INTELLIGENT COOPERATIVE SENSING FOR IMPROVED TRAFFIC EFFICIENCY

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D7.1 - DEFINITION OF THE TRIAL SCENARIOS AND METRICS

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Abstract:

This report will firstly define the trial scenarios identified for the two different experimental facilities to be set-up: the smart urban and the highway environments. In this respect, the infrastructure definition in agreement with the respective providers, namely Pisamo and BRISA, will be described and specifications will be given. Secondly, metrics for assessing the consistency, correctness, and the performance with respect to global requirements will be defined and described. Among these, a major relevance will concern: real-time traffic monitoring, real-time traffic flows, vehicle tracking and V2X communications.

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Document History

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Executive Summary

This deliverable describes the trial scenarios selected for the demonstration ad validation of ICSI achievements and introduces a set of metrics for the evaluation of trial results.

Such metrics will be used during the actual deployment of ICSI systems. The collected results will be gathered in D7.2.1 “Report on the execution of the experiments and results” (interim version) and subsequently refined in the final version D7.2.2. Such deliverables will contain the mid-term and final snapshots of the performance of the trails.

The ICSI - Intelligent Cooperative Sensing for Improved Traffic Efficiency – project targets at significantly reducing energy consumption in transportation through faster, dependable, and more accurate sensing cycles and reactions, as enabled by a fully distributed architecture. The end goal of ICSI project is to define an innovative system architecture to enable cooperative sensing in intelligent transportation systems and to develop a reference end-to-end implementation.

The work carried out during ICSI is being demonstrated through the activities of WP7, which is a work package of “Demonstration” type. In particular, the ST goals of the project have to be successfully represented in this trial activity.

This deliverable aims at describing the work that has been carried out towards trail preparation. This work has ended up with the identification of a set of trial scenarios. In particular, we first introduce the urban and high way scenarios and discuss their relevance both in the context they are operated and towards the ICSI goals. Then, we review the ICSI use cases reported in D1.1.2 and select a set of relevant use case for actual implementation. The experimental set up is then described.

Finally, we distinguish the features to be monitored during the trial period in subsets relevant to the various ICSI subsystems and define a set of metrics for their evaluation.

Table of acronyms

Acronym	Expanded form
CALM	Communications Access for Land Mobiles
CLU	Cooperative Learning Unit
CoAP	Constrained Application Protocol
CPU	Central Processing Unit
CS	Central Sub-system
DA	Device Application
DB	Database
DDP	Data Distribution Platform
DDS	Data Distribution Service
DSCL	Device SCL
ECU	Engine Command Unit
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle
FPGA	Field-Programmable Gate Array
FT	Field Trial
GA	Gateway Application
GHU	Gateway Hardware Unit
GPS	Global Positioning System
GSCL	Gateway SCL
GUI	Graphical User Interface
GW	Gateway
GW-2-GW	Gateway-to-Gateway
H2M	Human-2-Machine
HMI	Human-Machine Interface
HTTP	Hypertext Transfer Protocol
I2V	Infrastructure-to-Vehicle
ICSI	Intelligent Cooperative Sensing for Improved traffic efficiency
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITS	Intelligent Transport System
ITSC	ITS Communication
ITS-S	ITS Station
KPI	Key Performance Indicator
M2M	Machine-to-Machine
MAC	Media Access Control
MVC	Model-View-Controller
MVP	Model-View-Presenter
MVP-PV	Model-View-Presenter with Passive View
NA	Network Application
NSCL	Network SCL
OBD-II	On Board Diagnostics - II
OBU	On-Board Unit
OSI	Open Systems Interconnection

PS	Personal Sub-system
QoS	Quality of Service
REST	Representational State Transfer
RF	Radio Frequency
RPC	Remote Procedure Call
RS	Road-side Sub-system
RSU	Road-Side Unit
SBC	Single Board Computer
SCL	Service Capabilities Layer
SOA	Service Oriented Architecture
TMC	Traffic Management Centre
URI	Uniform Resource Identifier
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-X
VANET	Vehicular Ad-Hoc Network
VC	Vehicular Communication
VMS	Variable Message Sign
VS	Vehicle Sub-system
WAVE	Wireless Access in Vehicular Environments
WG	Working Group
WLAN	Wireless Local Area Network
WP	Work Package
WSN	Wireless Sensor Network
xAE	Application Enablement
xCB	Compensation Broker
xCS	Communication Selection
xGC	Generic Communication
xHDR	History and Data Retention
xIP	Interworking Proxy
xRAR	Reachability, Addressing and Repository
xREM	Remote Entity Management
xSEC	SECurity
xTM	Transaction Management
xTOE	Telco Operator Exposure

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1 Introduction

1.1 Overview of the project

The main goal of ICSI is to provide a platform for the deployment of cooperative systems, based on Vehicular Network (VN) and Wireless Sensor Network (WSN) communication technologies, with the aim of enabling a more efficient mobility in both urban and highway scenarios.

The purpose is to define a new architecture to enable cooperative sensing in intelligent transportation systems and to develop a reference end-to-end implementation. It is expected that the project results will enable advanced traffic and travel management strategies, based on reliable and real-time input data. The effectiveness of such new strategies, together with the proposed system, will be assessed in two field trials.

ICSI platform intends to provide a prototype of a European traffic monitoring and information system that could have an impact in different ways:

- Provide accurate real-time traffic flow monitoring;
- Provide continuous traffic data that helps to maintain roads capacity within normal level and minimize traffic jams and congestions;
- Reduce car accidents due to immediate information circulation regarding traffic conditions;
- Reduce travel time, especially in urban environments, where citizens spend significant time for transportation;
- Provide a new field of context aware personal services including personalized travel planning before departure and during travel, vehicle tracking, parking lot management, etc.

1.2 ICSI Trial scenarios

As already stated in the DoW of the project [1], particular emphasis has been given to the execution of experiments for assessing the feasibility, efficiency and effectiveness of the solutions proposed by ICSI project in the target real environments.

In particular, an entire work package (namely WP7) has been devoted to demonstration activities. Among other objectives of WP7, the preparation and execution of trials for the two target use cases, i.e. smart urban environment and highway, play a crucial role. Two trial phases are planned for the experiments: one after the first system integration, where only laboratory experiments are envisaged, whose output will be fed back to the development work package, and another after the second, and last, system integration, which will also include tests in real environments to evaluate the system at its full complexity. The following experimental facilities will be set up:

Smart urban environment: This facility will be operated by INCS and CNR, who will run the laboratory tests in their own premises and, then, deploy the prototype within the transport infrastructure in Pisa, which is provided by Pisamo, whose has granted external support to the project.

Highway: This facility will be hosted and operated by BRISA. IT will contribute to the preparation and execution of trials, so as to verify compliance with the V2X communication requirements in the challenging highway environment.

1.3 Purpose and scope of this deliverable

The objective of Task 7.1 is the overall design of trials, taking into account the functional and operational requirements defined in WP1, as well in the technological aspects and definitions found in the technical work packages ranging from WP2 to WP5.

This Deliverable aims at describing the trial scenarios that have been identified both for the urban and highway cases. In particular, we first discuss the relevance of the selected sites for trial implementation with respect i) their impact in the current mobility setup and ii) their interest for demonstrating the ICSI aims and goals. Then, we select a set of use cases (elicited from [2]) identifying which features will be implemented and tested on real data in the actual scenarios. Some other features of the use cases will be instead tested on data whose sources are not directly integrated in the ICSI system; nevertheless, these data will be injected form external sources or simulated.

The experiment setup is finally described, including the prototypes that will be deployed on the field. Finally, with reference to the system architecture, a set of metrics for the evaluation of the various involved subsystem is presented.

1.4 Methodology

In this document, the main development lines of the trial scenarios have been defined in agreement with crucial aspects of the projects such as:

- The S&T objectives of the project as reported in the DoW [1] which have to be demonstrated through a trial activity. The trials should have enough features deployed to show the tangible results obtained during the projects (in terms also of hardware and software prototypes) and to validate the advances with respect of the baseline (see Table 6 of [1]).
- The identified use cases and user requirements [2,3], a subset of which is selected for actual implementation
- The system architecture [4] which should be well represented in the overall trial scenarios and whose subsystems are used to organize the metrics for evaluation in significant subsets.
- The data distribution platform [5] which is a core component of ICSI systems orchestrating the other subsystems

In addition, we decide to treat in parallel the urban and highway scenarios by describing separately their relevance, use cases of interest and experimental setups. This choice is coherent with other Deliverables such as [2] where the use cases are treated separately. Nevertheless, we decided to present globally the metrics for trial evaluations by organizing them into subsystems.

In selecting such metrics, some foresight has been necessary in order to select metrics measurable in an accurate and non-generic way and to identify target values consistent with the S&T objectives of the project.

1.5 Organization of the document

After this Introduction, in Section 2 we address the urban scenarios by describing their relevance (Section 2.1), by discussing and selecting suitable use cases (Section 2.2) and, finally, by presenting the actual experimental setup (Section 2.3). Following a very similar organization, in Section 3 we address the highway scenario. In Section 4 we introduce the metrics for trial evaluation and distinguish those concerning the Data Distribution Platform (Section 4.1), the Cooperative Learning Unit (Section 4.2),the Roadside Subsystem (Section 4.3) and the Vehicular Subsystem (4.4). Finally, Section 5 ends the present deliverable.

2 Urban scenarios

In this section, we address the urban scenarios by describing their relevance (Section 2.1), by discussing and selecting suitable use cases (Section 2.2) and, finally, by presenting the actual experimental setup (Section 2.3).

2.1 Relevance of the selected urban scenarios

In Pisa, for the ICSI project, many areas of interest have been evaluated for actual implementation of use cases. In an urban context, the need is to offer integrated solutions to different users such as tourists, students and citizens.

In this disparate set of users having different demands, ICSI is proposed as an innovative technical answer to promote a solution for sustainable mobility (smart mobility) that can be easily integrated in the existing infrastructures and services.

ICSI, thanks to a multi-layer platform compliant with ITS standards such as ETSI ITS and ETSI M2M, allows to interface different kind of heterogeneous data sources typical of ITS domain.

ICSI solution is an innovative and real opportunity from stakeholder point of view because permits the integration in an already present infrastructure and offers innovative services with cost reductions and high level quality solutions.

The analysis process for the choice of field trial has been executed evaluating the candidate areas for their topography, offered services and number of served users. As result of this phase, the intermodal parking of via Pietrasantina has been chosen because it satisfied all the requirements necessary to validate ICSI system in a complex urban context.

Indeed, for the city of Pisa, this parking lot is the main hub that offers accesses to tourists, students and commuters that reach the city every day.

Pisa has ideal requisites as Italian candidate to hold an advanced technological trial because the city is present in Smart Cities national classification and at the same time has an historical and cultural heritage of international interest. For these reasons, each day the medium number of vehicles that reach the city is 80.000 units: so this is a great and ideal catchment area for ICSI system trial.

It is important to underline that the local government puts great emphasis on updating of infrastructure for mobility, health and energy issues: on account of this, the consortium has found a great sponsorship in Pisamo, the main actor for Pisa mobility.

The goal of Task T7.1 is to plan and realize the greater number of use cases inside the urban trial, so the most representative and strategic cases have been chosen in order to emphasize the innovative perspective of the project from a point of view of technological and social impact.

The choice is been supported by the fact that the intermodal parking of via Pietrasantina provides services such as bike sharing, bus connection, tourist bus and car parking, e-charging slots that are basic for the real realization of the selected use cases.

Regarding the vehicular mobility Pisa has an important systematic flow and this indicates that the city is a center of attraction for many workers, students and commuters.

An analysis of traffic flows entering the city of Pisa can help to identify which are the ways of preferential access to the city from the surrounding areas / municipalities and what are the extent of the flows.

Using a methodology of data mining (clustering) on the trajectories of travelers, a series of typical pathways to the city were systematically identified. The clusters highlight both the areas of origin and the preferred access to the city. In general, users who come from more distant places prefer to use large-capacity roads (highway or freeway). This behavior is evident in clusters colored in red, blue, yellow and purple (**Figure 1**). The case of the pink cluster, where the trajectories are individuals from neighboring communities, is instead different. These have a greater diversity in the mode of access to the city due to greater choice on the road network.

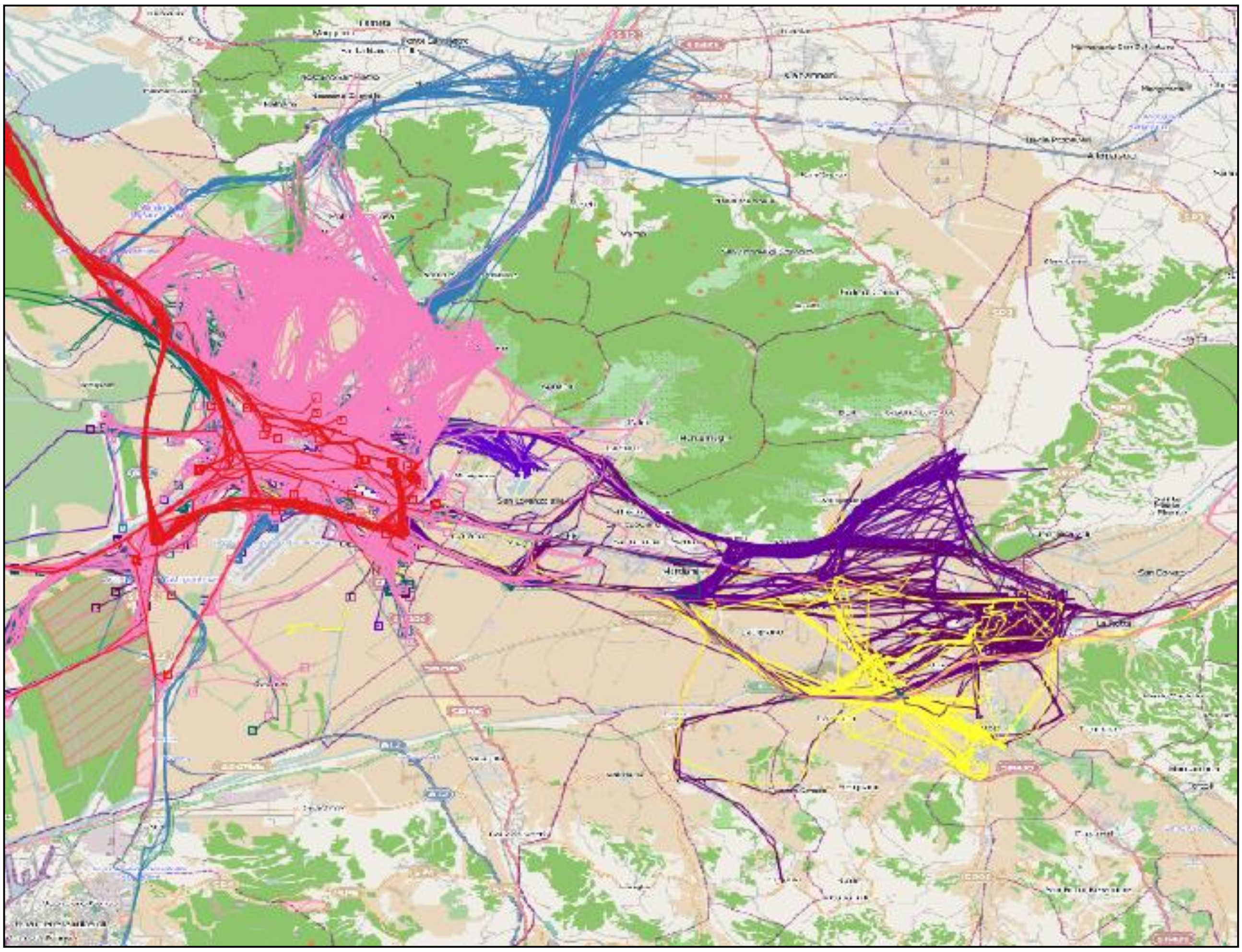

Figure 1 - Travels on access routes to Pisa

The document "Study of Urban Mobility Area Pisana 2012" (see [6]) provides an overview of the current state of mobility within the city of Pisa and surrounding municipalities.

Pisamo contributed to this document by providing data collected from variable message signs (VMS), which are equipped with instruments for monitoring traffic. They allow estimating flow statistics along the selected road arches. Indeed, in Pisa, the VMS are distributed along major directives to the city and are managed by Pisamo.

The time window for data collection is from 14 June 2010 to 18 July 2010. For each hour of the day, the total number of transited vehicle is reported in **Figure 2**. The plot exhibits two peaks (one in the morning and one in the afternoon) and a central valley, with a sharp drop in attendance at night.

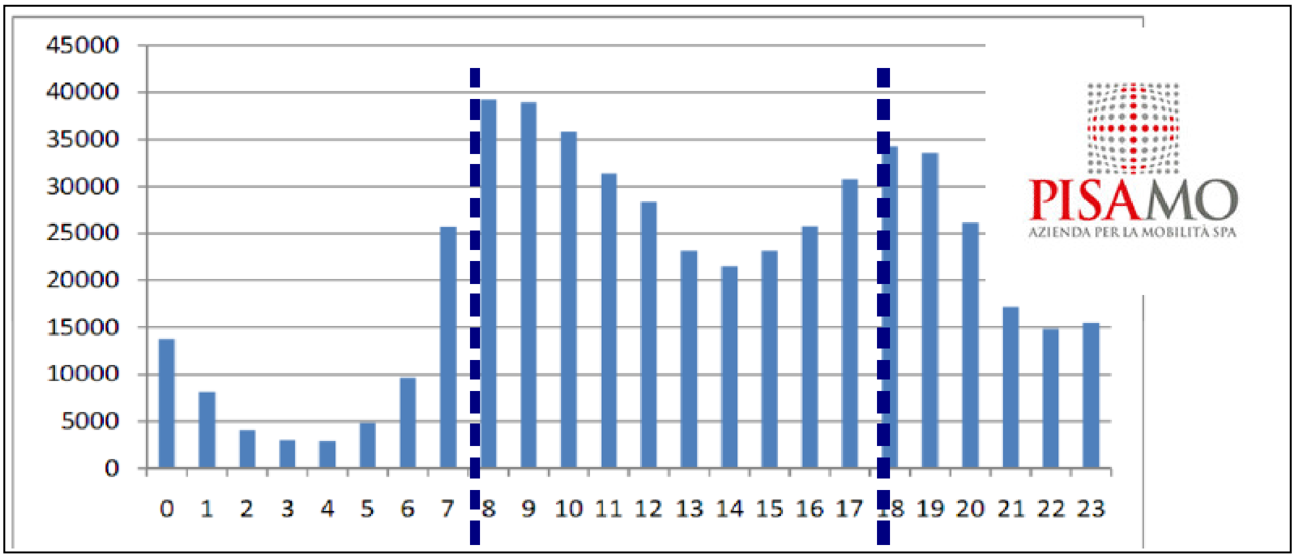

Figure 2 – Hourly Incoming vehicular traffic to Pisa (from 14 June 2010 to 18 July 2010)

The study led to the identification of the traffic congestion on the main streets of the city of Pisa. The dataset was used as input to the data mining algorithm that has led to identify the flock patterns shown in **Figure 3** and which are geo-referenced on the highway Genova-Rosignano, on the State Road n°1 Aurelia and the motorway close to the historic center.

The flock patterns extracted are classified for different values of the proposed measure (red = traffic jam).

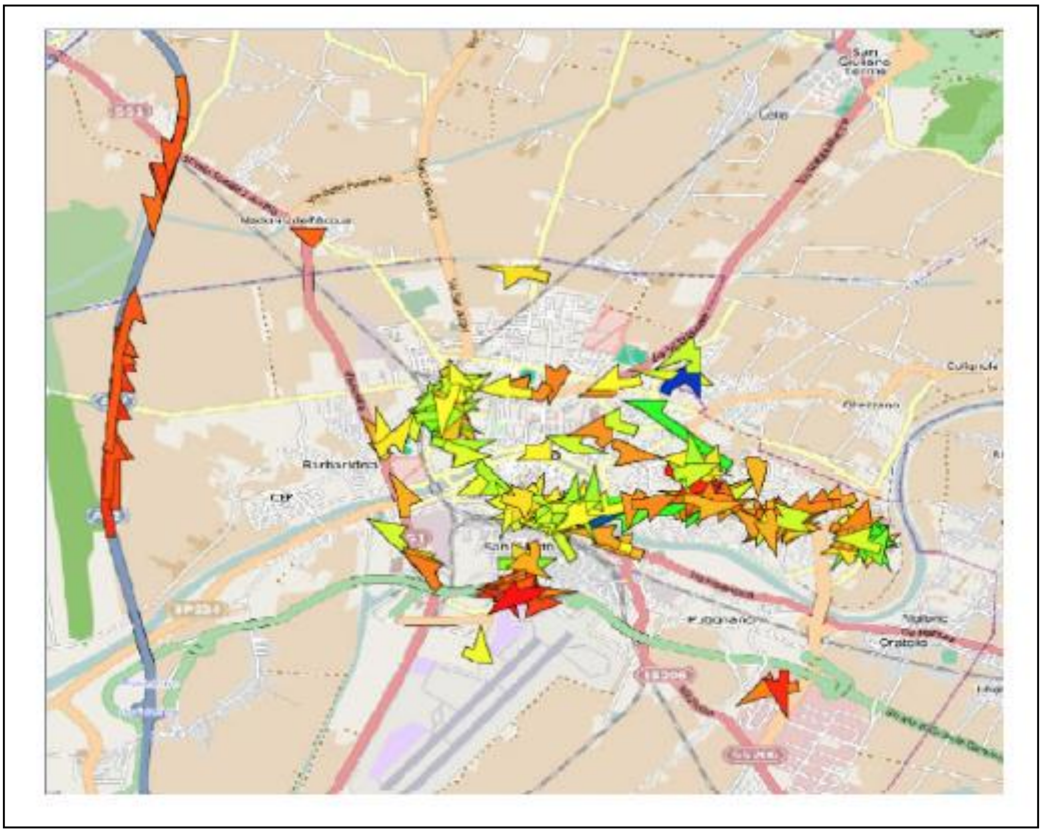

Figure 3 – The flock patterns in Pisa Urban Scenario

2.2 Selected use cases for trial implementation

Following the aforementioned issues and previously described Use Cases (see [2]), an accurate screening of all use cases and selection of the most suitable and feasible ones was performed. This selection is necessary primarily in order to reduce the amount of time needed for their achievement, and due to the number of permits to perform the needed tests (e.g. requests to local police, municipality…), which will make some of the use cases challenging to be completed. Moreover, taking into account the final goal, that is to prove the technological objectives of ICSI Project, an evaluation has been performed in order to reduce them to a selected subset proved sufficient for accomplishing it. Furthermore, for the general use cases, when not all of the features that have been foreseen as input data cannot be retrieved from the real trial scenario site, then, a work has been performed in order to be ready and able to emulate or simulate them (e.g. via dummy data), and injecting them to the ICSI platform.

Here below the total list of the Use Cases from D1.1.1 is reported:

1. Alternative transport services
2. Monitoring and reduction of air pollution
3. Car sharing and external system integration
4. Monitoring of anomaly in traffic flows (e.g. car accident)
5. Cooperative parking lots monitoring
6. E-vehicle parking lots monitoring
7. "Vehicle stopped on road" warning signalled by VMSs
8. Traffic monitoring in special lane

9. Transport priorities

Among all these, the Use Cases which have been identified as completely feasible and covering the technological objectives of ICSI have been identified as two subsets. The first one includes those that will be physically implemented on the trial scenario site; the second set are the ones that will be implemented as real laboratory simulation using both real and simulated data.

The Use Cases to be realized on site are:

- Alternative transport services (#1)
- Car sharing and external system integration (#3)
- Monitoring of anomaly in traffic flows (e.g. car accident) (#4)
- Cooperative parking lots monitoring (#5)
- E-vehicle parking lots monitoring (#6)

2.3 Experimental set up

The experimental facilities to set up are identified following the above described and selected urban scenarios. In particular, in the global map below (**Figure 4**) the area comprising the parking lot and the flow monitoring are represented, on the north-west border of the city of Pisa (around Via Pietrasantina).

Figure 4 – The Via Pietrasantina area, site of the urban scenarios.

More in detail, two different installations are foreseen regarding the parking lot and the traffic flow monitoring respectively. The two areas are within less than one kilometre of distance each other. In the following **Figure 5**, the site of the parking lot monitoring is shown. While the placement of the flow monitoring site is shown in **Figure 6**.

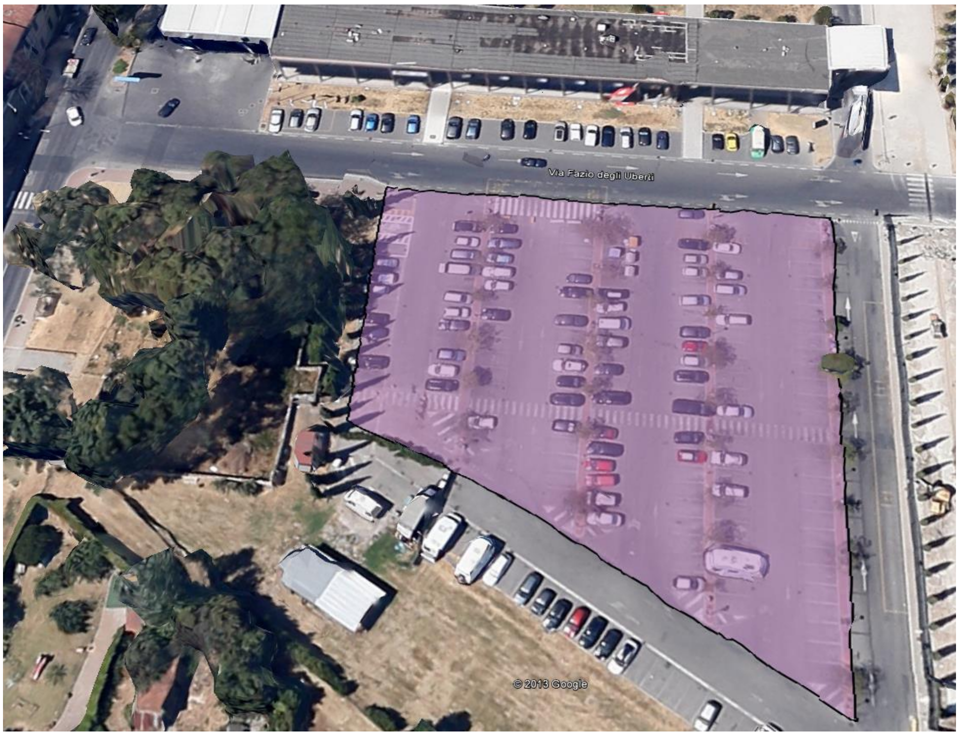

Figure 5 – Highlighted part of the Pietrasantina parking lot used for parking monitoring.

Figure 6 – Views of the selected installation for the flow monitoring (left) and the transit area along Via Pietrasantina (right).

The specifications of the devices to be installed for the urban scenarios are listed in the table below, reporting both typologies of device, i.e. flow traffic monitoring devices and parking slot monitoring devices.

ID	Device	Number of slots covered (plus special slots)	Scenario	Pole No.
DV-P.1	Embedded Vision Node	6 (+ 1 disabled slot)	Parking	3
DV-P.2	Embedded Vision Node	6	Parking	4
DV-P.3	Embedded Vision Node	5 (+ 1 disabled slot)	Parking	1
DV-P.4	Embedded Vision Node	6	Parking	2
DV-P.5	Embedded Vision Node	5 (+ 2 e-charging slots)	Parking	1
DV-P.6	Embedded Vision Node	5	Parking	2
DV-P.7	Embedded Vision Node	5 (+ 1 disabled slot)	Parking	5
DV-P.8	Embedded Vision Node	6	Parking	6
DV-P.9	Embedded Vision Node	6	Parking	5
DV-P.10	Embedded Vision Node	6	Parking	6
DV-F.1	Embedded Vision Node	N.A.	Flow	F

A planning of the placements of the above described devices has been performed and the final locations decided taking into account several aspects. Among them: the coverage of a suitable and needed number and typology of parking slots (i.e. electric car slots, disable parking slots…), the availability of infrastructures (e.g. existing poles), proximity to available electric facilities, costs of installation, maximization of slots/device ratio. While for the traffic flow monitoring the decision regarding the location of the device was quite straightforward (see above **Figure 6** right), the slots coverage for the parking lot was more demanding, and required several plans among which the most suitable one has been chosen.

In the following **Figure 7**, the final map of the deployment positions for the poles is shown in the monitored parking lot, some of the poles are mounting two devices monitoring different slots, some only one. Along with the poles positions (numbers in red circles), the coverage map of the slots is reported (yellow areas).

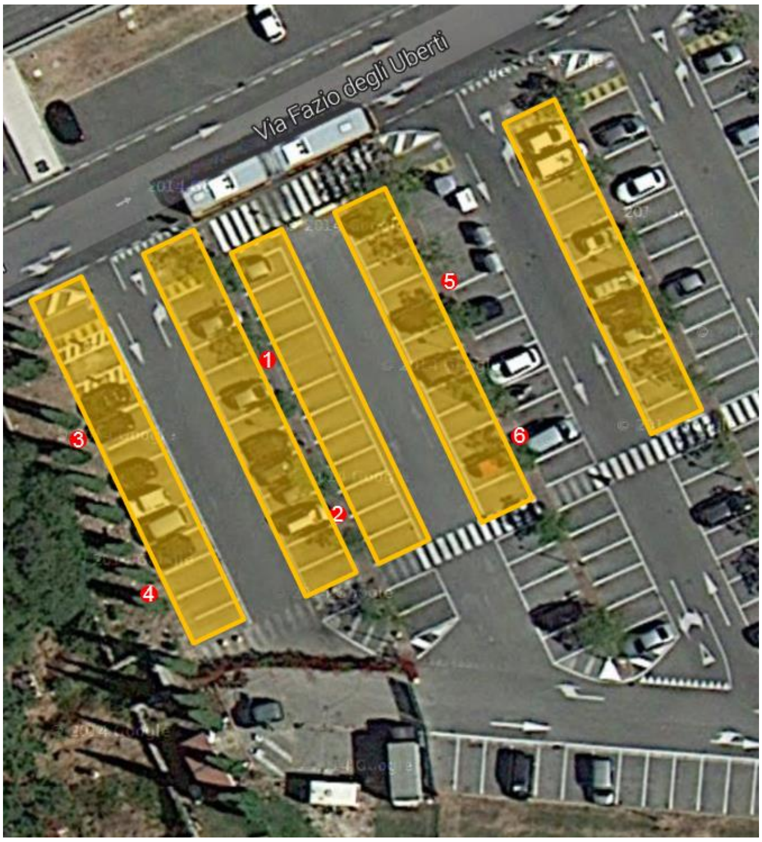

Figure 7 – Location of the poles installed for the parking monitoring scenario and slots coverage.

For the configuration chosen, regarding the parking lot scenario, the final number of slots monitored in the area is reported in the following table along with the specifications on the number of special slots.

TOTAL SLOTS	E-charging slots	Disabled slots	Normal slots	Devices
62	2	3	57	10

Finally the prototypal installation of the parking lot monitoring devices is shown as of the state-of-the-art before the beginning of the works for the installation of the galvanized poles suited for the scenario site. The setup shown in **Figure 8**, resemble to what will be the final one, whereas the tripod allows bringing a device to the same height scheduled for the poles (i.e. around 3.6 metres).

Figure 8 – Prototype installation of the parking lot monitoring devices as mounted onto a tripod.

The Urban Scenario configuration is also equipped with 3 ICSI GWs. Two of them are positioned in the middle of the Via Pietrasantina Parking area (**Figure 9**). These GWs are configured to define a local area and they are also connected with another GW in the INTECS premises in Pisa by a 3G antenna.

Figure 9 – GWs deployment in the Urban scenario

In the **Figure 10** is shown the main connection between ICSI devices deployed in the Urban Scenario.

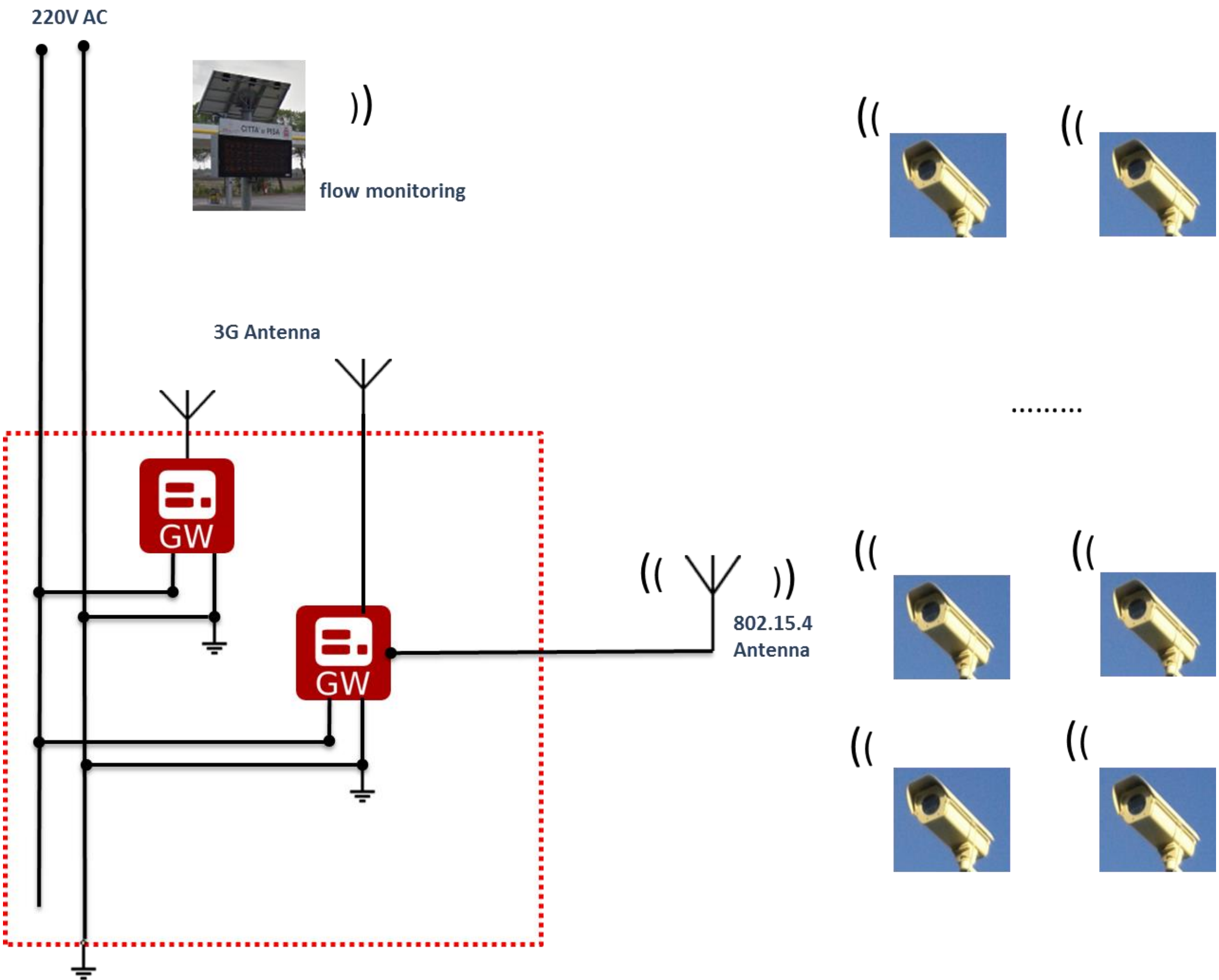

Figure 10 – ICSI GWs schema in the Urban Scenario

3 Highway scenarios

In Lisbon, the ICSI will be tested along the Lisbon highway A5. The A5 is a 25 km (15 miles) long highway in Portugal and connects Lisbon to Cascais. The first section of this infrastructure was opened in 1944 (Lisbon - Estádio Nacional), becoming the first highway in Portugal and one of the first in the world.

The A5 is, on average, the most congested highway from Portugal, and its section Lisbon Monsanto - National Stadium the most congested of the entire national road network, due to the high population concentration that is located along the infrastructure.

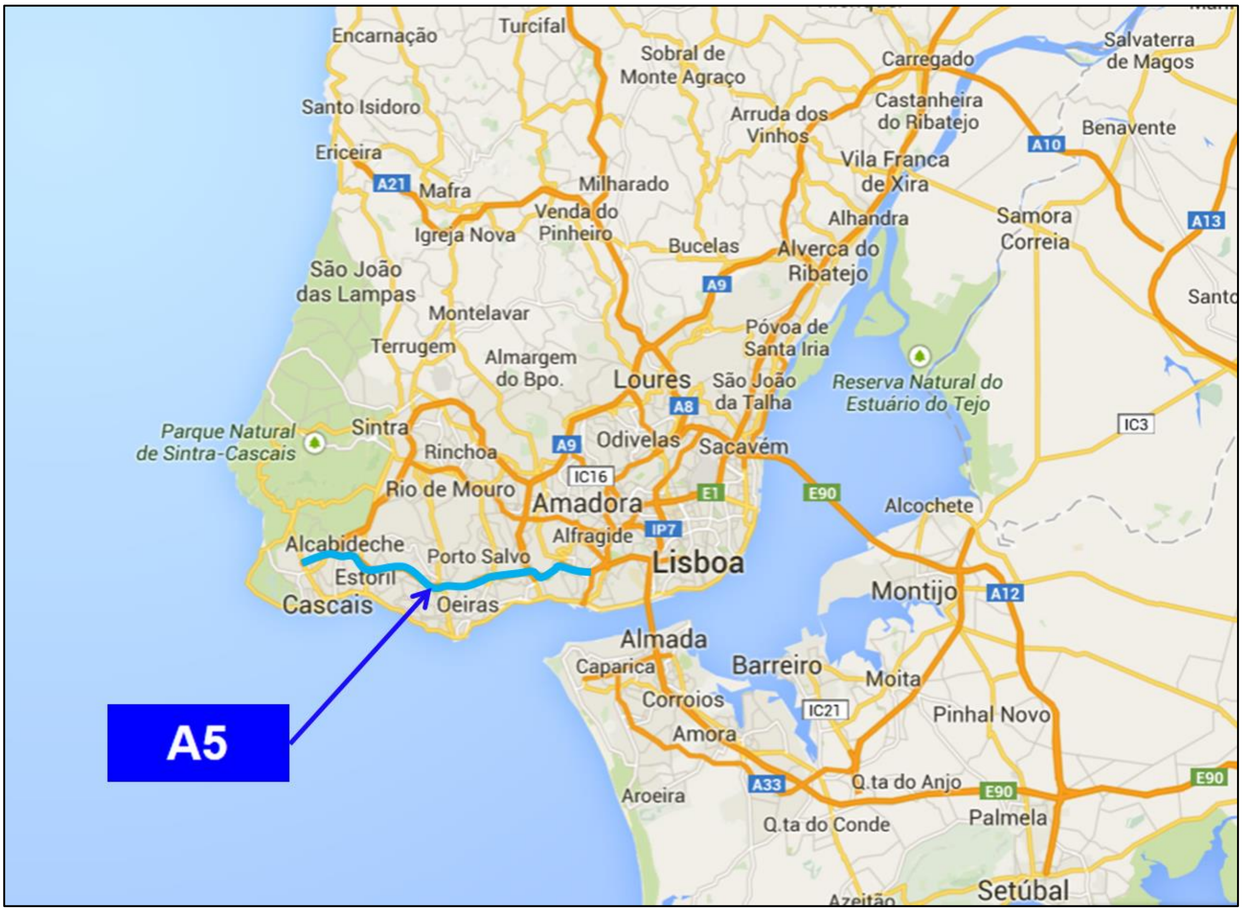

Figure 11 – Lisbon Metropolitan Area and A5 highway

3.1 Relevance of the selected highway scenarios

Several uses cases were defined on the deliverable D1.1.2 [2], with a strong focus on safety, identified according several inputs:

- European ITS strategy documents
- Literature review of other research projects
- Inputs for analysis are provided by several experts, from operations and technical fields, led by Brisa.

3.2 Selected use cases for trial implementation

Based on the use case description and the project objectives, the following uses cases were selected for implementation on the field trial (FT):

- Route guidance and intermodal support (UCH1-RG)
- Wrong Way Warning (UCH2-WWW)
- Hazardous Location Warning (UCH3-HLW)
- Roads Works Warning (UCH4-RWW)
- Traffic Jam Warning (UCH5 – TJW)
- Emergency Vehicle Warning (UCH6 – EVW1)

Some of the features of the use cases cannot be implemented on the FT, so certain inputs will be emulated using dummy data.

The Cooperative (V2I) ramp metering (UCH7-CRM) and Mainstream traffic flow control (UCH8-MTFC) use cases will not be implement on this FT, regarding the feasibility of their application according the current conditions of the FT environment. They could be simulated and tested using a virtual environment e.g. computer simulation.

The basic methodology for the above use cases is depicted in figure 7. The methodology will consider and cover all the parameter defined for field trials. The network parameters cover all the important parameters from RSUs deployments to the traffic types and mobility patterns of the OBUs. The RSUs will be deployed based on the use case scenarios and density of traffic in a specific zone. A heterogeneous distribution will be adopted for OBUs deployment to reflect more realism in the scenarios. The spatial and temporal variations of network performance along a road in the real-world settings such as traffic lights, congestion at the intersections, mobility, direction etc. will be captured in the models. All the relevant parameters will be applied to the ICSI protocols and models to test them for targeted performance. The performance models represent the type of performance test we want to perform. For instance, if we want to check the broadcasting of a safety message from I2V, the relevant model will be applied and the results will be generated to access the system.

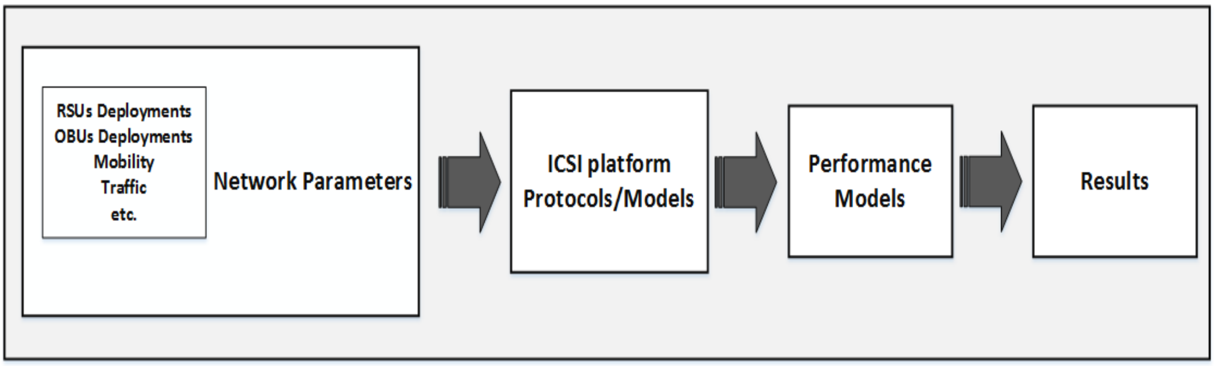

Figure 12 –Methodology for use case scenarios.

3.3 Experimental set up

The FT experimental set up will be implemented on a stretch of the A5 highway, between the Lisbon Monsanto and the National Stadium; this is the most congested part of the A5 highway.

Figure 13 – A5 highway, Monsanto stretch

Around 6 G5 RSU (Road Side Units), mark at yellow on the following picture, will be mounted on several road side equipment cabinets. These RSUs will be interconnected by TCP-IP network and together with the ICSI gateways, will implement the ICSI platform on the FT location.

Figure 14 – RSUs position on A5 stretch test site

The ITS G5 stations, depicted in **Figure 15** and detailed in the deliverable D3.5.2, will be deployed both as RSUs and OBUs.

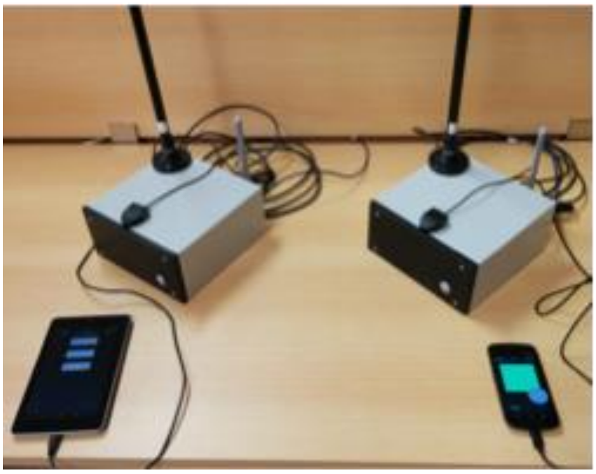

Figure 15 – ITS G5 stations with external antennas (GPS and 5.9 GHz) and Android devices.

For the case of the OBU, the driver interface will run on an Android device connected to the ITS G5 station through the USB bus. The ITS G5 station (Single Board Computer and IT2S platform) will be also connected to the vehicle's OBDII port, as depicted in Figure 16. ICSI applications will run on the Android device and on the ITS G5 station single board computer. Vehicles will also be equipped with three removable magnetic antennas, two for the 5.9 GHz and one for GPS. The user test group will be workers and partners from Brisa Innovation that will test the ICSI platform with units installed on their cars.

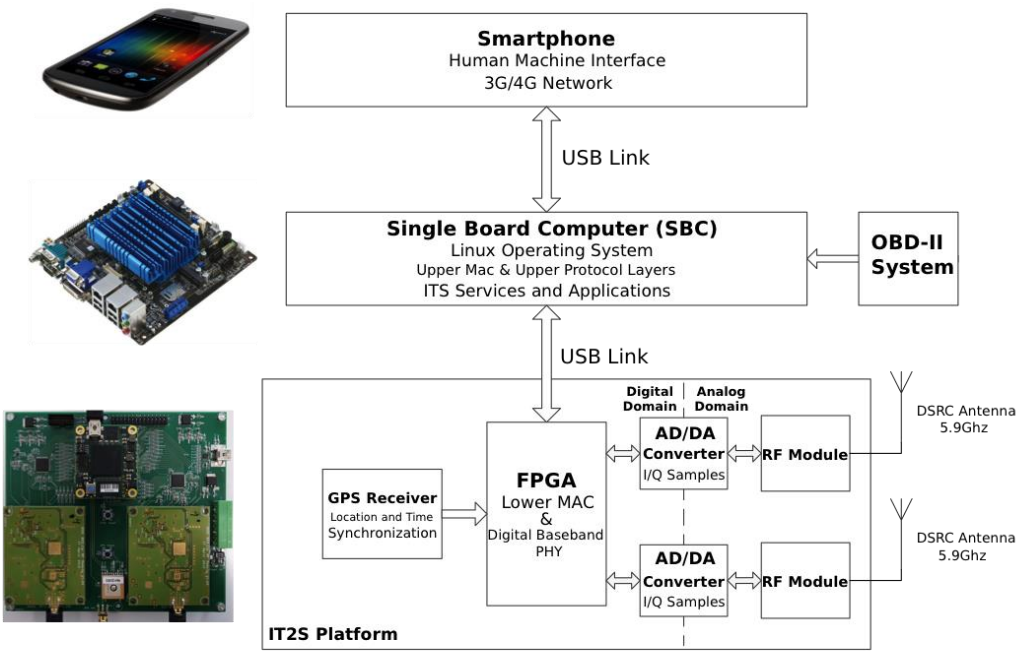

Figure 16 - OBU architecture.

4 Evaluation of trials and metrics

In this section, we report the metrics that will be used for trial evaluation. In particular, we have defined four main groups to be evaluated which regards:

- The Data Distribution Platform (DDP) which is a key component orchestrating many of the other available subsystems
- The Cooperative Learning Unit (CLU) which is in charge of offering prediction services on the base of the data made available by the DDP;
- The Roadside Subsystem (RS) which includes the WSN segment targeted at parking and traffic flow monitoring
- The Vehicle Subsystem (VS), which included the OBUs and the RSUs for vehicular communications

With respect to these groups, we have identified a number of technological parameters to be evaluated. The parameters are chosen to be quantitative values that can be assessed and monitored during trial execution. Indeed, these metrics will be evaluated throughout the trial and results will be reported in D7.2.1 and D7.2.2.

For sake of clarity, the proposed metrics are reported in a tabular format. Each metric is described by an ID, a name and a short description. The units selected for the metric measurement are also declared as well as the target valued that we expect to reach at the end of the trial phase.

4.1 ICSI Data Distribution Platform

The following KPI are provided in order to measure performance of the DDP in real case scenarios. The effective performance could be affected by specific implementation choices such as physical channels used for the underlying communication networks and hardware used for the gateway hardware unit (GHU). KPIs have been individuated considering the high-level capabilities provided by the DDP.

ID	Name	Description	Unit	Target
DDP.1	Local area latency	Latency in sending message over a ICSI Local Area	s	~1
DDP.2	Global Area latency	Latency in sending message over the ICSI Global Area	s	<5
DDP.3	Subsystem event integration	Time to parse and publish subsystem data into the DDP	ms	hundreds
DDP.4	Subsystem packet loss ratio	Number of packets sent by an attached subsystem that are lost	%	< 5
DDP.5	Area communication packet loss ratio	Number of packet loss in GW to GW communications	%	<5

ID	Name	Description	Unit	Target
DDP.6	DDP mean time to failure	The time that an RSU will operate without failure in a realistic operating scenario	Months	>3

Table 1 - DDP KPI

4.2 ICSI Collaborative Learning Unit

The following KPIs are provided in order to measure performance of the CLU in real case scenarios. The effective performance could be affected by specific implementation choices such as the underlying DB for the global storage or the computing power of the CPU. KPIs have been individuated considering the high-level capabilities provided by the CLU.

ID	Name	Description	Unit	Target
CLU.1	Traffic Model Configuration time	Time needed to set the Traffic Model allowing the CLU to subscribe to remote events / GWs	s	<3
CLU.2	Contingency Plan Configuration time	Time needed to set the Contingency Plans allowing the CLU to respond to remote events / GWs	s	<3
CLU.3	Latency in the decision making process	Time to parse the message and choose the correct service to manage the received event	ms	Hundreds
CLU.4	Time to generate a new model	Time needed to generate a new prediction model from stored data	s	<30
CLU.5	Global storage access time	Average access time to the global storage component (permanent data storage)	s	~1
CLU.6	Service execution time	Average time to execute the decision logic provided by the CLU	s	<5
CLU.7	Maximum Event frequency	Maximum number of events per second the CLU can process	# of events/s	~2

Table 2 - CLU KPI

4.3 Roadside subsystem

The KPI reported in Table 3 were defined to measure the overall performance of the WSN segment that is deployed in the urban scenario for traffic flow monitoring and parking lot availability analysis. The proposed KPIs regard the network functionalities as well as the capability of the WSN middleware to perform complex event processing.

ID	Name	Description	Unit	Target
RS.1	Refresh latency	Latency in refreshing the status of a parking space after it has been freed or occupied	s	<5s

ID	Name	Description	Unit	Target
RS.2	Traffic flow frequency	Maximum reachable update frequency for messages containing vehicular flow count	Hz	>1Hz
RS.3	Parking detection error rate	Ratio of false and missed events over total events detected by computer vision algorithms during selected observation periods. An event correspond to a parking space becoming occupied or vacant.	%	<5%
RS.4	Traffic flow detection rate	Vehicle detection rate by computer vision algorithms during selected observation periods when monitoring a lane.	%	>95%
RS.5	Traffic flow false alarms	Number of false vehicle detections over total number of detections during selected observation periods when monitoring a lane.	%	<5%
RS.6	End-to-end delay	Latency in transmitting a message from a WSN node to the gateway	s/ # of hops	<30*10-3 per hop
RS.7	Middleware integration	Number of sensors on which the middleware perform complex event processing	unit	>=3 units
RS.8	WSN Packet loss ratio	Ratio of packet loss with respect total sent packets during a communication test within the WSN	%	20%
RS.9	Network failure frequency	Number of failure events logged by the WSN in a day	# of events/ 24h	< 1 event/24h
RS.10	Network failure reaction	Latency in rebuilding a new route in case of resolvable failure	s	<30s

Table 3 – Roadside subsystem KPI

4.4 Vehicle subsystem

The KPI regarding subsystems performance evaluation are represented in Table 4. Once the RSUs are deployed and the OBUs are functional, we can use these KPIs to evaluate the overall system performance. The defined KPIs are crucial to the success of the ICSI system in general and to the IT2S system in specific. Since, the OBUs and RSUs will exchange messages, for example CAM and DENM, it is important to know all related Delays, the Jitters, Packet error rates etc. Besides considering several other parameters for tests, the packet error rate is used to assess the performance of terminal's receiver (OBU and RSU). In addition, confidence states of the systems will be defined to control and check whether the defined confidence level is achieved during the PER measurement of the system. For this system, the required confidence level of the

PER requirement is set in the range 75% to 99.99%. Minimum Packet Count, Maximum Packet Count and PER Target Slots are other sub-parameter in the PER that will be considered in the evaluation. The probability that our system, especially RSU, will work as required and when required during the period of trials and after the commercial deployment is crucial to know. Therefore, the time that an RSU will operate without failure in a realistic operating scenario for a minimum period of 6 months has been included in the tests.

These KPI will lead to more useful findings to evaluate and enhance the system further.

ID	Name	Description	Unit	Target
VS.1	End-to-end delay	Latency in transmitting a message from an OBU and receiving it a RSU	s	$<20*10^{-3}$
VS.2	Round-trip delay	Latency in transmitting a message from an OBU, receiving and processing it in a RSU, and transmitting a reply	s	$<10*10^{-3}$
VS.3	Jitter	Time variation in the transmission of periodic messages	s	$<10*10^{-6}$
VS.4	Packet error rate	Percentage of corrected received packets over time inside the effective coverage area of an OBU/RSU	%	> 75%
VS.5	RSU Mean Time to Failure	The time that an RSU will operate without failure in a realistic operating scenario	Months	> 6

Table 4 – Vehicular subsystem DDP KPI

5 Conclusions

As promised in the project document, this deliverable D7.1 entitled “**Definition of the trial scenarios and metrics”** defines the trial scenarios identified for the two different experimental facilities set-up: the smart urban and the highway environments

More in detail, we have reported and discussed the trial scenarios that have been selected for the field demonstration of ICSI. Such scenarios were defined in agreement with the development lines contained in the ICSI use cases and requirements [2,3] and aim at demonstrating the achievement of the project S&T objectives.

In particular, in strong collaboration with the technological WPs of the project, the activities of this demonstration action focused on finding a suitable show place for the tangible results produced during the project.

To this end, urban and highway trial scenarios have been identified. In each of such scenario, in accordance with the stakeholder maintaining the areas (i.e. Pisamo which offered external support to the project for the urban one and Brisa for the highway one), a set of key use cases will be implemented and tested in real situations. The experimental set up and the facilities used are also reported in this document, which features several maps regarding the urban and high way area that will be interested by the trial installations.

Finally, a set of metrics has been introduced. This metrics will drive the on-going and final evaluation of the trial. They consist in technological KPI, which are measurable in a quantitative and objective way with no bias. The results of such measurements will be gathered and reported in in D7.2.1 “Report on the execution of the experiments and results” (interim version) and subsequently refined in the final version D7.2.2. Such deliverables will contain the mid-term and final snapshots of the performance of the trails.

6 References

[1] ICSI, *“Description of Work”*

[2] *ICSI D1.1.2 “Use cases definition and analysis"*

[3] *ICSI D1.2.2 "User and system requirements"*.

[4] *ICSI D1.3.2 "System architecture"*

[5] *ICSI D2.1.2 "Design of the Data Distribution Platform "*

[6] http://www.tages.it/en/activities/experience.html