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INTEGREEN

Action 5: Testing & Validation

D.5.2.1

Test Bed plan and test scenarios

Project Coordinating Beneficiary	Municipality of Bolzano
Project Associated Beneficiary n.2	TIS innovation park (TIS)
Project Associated Beneficiary n.3	Austrian Institute of Technology (AIT)

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1 Introduction

Action n.5 aims not only at verifying in a real scenario the first benefits and environmental impacts that the INTEGREEN system has produced through its first deployment. The long-term objective of this action, the last technical phase of the project execution, is in fact to identify the key advanced eco-friendly traffic policies that can be implemented on top of this novel system.

The activities of Action n.5 are organized in three different tasks, and very strictly connected to the ones completed in the previous project actions as illustrated in Figure 1. The comprehensive methodology followed for the technical implementation of the project is the V-model, which is a very common technique for (ITS) projects based on intelligent transportation systems (ITS).

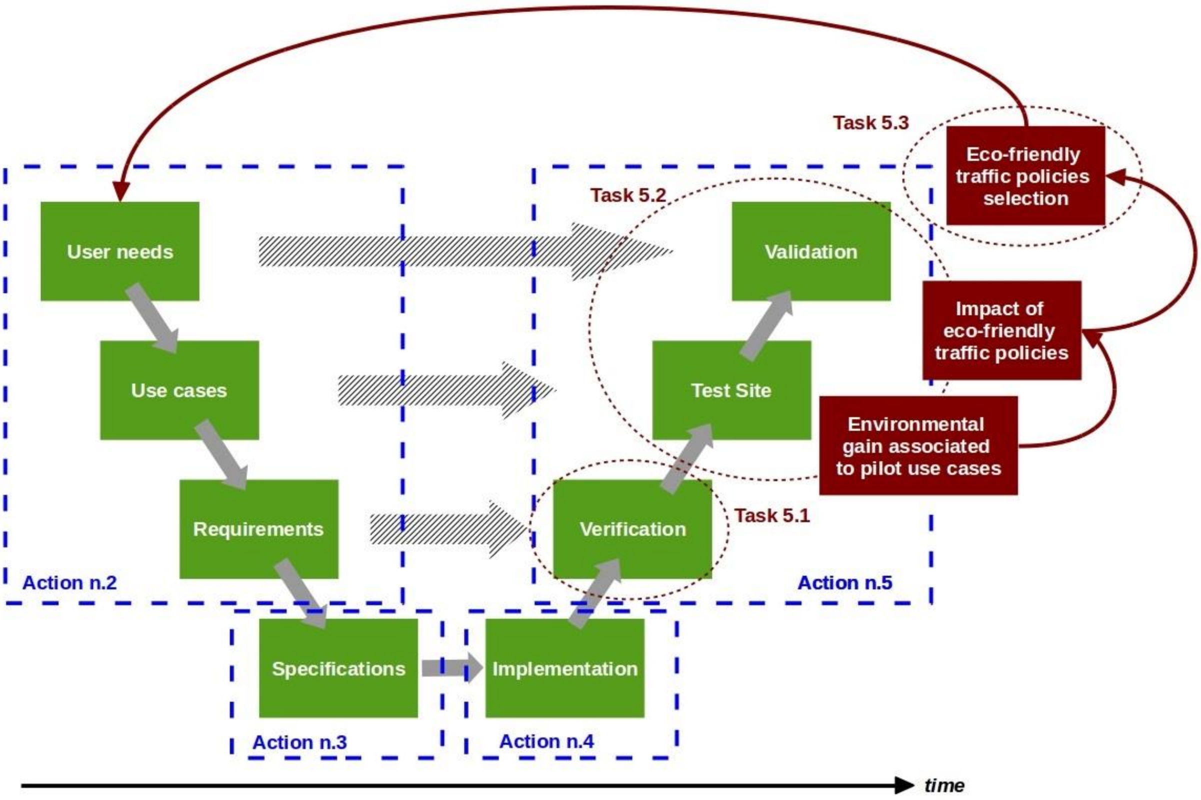

Figure 1: The V-model methodology followed in the technical implementation of the project and a graphical presentation of Action n.5 activities.

Action n.5 is organized in three different tasks:

- **Task 5.1** ("components tests"), in which system components are technically analyzed in order to verify that original system requirements are properly fulfilled.
- **Task 5.2** ("outdoor urban tests"), in which the INTEGREEN system is used empirically within the city of Bolzano to quantify the environmental impact associated to a set of

initial eco-friendly traffic policies introduced in the final part of the project, in particular by:

- initially investigating the potential local environmental gain associated to a set of "pilot use cases", i.e. an empirical expression of the "ideal use cases" identified during the requirements' consolidation process;
- finally experimenting the large-scale application of the initial eco-friendly traffic policies.

Task 5.2 is also responsible to preliminary assess how far initial user needs have been satisfied.

- **Task 5.3** ("eco-friendly traffic policies"), in which the pilot experience of INTEGREEN is used to:
  - identify the most cost-effective strategies for reducing the environmental impact of urban traffic through dynamic traffic and mobility management policies;
  - consolidate the project contribution to the implementation of the enhanced EC policies in the field of environment and mobility governance.

The implementation of the future, selected eco-friendly traffic policies can furthermore represent the kick-off of a new cycle of the V-model, with an increasing engagement of local travelers and stakeholders in the calibration of the proposed measures.

1.1 Purpose of the document

The purpose of this document is to define the Test Bed plan which will govern the implementation of the core "test and validation" activities of Action n.5, whose results are presented in deliverable D.5.2.2 [1].

For a proper analysis of the contents that are presented, it is recommended to read this deliverable together with all the other outputs produced by Action n.5, i.e. D.5.2.1, D.5.1.1, in which the results of the system components are presented [2] and D.5.3.1, in which the results of this first investigation on the most suitable eco-friendly traffic policies for the city of Bolzano are presented [3].

1.2 Document structure

This deliverable is structured as follows. In Chapter 2 the reference methodology for Field Operational Tests of ITS systems, "FESTA" is presented and discussed. Based on this preliminary analysis, Chapter 3 evaluates how FESTA methodology can be applied for the testing and validation purposes of INTEGREEN. Pilot use case scenarios and functionalities to be assessed are identified, including a preliminary quantification of the traffic and environmental improvements expected. Finally, Chapter 4 gives an overview of how identified testing and validation activities are carried out from a temporal point of view.

2 FESTA methodology

Field Operational Tests (FOTs) were introduced several years ago primarily as an evaluation method for on-board driver support systems and functions, with the aim of proving the real-world benefits they could be in the conditions to deliver.

A significant number of such FOTs have been conducted at a regional, national and international level. They have proven their added value for verifying the real-world impacts of new systems. However, at a certain point two needs have emerged:

- the necessity to expand the systems and functions to be evaluated (not only on board, but during the **whole travelling experience**), by taking also account the role of the operators managing traffic and mobility conditions;

- the necessity to introduce a **standardized methodology** that each project initiative could implement in practice, which can make comparisons of the results obtained in different FOTs reasonable.

In order to address these needs, the European Commission has launched the initiative **FOT-net**, a support action funded by the European Commission DG Information Society and Media under the Seventh Framework Programme. FOT-Net aims to gather together all key international stakeholders, identify and discuss common working items and promote a common approach for FOTs - the **FESTA** (*Field opErational teSt supporT Action*) methodology. Thanks to the involvement of key partners of this project, the adoption of the FESTA methodology in projects with FOTs is spreading very quickly in Europe (Figure 2). This overview is however incomplete, since does not take in consideration the most recent initiatives for the large scale evaluation of cooperative systems and applications, like COMPASS4D or DRIVE C2X.

One of the main outputs of FOT-net is the production of a **FESTA handbook**, freely downloadable on the project website [4]. The main aim of this chapter is to briefly summarize the contents of this handbook, highlighting the most relevant aspects for the INTEGREEN project.

2.1 The reference FOT V-model methodology

Before entering into the details of the FESTA methodology, it is important to give an overview of what is meant under the term "**Field Operational Test**" (FOT).

A study undertaken to evaluate a function, or functions, under normal operating conditions in road traffic environments typically encountered by the participants using study design so as to identify real world effects and benefits.

Figure 2: Pilot areas in Europe in which FOT activities are in place according to FOT-net project [4].

The high level FESTA methodology is presented in Figure 3. It indicates all the steps that one should typically consider when conducting the FOT. As it is immediately possible to observe, it appears as a detailed declination of the V-model approach which is used for the entire implementation of an ITS system. The various phases are more specifically evaluated in the following paragraphs

An important aspect to be immediately considered is moreover the level of "**experimental**

control" of a FOT. In some cases, the functions and applications to be tested are evaluated by project staff, while in other cases (which are going to become the most likely situations) they are directly evaluated together with normal travelers. In this latter case, these studies are defined as "**Naturalistic Driving Studies**" (NDS). There could be an overlapping between the two different conditions – in this case FOT are indicated as "**Naturlistic FOT**" (N-FOT).

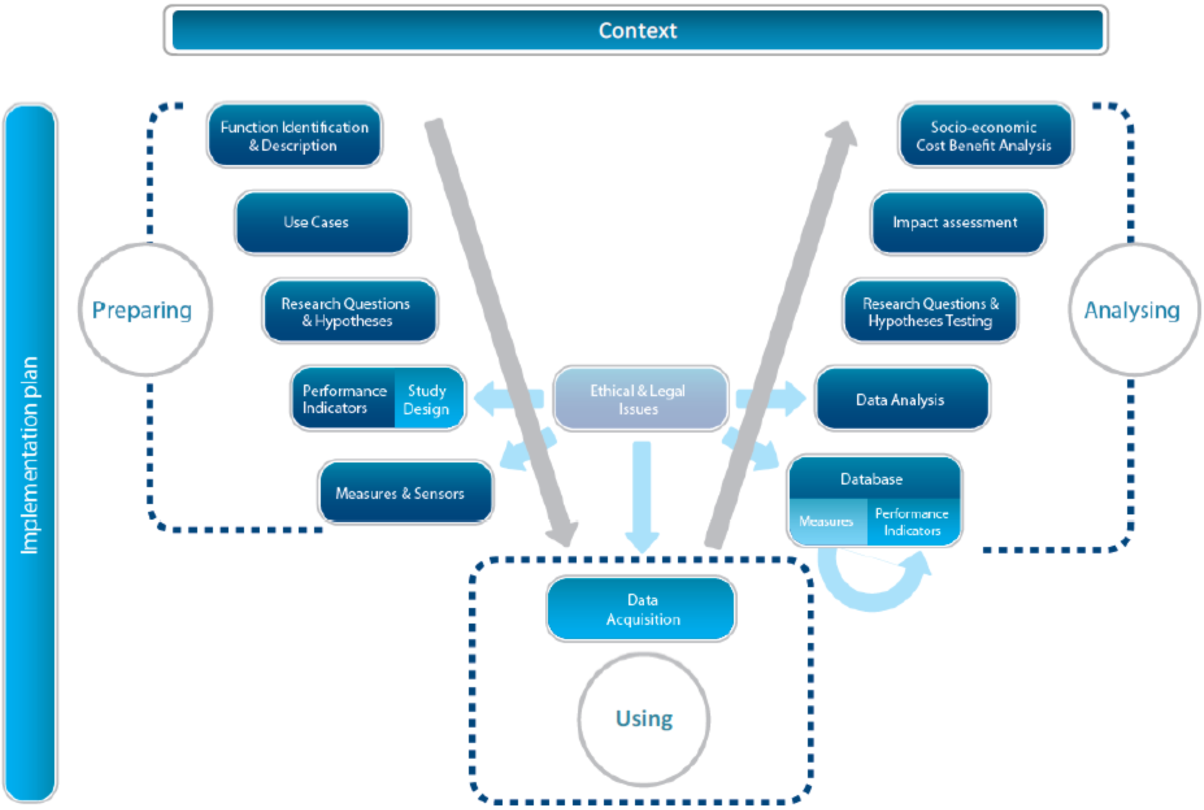

Figure 3: The V-model methodology proposed by FESTA [4].

Before starting with the organization of a FOT, certain legal and ethical issues must be considered, in particular:

- **need for participant recruitment and agreements definition**, in case there is the need for "naturalistic" personnel testing the system;
- **data protection and ownership**, i.e. the need for defining how personal data (if any) are going to be managed, who will be the owner of the data and under which conditions they are going to be reused (with eventual identification of confidential data). A specific agreement could be defined in advance between all involved partners;
- **risk assessment and system safety**, i.e. the preliminary evaluation of possible safety issues related e.g. to equipment to be installed on test vehicles;
- **approval for on-road use**, i.e. the possible necessity for modified vehicles to drive;

- **insurance and responsibility**, in order to distribute responsibility among all partners and stakeholders (also in this case, agreements could be formulated).

2.2 From functions to hypothesis

The core in the preparation of a FOT is however in these key tasks:

- select the functions to be tested;
- define the use cases in which these functions will be tested;
- formulate research questions related to the selected use cases;
- formulate hypothetical answers to research questions;
- link hypothesis to performance indicators, which can be clearly measurable.

2.2.1 Step 1: select and describe the functions

The FESTA methodology includes different types of systems and functions to be tested in a real life environment, namely:

- **in-vehicle systems**, which aim to improve drivers' safety, comfort and mobility. Examples are applications for improving driver attention during hazardous situations, or for the automation of vehicle's maneuvers during critical conditions, but also dynamic navigation functions;
- **cooperative systems**, intended as systems based vehicular-to-X (V2X) communications. FOTs related to cooperative systems are still in an infant stage, since a lot of issues need to prorperly addressed like:
  - the specific training of participants, which are not experiences with these new systems;
  - the penetration rate problem (since noticeable benfits are visible only if the penetration of connected vehicles is higher than 10%);
  - the frequency of targeted events, which can make the use of FOT questionable and the use of ad-hoc simulation tools necessary (e.g. in case of safety applications, the number of occurrence of a targeted event can be statistically insignificant);
  - the installation of new road side units;
  - the management of "big data", since it has been estimated that such FOTs can generate about 500 [Mbytes/vehicle/day]. This can have an impact on connection and storage costs as well;

- **nomadic devices**, intended both as OEM or aftermarket in-vehicle device that a traveler can use event outside a vehicle. Applications running on such devices can more easily open the doors for naturalistic / non naturalistic experiments, and determine a wider evaluation in terms of:
    - **user behavior and acceptance**;
    - **safety & human machine interface** (HMI);
    - **travel & traffic implications**;
    - **environmental implications**;
    - **mobility implications** (i.e. impact on route / mode choice, or trip generation);
- **combination of functions**, i.e. the idea to start to evaluate one function and then gradually introduce additional one, in order to evaluate the “combined” system as a whole at the end of the FOT.

Once selected, the functions must be properly described, not only in terms of what they can be able to carry out, but also considering the reference context and limitations of use, including:

- **infrastructure requirements**, in case they need to be supported by road side equipment installations;
- **drivers requirements**, since a function might be specifically designed for a specific category of users. The driver profile must take in consideration the following characteristics:
    - demographics (e.g. age, gender, country, education, etc.);
    - driving experience;
    - physical characteristics (e.g. physical impairments);
    - attitudes (e.g. towards safety, environment, technology);
- **geographical and road context requirements**, since such functions can be tested only in certain roads with specific charactersitiscs (e.g. road type, road layout, etc.);
- **environmental requirements**, since the functions can be tested only certain environmental conditions;
- **traffic requirements**, since the functions can be tested only certain traffic conditions.

2.2.2 Step 2: define the use cases and the use situations

Before selecting the reference situations in which the selected and described functions are going to be tested, one must have clear the distinction between use case, use situation and use scenario, which is the following:

- **use case**: "a specific event in which a system is expected to behave according to a specified function";
- **use situation**: "one specific level or a combination of specific levels of situational variables";
- **use scenario**: "a use case in a specific situation".

Basically, the use case is the reference "ideal" situation in which the targeted function is executed. The use situation indicates in a detailed way a specific condition in which this might take place. The use scenario is simply the combination use case – use situation.

A use situation must be characterized in terms of:

- **systems and vehicle specification**, with an evaluation of:
  - **system status** (on/off);
  - **system action status** (in case the system has a direct control on vehicle maneuvers, e.g. an adaptive cruise control system controlling the speed or not);
  - **system function characteristics** (since there could be some effects on the vehicle type);
  - **interaction between systems** (e.g. two advanced drivers assistance systems can influence driver behavior in a different way if applied singularly);
- **environmental conditions**, with an evaluation of:
  - **traffic conditions** (e.g. traffic density);
  - **environmental conditions** (e.g. day/night, weather, air pollution, etc.);
  - **road characteristics** (e.g. urban / rural roads);
  - **geographical characteristics** (e.g. mountainous area, street canyon, etc.);
- **driver characteristics and status specification**, with an evaluation of:
  - **driver specification** (e.g. age, gender, educational level, driving experience);

- **driver status** (e.g. distracted, impaired, etc.);
- **purpose, distance, duration.**

Situations must be defined so that they are complementary (i.e. no overlapping between two different situations), entire (i.e. the entire set of situations must fully represent the use case), comparable with baseline conditions (i.e. there could be the same situation without the use of the system), comparable (with other FOTs) and sufficiently variable in terms of the situational descriptors. Typically a FOT is not in the conditions to fully assess all possible use scenarios because of time and cost limitations, so a selection of the most relevant use scenarios to be evaluated during the FOT has to be made.

2.2.3 Step 3: identify the research questions

Research questions must be focused on the impacts generated by the selected functions / systems, and cover the following domains:

- **level of system usage:**
  - **which factors affect the usage of the functions** (e.g. purpose of journey, type of road, traffic density, headway, weather condition, ambient lighting, etc.)?
  - **how do driver characteristics affect the usage of the functions** (e.g. personal characteristics, socio-economic characteristics, journey related – presence of other people on board)?
- **impacts of system usage:**
  - impacts on **safety**;
  - impacts on **personal mobility** (e.g. individual driver and travel behavior);
  - impacts on **traffic efficiency** (e.g. traffic flow and volume);
  - impacts on **environment** (e.g. emissions, pollution level, noise);
- **implication of measured impacts:**
  - impacts for **policy**;
  - impacts for **business models** (e.g. system uptake, users' expectations, pricing model);
  - impacts on **system design and development** (e.g. improvement of HMI, value of service, interoperability);
  - impacts on the **public** (e.g. education, inclusive access, data protection).

2.2.4 Step 4: creation of hypothesis

An hypothesis is defined as follows:

A specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change.

Hypothesis can be formulated according to two different approaches, namely:

- **Top down approach**. The idea is to check different areas in which functions can have an impact and formulate general hypothesis. Six areas are typically considered:
  - **direct effects of a system on the user and driving;**
  - **behavioral adaptation effects of the system on the user;**
  - **behavioral adaptation effects of the system on the non-user** (e.g. vulnerable road users);
  - **modification of interaction between users and non-users;**
  - **modification of accident consequences;**
  - **effects of combination with other system.**

  This approach typically takes in consideration the **driving task model** (Figure 4). In the strategical level, the traveler make long-term planning and takes decisions related to current traffic conditions. Modification to mode choice, route choice, frequency and length of travel could take place. During the maneuvering level, modifications of speed and interactions with other road users are considered. Finally, in the control level, modifications on the vehicle control systems are evaluated.

- **Bottom-up approach**. In this case, the idea is to consider specific use scenarios and formulate very specific hypothesis covering different relevant areas:
  - **efficiency;**
  - **environment;**
  - **mobility;**
  - **safety;**
  - **user uptake**

Through this approach, the workflow is typically the following:

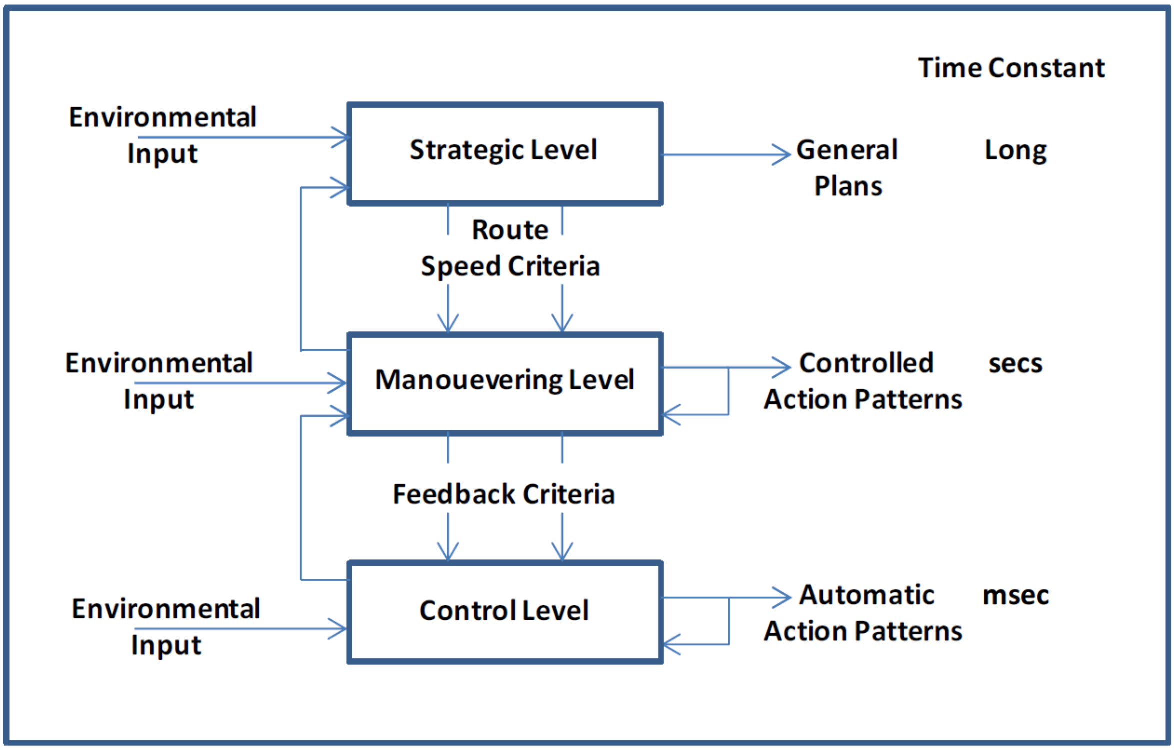

Figure 4: The model of the driving task considered in FESTA [4].

- **understanding where the function will generate an impact;**
- **identification of primary measures** (e.g. for safety, the number and the severity of events);
- **identification of secondary factors that can be used to determine variations in primary measures** (e.g. exposure of vehicle on road, driving style, driving distraction);
- **identification of variables affecting secondary measures** (e.g. road type used);
- **definition of research questions and hypothesis** (e.g. does the system affect the duration of the journey? Yes, it will increase by…).

Both approaches are not alternative, but can efficiently complement one to each other. The typical method is to start with the bottom-up approach and then generalize it using the top-down approach. Even in this case, one must make a selection of the most relevant hypothesis, also taking into account the importance of user needs and the effort to derive a performance indicator and the possibility to prove or not a certain hypothesis.

2.2.5 Step 5: link hypothesis to performance indicators

Performance indicators are:

"quantitative or qualitative indicators, derived from one or several measures, agreed on beforehand, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria.

Performance indicators must be therefore comparable, i.e. a common denominator must be considered. This is the main difference with **measures**, which are directly taken from sensors measurement processes. Measures can be classified as:

- **direct measure**, e.g. directly logged from a sensor, without pre-processing;
- **derived (pre-processed measure)**, e.g. raw measurement that has been filtered or which is a combination of other measures;
- **events**, defined as a situation where one or more preconditions are fulfilled. Typically events, despite very useful to evaluate the system, are very limited in number. For this reason, sometimes "surrogate" events are considered, i.e. situations "near events";
- **self-reported measures**, e.g. questionnaires or similar evaluation instruments;

Performance indicators can be global or detailed, based on continuous or discrete data, and based on observed or self-reported measurements.

FESTA makes at disposal a complex matrix associating sensors to measures and performance indicators, so that one can make a "standardized" selection of which performance indicator could use based on the available measures. Performance indicators are divided per **impact areas**, namely:

- **driving performance and safety**. In this impact area, traffic safety is defined as a function of exposure, accident risk and injury risk, which are associated to the three levels of the driving model;
- **system performance and influence on driver behavior**. In this impact area, system performance is evaluated in terms of false alarms and misses, which indicate how far the system has functioned as expected. Other useful indicators are the availability of the system over driving time and the frequency of take-over requests. The influence on driver behavior is evaluated in terms of number of interventions the driver must do.
- **environmental aspects**. Associated performance indicators available are the calculation of emissions, which can be measured or more likely calculated;
- **traffic efficiency**. Associated performance indicators available are fundamental traffic flow parameters;

- **acceptance and trust**. Associated performance indicators available are:
    - **ex-ante / ex-post usefulness;**
    - **observed rate of use;**
    - **perceived system consequences** (i.e. the impressions of the user regarding the potential consequence when using the system);
    - **motivation vs. behavioral intention;**
    - **response to perceived social control / expectation** (i.e. the users feed a social benefit when using the system or not?);
    - **usability / level of perceived usability.**

2.3 Step 6: FOT execution

Once performance indicators have been individuated, the FOT can be carried out following these tasks:

- selection of measures and sensors;
- preparation and installation of equipment and data storage capabilities;
- kick-off of data acquisition process;
- analysis of collected data;
- testing of research questions and hypothesis;
- impact assessment and socio-economic cost-benefit analysis.

3 Application of FESTA methodology in INTEGREEN FOT

The application of the FESTA methodology is not immediate, since the developed system is a comprehensive environment in which applications for the local travelers are only a small part of it. Moreover, the ability of traffic operators to check the presence of traffic and air pollution conditions must be considered, as well as the possibility to measure the impact of specific eco-friendly traffic policies that are experimentally introduced.

Before starting evaluating how FESTA methodology can be applied to the testing and validation activities foreseen in INTEGREEN, it is important to consider again the V-model approach for the entire technical implementation of the system (Figure 5), which is the main reference for the activities of Action n.5.

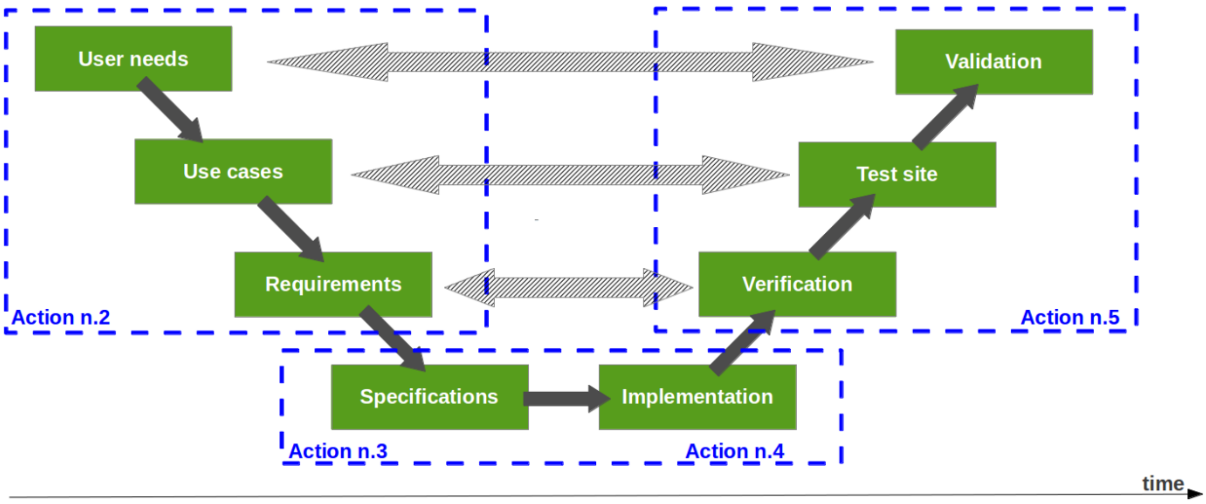

Figure 5: The INTEGREEN V-model introduced at the project start [6].

3.1 Verification process

The first statement is that the **verification process has to be carried out without following the FESTA methodology**. The objective of verification (Task 5.1) is to check if the list of requirements, presented for completeness sake in Table 1 and Table 2, have been properly fulfilled. Specific driving sessions with the mobile system installed on test cars must be included as well, and should give an evidence of the calibration of the system as a whole in terms of its ability to measure the real-time traffic and environmental conditions on the roads.

Components	ID	Name	Type	Priority
Supervisor Center	SC_1	System capability	F	M
	SC_2	Layer interoperability	I	M
	SC_3	Open data approach	I	M
	SC_4	Output delay	P	M
Data-Sources Layer	DSL_1	Data gathering	F	M
	DSL_2	Data-source isolation	F	M
	DSL_3	Data pre-validation	F	M

	DSL_4	Data formatting control	F	M
	DSL_5	Data-source forwarding service	F	M
	DSL_6	Source position	F	M
	DSL_7	Source status and data consistency	F	S
	DSL_8	Warning capability	F	S
	DSL_9	Authentication capability	N-F	M
	DSL_10	Source trustworthiness	N-F	M
	DSL_11	Data timestamp	N-F	M
	DSL_12	Source identification	N-F	M
	DSL_13	Source interoperability	I	M
	DSL_14	Elaboration time	P	M
Vehicle Data-Source	VeDS_1	Data type – position and timestamp	F	M
	VeDS_2	Traffic data type	F	M
	VeDS_3	Environmental data type	F	M
	VeDS_4	Data type – position (optional)	F	S
	VeDS_5	Environmental data type (optional)	F	S
	VeDS_6	Data frequency update	P	M
Traffic Station Data-Source	TSDS_1	Data type	F	M
	TSDS_2	Data type (optional)	F	S
	TSDS_3	Data frequency update	P	M
Environmental Station Data-Source	ESDS_1	Data type – environmental parameters	F	M
	ESDS_2	Data type – meteorological parameters	F	M
	ESDS_3	Data type – environmental parameters (optional)	F	S
	ESDS_4	Data frequency update	P	M
User Data-Source	UDS_1	Data type	F	M
	UDS_2	Data type (optional)	F	S
	UDS_3	User identity authentication	N-F	M
	UDS_4	User position	N-F	M
	UDS_5	User identity	N-F	M
	UDS_6	Human machine interface	I	M
3rd Parties Data-Source	3PDS_1	Data type	F	M
	3PDS_2	Data aggregation	F	M
	3PDS_3	3rd parties source authentication and authorization	N-F	M
	3PDS_4	Standard data transfer	I	M
Operator Data-Source	ODS_1	Data type	F	M
	ODS_2	Notification characterization	N-F	M
	ODS_3	Operator role	N-F	M
	ODS_4	Operator authentication	N-F	M
	ODS_5	Human machine interface	I	M
Video data-source	VDS_1	Data type	F	M
	VDS_2	Data type (optional)	F	S
	VDS_3	Notification position	N-F	M
O/D data-source	ODDS_1	Data type – raw generated data	F	M
	ODDS_2	Data type – raw generated data (optional)	F	S
	ODDS_3	Data type – pre-elaborated generated data	F	S
	ODDS_4	Pre-elaboration time interval	P	M

	ODDS_5	Data frequency update	P	M
Meteo data-source	MDS_1	Data type	F	M
	MDS_2	Data type (optional)	F	S
	MDS_3	Data frequency update	P	M
Parking data-source	PDS_1	Data type – generated data	F	M
	PDS_2	Data type – basic information	F	M
	PDS_3	Data frequency update	P	M
Data center layer	DCL_1	System capability	F	M
	DCL_2	Security control	N-F	M
	DCL_3	Performance	P	M
	DCL_4	Flexibility and scalability	P	M
Data center collector	DCC_1	Uniqueness	F	M
	DCC_2	Source and data-source identification	F	M
	DCC_3	Data type recognition	F	M
	DCC_4	Database connection	F	M
	DCC_5	Authentication and security	N-F	M
	DCC_6	Data-source authentication management	N-F	M
	DCC_7	Multiple data-source connections support	P	M
Database	DB_1	GIS capability	F	M
	DB_2	Generated data storing capability	F	M
	DB_3	Intermediate and final elaboration outputs storing capability	F	M
	DB_4	History capability	F	M
	DB_5	Standard logging and reports	F	S
	DB_6	Reliability, security and data incorruptibility capabilities	N-F	M
	DB_7	Data export	N-F	M
	DB_8	Interface	I	M
	DB_9	Performance	P	M
Data center tasks	DCT_1	System capability	F	M
	DCT_2	Output storing capabilities	F	M
	DCT_3	Data accessibility	N-F	M
	DCT_4	Task triggering	N-F	M
	DCT_5	Warning generation management	N-F	S
	DCT_6	Interface mandatory constraints	I	M
	DCT_7	Interface optional extensions	I	C
Pre-elaboration task	PreET_1	Calibration problems discovery	F	M
	PreET_2	Malfunctioning problems discovery	F	S
	PreET_3	Triggering	N-F	M
Elaboration Task	ET_1	Elaboration outputs format	F	M
	ET_2	Traffic elaboration – periodical outputs	F	M
	ET_3	Environmental elaboration - periodical outputs	F	M
	ET_4	On-demand outputs	F	M
	ET_5	Data processing capabilities	N-F	S
	ET_6	Traffic elaboration outputs – spatial resolution	P	M
	ET_7	Environmental elaboration outputs – spatial resolution	P	M
Post-Elaboration Task	PostET_1	Elaboration outputs post-validation	F	M

	PostET_2	On-demand routines management	F	M
	PostET_3	Eco-friendly traffic policies actuation capability	F	M
	PostET_4	Traffic lights center warnings visualization	F	M
	PostET_5	Graphical operator interface	N-F	M
Data center dispatcher	DCD_1	Front-ends request gathering and translation	F	M
	DCD_2	Queries results delivery	F	M
	DCD_3	Architecture hiding	N-F	M
	DCD_4	Multiple front-ends connections support	P	M
Front-ends layer	FEL_1	Output information delivery requests	F	M
	FEL_2	Front-ends isolation	F	M
	FEL_3	Incoming requests pre-validation	F	M
	FEL_4	Front-end requests forwarding service	F	M
	FEL_5	Front-end output information forwarding service	F	M
	FEL_6	Clients request management	N-F	M
	FEL_7	Security management	N-F	M
	FEL_8	Authentication capability	N-F	M
	FEL_9	Client identification	N-F	S
	FEL_10	Client interoperability	I	M
	FEL_11	Scalability	P	M
	FEL_12	Elaboration time	P	M
3rd_parties front-end	3PCF_1	Information type	F	M
	3PCF_2	Standard communication protocols	N-F	M
	3PCF_3	Distribution license	N-F	M
	3PCF_4	Client identification	N-F	M
	3PCF_5	Log records storage	N-F	S
Variable message signs Front-end	VMSF_1	VMSs connection	F	M
	VMSF_2	VMSs messages forwarding service	F	M
	VMSF_3	VMSs maintenance support	F	M
	VMSF_4	Standard communication protocol	N-F	S
	VMSF_5	VMSs information management	N-F	S
Traffic lights center front-end	TLCF_1	Traffic lights dynamic regulation forwarding service	F	M
	TLCF_2	Traffic lights center warnings management	F	M
	TLCF_3	Traffic lights regulation data packet format	F	M
	TLCF_4	Traffic lights centre acknowledgments management	F	S
	TLCF_5	Standard communication protocol	N-F	S
	TLCF_6	Traffic lights information management	N-F	S
Public broadcast channels front-end	PBCF_1	Information type	F	M
	PBCF_2	Information formatting and forwarding service	F	M
	PBCF_3	Broadcast transmission communication	F	M

Public IP channels front-end		technology independency		
	PBCF_4	Standard communication protocols	N-F	M
	PICF_1	Data and information type	F	M
	PICF_2	Data and information formatting and forwarding service	F	M
	PICF_3	Exploitation opportunities	F	M
	PICF_4	Standard communication protocols	N-F	M
	PICF_5	Open data distribution license	N-F	M

Table 1: Supervisor Centre requirement list table.

Components	ID	Name	Type	Priority
On-board telematic unit	OBU_1	Computing capacity	F	M
	OBU_2	Storage capacity	P	M
	OBU_3	Storage capacity (optional)	P	C
Communication unit	CU_1	Communication technology	NF	M
	CU_2	Communication protocols	NF	M
	CU_3	Communication load	P	M
HMI	HMI_1	HMI - Information content	F	M
	HMI_2	GUI - Information content	F	C
On-board traffic monitoring unit	OBTU_1	Kinematic sensors	F	M
	OBTU_2	Kinematic sensors plus	F	M
	OBTU_3	Kinematic sensor quality	F	S
On-board traffic environmental unit	OBEU_1	Environmental sensors	F	M
	OBEU_2	Meteorological sensors	F	M
	OBEU_3	Environmental sensors plus	F	C
	OBEU_4	Environmental sensor quality	F	S

Table 2: Mobile system requirements list table.

Given this statement, the verification process does not include only the **compliancy with the original set of requirements**, which includes if needed a justification for specific implementation choices does not matching 1:1 the list of requirements, for non-crucial implementation activities postponed after the project's end.

In the original planning of the proposal, the Test site (Task 5.2) must be divided in two parts:

1. validation of INTEGREEN system as a whole in the perspective of an overall measurement system capable to detect on a real-time and distributed basis the traffic and environmental conditions in the city;

2. evaluation of the environmental gain associated to identified INTEGREEN use case scenarios.

The first point must be covered in this verification process as well, and must be analyzed in the output of Task 5.1 as well (D.5.1.1 [2]). This part of the verification activities can be carried out by properly checking the level of accuracy of the outputs of the central elaboration tasks specified in D.3.1.1 [7], as illustrated in Figure 6.

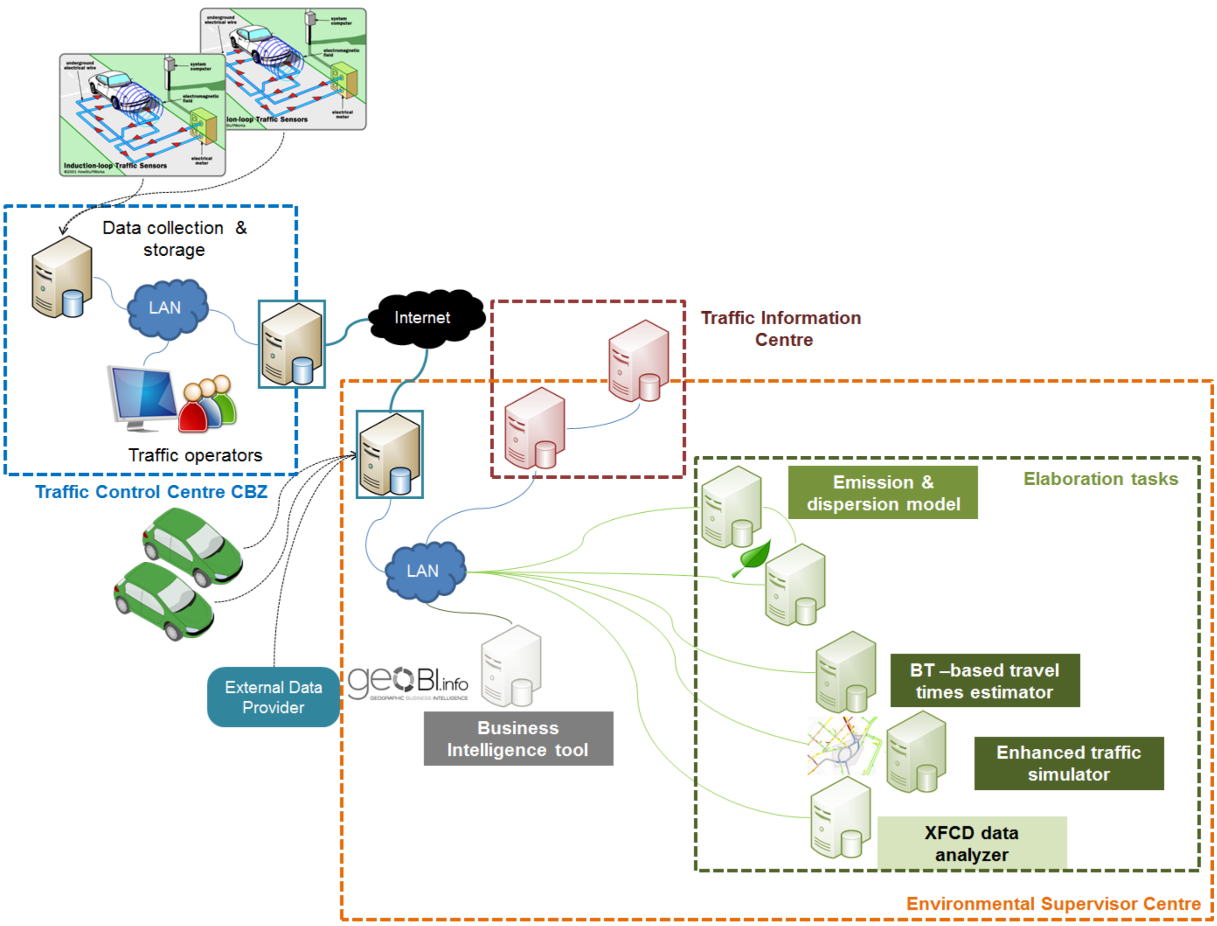

Figure 6: The elaboration tasks included in the INTEGREEN Supervisor Centre [7].

The instructions for the verification of the INTEGREEN system capabilities are summarized in Table 3.

Elaboration task	Verification approach
Emission and dispersion model	**Emission model**: traffic inputs must be validated (see traffic model). **Dispersion model**: information must be consistent with outputs from XFCD data analyzer and above all with reference values given by reference fixed (calibrated) air pollution stations.
BT-based travel times estimator	Empirical travel times must be compatible with one can typically experience on the road stretches considered. An added value for that could be the comparison with travel times measured by the mobile system or an equivalent system recording GPS positions.
Traffic model	Traffic information (number of vehicles / speed) on specific archs of the road network must be compared with information gathered by traffic stations and Bluetooth detectors. In case traffic volumes are estimated on top of Bluetooth detections, this must be validated through specific comparison analysis with traffic stations data.
XFCD data analyzer	The air pollutant map will be validated on top of the

	measures given by the fixed air pollution stations.

Table 3: Reference methodology for the validation of the INTEGREEN system in terms of overall traffic / air pollution measurement system.

3.2 Test bed process

This part of the testing and validation of INTEGREEN aims to cover the above point 2., i.e. the 2.evaluation of the environmental gain associated to identified INTEGREEN use case scenarios. This is the phase in which the **FESTA methodology** is directly applied. The workflow which is considered is the following:

- re-evaluation of the use cases defined during the requirements process of INTEGREEN (Action n.2);
- functions identifications;
- “pilot” use cases and scenarios selection (including eco-friendly traffic policies);
- identification of research questions;
- creation of hypothesis;
- creation of link with performance indicators.

3.2.1 Step 1: original INTEGREEN use cases analysis

The full list of use case analyzed during the requirements process is reported in Table 4.

ID	Use case	Trip phase	Reference User
UC_1	**Local travelers getting information for an eco-trip**	Pre-trip	Local travelers
UC_2	**Local fleet managers getting information for an eco-trip**	Pre-trip	Local transport planners
UC_3	**En-route driver information through VMS**	En-route	Local travelers
UC_4	**En-route driver information on-board demonstrator**	En-route	Mobile probes drivers
UC_5	**Traffic and environmental status assessment: INTEGRATED MONITORING**	Pre-trip / En-route	Traffic officers / engineers
UC_6	**Traffic controllers adaptive coordination: ACTUATION**	Pre-trip / En-route	Traffic officers / engineers

Table 4: Full set of INTEGREEN use cases [6].

Each use case is associated to a specific number of use scenarios, namely:

UC_1: Local travelers getting information for an eco-trip

- **UC_1.1**: travelers optimizing route plan based on traffic jams and/or pollution peaks
- **UC_1.2**: travelers optimizing travel plans in the time domain
- **UC_1.3**: travelers optimizing travel plan by means of efficient multi-modal choices

UC_2: Local fleet managers getting information for an eco-trip

- **UC_2.1**: local freight transport services managers optimizing travel plan based on traffic jams and/or pollution peaks
- **UC_2.2**: local public transport services managers optimizing transport services based on typical traffic and air pollution patterns

UC_3: **En-route driver information through VMS**

- **UC_3.1**: drivers change planned route based on a sudden air pollution peak displayed on a VMS
- **UC_3.2**: drivers change planned trip (i.e. change transport mode) based on a sudden traffic jam displayed on a VMS
- **UC_3.3**: drivers optimize their speed when intersecting a traffic light in order to take the green phase

UC_4: En-route driver information on-board demonstrator

- **UC_4.1**: bus drivers optimize transport service en-route based on the individual information received by the Supervisor Centre
- **UC_4.2**: taxi drivers optimize transport service en-route based on the individual information received by the Supervisor Centre
- **UC_4.3**: car sharing drivers optimize their route plans based on the individual information received by the Supervisor Centre

UC_5: Traffic and environmental status assessment: INTEGRATED MONITORING

- **UC_5.1**: monitoring actors providing real-time data about traffic and/or air pollution conditions;
- **UC_5.2**: traffic officers evaluating current traffic and air pollution conditions;
    - **T1: Traffic state estimation**. Traffic data acquired by static traffic detectors

and mobile probes are combined together in order to determine a real-time estimation of the traffic conditions in the urban area of interest.

- **T2: Estimation of emissions caused by motorized individual transport**. Traffic data will be even used in order to determine an estimation of the air pollutants emissions produced by traffic in the city.

- **T3: Air quality estimation**. Air pollution data acquired by static air pollution detectors and mobile probes are used within the Supervisor Centre in order to calibrate a dispersion model, which is fed by the estimated emissions, the surrounding conditions data (e.g. meteorological conditions) and eventually by other third parties data (e.g. emissions produced by other sources not related to traffic) in order to create air pollution concentration maps.

- **UC_5.3**: traffic officers coordinating info-mobility channels information

UC_6: Traffic controllers adaptive coordination: ACTUATION

- **UC_6.1**: traffic officers actuating changes in traffic lights cycles;

- **UC_6.2**: traffic officers actuating changes in speed limits;

- **UC_6.3**: traffic officers actuating temporary changes in the road network use.

Please note that UC_5.1 is actually covered by the validation of the INTEGREEN system explained before.

3.2.2 Step 2: INTEGREEN functions selection

The definition of functions has been slightly extended so that there is the possibility to include the evaluation of specific actions carried out by the traffic operators, i.e. the introduction of eco-friendly traffic policies. The focus is however on the end-users applications developed in the project, as reported in Table 5.

Function ID	Description
F1	End-users applications: BZBus, BZTraffic (and BZParking)[2]
F2	Traffic officer application: BZAnalytics
F3	Traffic / air pollution information on VMS
F4	Eco-friendly policies (speed detectors, traffic lights cycles, end-users application launch)

Table 5: List of INTEGREEN functions.

[2] Despite the BZParking has been developed in the scope of another complementary project, the evaluation takes in consideration this function as well since it can cover a certain number of interesting use scenarios.

3.2.3 Step 3: Definition of INTEGREEN "pilot use cases"

Functions are INTEGREEN outputs that are clearly matched to original use scenarios, as indicated in Table 6.

Function ID	"Original" use cases
F1	UC_1.1, UC_1.2, UC_1.3, UC_2.2, UC_4.3
F2	UC_5.2
F3	UC_3.1, UC_3.2, UC_3.3
F4	UC_6.1, UC_6.2, UC_6.3

Table 6: Association INTEGREEN functions – original use scenarios.

The functions will be however evaluated with reference a set of "pilot use cases and scenarios", which have as a common denominator the urban road network of Bolzano and more in particular the road stretches monitored by the fixed monitoring system of INTEGREEN. Pilot use cases 1, 2, 3 and 4 can have both a non-naturalistic and a naturalistic dimension, while the pilot use case 5 is naturalistic only. It is important to underline that pilot use case n.5 is by definition a use case, but is treated as such. The non-naturalistic approach is however preferred for the four pilot use cases, since the purpose of this FOT is to analyze the maximum potential environmental improvements that can be obtained on top of the INTEGREEN system. Non-naturalistic analysis can therefore produce more scientific and useful results.

Pilot Use Case 1: Local citizen wanting to improve his/her travel / routing plan for an internal O/D trip based on real-time conditions offered by BZBus / BZParking / BZTraffic applications.

Situations covered:

- **Trip origin**: industrial zone / city periphery;
- **Trip destination**: historical city centre;
- **Period**: working days while schools are open. The period in which the Christmas market is open has not to be considered.

The full set of use scenarios to be considered is presented in Table 7. The two dimensions of improvements to be considered are **trip improvement** (routing plan adaptation, which can take place in time or space), and **modal improvement** (which takes in consideration to take a bicycle or a bus instead than a car). Since meteorological conditions have a strong influence of the reference conditions, two target situations must be evaluated: **rainy days** with heavy traffic and **non-rainy days** with normal traffic conditions.

ID	Weather / traffic	Trip / routing improvement
US_1.1	Rainy day with heavy traffic	Trip improvement (routing plan adaptation)
US_1.2	Non-rainy day with normal traffic conditions	Trip improvement (routing plan adaptation)
US_1.3	Rainy day with heavy traffic	Modal improvement (bus is preferred to car)
US_1.4	Non-rainy day with normal traffic conditions	Modal improvement (bicycle is preferred to car)

Table 7: List of pilot use scenarios associated to pilot use case 1.

<u>Pilot Use Case 2</u>: Tourists wanting to reach Bolzano's historical city centre improving their travel plans towards sustainable multi-modal options based on real-time conditions offered by BZBus / BZParking / BZTraffic application.

<u>Situations covered</u>:

- **Trip origin**: outside the city of Bolzano (external centroid);
- **Trip destination**: historical city centre;
- **Period**: with / without presence of Christmas market.

The full set of use scenarios to be considered is presented in Table 8***Table 7***. The trip improvements to be considered with respect to the reference car trip are represented by two viable options that tourists can already consider instead of reaching by car the city centre:

- arrival by train at Bolzano South rail station, and last mile by bus;
- arrival by car at Fiera Parking, and last mile by bus.

Since meteorological conditions have a strong influence of the tourist demand, the above target situations (rainy / non rainy conditions) are evaluated.

ID	Weather	Period	Trip improvement
US_2.1	No-precipitation weather conditions	Non-Christmas market	Arrival by train at Bolzano South rail station and last mile by bus
US_2.2	No-precipitation weather conditions	Non-Christmas market	Arrival by car at Fiera Parking rail station and last mile by bus
US_2.3	Bad weather conditions	Non-Christmas	Arrival by train at Bolzano South rail

	(heavy rain / snow)	market	station and last mile by bus
US_2.4	Bad weather conditions (heavy rain / snow)	Non-Christmas market	Arrival by car at Fiera Parking rail station and last mile by bus
US_2.5	No-precipitation weather conditions	Christmas market	Arrival by train at Bolzano South rail station and last mile by bus
US_2.6	No-precipitation weather conditions	Christmas market	Arrival by car at Fiera Parking rail station and last mile by bus
US_2.7	Bad weather conditions (heavy rain / snow)	Christmas market	Arrival by train at Bolzano South rail station and last mile by bus
US_2.8	Bad weather conditions (heavy rain / snow)	Christmas market	Arrival by car at Fiera Parking rail station and last mile by bus

Table 8: List of pilot use scenarios associated to pilot use case 2.

Pilot Use Case 3: Commuters entering into the city on a daily basis improving his/her travel plan in the time domain thanks to the support offered by the BZTraffic application.

Situations covered:

- **Trip origin**: outside the city of Bolzano (external centroid);
- **Trip destination**: inside the city (but route must include Druso Street access gate);
- **Period**: with / without presence of Christmas market (working days).

The full set of use scenarios to be considered is presented in Table 9***Table 7***. In this pilot use case, the only trip improvement considered is in the temporal planning of a car trip. Since meteorological conditions have a strong influence of the amount of people deciding to switch transport mode, the above target situations (rainy / non rainy conditions) are evaluated even for this pilot use case.

ID	Weather	Period
US_3.1	No-precipitation weather conditions	Non-Christmas market
US_3.2	Bad weather conditions (heavy rain / snow)	Non-Christmas market
US_3.3	No-precipitation weather conditions	Christmas market
US_3.4	Bad weather conditions (heavy rain / snow)	Christmas market

Table 9: List of pilot use scenarios associated to pilot use case 3.

<u>Pilot Use Case 4</u>: Traffic officers making a quantitative and "real-time" evaluation of traffic and air quality conditions in the city (including emissions).

<u>Situations covered</u>:

- **traffic conditions**: normal / traffic jams;
- **air quality conditions**: normal / air pollution peaks.

For this pilot use case, the objective is to evaluate the capability of traffic officers to evaluate different traffic and quality conditions, as summarized in Table 10.

ID	Traffic conditions	Air quality conditions
US_4.1	Normal traffic conditions (no traffic jams)	Normal air quality conditions (no air pollution peak)
US_4.2	Traffic jams	Normal air quality conditions (no air pollution peak)
US_4.3	Normal traffic conditions (no traffic jams)	Air pollution peak

Table 10: List of pilot use scenarios associated to pilot use case 4.

<u>Pilot Use Case 5</u>: Traffic officers introducing eco-friendly traffic policies in the real road environment of the city of Bolzano

The list of eco-friendly traffic policies which are going to be tested are summarized in Table 11. The location, scope and duration of the policies strongly must take in consideration the limitations of daily activities of traffic operators and the political inputs.

ID	Traffic conditions
EP_1	Introduction of speed detection enforcement systems
EP_2	Changes in the traffic light phases
EP_3	End-users applications public available
EP_4	Enhanced VMS messages based on analytics engine
EP_5	Public transportation eco-drivers on SASA buses

Table 11: List of eco-friendly traffic policies associated to pilot use case 5.

3.2.4 Step 4: INTEGREEN research questions consolidation

In terms of research questions, the focus of the INTEGREEN FOT is on the impacts of system usage and the implications of measured impacts, as summarized in Table 12. Listed impacts have been completed with the impact related to daily activities of traffic operators.

Research questions category	Type of impact	Research question
Impacts on system usage	Impact on **personal mobility**	What is the impact on **modal split**?
	Impact on **traffic efficiency**	What is the impact on **traffic flow parameters** (speed, travel times, volumes)?
	Impact on **environment**	What is the impact on the **emissions** of air pollutants / greenhouse gases and on the levels of **air pollutants concentrations**?
	Impact on **traffic operators daily activities**	What is **time to reaction** after an extraordinary environmental event? What is the **ability to prevent** critical conditions? What can the **update times for traffic and ecology plans**?
Implications of measured impacts	Implications on **policy**	Which **eco-policies** is the Municipality of Bolzano now in the condition to introduce?
	Implications for **business models**	What are the predictions for **system uptake**, not only at local level?
	Implications for **system design and development**	What is the **HMI usability** of end-users applications? What is the **perceived value** of these new advanced services? Would be they willing to pay for something?

Table 12: List of research questions associated to INTEGREEN FOT.

3.2.5 Step 5: INTEGREEN hypothesis definition

Pilot use cases have a different scope and a different level of demonstration, so the hypothesis associated cover a different number of research questions. In particular, the last pilot use case associated with the real-life introduction of the eco-friendly policies is the only one which is evaluated in terms of implications of measured impacts as well. For the other pilot use cases, which have more the intention to demonstrate the potential environmental gain, a selection of the research questions associated to the impacts on system usage is made.

For **pilot use case 1**, the aim is to demonstrate that the end-users applications can determine a reduction of car travel times or trip duration (in case of mode change). In the first case, a reduction in terms of CO_2 emissions is also important.

ID	Description	Hypothesis
US_1.1	Routing improvement during rainy days with heavy traffic	Travel times improved up to 30%. CO_2 emissions reduced up to 20%.
US_1.2	Routing improvement during normal days with normal traffic	Travel times improved up to 15%. CO_2 emissions reduced up to 10%.
US_1.3	Modal improvement during rainy days with heavy traffic (bus)	Trip duration by bus is lower than trip duration by car[3]
US_1.4	Modal improvement during normal days with normal traffic (bicycle)	Trip duration by e-bicycle is lower than trip duration by car[4]

Table 13: Hypothesis associated to scenarios associated to pilot use case 1.

For **pilot use case 2**, the aim is to demonstrate that the end-users applications can guarantee the same trip duration in case of “normal conditions” and an improvement during “abnormal conditions” (bad weather, city events) even if they don’t use the private car (in part or at all).

ID	Description	Hypothesis
US_2.1	Tourists arriving in Bolzano by train + bus, no Christmas market period, good weather	Travel time by train + bus is comparable to the travel time of an entire car trip.
US_2.2	Tourists arriving in Bolzano by car + bus, no Christmas market period, good weather	Travel time by car + bus is comparable to the travel time of an entire car trip.
US_2.3	Tourists arriving in Bolzano by train + bus, no Christmas market period, bad weather	Travel times improved up to 15%.
US_2.4	Tourists arriving in Bolzano by car + bus, no Christmas market period, bad weather	Travel times improved up to 10%.
US_2.5	Tourists arriving in Bolzano by train + bus, Christmas market period, good weather	Travel times improved up to 20%.
US_2.6	Tourists arriving in Bolzano by car + bus, Christmas market period, good weather	Travel times improved up to 10%.

[3] Trip by car includes parking time as well. Destination point should be place within the historical city centre of Bolzano which is limited to vehicular traffic.
[4] Electric bicycles are only considered for the validation of this use case.

US_2.7	Tourists arriving in Bolzano by train + bus, Christmas market period, bad weather	Travel times improved up to 30%.
US_2.8	Tourists arriving in Bolzano by car + bus, Christmas market period, bad weather	Travel times improved up to 20%.

Table 14: Hypothesis associated to scenarios associated to pilot use case 2.

For **pilot use case 3**, the aim is to demonstrate that the end-users applications can guarantee an improvement in the trip duration (and CO_2 emissions) of commuters planning to enter in the city. This improvement is associated to a smarter selection of the time window in which the access to the city is carried out.

ID	**Description**	**Hypothesis**
US_3.1	Commuters entering into the city, no Christmas market period, good weather	Travel times improved up to 15%. CO_2 emissions reduced up to 10%.
US_3.2	Commuters entering into the city, no Christmas market period, bad weather	Travel times improved up to 30%. CO_2 emissions reduced up to 20%.
US_3.3	Commuters entering into the city, Christmas market period, good weather	Travel times improved up to 15%. CO_2 emissions reduced up to 10%.
US_3.4	Commuters entering into the city, Christmas market period, bad weather	Travel times improved up to 35%. CO_2 emissions reduced up to 25%.

Table 15: Hypothesis associated to scenarios associated to pilot use case 3.

For **pilot use case 4**, the purpose is slightly different, since the target is to demonstrate the operational added value that the data mining tool offered through the BZAnalytics application is in the condition to give to traffic operators. This can be mainly summarized as (i) the potential to know traffic and air quality conditions in a combined way and with a very frequent update time, (ii) the possibility to detect in advance traffic jam situations, and (iii) the possibility to discover air pollution hotspots caused by urban traffic.

ID	**Description**	**Hypothesis**
US_4.1	Traffic officer controlling traffic / air quality levels in normal traffic / air quality conditions	Traffic officer can take under control traffic / air quality conditions with an update time lower than 15 [minutes]
US_4.2	Traffic officer controlling traffic / air quality levels in traffic jam conditions	The ability of traffic officer to anticipate traffic jam conditions is increased up to 30%, i.e. in 30% of traffic jams situations traffic officers are able to identify an abnormal travel time pattern.

US_4.3	Traffic officer controlling traffic / air quality levels in air pollution peak conditions	Traffic officer are able to detect air pollution hotspots associated to urban traffic, and manage traffic as a consequence of this information.

Table 16: Hypothesis associated to scenarios associated to pilot use case 4.

For **pilot use case 5**, the purpose is to measure the impact of the application of the five **eco-policies** which are proposed in the project. The expected impact on environment refers directly to the initial hypothesis done at the proposal stage: **the overall gain is estimated in the order of 30% of reduction of CO_2 emissions**. The combination of the different factors will however not bring the linear combination of the single expected gains, so in practice the reduction will be probably lower than this upper bound.

ID	Description	Hypothesis
Eco-policy 1	Speed detectors installed in Druso Street	Vehicular travel times are reduced up to 5%, CO_2 emissions up to 10%, and pollutants levels up to 3%. Pilot results will lead the Municipality of Bolzano to better understand how to best use this measure.
Eco-policy 2	Traffic light phases adapted in Druso / Resia Streets	Vehicular travel times are reduced as a whole within the affected roads up to 15%, CO_2 emissions up to 8%, and pollutants levels up to 1-2%. Pilot results will lead the Municipality of Bolzano to better understand how to best use this measure.
Eco-policy 3	End-users apps public launched	End-users apps determine an increase in the public transport modal share of up 3%. Vehicular travel times are reduced as a whole within the affected roads up to 10%, CO_2 emissions up to 5% and pollutants levels up to 1-2%. The majority of users (at least 70%) consider usability of the applications as "high", while it is expected to have a non-negligible share of users (at least 30%) revealing to be willing even to pay a little fee for certain RTTI services.
Eco-policy 4	Enhanced VMS messages by traffic operators (through BZAnalytics)	Travel times and traffic volumes are reduced up to 15%, air pollution levels are decreased up to 2-3%. Traffic operators confirm the added value estimated in pilot use case 4.
Eco-policy 5	PT eco-drivers	The contribution on air pollution levels is up to 5%. Fleet managers involved (SASA and Car Sharing South Tyrol) provide useful insights for large scale mobile system uptake.

Table 17: Hypothesis associated to scenarios associated to pilot use case 5.

3.2.6 Step 6: INTEGREEN performance indicators selection

Based on the performance indicators suggested by FESTA, the proposal is to focus on the impacts areas indicated in Table 18. It is very important to underline that most of the performance indicators will be measured through the INTEGREEN system, which probably represent the main added value of the project on top of which future advanced applications and policies can be implemented.

Performance indicator category	Performance indicator	INTEGREEN measure
Environment	Air pollutants and greenhouse gases emissions	Emission model
	Air pollutants dispersion	Dispersion model
	Air pollutant concentrations	Fixed and mobile air pollution monitoring system
	Fuel consumption	Mobile monitoring system
Traffic efficiency	Speed / travel times / traffic volumes	Bluetooth and traffic measurement detectors
Acceptance and trust	Usefulness, perceived consequences, motivation, social impacts, usability	User questionnaire
	observed rate of use	Number of accesses to end-users applications

Table 18: List of research questions associated to INTEGREEN FOT.

3.3 Test Bed Plan

The proposed plan for the execution of the Test Bed activities is reported in Figure 7.

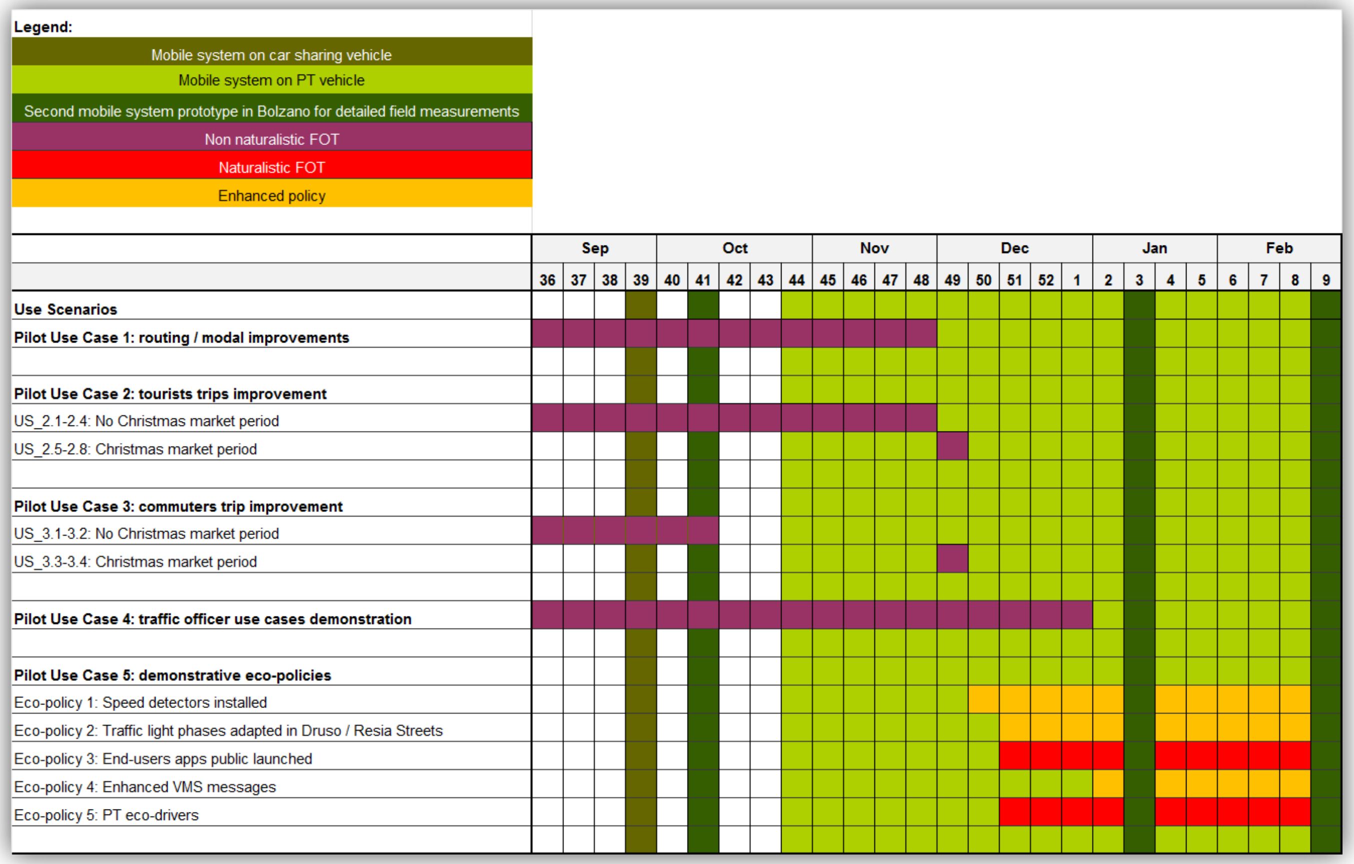

Figure 7: The reference Gantt diagram for the Field Operational Tests.

The plan is to dedicate the first part of the Test Bed activities to the evaluation of the first four pilot use cases, to be investigated with a non-naturalistic approach. The last part of the evaluation activities will cover the assessment of the eco-friendly traffic policy, whose impact will necessarily cumulatively calculated, since the eco-friendly traffic policies will be introduced one after the other. Field operational activities will also benefit of the long-term deployment of the mobile system on a public transportation vehicle. Exceptional measurements will be carried out with the second mobile system prototype, linked to the presence of partner AIT in Bolzano.

Conclusions

This report contains a detailed plan on how testing activities of INTEGREEN will be carried out in the scope of Action n.5 (Test & Validation). In order to guarantee a reference with international standardized approaches, the document contains a brief presentation of the **FESTA methodology**, the reference method in Europe for Field Operational Tests of ITS systems. FESTA is particularly suited for real-life testing of in-vehicle applications and cooperative systems, but can be generalized also to nomadic services and other functions.

The **functions** which will be tested in INTEGREEN are the **end-users applications** (including the one destined to traffic operators), as well as the **eco-friendly policies** which will initially be investigated on top of the INTEGREEN demonstrative system.

Eco-friendly policies chosen include **speed detectors**, **adaptation of the traffic lights cycles**, **use of VMS message** as well the **public launch of the end-users applications** destined to local travelers. Selected performance indicators, linked to specific research questions, will be quantified thanks to the INTEGREEN monitoring system, and in particular on top of the mobile system, the emission and dispersion model and the Bluetooth travel times monitoring system.

The Test Bed activities are organized in **two phases**: in the first one the **pilot use cases** will be evaluated through a **non-naturalistic approach**, with the purpose of identifying the potential environmental gain associated to the end-users applications; in the second phase, the purpose is to empirically **measure the impact associated to the introduction of the eco-friendly traffic policies**.

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