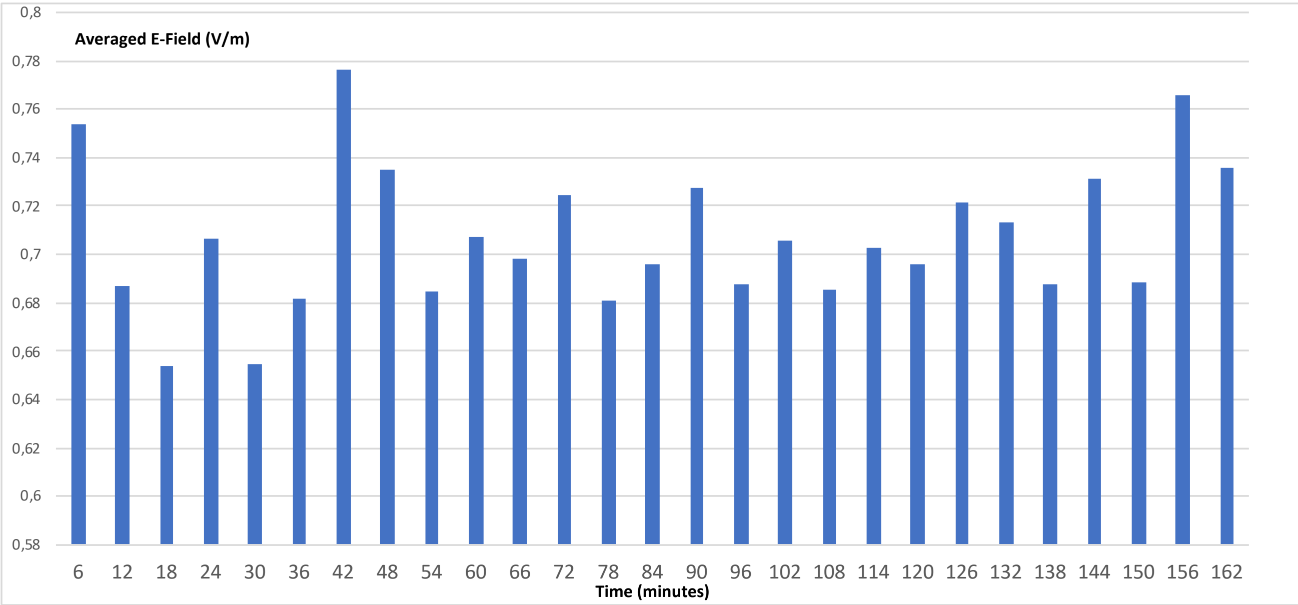


Figure 50: Scenario 1 – Bar chart of E-field averaged over 6 minutes and given in V/m for different periods of 6 minutes during the measurement itinerary

14.9.2 Scenario 2

In this scenario, the measuring antenna was been placed inside the vehicle such that the field measured would be representative of the field level a person present in the car would be exposed to during a trip in a connected car along roads and highways where R-ITS-Ss are deployed and where there is a regular ITS-G5 traffic. The maximum E-field levels are presented in Figure 51 on a map and the values are given in the bar-chart of Figure 51.

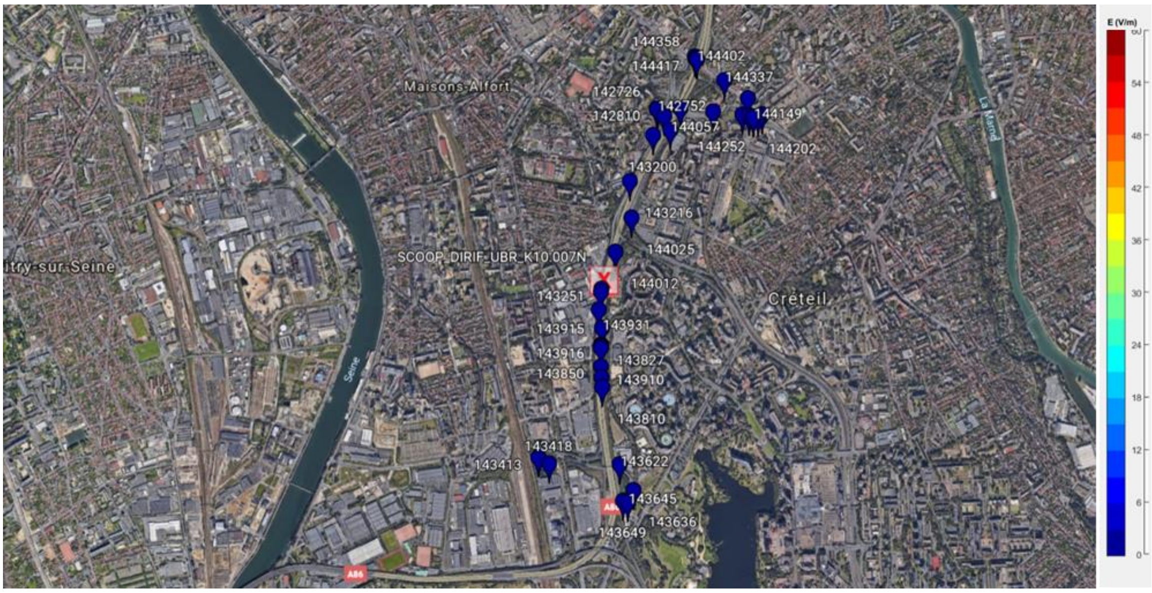


Figure 51 : Scenario 2 - Magnitude of electric field measured normalized to the reference value of 61 V/m recommended by ICNIRP

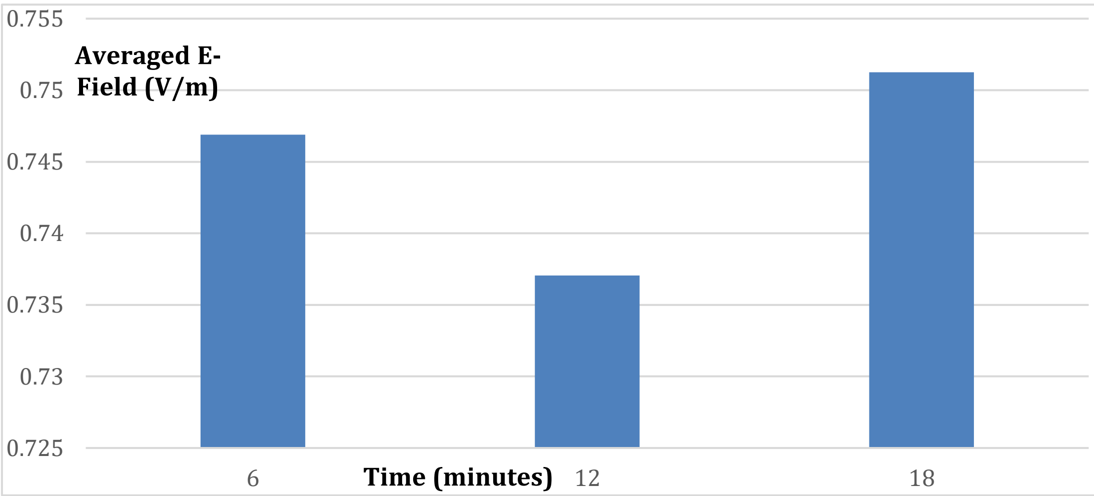


Figure 52 : Scenario 2 - E-field averaged over 6 minutes and given in V/m for different periods of 6 minutes during the measurement itinerary

The exposure levels of scenario 1 and scenario 2 show that the average value measured outside or inside the vehicle are close such that measurements performed outside the vehicle for a worst-case scenario are validated.

14.9.3 Scenario 3

Scenario 3 is an attempt to measure the cumulative exposure inside a vehicle based on a exposimeter. The instantaneous E-fields measured by the exposimeter are shown in Figure 53 and the E-field averaged over 6 minutes periods are shown Figure 54.

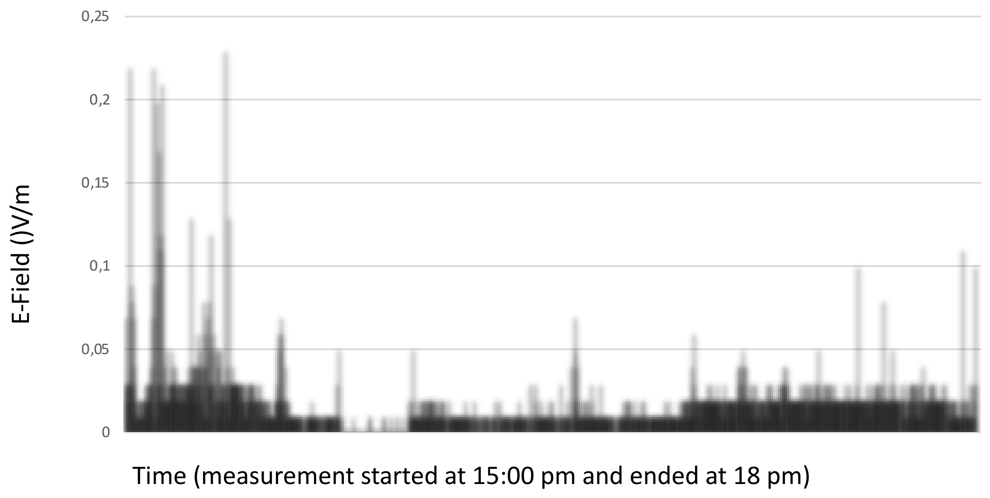


Figure 53 : Scenario 3 – Instantaneous E-field measured by the personal exposimeter during the measurement campaign

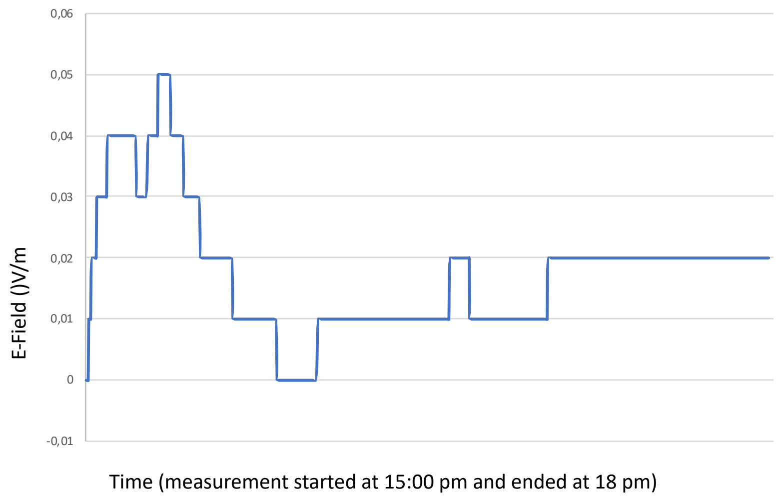


Figure 54 : Scenario 3 –E-field measured averaged over 6 minutes as per ICNIRP requirements by the personal exposimeter during the measurement campaign

The values are substantially lower than the values measured in Scenario 2 even if these measurements integrate the whole frequency band extending from 300 kHz to 8 GHz. This is certainly due to body proximity and to the fact it is not in free-space condition as the antenna in Figure 47. These first measurements with an exposimeter will be further explored in the C-Roads project.

14.9.4 Scenario 4

Scenario 4 deals with exposure assessment on a highway environment where R-ITS-Ss have been deployed according to itinerary 3 and with the equipped vehicle moving in the direction from Paris to Reims. The instantaneous fields are shown on the map of Figure 54. The fields are then cumulated over the whole ITS-G5 frequency band and averaged over periods of 6 minutes. These values are presented in a bar-chart configuration in Figure 56.

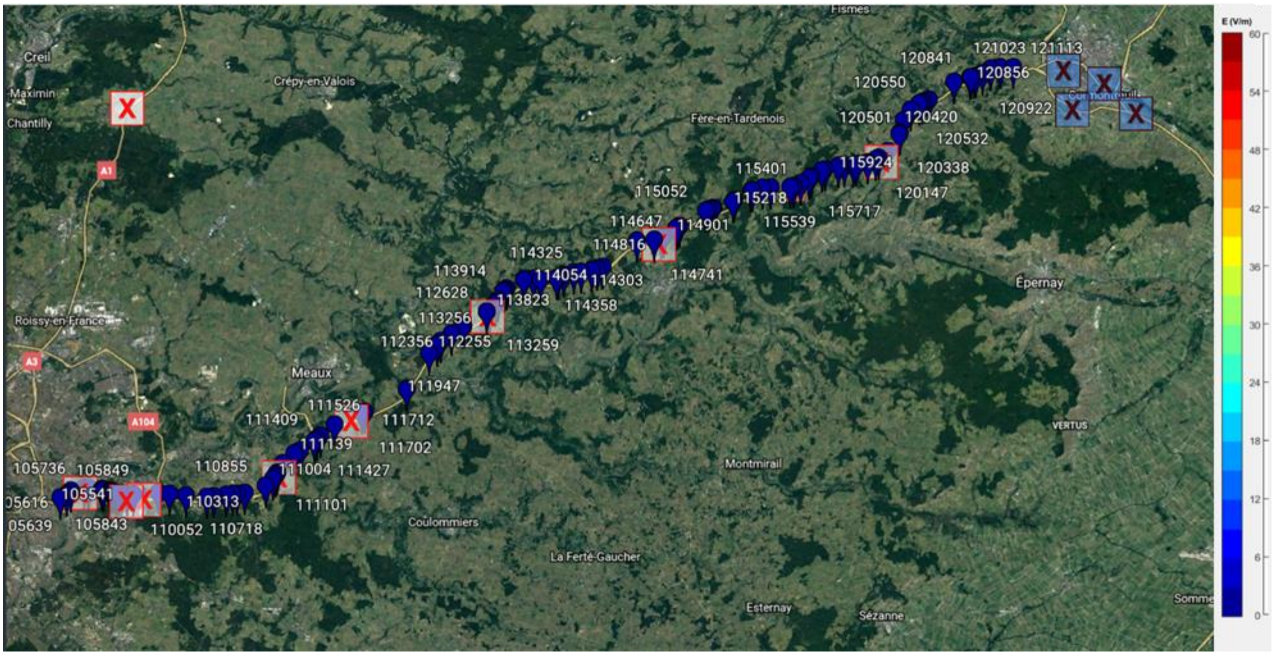


Figure 55 : Scenario 4 - Magnitude of electric field measured normalized to the reference value of 61 V/m recommended by ICNIRP

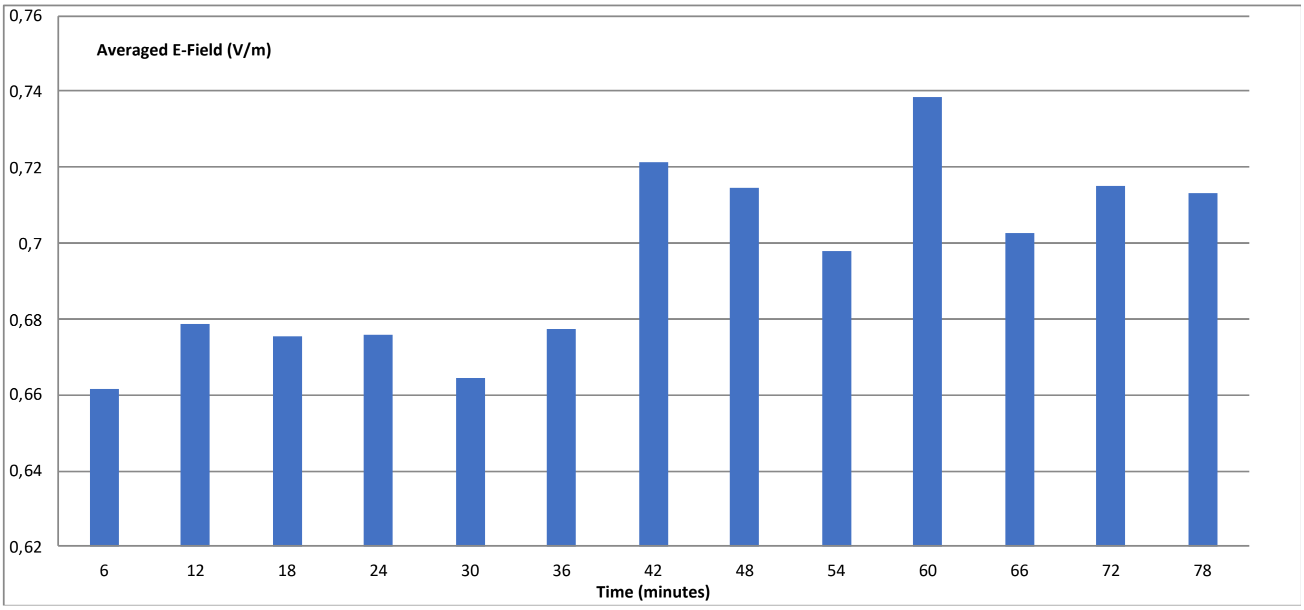


Figure 56: Scenario 4 - E-field averaged over 6 minutes and given in V/m for different periods of 6 minutes during the measurement itinerary

The maximum exposure level calculated with respected to ICNIRP requirements (integrated or cumulated on the frequency band and averaged over a period of 6 minutes) is close to 0.74 V/m.

14.9.5 Scenario 5

Scenario 5 is almost identical to scenario 4 except that the measurements were performed is the opposite direction (from Reims to Paris). These results are interesting for they allow to validate the reproducibility of our measurements which is not always obvious particularly in non-controlled environments such as the road environment. The E-field levels measured are given in the map of Figure 57.

Figure 57 : Scenario 5 - Magnitude of electric field measured normalized to the reference value of 61 V/m recommended by ICNIRP

These E-field levels cumulated over the ITS-G5 frequency band and averaged over a period of 6 minutes are given in Figure 58.

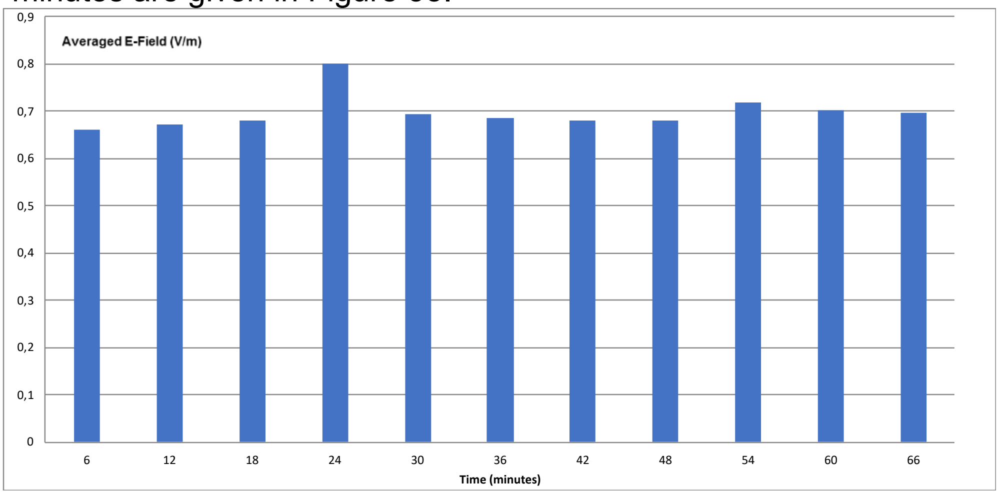


Figure 58 : Scenario 5 - E-field averaged over 6 minutes and given in V/m for different periods of 6 minutes during the measurement itinerary

The maximum level reached is around 0.8 V/m and these values are in good agreement with the values measured in Scenario 5 thus validating the reproducibility of results on the road environment.

14.9.6 Scenario 6

In Scenario 6, the exposure level around the city of Reims is measured and the presentation of results is identical to the previous scenarios. Figure 59 shows the magnitude of the instantaneous E-field level normalized to the threshold value of 61 V/m respectively. These field levels are then cumulated over the whole ITS-G5 bands and integrated over periods of 6 minutes and are given vin a bar-chart representation in Figure 60.

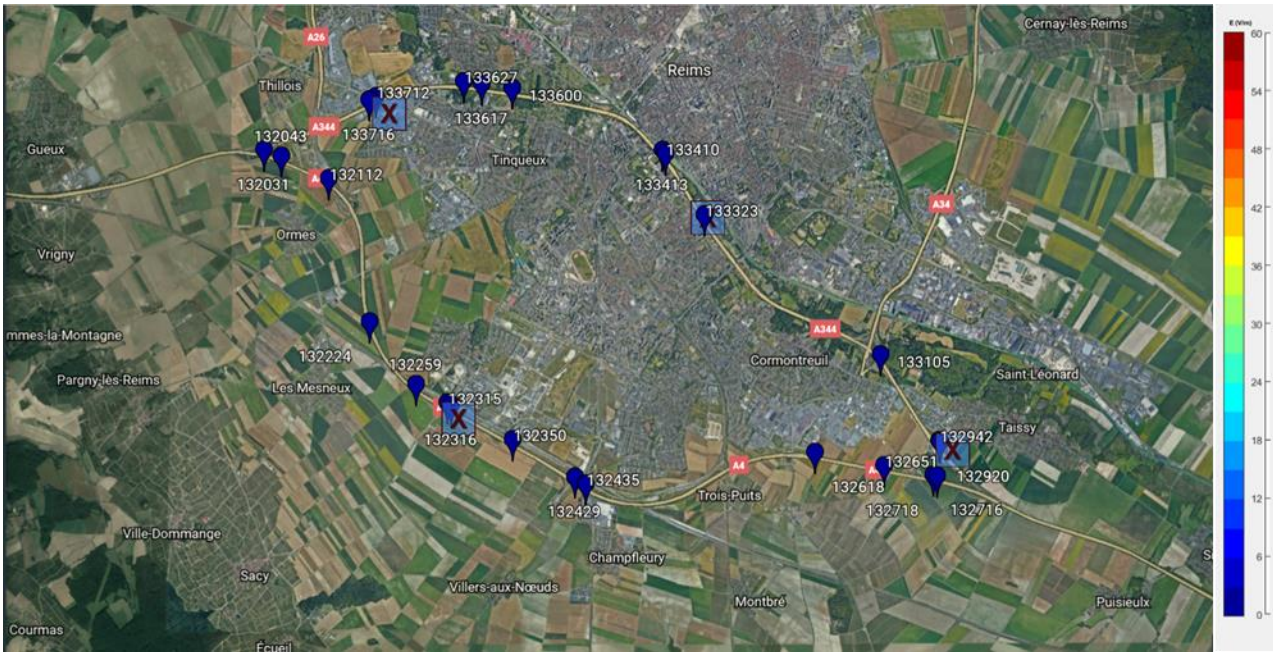


Figure 59: Scenario 6 - Magnitude of electric field measured normalized to the reference value of 61 V/m recommended by ICNIRP

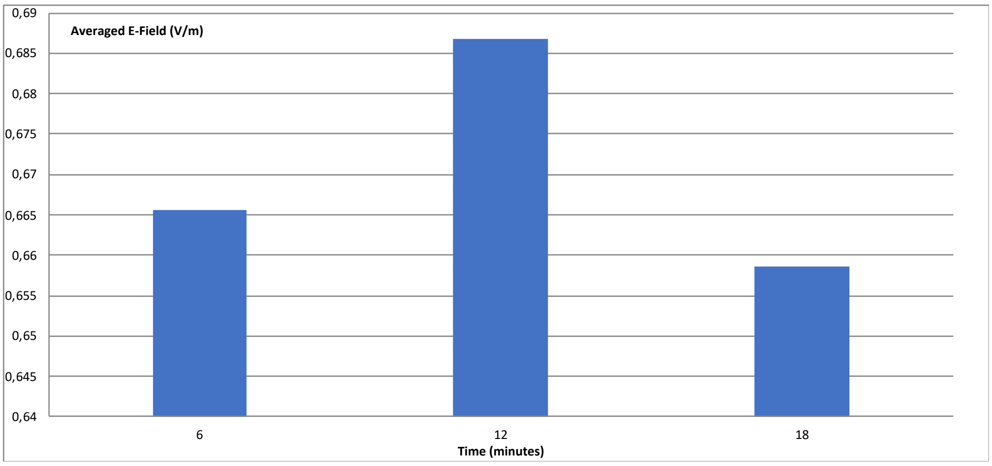


Figure 60: Scenario 6 - E-field averaged over 6 minutes and given in V/m for different periods of 6 minutes during the measurement itinerary

The max E-fields values reached here are lower than 0.69 V/m (to be compared to 61 V/m recommended by ICNIRP).

14.9.7 Summary of the main results

In this section the assessment results according to several scenarios have been presented in a detailed and quantitative manner while ensuring that the maps and field distributions can be understood and discussed with road operators not necessarily expert in the field of electromagnetism or telecommunications.

In the scenarios presented, we have considered several road environments: urban and suburban roads (around Paris and Reims) as well as highways. The measurement set-up onboard the Scoop equipped vehicles have as main configuration an outdoor antenna such that the field value measured represents a worst-case scenario – it has been validated (results of Scenario 2) that the outdoor measurement can be considered to be representative of the exposure inside the vehicle for the ITS G5 frequency band. Scenario 5 is also presented to ensure that our measurements are reproducible in these road environments.

Beyond those validations, the take-away message is that, based on our methodology where the electromagnetic signals of the ITS-G5 bands can be detected in a reliable manner, **our exposure assessments yield E-field exposure levels not exceeding 0.8 V/m, to be compared to the recommended threshold value of 61 V/m**. It should be noted that in this assessment, the exposure has been calculated based on the requirements of ICNIRP such that the field level is summed over the whole ITS-G5 frequency band and this level is then averaged over periods of 6 minutes.

If these averaged values are indeed much lower than the recommended threshold, one could still argue that the signals in the time-domain are not constant and that there are peak values that can be reached. Indeed, messages and CAM signals are only sent in a periodic manner and the peak values of the bursts can be monitored. In the context of these assessment, we have monitored the peak values of the bursts the **maximum value of the bursts measured, termed instantaneous E-field throughout the presentation of the results is of 2.8 V/m**.

15 Technical Evaluation

The goal is to assess technical performances on access layer, facilities and application layer during naturalistic experimentations of C-ITS in the 5 test sites based on real data collected in real environment over a period of 1 year. The aim of this evaluation is to determine whether the functional and technical specifications are in line with what is expected from the system's behavior, whether at the application or radio level.

The expected outcome is represented by research questions listed in the methodology section. Tools for this evaluation are also presented.

Answering these research questions will be the challenge of the results section.

15.1 Methodology

According to the FESTA method, research questions and hypothesizes are defined for several topics:

- Technical functionality and performance evaluation
- Service evaluation

For each group, research questions lead to the definition of key performance indicators and at the end to the related collected data definitions (see deliverable 24.3.1 cataOfDataTlog.xls).

Associated to the research questions, hypothesizes are given when it’s relevant. Indicators will have to answer the questions and validate or not the hypothesis.

15.2 Communication and ITSG5 research questions

Research question	Hypotheses
What are the geographical distribution of events triggered by R-ITS-S?	Event are equally distributed in all region
What are the geographical distribution of events triggered by V-ITS-S ?	Event are equally distributed in all region
What are the percentage of events’ type triggered by V-ITS-S?	Event are equally distributed between all use cases
What is the global volume of DENM sent by V-ITS-S?	
Is DE Repetition interval well defined for DENM sent by V-ITS-S?	Repetition interval is well defined in specifications for evaluated use cases
Is Update well defined for DENM sent by V-ITS-S	Updates is well defined in specifications for evaluated use cases

Is validity Duration well defined for DENM sent by V-IT-S? Is validity Duration well defined for for DENM sent by R-ITS-S?	Validity duration is well defined in specifications for evaluated use cases
What is the distribution of events for a week ? for a day?	Drivers are workers so they drive from Monday to Saturday and mostly during peak hours.
Are triggering conditions well defined for use cases? Nota: Stationary Vehicle use cases analysis Adverse weather condition – adhesion use cases analysis Adverse weather precipitation – Extreme weather condition	Triggering conditions are well defined in specifications for evaluated use cases
Do V-ITS-S receive Faulty messages?	We expect few messages at security level.
What are R-ITS-S locations communicating with V-ITS-S ?	All R-ITS-S will send at least one message to one V-ITS-S.
Do drivers go in all test sites ?	Cam sent are collected in all test site
How Messages are displayed to the driver?	The display duration is less than 1 minute per event. The display is equally distributed for all event.
What are the ITS-G5 performances for I2V, V2I, V2V?	Latency < 1s Range >300m

15.3 Tools

Data collection is based on the deliverable SCOOP_2.4.1.3_CataOfDataTlog. Each V-ITS-S collect all the sent or received messages each time there are in the range of another C-ITS station or each time a DENM is sent.

Table 31: Collection process for Data

TLog-UEVu-CAM-Sent	collect each CAM sent when there is another ITSS
Tlog UEVu-CAM received	collect each CAM revceived when there is another ITSS

Tlog-UEVu-DENM received	collect all DENM received
Tlog-UEVu-DENM sent	collect all DENM sent
TLog-UEVu-DriverRequest-Reception	collect all displayed message on HIMI
TLog-UEVu-DriverRequest-Sending	collect each time there is an action on HMI
TLog-UEVu-MapProjectionContext-DENMReceived	collect at each DENM received
TLog-UEVu-ClimaticEnvironmentContext	collect at each state changes
TLog-UEVu-NetworkAccessPerformance	collect every s durind a period activity + 30s before and 30s after
Tlog-UEVu-CAM-I	collect each CAM-I received
TLog-UEVu-DataStation	collect every 0.1s durind 15s before a new DENM sent
Tlog-UEVu-Radio	collect every s durind a period activity + 30s before and 30s after
Tlog-UEVu-faulty message	collect at each faulty message
uevu-SCOOPFunctionsSettingDriver	Collect at each function modification
uevu-MessagesDisplayedDriverStart	Collect at each displayed message
uevu-MessagesDisplayedDriverEnd	Collect at each end of displayed message
uevu-EventReportingContext	Collect of context associated to each record (3min before the event and 3minafter the event with a record every seconde.
Ulog-UEVu MultimediaReportingData	Collect at each state change

Data are sent by V-ITS-S through cellular with collection requirement defined in Table 31.

15.4 Tlog analyser

When receiving Tlog, they are converted in CSV files thanks to a specific tool developed by URCA, then stored in a Postgre database by IFSTTAR. Data are cleaned and intermediary indicators are calculated. Using SQL request, indicators are calculated and interpreted.

Different tools are developed to convert, extract relevant data and calculate indicators. To help understanding data and indicators, a visual tool is also implemented. It permits to describe the path of several vehicles and received events. Each path and each message can be displayed separately (Figure 61). For a better understanding, a replay of events is also available.

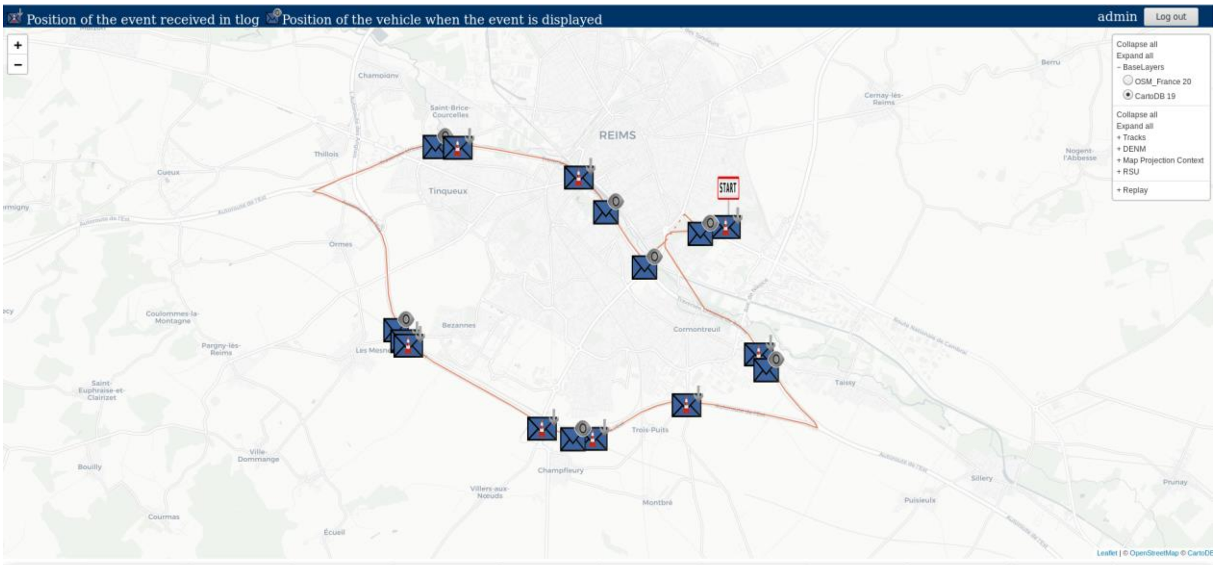


Figure 61: Visual tool

15.5 Experimental Framework

A large number of equipped vehicle drove in SCOOP@F test sites from first of September 2018 until the 31st of August 2019.

It's a naturalistic study so drivers have no driving instructions and real events are sent by road operators. Drivers can send at any time events (manual or automatic triggering).

No baseline is needed in case of technical study as our research questions are independent of driver's behavior.

15.6 Experimental set-up

- Tlogs (technical logs) and Ulogs (Usage logs) (see deliberable SCOOP_2.4.1.3_catalogueofTlog) from 01/09/2018 to 31/08/2019 for Vru-ITS-S
- 5 test sites in France
- All data were converted from ASN1 UPPER to CSV and then to SQL Database

15.7 Results

Definition

Nota: To avoid any misunderstanding between event and use case, below, the definition considered in this document:

- A use case is based on services defined in C-ITS French Use Cases Catalog deliverable.

- We call an event when a DENM is sent with a dedicated action ID.

For example, stationary vehicle from a vehicle is the use case defined as:

- « A vehicle detects that it has stopped for an undefined amount of time//has broken down and broadcasts an alert message to other vehicles. »
- The event stationary vehicle is a DENM with an action ID and an eventtype.

15.7.1 General overview

A few statistics

Table 32: Messages count during a year

Number of CAMI received from R-ITS-S	586 700
Number of CAM sent by V-ITS-S	10 174 437
Number of CAM received by V-ITS-S	140 208
Number of DENM Sent (including repetitions and update) by V-ITS-S	572 993
Total Number of DENM received by V-ITS-S (including repetitions and update) from V-ITS-S or R-ITS-S	109 019
Number of DENM received by V-ITS-S (including repetitions and update) from V-ITS-S	7414
Number of Faulty message	1 159 033
Number of action ID received	698
Number of received Events (85% from R-ITS-S and 15% V-ITS-S)	554
Number of DENM received with a termination	132
DENM of termination without a related event sent by R-ITS-S	144 (20% of total DENM received)
Number of events sent by V-ITS-S	3117 (10% manually triggered)
Rate of CAM received/CAM sent	1,4%

698 different actionID in DENM received including 554 event (132 with a termination and 422 without) and 144 termination and not the event.

Data analyses show that 3117 events were generated by V-ITSS (with 10 % manually triggered by the driver).

1,3% of event sent by a V-ITS-S were received by a V-ITS-S (V2V communication with eventually hop from V-ITS-S or R-ITS-S but the analysis is not able to discriminate direct messages or forwarded messages).

Among the 698 different actionID in DENM received, 554 were related to an event and 144 were related to a termination from a R-ITS-S with no received event by the V-ITS-S.

Knowing that:

- As described in section 15.7.5, validity duration can be up to 24h
- From SCOOP 2412 Specifications of DENM:*"The cancellation message is sent with the same values of validityduration, repetitioninterval, repetitionduration than the related DENM"*

So if there is a termination of a long event, the duration of this event can also be up to 24H. there is a strong probability that a V-ITS-S received terminations with no event associated. To avoid network load, it could be interesting to optimize the ratio DENM sent/standalone termination. Specification of the termination need to be changed in order to have a validity duration of the termination that will not exceed the validity duration of the related event.

For example if a RWW is set to be sent during 10 hours, and finally ended after 5 hours, termination should be sent for maximum 5 hours.

109 019 DENM (update and repetition included) from R-ITS-S or V-ITS-S were received (554 events) by a V-ITS-S with 7% from a V-ITS-S.

If we consider also DENM sent by R-ITS-S, 19% of DENM were received by a V-ITS-S.
4% of DENM sent by V-ITS-S were a cancellation of a DENM and 31% of them were received by a V-ITS-S.

10 174 437 CAM were sent by vehicles and 1,4% were received by a V-ITS-S

15.7.2 Geographical distribution of events triggered by R-ITS-S

R-ITS-S have sent during this experimentation event related to 9 Use cases. 6 Sub cause code associated were not specified in SCOOP_2.4.1.2 Specification of DENM. If road operators triggered these new events, There is probably a need not covered actually.

Table 33: events sent by R-ITSS

eventtype_causecode	eventtype_subcausecode	Label event type		Use case
2	0	Accident	unavailable(0): in case the information on the sub cause of the accident is unavailable,	Unprotected accident area

eventtype_cause code	eventtype_subcause code	Label event type		Use case
2	1		multiVehicleAccident(1): in case more than two vehicles are involved in accident,	Unprotected accident area – multi vehicle accident
2	2		heavyAccident(2): in case the airbag of the vehicle involving is accident is triggered, and accident requires important rescue and recovery work,	Unprotected accident area – heavy accident
2	3		accidentInvolvingLorry(3): in case the accident involves a lorry,	Unprotected accident areae –truck
2	4		accidentInvolvingBus(4): in case the accident involves a bus,	Unprotected accident area - Bus
2	5		accidentInvolvingHazardousMaterials(5): in case the accident involves hazardous material,	Unprotected accident area – hazardous material
3	0	Roadworks	Unavailable	Planned road works
3	1		majorRoadworks(1): in case a major roadworks is ongoing,	Not specified
3	2		roadMarkingWork(2): in case a road marking work is ongoing,	Not specified
3	3		slowMovingRoadMaintenance(3): in case slow moving road maintenance work is ongoing,	Planned road works - Slow moving Road Maintenance
6	0	Adverse weather condition - adhesion	unavailable(0): in case information on the cause of the low road adhesion is unavailable,	Temporary slippery road
6	1		heavyFrostOnRoad(1): in case the low road adhesion is due to heavy frost on the road,	Temporary slippery road - heavy frost on road
6	3		mudOnRoad(3): in case the low road adhesion is due to mud on the road,	Temporary slippery road - mud on road
6	4		snowOnRoad(4): in case the low road adhesion is due to snow on the road,	Temporary slippery road - snow on road

eventtype_cause code	eventtype_subcausecode	Label event type		Use case
9	0	Hazardous location - Surface condition	unavailable(0): in case further detailed information on the road surface condition is unavailable,	Not specified
9	1		rockfalls(1): in case rock falls are detected on the road surface,	Unsecured blockage of a road – rock falls
10	0	Hazardous location - Obstacle on the road	unavailable(0): in case further detailed information on the detected obstacle is unavailable,	Obstacle on the road
10	1		shedLoad(1): in case detected obstacle is large amount of obstacles (shedload),	Not specified
10	2		partsOfVehicles(2): in case detected obstacles are parts of vehicles,	Not specified
10	3		partsOfTyres(3): in case the detected obstacles are parts of tyres,	Not specified
11	0	Hazardous location - Animal on the road	unavailable(0): in case further detailed information on the animal on the road event is unavailable,	Animal on the road
11	1		wildAnimals(1): in case wild animals are detected on the road,	Animal on the road - Wild animal
11	2		herdOfAnimals(2): in case herd of animals are detected on the road,	Animal on the road - herd of animal
12	0	Human presence on the road	unavailable(0): in case further detailed information on human presence on the road is unavailable,	People on the road
12	1		childrenOnRoadway(1): in case children on the road event is detected,	Not specified
12	2		cyclistOnRoadway(2): in case cyclist presence is detected on the road,	Not specified

eventtype_cause code	eventtype_subcausecode	Label event type		Use case
18	0	Adverse weather condition - visibility	unavailable(0): in case information on the cause of low visibility is unavailable,	Reduced visibility
94	0	Stationary vehicle	Unavailable	Stationary vehicle
94	2		Vehicle breakdown	Stationary vehicle, breakdown

Figure 62: Event sent by a R-ITSS in Ile-De -France

Figure 63: Event sent by a R-ITSS in Rennes

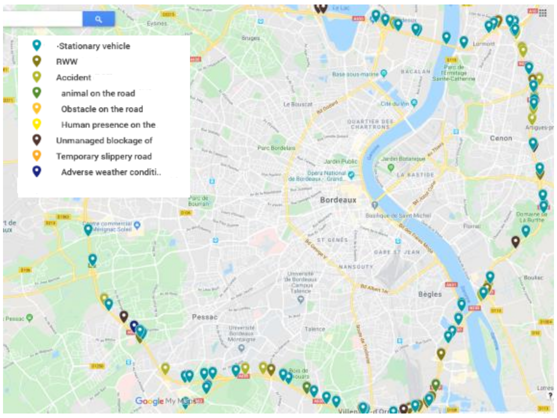


Figure 64: Event sent by a R-ITSS in Bordeaux

Among the 474 events generated by R-ITS-S and received by V-ITS-S, 13 actionIDs have 2 different cause codes or sub cause codes and one changed twice.

Table 34: example of cause code change for the same actionID

Cause code	sub causecode	originating station id	sequence number
2 - Accident	1	586172488	1

2 - Accident	2	586172488	1
12 – Human presence of the road	0	586172488	1

When a road operator triggers an event, he has the ability to change the nature of this event if he receives additional information.

Definition of an action ID is:

- From C-Road platform specifications: The actionID is the unique identifier of a DENM
- From the DENM standard: identifier of an detected event

Definition of an update:

- From DENM standard: indicate an evolution of the event

From these definitions, road operators consider they can change cause code and subcause code for one action ID where OEM consider that if it's the same action id, the event type is the same (same cause code/subcause code).

A clearer definition is needed so OEM and road operators have the same understanding; and at the end, the driver can have the relevant information on his HMI. At least V-ITS-S should be able to update the even type in the display of an action ID (modification of the text/panel).

15.7.3 Geographical distribution of events triggered by V-ITS-S

From DENM received by V-ITSS we are able to extract map of the different use cases and eventually define where are most often triggered event. Figure 65 represents event distribution in France triggered manually or automatically by vehicles. We can notice that vehicles drive all around the country and also in Portugal, Italy and Belgium.

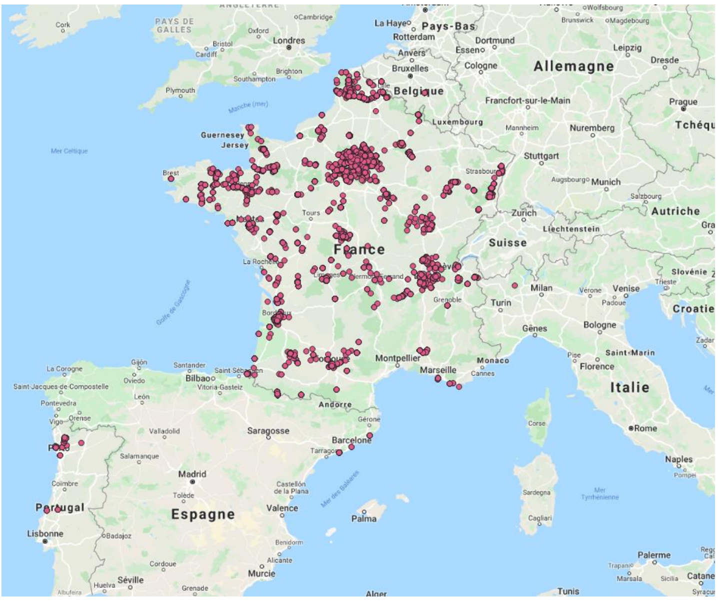


Figure 65: Event distribution in France during the experimentation all causecode combined

SCOOP Vehicles drove all around the territory but also in Spain, Portugal, Belgique and Italy. They triggered events even if the probability that another vehicles received it were low.

10 types of event were generated by V-ITS-S (see Table 35)

Table 35: event triggered by V-ITS-S

eventtype_causecode	eventtype_subcausecode	Event label		Use case Label
2	0	Accident	Unavailable	Unprotected accident area
6	0	Adverse weather condition - adhesion	Unavailable	Temporary slippery road
9	0	Hazardous location - Surface condition	Unavailable	Unsecured blockage of a road
10	0	Hazardous location - Obstacle on the road	Unavailable	Obstacle on the road
11	0	Hazardous location - Animal on the road	Unavailable	Animal on the road
12	0	Human presence on the road	Unavailable	People on the road
18	0	Adverse weather condition - visibility	Unavailable	Reduced visibility
19	0	Adverse weather precipitation – Extreme weather condition	Unavailable	Extreme weather conditions
94	0	Stationary vehicle	Unavailable	Stationary vehicle
94	2	Stationary vehicle	2 : Vehicle breakdown	Stationary vehicle, Breakdown
94	3	Stationary vehicle	3 : Postcrash	Unprotected accident area
99	1	Dangerous situation	Emergency Electronic Brake Light	Emergency break

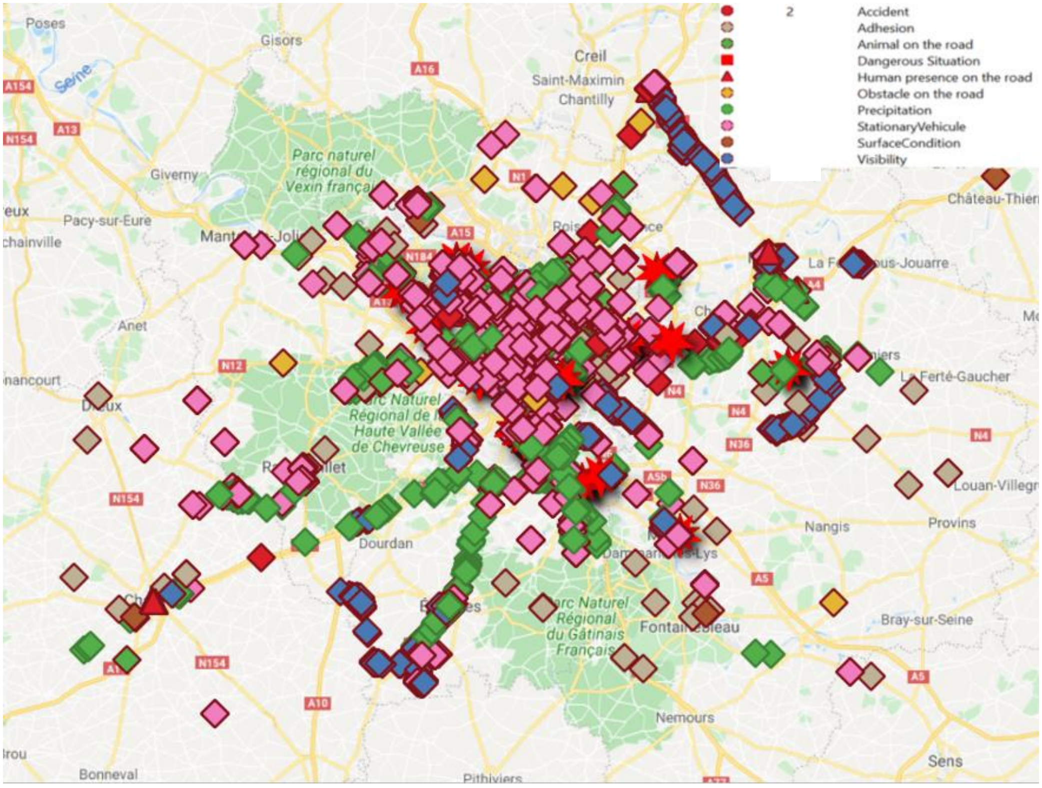


Figure 66: Event distribution in Ile-De- France during the experimentation

Stationary vehicle is the most triggered event (See Figure 66). First thought is that this event is mostly related to traffic jam. Deeper analysis is made in section 15.7.6.

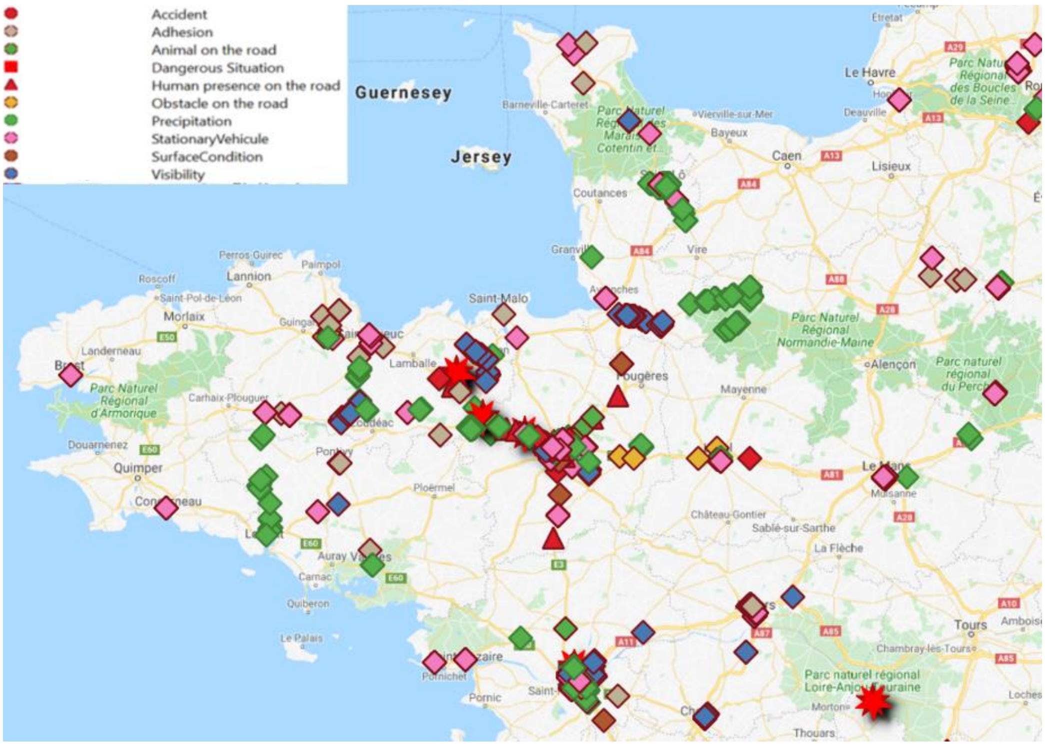


Figure 67: Event distribution in Brittany during the experimentation

Most events triggered in Brittani are linked to the weather (precipitation, Visibility and adhesion) (see Figure 67).

15.7.4 Events' type triggered by V-ITS-S

The most triggered event is Stationary vehicle.

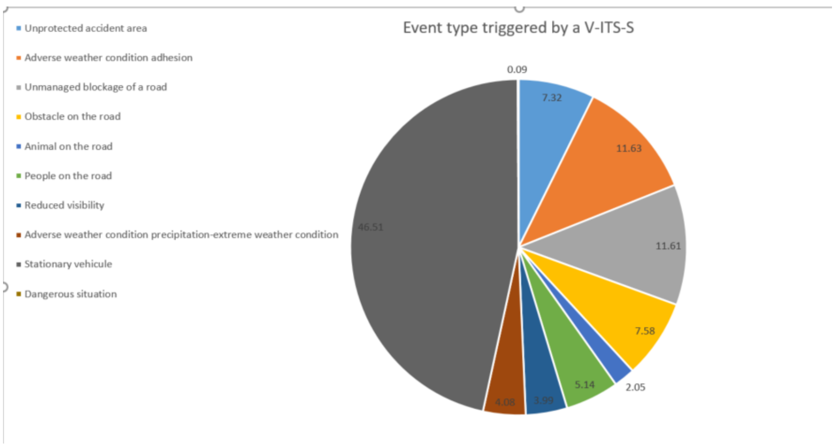


Figure 68: Event type distribution including repletion and update

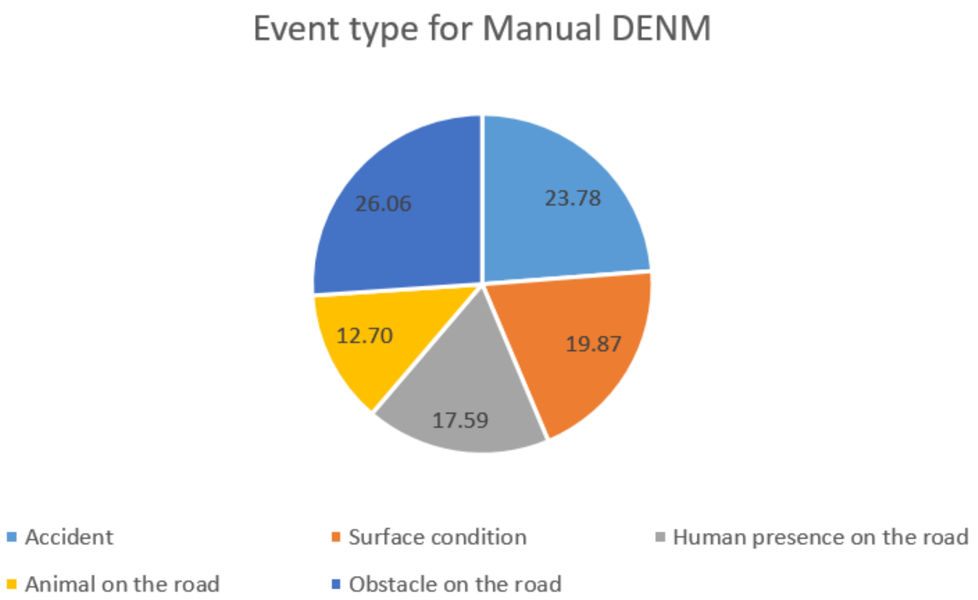


Figure 69: Manual event type distribution

Accident and Obstacle on the road are the most used by drivers to signal an event. The less used is animal on the road. Further analysis on HMI is needed to help understand drivers preferences on HMI signaling.

15.7.5 Validity Duration analysis for DENM sent by R-ITS-S

Figure 70: Validity Duration for DENM sent by R-ITS-S

Validity duration chosen by road operators are not compliant with SCOOP_Specifications of DENM (

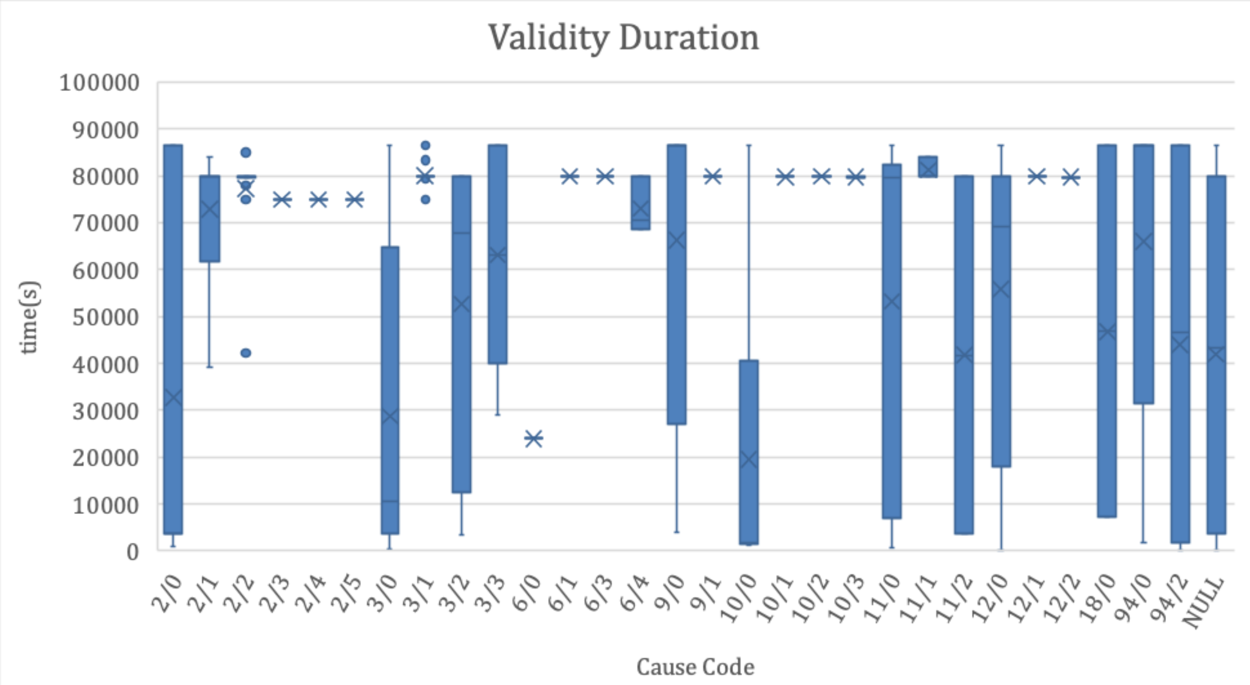


Table 36).

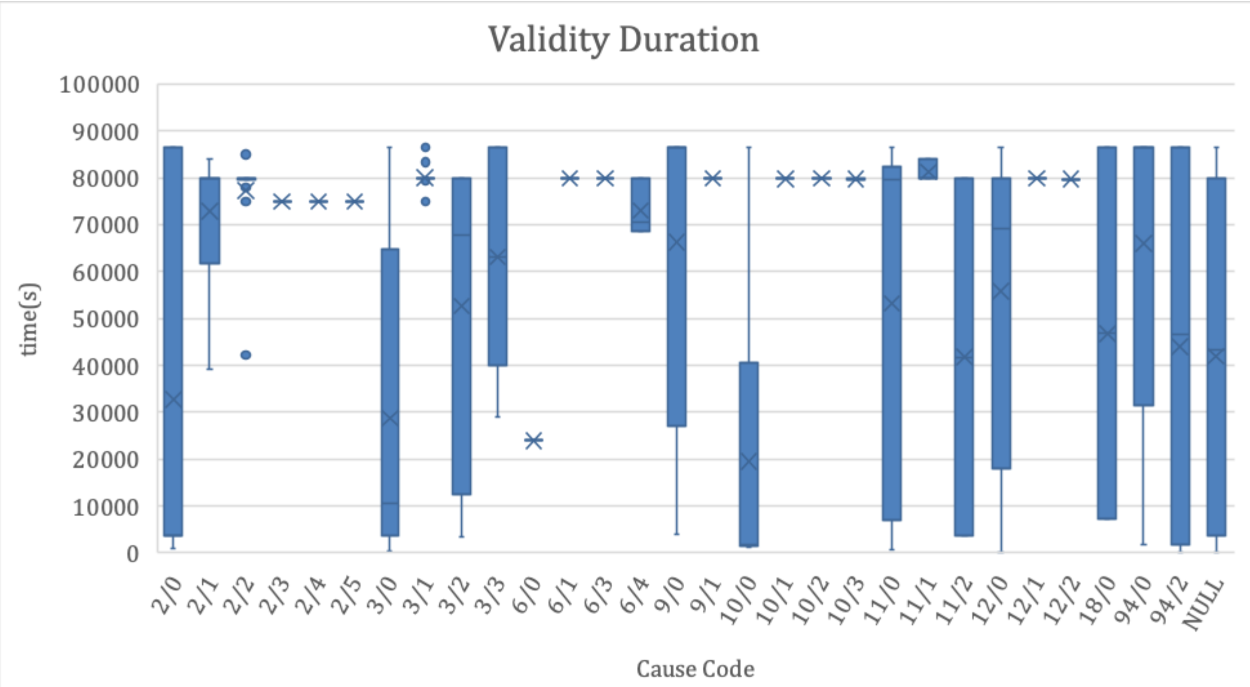


Table 36: extract of Validity Duration from SCOOP_Specifications of DENM

Name	cause code	sub-cause code	ValidityDuration (s)
Planned road works	3	0 : unavailable	duration of the RW

Planned road works	3	3 : Slow moving Road Maintenance	duration of the RW
Temporary slippery road	6	0 : Unavailable	1800
Temporary slippery road	6	1 : heavy frost on road	
Animal on the road	11	0 : Unavailable	1800
Animal on the road - Wild animal	11	1: wild animal	
Unprotected accident area – heavy accident	2	2 : heavy accident	7200
Unsecured accident area – truck	2	3 : accident involving lorry	7200
Unsecured accident area - Bus	2	4 : accident involving bus	7200
Unsecured accident area – hazardous material	2	5 : accident involving hazardous materials	7200

Road operator send long event in order to compensate for possible connection faults with the R-ITSS, with a subsequent termination sending to close the event. But for Slippery road(cc=6), human presence on the road (cc=12) and animal on the road, that seems way too much. It’s not necessary to increase de network load with messages that are no longer useful.

This way can be efficient if the termination hasn’t the same validityduration which is not the case. At least termination duration need not to exceed the time set by the originating event validity duration.

The road operator needs to choose validityduration by taking into account realities on the ground but also the usefulness of sending a message if it is no longer relevant and the induced network load.

15.7.6 Stationary vehicle use cases analysis

From DENM received by V-ITSS we are able to extract map of the different use cases and eventually define where are most often triggered event.

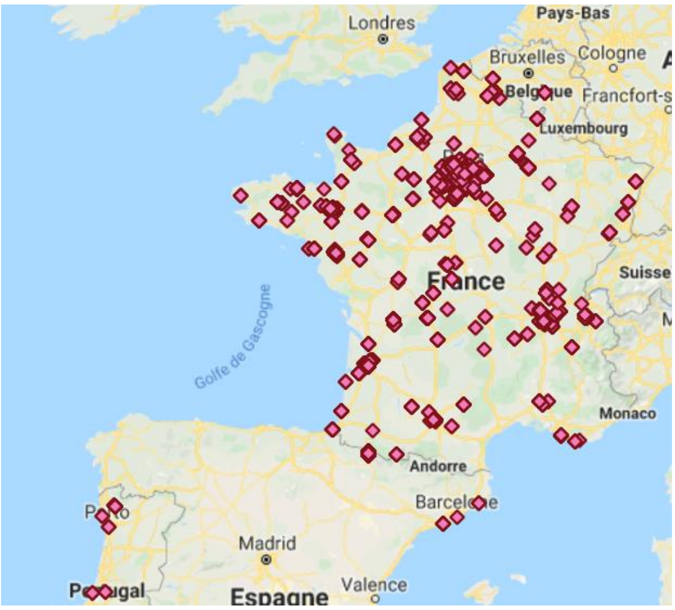


Figure 71: Stationary vehicle use case map

82% of stationary vehicle event are sent with an information quality of 3. From SCOOP@F specifications, Information quality of 3 is set if there is:

- Warning light
- an arbitrary number of doors is open for at least 3s or if the hood is open.

The high percentage of triggered event with IQ=3 is disturbing due to the fact that it represents almost 30% of all event generated by vehicles.

Among the multitude of triggers, we have double-lined vehicles, vehicles stopping at school or nursery level, parking on the side of the road with warning lights. These situations remain important to report in urban areas because they are dangerous.

In urban areas, the trigger can be crowded. But Stationary vehicle with an IQ=3 may also trigger events without a real associated danger.

In dense urban areas, the number of triggers is very high and may require future adaptation of the signage to the road situation. To consider such an adaptation, additional studies are necessary.

15.7.7 Succession of use cases

We have 55 events for Emergency break light. 9 V-ITS-S sent other events just before or after:

- 4 V-ITS-S triggered a CC=6 (adhesion) and then 99 (Emergency brake Light).
- 1 V-ITS-S triggered a CC=18 (Visibility) and then 99 (Emergency brake Light).
- 1 V-ITS-S triggered a CC= 99 (Emergency brake Light) then CC=18 (Visibility) and then 99 (Emergency brake Light).
- 3 V-ITS-S triggered a CC=99 (Emergency brake Light) and then 6 (adhesion).

Events' succession is logical as they occur close together

15.7.8 Faulty messages

Figure 72 shows that most errors come from a default in non-secured packed messages at Geonet level. The second higher percentage is related to unsupported BTP port.

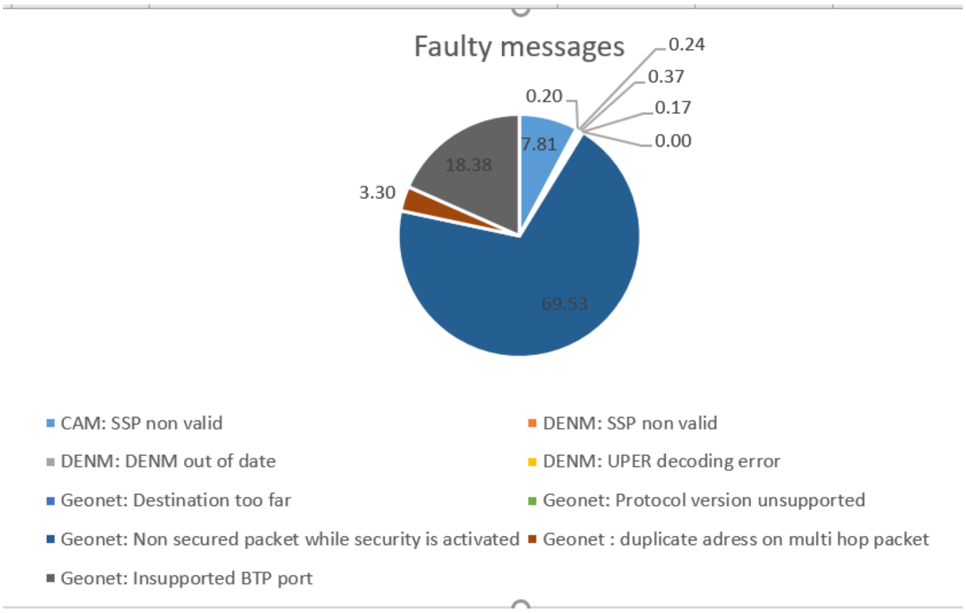


Figure 72 : faulty messages repartition

Most of errors occurs for a default of signature of the received message. SCOOP@F V-ITSS crossed V-ITS-S or R-ITS-S with different security specifications.

15.7.9 R-ITS-S location

From DENM received by V-ITSS and sent by R-ITSS, a cartography of R-ITS-S was done (see Figure 73)

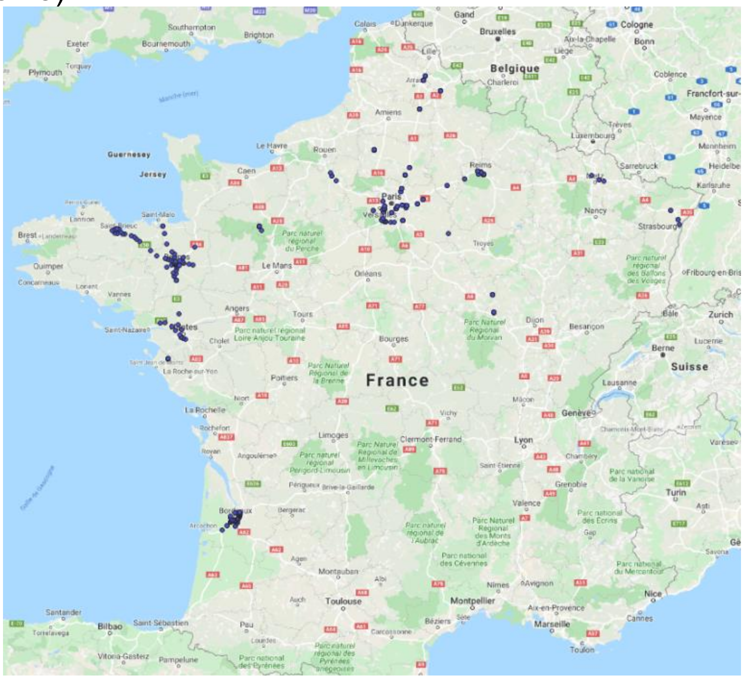


Figure 73: R-ITS-S (which sent DENM to V-ITS-S) location

R-ITS-S have their location calculated by GPS. As we can see Figure 74, multiple positions exist for one R-ITS-S. Maybe it will be more efficient to have a fix position defined in the R-ITS-S to avoid this variation. For example R-ITS-S with the stationed 2628834093 has up to 200 positions.

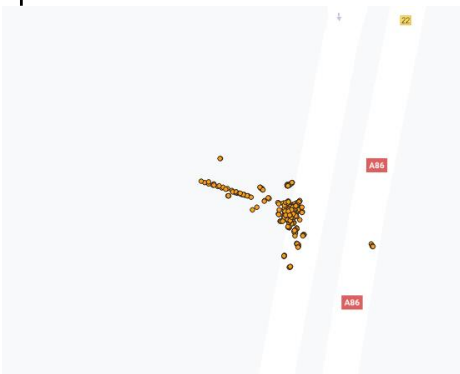


Figure 74: Positions of the R-ITSS 2628834093 in DIRIF test site

15.7.10 R-ITS-S Range

For 12 R-ITS-S, we calculated the range between them and V-ITS-S using CAMI and DENM received by V-ITSS from a R-ITSS(Figure 75). The highest range is for R-ITS-S located on highway with a long line of sight (Figure 76) : respectively 1461m and 1034 m.
Lowest value are for R-ITS-S located in urban area, near bridge or even in a curve (Figure 77).

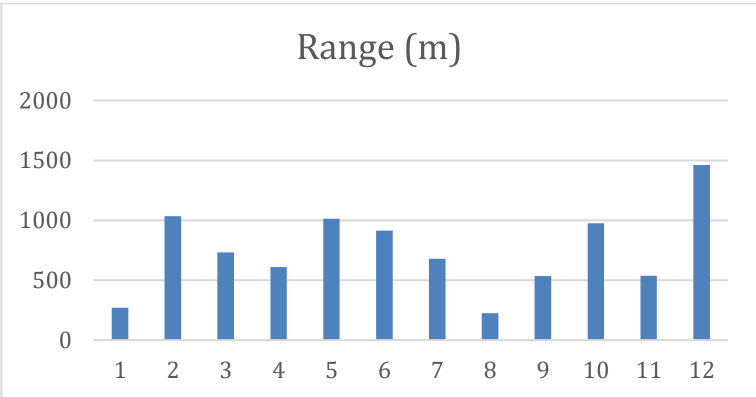


Figure 75: R-ITS-S range

Figure 76: Location of R-ITS-S with more than 1km range.

A R-ITSS located in a road interchange, in a curve, seems not to be a good location regarding the range (271m) (Figure 77) in fact event if the range is smaller due to geographical characteristic of the round-about, the R-ITSS is able to reach all V-ITSS that drive in or out the ring road.

Location choice for that R-ITSS was made due to that area is Accidentogenic. This R-ITS-S also makes it possible to relay vehicle or road operator information upstream of this area.

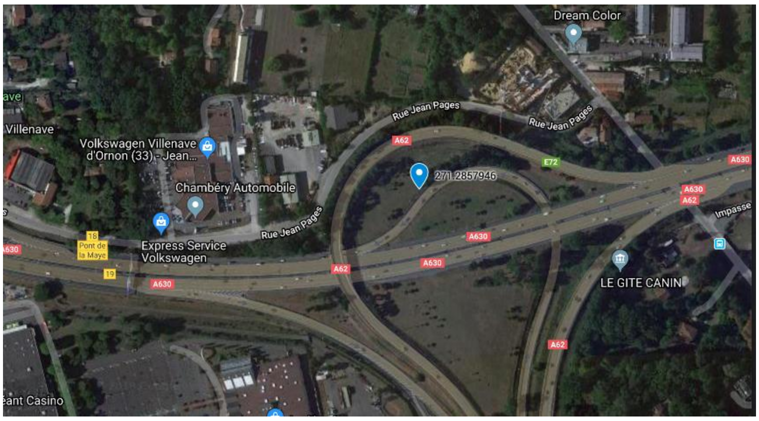


Figure 77: DIRA R-ITSS location

Most of R-ITS-S are not located near another R-ITS-S. In SCOOP, some road operator have made the choice to have R-ITS-S located closed enough to be able to communicate. This lead to have range of more than 3500 m due to the messages forward by R-ITS-S.

15.8 V-ITS-S Range

Table 37:Value for V-ITS-S range

	Distance in m
max	1829.584309
mean	227.2998289
median	147.0549974
1st quartil	63.27680925
3rd quartil	293.7348969

Range for V-ITS-s in real environment has no sense with no information of the road topology. A mean value of 227 seams a low value but if all V-ITS-S are located in urban area, it will make sense.

An interesting value is the max. It's not a real range but the result of forwarded messages by R-ITS-S.

15.8.1 Latency

Latency between V-ITSS was calculated using CAM and DENM. Latency between V-ITS-S and R-ITS-S was calculated using only CAMI.

15.8.1.1 Latency between V-ITS-S

Latency have been calculated for CAM, DENM between V-ITSS.

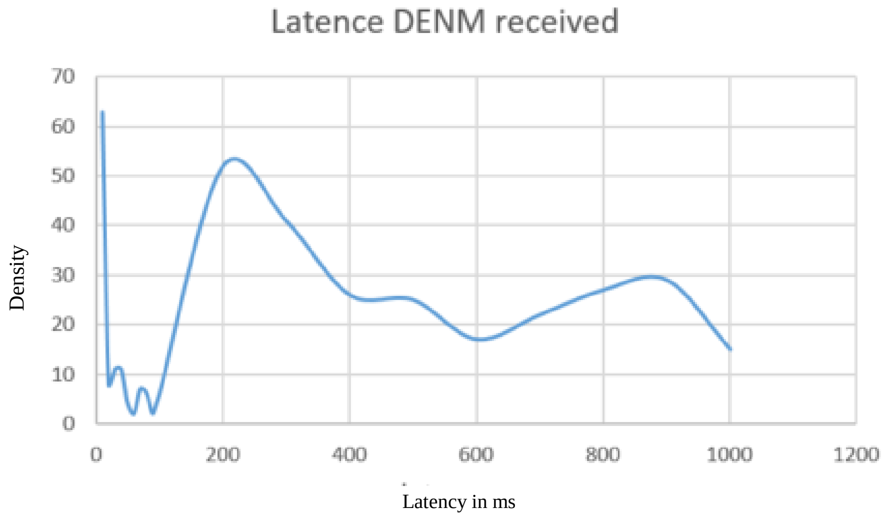


Figure 78: Latency density for DENM

Mean value for DENM latency between V-ITS-S is 331ms with a median value of 243 ms.

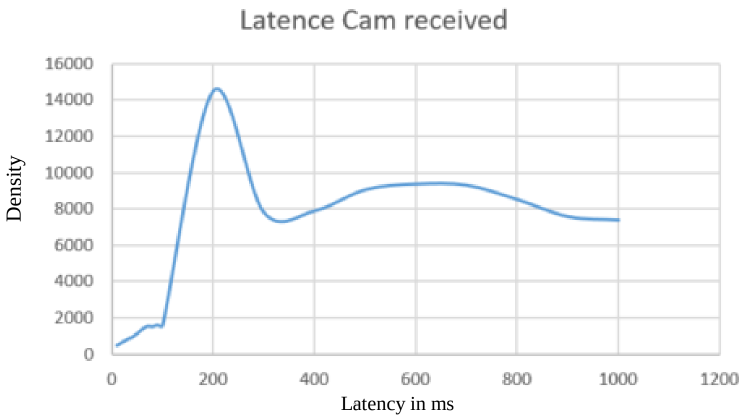


Figure 79: Latency density for CAM

Mean value for CAM latency between V-ITS-S is 457 ms with a median value of 453 ms. Differences between CAM and DENM latency is certainly due to treatment priorization by V-ITSS.

Latency are in line with standard requirement, 300 ms to 1 s depending on the use case.

15.8.1.2 Latency between V-ITS-S and R-ITS-S

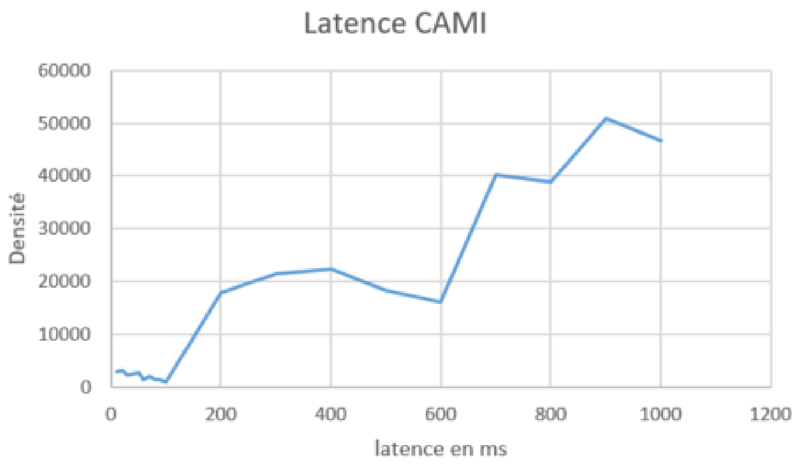


Figure 80: Latency density using CAMI

Mean value for latency between R-ITS-S and V-ITS-S is 458 ms. This result is obtained considering 20% of CAMI received. 80% present abnormal value (negative value for latency or value closed to the modulo used for calculating the generationdeltatime :65535 ms).

From this abnormal value, 11 couples R-ITS-S/V-ITS-S have more than 1s of latency for cumulative desynchronization duration up to 1 min. The maximum duration of desynchronization is 2min 38s between a R-ITS-S and a V-ITS-S.

To avoid such desynchronization, V-ITS-S and R-ITS-S need to share the same time referential.

15.8.2 CAM analysis

Figure 81 represents trajectory of all V-ITS-S based on CAM sent and recorded only when another C-ITS-S I is nearby. Most of travels are in Paris, DIRA and DIRO region (SCOOP@F test sites) but also in other regions (North, east and center).

Figure 81:Cam sent by V-ITSS

15.8.3 Message displayed to the driver

From data collect called ULog, we have 126 messages that have been displayed to drivers by 168 pop-up.

78 V-ITS-S displayed messages listed in Table 38.

Table 38: display percentage by causecode.

Label	Display percentage by cause code (%)
Alert planned closure of a road or a carriageway	21
Alert Unmanaged blockage of a road	2
Alert Temporary slippery road	1
Alert Temporary slippery road - snow	0
Alert Animal on the road	13
Alert people on the road	10
Alert Obstacle on the road	4
Alert Stationary vehicle, breakdown	3
Alert Stationary vehicle, breakdown	22
Alert Accident area	24
Alert Reduced visibility	1

Table 39: Display duration

	Display duration ms	Display duration
min	993	1s
max	443985	7, 4 min
mean	27043,6369	27 s

Event were displayed by pop up with a mean display of 27s.

15.9 Conclusion

Technical evaluation is about defining if specifications are good enough to ensure C-ITS services optimal performances.

The challenge was to assess technical performances of the ITS stations (V-ITS-S and R-ITS-S) as well as that of the use cases.

Despite the number of vehicles below our expectations, the substantial volume of data generated by vehicles over 1 year allowed us to carry out an in-depth statistical analysis and thus answer our research questions. However, some analyses require further investigation because of missing background information that we were not able to collect (road situation, stationID-vehicle correlation, fine weather data, etc.).

Through the statistical analysis of the data collected by vehicles, we were able to observe that:

- The performances in terms of latencies and range are in line with what is expected thanks to the extensive work carried out in terms of validation of the systems prior to experimentation.
- A more in-depth analysis of the triggering conditions of the stationary vehicle use case must be carried out in order to avoid an overload of information for the driver.

Despite the harmonization work in France and within the C-Roads platform, definitions of actionID and termination need to be discussed between C-ITS Actors in order to have harmonized specifications, avoid unnecessary network overload and allow a consistent display for the driver.

Thanks to this analysis, requests for modifications of specifications or requests for additional reflections have been made and brought back to the project level.

16 Relevance analyses and deployment requirements

16.1 Introduction and context

This deliverable taken from the R-ITS-S Specifications had the initial objective of providing the main deployment and installation recommendations for managers. During the project, it was necessary to develop the document with concrete examples given the progress of the deployments made.
The deliverable was the subject of a reorientation in order to enrich it with feedback brought not only by managers, but also by suppliers of technical solutions adapted to real situations.

> For example, one can specify autonomous and mains power supply or wired and wireless communications, depending on the installation methods on mast or gantry.

This made it possible to identify different deployment conditions and installation methods which were taken into account by the managers according to their road network.

> *For example, one can optimize the deployment of R-ITS-S compared to existing equipment (traffic measurement stations, VMS), depending on the issues selected for different road configurations (motorway type, secondary network).*

The first part allows to propose criteria for the R-ITS-S deployment from a functional point of view, by selecting macroscopic positioning zones according to the levels of services sought which will make it possible to define an R-ITS-S density.

> *For example, for a suburban network one can define R-ITS-S densities, depending on the areas identified at risk in road safety or for traffic management and exploitation needs*

After selecting the R-ITS-S equipment zones, the second step allows to specify the R-ITS-S deployment methodology using an installation guide which will give practical recommendations for installation.

> *For example, one can preconize the height of different types of antennas in order to avoid masking and shadow areas, while optimizing the coverage area.*

16.2 Deployment criteria

This first part aims to give methodological elements and different indicators allowing to choose the zones to be equipped in R-ITS-S, as well as the optimal positioning of the equipment according to the installation constraints.

16.2.1 Stages of the method

The overall R-ITS-S deployment methodology includes several stages:
0. Preliminary study : Identification of issues according to the needs of managers (existing services, to be completed or new)

1. Macroscopic (theoretical) study to define the deployment criteria: definition of the geographic perimeter, evaluation of wireless communication networks, taking into account interactions and context (existing equipment, neighboring networks, road projects, etc.)
2. Detailed study (field visit) to refine the choice of installation: adjustment of the locations according to constraints and alternatives, preparation of technical sheets for each site, studies of installation of equipment (mast supports, gantry, power supply, autonomous, transmissions wired, wireless), GC (massifs, connections, etc.), other points of vigilance (equipment protection, agent security, accessibility, maintenance, etc.)
These stages take place iteratively on the basis of discussions with the teams (working meetings and validation stages).

16.2.2 R-ITS-S description

A roadside station or unit, R-ITS-S or R-ITS-S, consists of:

- **sensor** part: which includes the transmission antennas for ITS-G5, 3G (cellular) and GNSS (satellite)
- **station** part: which includes the modules for power supply, storage, processing, transmission, safety and supervision
- **connections** part: which includes the different possible interfaces for power supply (mains or autonomous) and transmission (local and remote)

16.2.3 Objectives

The deliverable is used to clarify a manager's decision, without imposing densities of R-ITS-S equipment to be applied everywhere, but by guiding the choice for preferential locations, according to the objectives identified prior to the deployment studies.

16.2.4 R-ITS-S densities

The installation step of R-ITS-S depends on the level of service desired by the manager by prioritizing high, intermediate or moderate issues.
On a peri / interurban network such as that of the DIRN one can provide a density of R-ITS-S ranging from 3 km - 5 km - 10 km according to different zones: at risk (accidents, traffic jams), traffic management (interchanges, measures of TP), operating services (logistics and multimodal sites).
The DIRO manager took the advantage of an average installation every 4 km approximately, by inserting additional R-ITS-S on the sections with high stakes or on the isolated sections.
The theoretical number of priority R-ITS-S was determined according to the operating environments (two-way roads, motorways or urban network) and the location was adjusted according to the connection to the power supply and telecommunications networks.

16.2.5 General criteria

This part lists the decision support criteria to determine the areas to be studied. Depending on the speed of the vehicles, the position will have to be sufficient to allow the on-board system to display the information to the user, so that the user can take note of it and can act quitely.

16.2.5.1 Sensitives areas

The R-ITS-S should be positioned upstream of sensitive areas and before the last intersection to possibly allow the vehicle to exit. The following are considered to be sensitive areas:

- risk areas already known to the manager
- accident accumulation areas (black dots)
- dangerous descents and turns, tunnels, bridges, structures
- areas with unfavorable weather conditions: regular fog, high risk of snow, flood, gusts of wind, etc.
- areas of recurrent congestion, high traffic density
- areas of recurrent presence of animals (wood, forest, farm exit, stud farm, etc.)
- city-specific danger zones (school, zone 30, etc.)
- recurring event areas (sporting or cultural events).…

16.2.5.2 Road network configuration

To determine the priority zones to be equipped with R-ITS-S, the manager must have a map of his network, with the presence of inputs - outputs, speed limits, sensitive zones, equipment present on the ground, etc. He can rely on the service levels on his network, or contractual constraints, such as:

- traffic levels (per direction or per route): low, fluid, dense, congestion
- time of detection of an incident by equipment already functional on the network
- response time in the event of an accident
- time for uploading information to the local or central traffic management server (website update time, sending data, etc.)
- coverage area of existing equipment
- equipment and networks nearby…

It is preferable that the R-ITS-S do not cover the entire network and leave “white areas”, rather than several areas of coverage overlap, for the purpose of optimizing the locations and in order to avoid signal disturbance between the nearby R-ITS-S.

16.2.5.3 Type of roads

R-ITS-S work optimally in open ground because any element can cause a masking or reflection effect of the waves (ITS-G5 and GNSS), more or less significant depending on the nature of the element and the type of roads.

- urban: the masking phenomena of buildings and the effects of reflection, refraction and diffusion cause a significant attenuation of the signals and longer reception times. The density of R-ITS-S should therefore be higher in urban areas, compared to an area in the open countryside.

- suburban: in dense areas of forest, attenuation phenomena are also present, both for the G5 and the GNSS.
- tunnels: it is recommended to favor a positioning of the R-ITS-S at entry and / or exit for short tunnels, otherwise use the fixed position of the R-ITS-S because GNSS geolocation does not work in long tunnels.
- roundabout: the R-ITS-S must be placed in the center of the roundabout if there are no obstacles to transmissions, in order to optimize the discussion time between the vehicle and the R-ITS-S or far before the roundabout, in order to prevent that the central part of the roundabout does not act as a mask and prevent not correct coverage of the antenna.
- exchangers: the positioning of R-ITS-S proves useful upstream of the exchangers, however optimizing the installation according to the technical constraints, in particular for exchangers with several levels.

The following elements, although often important in traffic management, are assumed to have no impact on the functioning of the system implemented:

- viaduct (which can be considered as a sensitive area and of which certain constituent parts can create masks for transmissions): it is recommended to install R-ITS-S at the 2 ends of the viaduct in order to ensure direct visibility.
- number of lanes of the route considered, which can however cause a saturation effect of communications and disturbances between the signals transmitted according to the lanes, by generating false alerts.

16.2.5.4 Communications network coverage

Before the deployment of R-ITS-S, the quality and coverage of the communications network (cellular, Ethernet, optical fiber, copper cable, etc.) must be studied, taking into account the field equipment already connected (PMV, candelabras, technical site, camera mast).).
This is an upstream study of the communications network in order to assess the connection between the R-ITS-S and the control system by: cabling, optical fiber, cellular.
For the cellular network, it will be necessary to look at the quality (signal level, range, duration) and the type of coverage (3G, 4G, etc.) according to local maps. The cost of future operation (3G subscription price) and market renewal will be taken into account by the operator.
If the R-ITS-S considered requires GNSS access (for geolocation and synchronization of clocks), a mapping of the white areas of the GNSS network should also be used (for example for connection to universal time, or for use cases requiring synchronization GNSS).
Details of the connection constraints are given in the paragraph relating to the installation of R-ITS-S.

16.3 Installation guide

The second part of the deliverable specifies the deployment of R-ITS-S using an installation guide, from a macroscopic mapping already defined. These installation recommendations therefore come after the choice of R-ITS-S and after the selection of study areas.

We therefore assume that the manager has prior documentation including:

- specifications and installation advice from the manufacturers of the R-ITS-S to be installed
- analysis of the longitudinal and cross profiles for this area
- description of the obstacles that may mask this area (structures, buildings, trees, etc.)
- location of existing structures and equipment in this area: dynamic equipment and traffic measurement sensors, electrical cabinets, connection point to the computer network, etc.
- cellular, satellite or other network coverage (WiFi, bluetooth ...) in the R-ITS-S area

16.3.1 Installation constraints

The different parts of an R-ITS-S (antennas, station) can be grouped in a single cabinet, to be installed in height around 8-10m in general, except in special cases on camera masts with limited heights or on motorways where the view unobstructed allows to consider higher heights. This should provide good coverage and protection against vandalism, but accessible to operation and maintenance.
It is possible to separate these parts (the connections being separable), by installing the sensor part (including the antennas) in height and by deporting the station part in a box at the foot of the mast in order to facilitate the intervention of authorized operators. In this case, provide additional protection against vandalism, by using a padlock on the box thus deported.

16.3.1.1 Existing support

Before installing on an existing structure, a new calculation note must be made to ensure the resistance of the support to the new load. It will also be necessary to ensure that the power and transmission cables can well support the installation of new equipment such as the R-ITS-S. For VMS (Variable Message Sign), the R-ITS-S must be installed only on gantry (brackets prohibited).

16.3.1.2 Support to be installed

The manager must refer to the guides to be observed and studies to be carried out for the installation of a mast and the complete R-ITS-S system, with a few points of vigilance:

- the mast must not constitute a dangerous obstacle for users
- it is preferable to position the mast behind a slide (especially on the national road or motorway network)
- in the absence of a safety barrier, the mast must be placed at a minimum distance of 4-8.5m from the edge of the right lane in order to guarantee safety for users
- if a fuse mat is used in the absence of a slide, it is possible to position it closer to the side of the track (refer to the guide for installing fixed obstacles near intersections / roadways)

- the sizing of the massif must take into account the wind resistance of the equipment (in particular solar panels for an autonomous mast)

16.3.1.3 Installation configurations

In order to install the R-ITS-S, it is necessary to take into account the configuration of the network (interurban, suburban, urban) and technical and functional constraints (existing supports or those to be installed, mains or autonomous power supply, wired transmission modes or wireless, etc.). Several R-ITS-S installation configurations can be considered, see Table 40.

Table 40: R-ITS-S installation configurations

N°	Configurations	Support	Power supply	Transmission	Roadway
1	on VMS gantry wired	on VMS gantry	mains	optic fiber	highway
2	on VMS gantry 3G	on VMS gantry	mains	cellular 3G	highway
3	on existing mast 3G (requires a design calculation note)	existing mast (candelabrum, camera's pole)	mains	cellular 3G	urban and suburban
4	on mast to be installed near a point of energy	mast to be installed (near traffic or weather station)	mains	cellular 3G	interurban (equipped secondary roads)
5	on mast to be installed autonomous 3G	mast to be installed	solar panels	cellular 3G	interurban (not-equipped secondary roads)

16.3.2 R-ITS-S positionning

The standards concerning ITS-G5 communications do not set minimum or maximum R-ITS-S coverage by the ITS-G5. In fact, the antennas available on the market can have maximum ranges between 300 and 1000m, or even greater depending on the installation height (1300m if positioning on radio towers> 20m high, in the specific installation configuration on highways).
In order to have maximum efficiency, the installation of R-ITS-S must be carried out in an open area over a radius of at least 500 m, without obstructing the propagation of waves, without mask through vegetation, vertical or other signage for maximum direct coverage, especially in urban areas.
It is necessary to set up the R-ITS-S taking into account the relief for better communication and to maximize the coverage of the R-ITS-S so favor flat and overhanging areas.
The R-ITS-S must therefore be positioned high and at the right angle of emission and reception (according to the specifications of the manufacturer of the R-ITS-S) using an existing support or to be installed, having a sufficient height (at minus 8 m). To

determine the height of the R-ITS-S installation, it is also necessary to take into account the regulations of the implantation site (PLU, particular area, etc.). However, it must be taken into account that the higher the height, the larger the radio shadow area under the R-ITS-S is for directional antennas.
This first positioning study must be validated by a field visit (on site) in order to ensure that the indicators (constraints) taken into account have not changed.

The example below shows the detection area of an R-ITS-S with an omnidirectional antenna within a radius of 800 m. The main masks in this case are the vegetation and some buildings in the village.

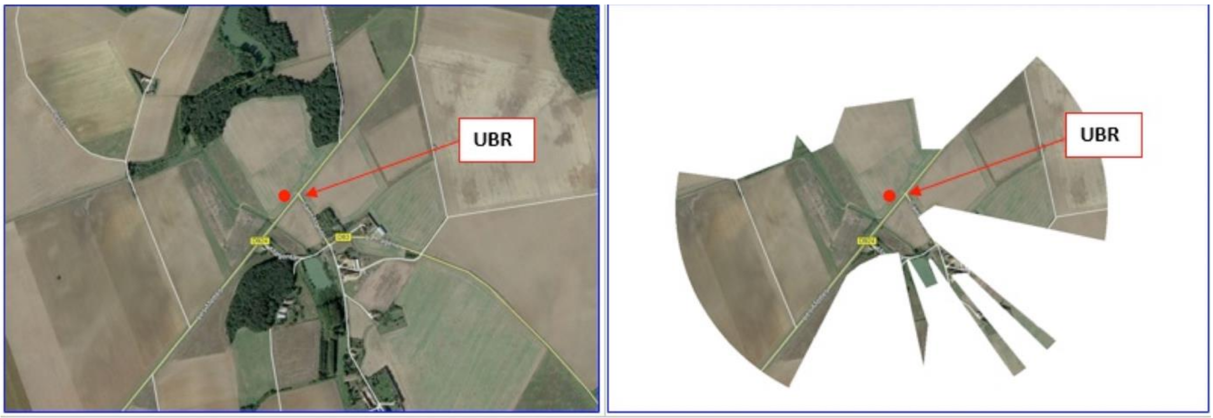


Figure 82: Example of R-ITS-S location and actual coverage area (omnidirectional antenna)

16.3.3 Power supply

Given the low powers necessary for the operation of the device, the power supply can be done by ethernet: Power over Ethernet (PoE), via the cables which electrically supply the equipment while allowing data transmission to the wired telecommunications network. Depending on the place of installation, it will be necessary to pay attention to the choice of power supply: electrical network, battery, wind or solar. It will be necessary to check in order: the type of network present, the feasibility of the connection, the possibility of extending the network.
The manager will have to be vigilant in the choice of R-ITS-S because the energy consumption varies according to the manufacturers. If possible, favor the pooling of an existing energy point and if the mains connection is not available provide for autonomous power supply by solar panels.
Before installing, make sure that the R-ITS-S are separated as much as possible from other existing equipment, by isolating them electrically (circuit breaker) and by computer (switch), in order to establish real service limits between the networks. and maintenance contracts.
If solar panels are used, it must be ensured that the dimensions are sufficient in view of the total consumption of the R-ITS-S and its ancillary systems (transmissions, etc.). A sizing study of the solar panels must be carried out beforehand, at the exact location of their positioning. There are some points of vigilance for solar panels: sizing must be carried out on winter data, positioning must be optimized to the south, without masking effect due to buildings or trees, plan a preventive visit at least every year in order to to clean their surface and to preserve their energy efficiency.

According to the manager's policy, one or more batteries can be integrated to compensate for electrical network failures or to back up the solar panel. In the event of a power failure, the R-ITS-S must shut down its system properly and wait for the energy to return before restarting.

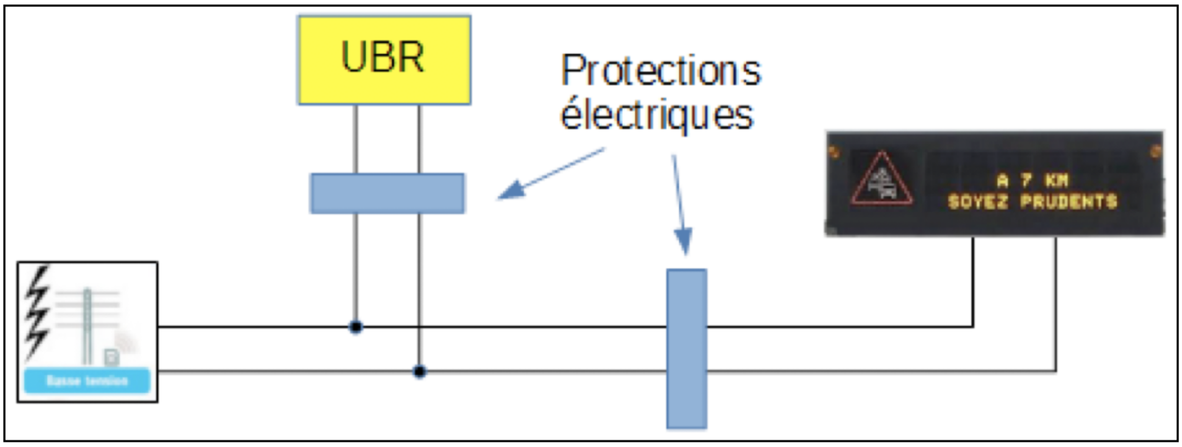


Figure 83: Diagram of electrical protections to isolate networks

16.3.4 Transmissions

The R-ITS-S provides the interface between connected vehicles and the platforms of road managers.
Exchanges of R-ITS-S are wired or wireless in short / long range:

- with equipped vehicles: wireless by ITS-G5
- with the platform: wired or cellular (3G / 4G)
- for satellite geolocation (GNSS)

16.3.4.1 Choice of communication network

In order for the R-ITS-S to communicate with the management center, it must be located in areas covered by at least one of the following computer networks:

- manager's network, for example for dynamic equipment: VMS, candelabra, technical site, camera mast, etc.
- wired network passing nearby (access provider to contact) PSTN or fiber optic (efficient in the event of saturation of the cellular network in times of crisis)
- cellular network: the manager will have to carry out a study of the networks and access providers covering this area and plan to equip its R-ITS-S with adapted cards, taking care when renewing the markets that the coverage of the new provider covers all the areas deployment of R-ITS-S. These areas will be geolocated and will be mentioned in the specifications of the market(s).
- WiFi network (carry out a study of WiFi networks and access providers)
- satellite network
- radio or any other system that the manager would have at his disposal

In the case where several possibilities are available to the manager, to choose the type of network, it will be necessary to compare:

- the bandwidth of this network: copper vs optical fiber vs 3G, vs 4G…
- the cost: connection, operation, others ...
- the constraints imposed on the manager: maintenance / risk of theft, freedom of access to data (clean network vs external operators), confidentiality, etc.
- the encryption mode possibly associated

In areas with little coverage, it may be interesting to study the possibility of centralizing information to organize their reporting to the central via a single channel. For example with a central R-ITS-S connected to others by ITS-G5 or wiring. This solution will only be possible if the R-ITS-Ss are close to each other. The white areas between the R-ITS-S will be minimized.

16.3.4.2 ITS-G5 transmissions

ITS-G5 transmissions enable fast, high-speed wireless communication over R-ITS-S location areas. The manager will refer to the instructions supplied with the equipment for optimal installation of the antennas.
The type of antenna (directional or omnidirectional) depends on the location:

- on a road in the current section: favor directional antennas that cover long lengths
- on a crossroads: omnidirectional antennas make it possible to receive signals from different axes, to be installed centrally, if not upstream

However, there are some disadvantages for antennas to consider:

- omnidirectional: diffusion of waves near homes (check protective screens) and masks for transmissions that can be created by the central reservation
- directional: implementation and maintainability constraints due to greater sensitivity, shadow area under the antenna

16.3.4.3 Cellular transmission

The cellular antenna (3G or more) must make it possible to establish the link with the platform via a VPN network. It is an omnidirectional antenna.
Cellular connections can be integrated with a SIM slot in a modem located in the R-ITS-S. If necessary, the antennas can be multi-use since under their protective dome some models can house 2 antennas (dual-band): one for the ITS-G5 connection and the other for the cellular.

16.3.4.4 GNSS transmission

A GNSS receiver will also be installed for time synchronization (UTC) with respect to the satellite network and differential position calculation (which can be inhibited if need be for a fixed position). It is an omnidirectional antenna for receiving GNSS signals and synchronizing the time base of the R-ITS-S for time stamping of events.

16.3.5 Other recommendations

It is preferable to position the R-ITS-S in a secure manner for the intervening agents, near a place where to park for maintenance and other interventions, requiring the connection from a station embedded in a vehicle.
When the security conditions for the agents allow it, it is possible to install the R-ITS-S at the level of the central reservation, this in order to reduce the risks of vandalism. However, access will be more difficult and it will be necessary to take into account this strong constraint of security of the agents for maintenance and for all interventions.

16.4 Conclusion

This methodological document gives the general lines, although detailed at several technical or strategic levels, to be taken into account by managers for the R-ITS-S deployment and installation.
It is not a model of acquisition, deployment or maintenance market, because the road networks are different, as well as the means and objectives sought.
The deliverable provides recommendations from feedback from the field, corresponding to a given progress report on developments and deployments. Consequently, the document aims to be progressive and cooperative in order to take into account potential developments in technology and needs.

17 Annex A - Legal assessment: Main legal texts cited or to be taken into account

17.1 On ITS

- Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport (Art. 10 on personal data protection)
- Commission Delegated Regulation (EU) No 885/2013 of 15 May 2013 supplementing ITS Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of information services for safe and secure parking places for trucks and commercial vehicles
- Commission Delegated Regulation (EU) No 886/2013 of 15 May 2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users
- Commission Delegated Regulation (EU) 2015/962 of 18 December 2014 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services
- Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services
- European Parliament resolution of 13 March 2018 on a European strategy on Cooperative Intelligent Transport Systems (2017/2067(INI))
- European Parliament resolution of 13 March 2018 on a European strategy for cooperative intelligent transport systems (2017/2067(INI))
- Draft Delegated Regulation (2019) 1789 final supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems

17.2 On eCall

- Regulation (EU) 2015/758 of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service
- Commission Implementing Regulation (EU) 2017/78 of 15 July 2016 establishing administrative provisions for the EC type-approval of motor vehicles with respect to their 112-based eCall in-vehicle systems and uniform conditions for the implementation of Regulation (EU) 2015/758 of the European Parliament and of the Council with regard to the privacy and data protection of users of such systems.

- Commission Delegated Regulation (EU) 2017/79 of 12 September 2016 establishing detailed technical requirements and test procedures for the EC type-approval of motor vehicles with respect to their 112-based eCall in-vehicles systems, of 112-based eCall in-vehicle separate technical units and components. *In particular, this Regulation contains an annex on measures concerning the protection of drivers' personal data*.

17.3 In French Law

- Bill 2012-260 of 22 February 2012 reforming overseas ports under the jurisdiction of the State and various provisions for adapting legislation to European Union law in the field of transport. *This bill authorizes the Government to take the necessary measures to transpose directive 2010/40 (art. 6)*
- Ordinance 2012-809 of 13 June 2012 on TSIs ratified by Bill 2013-619 of 16 July 2013 on various provisions for adapting to European Union law in the field of sustainable development (art. 36)
- Decree 2015-474 of 27 April 2015: establishes in particular the list of events or circumstances covered by the minimum information service (directive, art. 3c, RD 886/2013, art. 3), establishing the *bison futé* website (https://www.bison-fute.gouv.fr) as the entry and reference point for data from road managers and operators.
- Order of 27 April 2015: provides details on the site and access to it, designates AFIMB as the national body responsible for assessing the conformity of services with the requirements of DR 886/2013 of the Commission
- Decree 2017-1517 of 30 October 2017: provision of real-time information services; listing of the available data on a national access point (*bison futé* website), including data available from service providers; grouping of access points established by road operators.
- Order of 30 October 2017: provision of real-time traffic information services. Technical characteristics of the national access point.

17.4 On the protection of personal data

- Regulation 2016/679 of 27 April 2016: General Data Protection Regulation (GDPR) repealing the Directive from 1995 to 25 May 2018
- Directive 2002/58/EC of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector in the process of being replaced by a Regulation [Proposal of 10 January 2017 (COM/2017/010 final)] (*draft Regulation in progress*)

See also G29. Opinion on the processing of personal data in the context of ITS-C, adopted on 4 October 2017

In French law

- Bill 78-17 of 6 January 1978 amended relating to data processing, files and freedoms

- Decree 2019-536 of 29 May 2019 implementing the 1978 Bill on Data Processing, Data Files and Individual Liberties, as last amended by Order 2018-1125 of 12 December 2018 implementing Article 32 of Law 2018-493 of 20 June 2018 on the protection of personal data and amending Bill 78-17 of 6 January 1978

17.5 Texts more fundamental in nature (nevertheless applicable)

- Charter of Fundamental Rights of the European Union, Article 7 (privacy), Article 8 (protection of personal data).
- Convention for the Protection of Human Rights and Fundamental Freedoms of the Council of Europe (4 November 1950) and Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data (28 January 1981) (Convention 108), modernised in 2018 (128th Session of the Committee of Ministers of the Council of Europe Member States, 17-18 May 2018).

18 Annex B - Health impact

18.1 Standards

CENELEC European Committee for Electrotechnical Standardisation, 2008. Basic Standard for the In-situ Measurement of Electromagnetic Field Strength Related to Human Exposure in the Vicinity of Base Stations. TC 106x WG1 EN 50492 in situ. European Committee for Electrotechnical Standardization, Brussels, Belgium.

European Council Recommendation 1999/519/EC ECR, 1999. Limitation of Exposure of the General Public to Electromagnetic Fields (0 Hz to 300 GHz).

Federal Communications Commission (FCC), 2001. Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields. Washington, DC, Tech. Rep. Suppl. C to OET Bulletin 65.

EN 50 383 - Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz), Juin 2013.

EN 50 400 - Norme de base pour démontrer la conformité des équipements fixes de transmission radio (110 MHz - 40 GHz), destinés à une utilisation dans les réseaux de communication sans fil, aux restrictions de base ou aux niveaux de référence relatives à l'exposition des personnes aux champs électromagnétiques de fréquence radio, lors de leur mise en service, Sep 2006.

Institute of Electrical and Electronics Engineers IEEE C95.1, 2005. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. IEEE, Piscataway New York.

International Commission on Non-ionizing Radiation Protection (ICNIRP), 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74 (4), 494-522.

18.2 Scientific and technical papers and books

Foster, R.K., 2007. Radiofrequency exposure from wireless LANs using Wi-Fi technology. Health Phys. 92 (3), 280-289.

Joseph, W., Olivier, C., Martens, L., 2002. A robust, fast and accurate deconvolution algorithm for EM-field measurements around GSM and UMTS base stations with a spectrum analyzer. IEEE Trans. Instr. Meas. 51 (6), 1163-1169.

Joseph, W., Verloock, L., Goeminne, F., Vermeeren, G., Martens, L., 2012. Assessment of RF exposures from emerging wireless communication technologies in different environments. Health Phys. 102 (2), 161-172.

Juhász, P., Bakos, J., Nagy, N., Jánossy, G., Finta, V., Thuróczy, G., 2011. RF personal exposimetry on employees of elementary schools, kindergartens and day nurseries as a proxy for child exposures. Progr. Biophys. Mol. Biol. 107 (3), 449-455.

Khalid, M., Mee, T., Peyman, A., Addison, D., Calderon, C., Maslanyj, M., Man, S., 2011. Exposure to radio frequency electromagnetic fields from wireless computer networks: duty factors of Wi-Fi devices operating in schools. Progr. Biophys. Mol. Biol. 107 (3), 412-420.

Kuhn, S., Lott, U., Kramer, A., Kuster, N., 2007. Assessment methods for demonstrating compliance with safety limits of wireless devices used in home and office environments. IEEE Trans. Electromag. Compat. 49 (3), 519-525.

Peyman, A., Khalid, M., Calderon, C., Addison, D., Mee, T., Maslanyj, M., Mann, S., 2011. Assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools; results of laboratory measurements. Health Phys. 100 (6), 594-612.

G. Anzaldi F. Silva, M. Fernandez, M. Quilez, and P. Riu, 2007. “Initial analysis of SAR from a cell phone inside a vehicle by numerical computation,” IEEE Transactions on Biomedical Engineering, vol. 54, no 5, pp. 921-930.

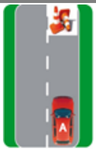
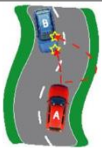
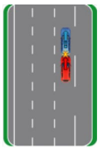
S. W. Leung, Y. Diao, K. H. Chan, Y. M. Siu and Y. Wu, 2012. "Specific Absorption Rate Evaluation for Passengers Using Wireless Communication Devices Inside Vehicles With Different Handedness, Passenger Counts, and Seating Locations," in IEEE Transactions on Biomedical Engineering, vol. 59, no. 10, pp. 2905-2912.

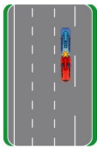
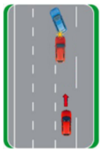
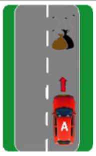
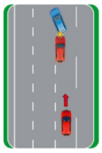
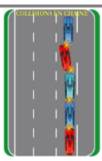
Anne Perrin, Martine Souques, 2010, "Champs électromagnétiques, environnement et santé", Springer.

Olivier Cachard, 2016. "Le droit face aux ondes électromagnétiques", Lexis Nexis.

Patrick Staebler, 2016. "Exposition humaine aux ondes électromagnétiques de 0Hz à 300 GHz", ISTE Editions Ltd.

19 ANNEX C: List of SCOOP@F use cases considered for the impact study on road safety.

Pictogram	Item	Specification
	Alert mobile road work site	Notification concerning a roadworks area. Modifications of driving conditions
	Alert operator vehicle in patrol	Notification concerning road operator in patrol on the road. Modifications of driving conditions.
	Alert winter maintenance vehicle	Notification concerning a priority vehicle intervening on the road.
	Alert Temporary slippery road	Report a local area with low ground stability/road grip due to ice, rain, grease, gravel, etc.
	Alert Animal	Notification concerning one or several animals on the road.
	Alert people on the road	Notification concerning one or several people on the road.
	Alert obstacle on the road	Notification concerning one or several obstacles on the road as a potential danger
	Alert stationary vehicle	Notification concerning vehicle stopped on the road.

	Alert breakdown vehicle	Notification concerning breakdown vehicle, stopped on the road.
	Alert accident area	Notification concerning vehicle stopped on the road after an accident occurs.
	Alert Reduced visibility	Report a local area with low visibility due to rain, snow, fog, smoke...
	Alert Unmanaged blockage of a road	Notification concerning a big obstacle on the road.
	Alert Emergency brake	In case of sudden braking of the previous vehicle and depending on the respective speeds and the inter-distances
	Alert End-of-queue	Notification concerning a traffic jam ahead.
	Alert Extreme weather conditions	Report a local area with low visibility and poor road grip due to rain, snow, fog,...