LIFE+10 ENV/IT/000389

INTEGREEN

Action 5: Testing & Validation

D.5.1.1

On-board modules and Supervisor Centre test results

Project Coordinating Beneficiary	Municipality of Bolzano
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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).

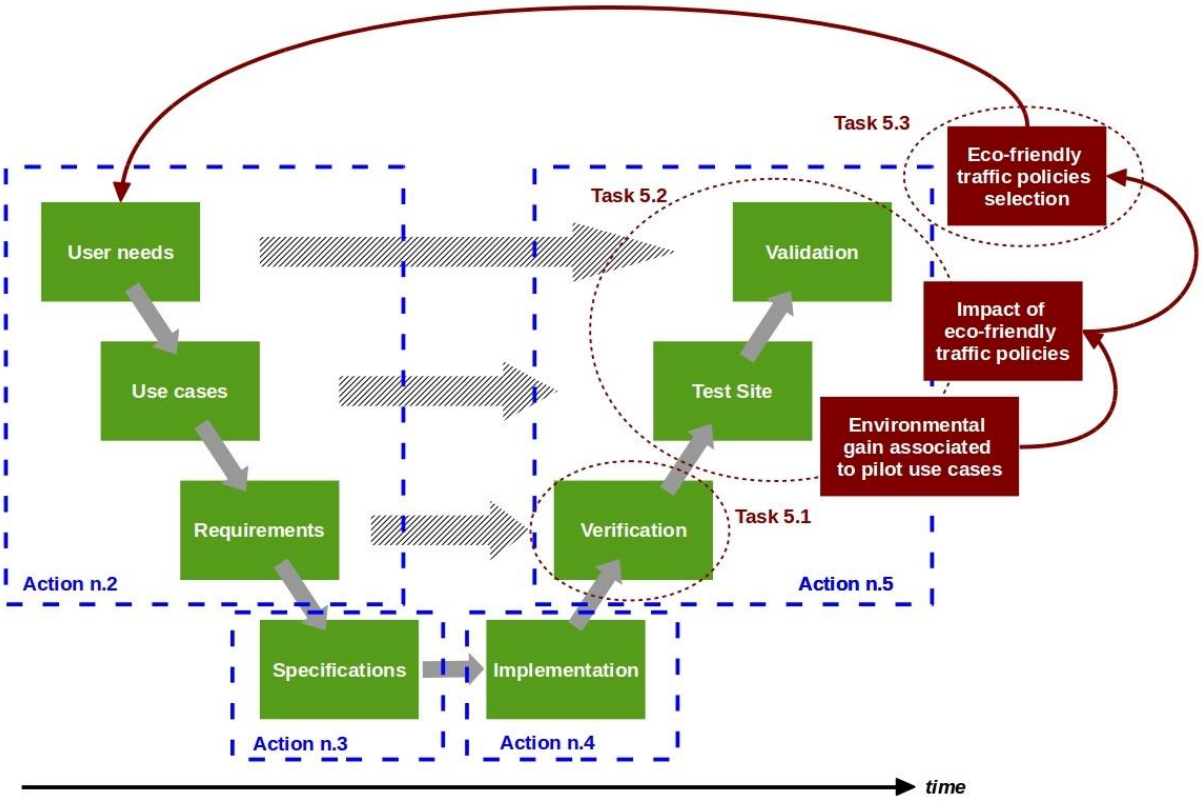

Figure 1: The V-model methodology followed in the technical implementation of the project and a graphical presentation of Action n.5 activities.

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 present the results of the verification activities on the system components, according to the list of requirements defined in Action n.2 [1] - [2]. 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, in which the organization of the following Test Bed plan activities is discussed [3], D.5.2.2., in which the results of the test and validation activities are illustrated [4], 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 [5].

The “verification” process is the first part of the final test and validation activities. Functional and non-functional requirements are evaluated in detail on top of the template table presented in Table 1.

ID	taken from requirements’ list
Name	taken from requirements’ list
Description	taken from requirements’ list
Type	taken from requirements’ list
Priority	taken from requirements’ list
Verification analysis	*A short comment whether the requirement has been fulfilled or not.*
Reference prototype deliverable	*Reference to the prototype deliverable in which the discussed implemented component is presented*

Verification result	*REQ. FULFILLED / PARTIALLY FULLFILLED / NOT FULLFILLED*
Relevancy of issue	*NONE / MINOR / MAJOR*

Table 1: Requirements' verification table template.

The content of each requirement is synthetically reported, and analyzed by means of four additional fields:

- **verification analysis**: a qualitative evaluation about how this requirement has been fulfilled, including explanations of relevant deviations during the implementation process;
- **reference prototype deliverable**: the indication of the prototype deliverable (if any) in which a careful reader can find more details related to the proper fulfillment of this requirement;
- **verification result**: it reports a final evaluation of whether the considered requirement has been fulfilled or not. Three different levels are considered:
    - "**fulfilled**", if the implementation verifies 100% the results of the requirements' analysis;
    - "**partially fulfilled**", if the implementation has addressed only in part the need considered in the requirement;
    - "**not fulfilled**", if the implementation has not verified the requirement.
- **relevancy of issue**: it indicates a level of relevancy of a possible technical issue related to the eventual not fulfillment of the requirement. Three different levels are considered:
    - "**none**", which is associated to the case of "fulfilled" requirement;
    - "**minor**", in case the issue is considered of small entity;
    - "**major**", in case the issue is considered of big entity.

  It is important to underline that it has not to be excluded the combination "not fulfilled"-"minor", or "partially-fullfilled"-"major", since requirements have a different level of importance with respect to the main objectives of the targeted implementation.

1.2 Document structure

This deliverable is structured as follows. In Chapter 2 the verification of the requirements of the different layers of the Supervisor Centre (data center, data source and front-end) is evaluated. Chapter 3 discusses the validation of the outputs of the elaboration tasks, with a particular focus on the Bluetooth-based travel times estimator and the emission and dispersion engine. Finally, in Chapter 4 the results of the final verification of the mobile system are presented.

2 Supervisor Centre components verification

In this paragraph, the requirements of the “core” layers of the Supervisor Centre are verified. The full list of requirements that are going to be discussed is reported for completeness sake in Table 2.

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
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 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 technology independency	F	M
	PBCF_4	Standard communication protocols	N-F	M
Public IP channels front-end	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 2: Summary of Supervisor Centre components' requirements.

All Supervisor Centre components must respond to a set of common requirements (SC_1-SC_4), which are verified first.

ID	SC_1
Name	System capability
Description	The Supervisor Centre must be able to (i) gather on a continuous temporal basis data of different nature concerning directly or indirectly with the

	present traffic and environmental conditions within the city of Bolzano, (ii) elaborate it automatically on a real-time basis (in correspondence of every data collection update), (iii) integrate the actuation inputs provided by the traffic control centre operators and (iv) properly coordinate the traffic control systems as well as the output information that feed the info-mobility channels for the end-users.
Type	Functional
Priority	Must
Verification analysis	The Supervisor Centre covers all expected abilities. The only exception if for point (iii), which has not been automated yet. During the design phase it has been decided to leave the actual systems managing actuation systems (traffic lights, VMS) out from this first Supervisor Centre implementation. This choice has however no impact on the possibility to implement the eco-friendly traffic policies.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 3: Verification of requirement SC_1 (system capability).

ID	SC_2
Name	Layer interoperability
Description	The components within any layer belonging to the SC must interact with the other layers through the layer interfaces by using well defined and documented services.
Type	Interface
Priority	Must
Verification analysis	Well defined and documented services are used for the communication between different layers. A common “library” has been developed so that similar components can use the same functions.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 4: Verification of requirement SC_2 (layer interoperability).

ID	SC_3
Name	Open data approach
Description	The Supervisor Centre architecture must follow the open data concept for exposing any general results (information, maps, reports, etc.) that is transferable to the end-user clients. The reference definition of open data is the one provided by a recent Italian national law, which states that[2] (i) the data are available under the terms of a license that allows everybody to use it, even for commercial purposes; (ii) the data are accessible through ICT systems and telematic networks, including the possibility for automatic use through specific software components; (iii) the data are published for free or at marginal costs caused by its reproduction and divulgation[3].
Type	Interface
Priority	Must
Verification analysis	The Supervisor Centre has been implemented according to the “open data” approach. All data and outputs are technically available to end-user clients through the front-end layer. A clear open data license has not been defined

[2] Decreto-legge 18/10/2012 “Ulteriori misure urgenti per la crescita del Paese”, article 9.
[3] Fees can be accepted only in exceptional cases under the approval of the Digital Italy Agency (Agenzia per l’Italia digitale).

	yet.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 5: Verification of requirement SC_3 (open data approach).

ID	SC_4
Name	Output delay
Description	The elaboration time of the system should be at maximum 5 minutes.
Type	Performance
Priority	Must
Verification analysis	This performance requirement is satisfied. The highest computation time is for the dispersion model, which takes some minutes to be completed. For the other elaborations, the time for computation is practically zero. From a computing point of view, there could be a further delay in the availability of the outputs due to the execution in series of all scheduled elaborations. This can be however improved in the future by planning more advanced computing logics.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 6: Verification of requirement SC_4 (output delay).

2.1 Data Center Layer

In this paragraph, requirements related to the data center layer and to its specific components (collector, database and dispatcher) are verified.

ID	DCL_1
Name	System capability
Description	The Data Center Layer (DCL) must be able to: • collect and store the generated data as well as the elaboration outputs and, where necessary, all relevant intermediate elaboration products; • coordinate the automatic data elaboration routines; • make validated data and elaboration outputs properly accessible at an upper layer.
Type	Functional
Priority	Must
Verification analysis	All these abilities have been implemented in the Data Center Layer.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 7: Verification of requirement DCL_1 (system capability).

ID	DCL_2
Name	Security control
Description	The Data Center Layer must present sufficient protection measures in order to prevent any kind of external attacks and thus maximize the overall

	security. In case of intrusion or other system violation, the Data Center Layer must be able to monitor and provide notifications to the authorized staff.
Type	Non-functional
Priority	Must
Verification analysis	At present, the Supervisor Centre is running inside a protected software environment hosted by TIS. Professional security measures are in place to prevent any kind of external attacks. In case of intrusion, the IT responsibles of TIS as well as the technical project staff maintaining the Supervisor Centre are automatically notified.
Reference prototype deliverable	-
Verification result	FULFILLED
Relevancy of issue	NONE

Table 8: Verification of requirement DCL_2 (security control).

ID	DCL_3
Name	Performance
Description	The Data Center Layer must be able to process all the received data in a "real time" mode, so that requirement SC_4 is properly satisfied.
Type	Performance
Priority	Must
Verification analysis	Elaborations are executed in "real-time", i.e. there is an automatic scheduler launching the different elaborations according to specific window observations of the input monitored data.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 9: Verification of requirement DCL_3 (performance).

ID	DCL_4
Name	Flexibility and scalability
Description	The Data Center Layer must be designed in a way such that a high degree of flexibility and scalability for matching present and future needs is possible.
Type	Performance
Priority	Must
Verification analysis	The Data Center Layer has been implemented in order to easily become a software environmental capable of managing big data. The database has been designed and implemented in a way so that it can be used with any type of data / elaborations.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 10: Verification of requirement DCL_4 (flexibility and scalability).

2.1.1 Data Center Collector

ID	DCCL_1
Name	Uniqueness
Description	The Data Center Collector must be the unique collection point for all data-

	sources.
Type	Functional
Priority	Must
Verification analysis	The Data Center Collector is the only component that has the privileges to write collected data in the database.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 11: Verification of requirement DCC_1 (uniqueness).

ID	DCCL_2
Name	Source and data-source identification
Description	The Data Center Collector must be able to identify the data-source which is providing the data and, based on requirement DSL_12, the specific source which has gathered it.
Type	Functional
Priority	Must
Verification analysis	The Data Center Collector recognized source and data-source, and stores the collected data in the database according to this identification information.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 12: Verification of requirement DCC_2 (source and data-source identification).

ID	DCCL_3
Name	Data type recognition
Description	The Data Center Collector must be able to identify the nature of the received data (i.e., environmental- or traffic related).
Type	Functional
Priority	Must
Verification analysis	The Data Center Collector associates data types to a specific source, and stores the collected data in the database according to this identification information.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 13: Verification of requirement DCC_3 (data type recognition).

ID	DCCL_4
Name	Database connection
Description	The Data Center Collector must be able to connect to the database and to store data on the base of its specifications.
Type	Functional
Priority	Must
Verification analysis	The Data Center Collector is connected to the database and stores the data according to its data model.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED

Relevancy of issue	NONE

Table 14: Verification of requirement DCC_4 (database connection).

ID	DCCL_5
Name	Authentication and security
Description	The Data Center Collector must authenticate itself to the database and execute the storing actions in a secure way
Type	Non-functional
Priority	Must
Verification analysis	No authentication functionalities have been implemented yet, since both Data Center Collector and database are executed on the same protected server environment. These functionalities will be needed to be implemented in case the components will need to pass over an unsecure channel (e.g. Internet).
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 15: Verification of requirement DCC_5 (authentication and security).

ID	DCCL_6
Name	Data-source authentication management
Description	The Data Center Collector must properly manage the authentication procedure with the underlying data-sources, in synergy with requirement DSL_9.
Type	Non-functional
Priority	Must
Verification analysis	The same considerations presented for requirement DCCL_5 apply also in this case.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 16: Verification of requirement DCC_6 (data-source authentication management).

ID	DCCL_7
Name	Multiple data-source connections support
Description	The Data Center Collector must have the capability to properly open and manage multiple connections with the underlying data sources. The presence of other open connections must be as much as transparent for a data-source, and not produce significant delays in the generated data transfer.
Type	Performance
Priority	Must
Verification analysis	The Data Center Collector can simultaneously manage multiple connections with the data sources.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 17: Verification of requirement DCC_7 (multiple data-source connections support).

2.1.2 Database

ID	DB_1
Name	GIS capability
Description	The Database must be spatial, i.e. able to store and handle geo-referenced data organized with complex data models
Type	Functional
Priority	Must
Verification analysis	The Database used is PostGIS, the spatial extension of PostgreSQL.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 18: Verification of requirement DB_1 (GIS capability).

ID	DB_2
Name	Generated data storing capability
Description	The Database must be able to store all data received by the Data Center Collector.
Type	Functional
Priority	Must
Verification analysis	The Database stores all data received by the Data Center Collector. Last data record is replicated in an additional table in order to speed up of the operations of real-time data publication.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 19: Verification of requirement DB_2 (generating data storing capability).

ID	DB_3
Name	Intermediate and final elaboration outputs storing capability
Description	The Database must be able to store all elaboration outputs, including where relevant the intermediate ones as well.
Type	Functional
Priority	Must
Verification analysis	The Database stores all elaboration outputs in different tables, separated from the ones used for the measured data. Even in this case, last elaboration output is replicated in an additional table in order to speed up of the operations of real-time elaborations publication.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 20: Verification of requirement DB_3 (intermediate and final elaboration outputs storing capability).

ID	DB_4
Name	History capability
Description	The Database must be able to efficiently store and manage the data and outputs history.
Type	Functional
Priority	Must

Verification analysis	Specific tables are used to manage data and elaboration history.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 21: Verification of requirement DB_4 (history capability).

ID	DB_5
Name	Standard logging and reports
Description	The Database should be able to log transactions and to generate standard reports.
Type	Functional
Priority	Should
Verification analysis	This functionality is an instrinsic ability of PostgreSQL.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 22: Verification of requirement DB_5 (standard logging and reports).

ID	DB_6
Name	Reliability, security and data incorruptibility capabilities
Description	The Database must be able to guarantee that storing and access activities are performed in a reliable and secure way, and that data are not corrupted over time.
Type	Non-functional
Priority	Must
Verification analysis	PostgreSQL guarantees high performances in terms of non-corruptibility of data
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 23: Verification of requirement DB_6 (reliability, security and data incorruptibility capabilities).

ID	DB_7
Name	Data export
Description	It must be able to dump a part or even the entire set of data stored in the Database
Type	Non-functional
Priority	Must
Verification analysis	This functionality is an instrinsic ability of PostgreSQL.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 24: Verification of requirement DB_7 (data export).

ID	DB_8
Name	Interfaces
Description	The Database must provide an external access via protocols and language bindings to the following components:

	• Data Center Collector; • Elaboration Tasks; • Data Center Dispatcher.
Type	Interface
Priority	Must
Verification analysis	The database has been designed and implemented so that only selected components can communicate with it.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 25: Verification of requirement DB_8 (interfaces).

ID	DB_9
Name	Performance
Description	The time needed by the Database in order to answer to entering queries must be negligible if compared to the total system elaboration time (ref. requirement SC_4) and must not be significantly influenced by: ● the number of parallel accesses opened by the single interface; ● the number of parallel accesses opened across several interfaces; ● the whole amount of different data.
Type	Performance
Priority	Must
Verification analysis	High performance of the automatic routines is guaranteed by the choice to store last data and elaboration records in separate tables.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 26: Verification of requirement DB_9 (performance).

2.1.3 Data Center Dispatcher

ID	DCD_1
Name	Front-ends request gathering and translation
Description	The Data Center Dispatcher must properly gather the requests coming from the front-ends and translate them into queries for the Database
Type	Functional
Priority	Must
Verification analysis	This is one of the main functionalities that the Data Center Dispatcher implements.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 27: Verification of requirement DCD_1 (front-ends request gathering and translation).

ID	DCD_2
Name	Queries results delivery
Description	The Data Center Dispatcher must forward the queries results generated by the Database to the front-end that has generated the request.
Type	Functional
Priority	Must

Verification analysis	This is one of the main functionalities that the Data Center Dispatcher implements.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 28: Verification of requirement DCD_2 (queries results delivery).

ID	DCD_3
Name	Architecture hiding
Description	The Data Center Dispatcher must hide the complexity of the architecture of the Data center layer, playing as the single point of access to the validated information base.
Type	Non-functional
Priority	Must
Verification analysis	The Data Center Dispatcher has been implemented exactly with the purpose to hide the complexity of the data center layer to the front-ends.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 29: Verification of requirement DCD_3 (architecture hiding).

ID	DCD_4
Name	Multiple front-ends connections support
Description	The Data Center Dispatcher must have the capability to properly open and manage multiple connections with the overlying front-ends. The presence of other open connections must be as much as transparent for a front-end, and not produce significant delays in the generated data transfer.
Type	Performance
Priority	Must
Verification analysis	This functionality is shared with the Data Center Collector.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 30: Verification of requirement DCD_4 (multiple front-ends connections support).

2.2 Data Source Layer

ID	DSL_1
Name	Data gathering
Description	Any data-source must be able to gather data only from one or more external sources which are in charge to collect corresponding field observations, depending on the monitoring application type.
Type	Functional
Priority	Must
Verification analysis	Data sources are responsible for specific data types with measurements obtained from specific monitoring stations.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 31: Verification of requirement DSL_1 (data gathering).

ID	DSL_2
Name	Data-source isolation
Description	Any data-source must be an independent entity with respect to the other data-sources and the data center collector.
Type	Functional
Priority	Must
Verification analysis	Data sources are isolated software components and don't have dependencies from the data center collector.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 32: Verification of requirement DSL_2 (data-source isolation).

ID	DSL_3
Name	Data pre-validation
Description	Any data received as input is dropped unless it follows the defined data type formats.
Type	Functional
Priority	Must
Verification analysis	Data sources implement automatic controls on the admitted data types, and drop data that are unproperly formatted.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 33: Verification of requirement DSL_3 (data pre-validation).

ID	DSL_4
Name	Data formatting control
Description	Any data-source must drop all received packets of data that are formatted in a different manner as expected.
Type	Functional
Priority	Must
Verification analysis	Data sources implement automatic controls on the expected data packets, and drop those that are unproperly formatted.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 34: Verification of requirement DSL_4 (data formatting control).

ID	DSL_5
Name	Data-source forwarding service
Description	Any data-source must forward all pre-validated generated data to the data center collector.
Type	Functional
Priority	Must
Verification analysis	Data sources forward pre-validated data to the Data Center Collector.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED

Relevancy of issue	NONE

Table 35: Verification of requirement DSL_5 (data-source forwarding service).

ID	DSL_6
Name	Source position
Description	Any data-source must be able to couple the generated data with the geographic position of the related source.
Type	Functional
Priority	Must
Verification analysis	This requirement has been implemented only for mobile probes. This information is available for all data sources only at the database side, where it is effectively necessary.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	NONE

Table 36: Verification of requirement DSL_6 (source position).

ID	DSL_7
Name	Source status and data consistency
Description	Whenever possible, the data gathered by the data-source should be marked with the current status of the source.
Type	Functional
Priority	Should
Verification analysis	When available, the information of the status of the source is included. This is true in particular for the parking DS.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 37: Verification of requirement DSL_7 (source status and data consistency).

ID	DSL_8
Name	Warning capability
Description	Any data-source should be able to generate a warning in case for example: • the source presents any kind of malfunctioning problems; • the data is inconsistent, not properly formatted and/or not pre-validated; • the client is not authorized.
Type	Functional
Priority	Should
Verification analysis	An automatic warning generation capability has been implemented by a certain number of data sources, in particular the vehicle DS and the O/D DS. Warning messages are delivered to the source in case something went wrong with the delivery of the data. The warning related to the malfunctioning of some sources is also managed through different automatic monitoring tools such as Ganglia and Nagios. In this case, notifications are delivered only to IT staff responsible for the maintenance of the Supervisor Centre.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	NONE

Table 38: Verification of requirement DSL_8 (warning capability).

ID	DSL_9
Name	Authentication capability
Description	Any data-source must be able to authenticate itself with the data center collector.
Type	Non-functional
Priority	Must
Verification analysis	No authentication functionalities have been implemented yet, since both Data Center Collector and data sources are executed on the same protected server environment. These functionalities will be needed to be implemented in case the components will need to pass over an unsecure channel (e.g. Internet).
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 39: Verification of requirement DSL_9 (authentication capability).

ID	DSL_10
Name	Source trustworthiness
Description	Any data-source must have the necessary capabilities in order to guarantee that the generated data are delivered by a trusted source.
Type	Non-functional
Priority	Must
Verification analysis	Data sources and sources are typically connected through web services and in some cases authentication procedures are implemented (e.g. environmental DS). In general, data source can gather data only from entities associated to authorized IP addresses, so the trustworthiness of sources is in general guaranteed.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 40: Verification of requirement DSL_10 (source trustworthiness).

ID	DSL_11
Name	Data timestamp
Description	Any generated data which is delivered to a data-source must be coupled with the timestamp of the monitoring instant.
Type	Non-functional
Priority	Must
Verification analysis	Data sources always couple data with the timestamp of the monitoring instant.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 41: Verification of requirement DSL_11 (data timestamp).

ID	DSL_12
Name	Source identification

Description	Any data-source must send to the data center collector the generated data coupled with the unique identity of the corresponding source.
Type	Non-functional
Priority	Must
Verification analysis	Data sources send to the data center collector the generated data coupled with the ID of corresponding source, so that a proper storage can be afterwards performed.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 42: Verification of requirement DSL_12 (source identification).

ID	DSL_13
Name	Source interoperability
Description	Any data-source must expose standard software and hardware interfaces, and must use well defined and documented protocols to gather the generated data from the related sources.
Type	Non-functional
Priority	Must
Verification analysis	Data sources and sources communicate on top of well-documented web-services using standard software communication languages.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 43: Verification of requirement DSL_13 (source interoperability).

ID	DSL_14
Name	Elaboration time
Description	The total amount of time which is needed by the data-source in order to (i) gather the generated data, (ii) perform the pre-validation controls and (iii) forward the pre-validated generated data to the upper layer has to be negligible with respect to the total elaboration time.
Type	Non-functional
Priority	Must
Verification analysis	The operation of the data sources are negligible if compared to the total elaboration time.
Reference prototype deliverable	P.4.1.2 / P.4.1.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 44: Verification of requirement DSL_14 (elaboration time).

2.2.1 Environment Station Data Source

ID	ESDS_1
Name	Data type – environmental parameters
Description	Each single generated data record must contain one value of air pollution concentration for each of the following pollutants: • CO • O_3 • NO_X

	• VOC • $PM_{2.5}$
Type	Functional
Priority	Must
Verification analysis	At present, the Environmental Station DS retrieves the official NO_2 air pollution concentrations measured by the air quality stations of the Province of Bolzano. A more comprehensive set of air pollution data (including meteorological parameters) is collected by the 3rd Parties DS, which implements the interface with the Traffic Control Centre of the city of Bolzano. For more information see the correspondent verification of the requirements for this component.
Reference prototype deliverable	P.4.1.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 45: Verification of requirement ESDS_1 (data type – environmental parameters).

ID	ESDS_2
Name	Data type - meteorological parameters
Description	Each single generated data record must contain one value for each of the following meteorological parameters: • temperature; • humidity; • speed and direction of the wind.
Type	Functional
Priority	Must
Verification analysis	Such additional meteorological parameters are currently not managed by the Environmental Station DS, in light of what has been illustrated for requirement ESDS_1.
Reference prototype deliverable	P.4.1.3
Verification result	NOT FULLFILLED
Relevancy of issue	MINOR

Table 46: Verification of requirement ESDS_2 (data type – meteorological parameters).

ID	ESDS_3
Name	Data type – environmental parameters (optional)
Description	Each record of generated data should contain values about the following air pollutants: • SO_2 • NO_2 • PM_{10} • BC
Type	Functional
Priority	Should
Verification analysis	Such additional environmental parameters are currently not managed by the Environmental Station DS, in light of what has been illustrated for requirement ESDS_1.
Reference prototype deliverable	P.4.1.3
Verification result	NOT FULLFILLED
Relevancy of issue	MINOR

Table 47: Verification of requirement ESDS_3 (data type – environmental parameters (optional)).

ID	ESDS_4
Name	Data frequency update
Description	The maximum time interval between two consecutive generated data packets delivered to the environmental station data-source must be 15 minutes.
Type	Performance
Priority	Must
Verification analysis	The interval between two consecutive generated data packets is 60 [minutes], which is equivalent to the frequency of official and validated air pollution measurements. The required frequency is however implemented for the air pollution data managed by the 3rd Parties DS.
Reference prototype deliverable	P.4.1.3
Verification result	NOT FULLFILLED
Relevancy of issue	MINOR

Table 48: Verification of requirement ESDS_4 (data frequency update).

2.2.2 Meteo Data Source

ID	MDS_1
Name	Data type
Description	Each single generated data record must contain one value for each of the following meteorological parameters: ● temperature; ● humidity; ● wind speed and direction; ● type, intensity and quantity of precipitation;
Type	Functional
Priority	Must
Verification analysis	The Meteo DS manages all data provided by the meteo station of the city of Bolzano managed by the Province of Bolzano. The data types covered are: • wind speed & direction and wind gust speed; • global radiation; • sunshine duration; • barometric pressure; • air temperature; • relative humidity; • precipitation amount. The only data which is missing is related to the type of precipitation, which however can be easily obtained by comparing precipitation with air temperatures.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 49: Verification of requirement MDS_1 (data type).

ID	MDS_2
Name	Data type (optional)
Description	Each record of generated data should contain the following additional fields with values covering the current state of: ● environmental pressure;

	• dew point; • solar irradiation.
Type	Functional
Priority	Must
Verification analysis	See verification of requirement MDS_1. The only data which is not available is dew point, which can be however estimated on top of air temperature and relative humidity.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 50: Verification of requirement MDS_2 (data type (optional)).

ID	MDS_3
Name	Data frequency update
Description	The maximum time interval between two consecutive generated data packets delivered to the meteo data-source must be 15 minutes.
Type	Functional
Priority	Must
Verification analysis	The time interval between two consecutive generated data packets is 5 minutes.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 51: Verification of requirement MDS_3 (data frequency update).

2.2.3 O/D Data Source

ID	ODDS_1
Name	Data type – raw generated data
Description	The O/D data-source must receive the raw generated data collected by a specific monitoring station of the O/D source, located at a specific point of the road network, i.e.: • the total number of vehicles recognized within the window observation; • a vehicle identifier which is anonymously associated to the number plate of each passing vehicle.
Type	Functional
Priority	Must
Verification analysis	The O/D data source collects only the vehicle detections, i.e. anonymous identifiers coupled with the Bluetooth device of the on-board unit. At present the data source does not manage data provided by ANPR systems, as originally planned. The total number of vehicles is not included, since it is calculated during the elaboration process.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 52: Verification of requirement ODDS_1 (data type – raw generated data).

ID	ODDS_2
Name	Data type – raw generated data (optional)

Description	The O/D data-source should optionally receive, as integration to the raw generated data collected by a specific monitoring station of the O/D source, a field which associates to each identified vehicle the corresponding vehicle category, based on the Italian 9+1 standard.
Type	Functional
Priority	Should
Verification analysis	The O/D data source at present only retrieves data from Bluetooth detectors. With this technology it is impossible to have a direct relationship with the vehicle type.
Reference prototype deliverable	P.4.1.3
Verification result	NOT FULLFILLED
Relevancy of issue	MINOR

Table 53: Verification of requirement ODDS_2 (data type – raw generated data (optional)).

ID	ODDS_3
Name	Data type – pre-elaborated generated data
Description	The O/D data-source should additionally receive the pre-elaborated generated data computed by the O/D front-end, i.e. for each O/D couple: • the total number of vehicles that have transited through these interest points; • a set of statistics concerning travel times.
Type	Functional
Priority	Should
Verification analysis	These elaborations are all made at the Supervisor Centre, in order to minimize the energy consumption and the complexity of the functionalities to be managed by the single detectors.
Reference prototype deliverable	P.4.1.1
Verification result	NOT FULLFILLED
Relevancy of issue	NONE

Table 54: Verification of requirement ODDS_3 (data type – pre-elaborated generated data).

ID	ODDS_4
Name	Pre-elaboration time interval
Description	The maximum time interval to be considered for the computation of pre-elaborated generated data must be defined according to the typical number of matches in the time unit for a specific O/D couple.
Type	Performance
Priority	Must
Verification analysis	The time interval for the computation of the travel times data is about 15 [minutes], which has revealed to be a good compromise in terms of minimum amount of matches that can provide a sufficiently accurate travel time data. Data are transmitted every 5 [minutes].
Reference prototype deliverable	P.4.1.1
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 55: Verification of requirement ODDS_4 (pre-elaboration time interval).

ID	ODDS_5
Name	Data frequency update
Description	The maximum time interval between two consecutive generated data

	packets delivered to the O/D data-source must be 5 minutes.
Type	Performance
Priority	Must
Verification analysis	The data frequency update has been set to 5 [minutes].
Reference prototype deliverable	P.4.1.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 56: Verification of requirement ODDS_5 (data frequency update).

2.2.4 Parking Data Source

ID	PDS_1
Name	Data type – generated data
Description	Each record of generated data must contain the number of free slots of a specific parking area.
Type	Functional
Priority	Must
Verification analysis	This requirement has been fully implemented. Every data record contains this information for all monitored parking areas.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 57: Verification of requirement PDS_1 (data type – generated data).

ID	PDS_2
Name	Data type – basic information
Description	The parking data-source must have basic information about the number of available slots that each controlled parking area can manage.
Type	Functional
Priority	Must
Verification analysis	The Traffic Control Centre of the Municipality of Bolzano exposes a method which retrieves this metadata as well. This information is controlled on a regularly basis (i.e. once every day).
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 58: Verification of requirement PDS_2 (data type – basic information).

ID	PDS_3
Name	Data frequency update
Description	The maximum time interval between two consecutive generated data packets delivered to the parking data-source must be 5 minutes.
Type	Performance
Priority	Must
Verification analysis	The real-time parking data are requested by the parking DS every 5 [minutes].
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 59: Verification of requirement PDS_2 (data frequency update).

2.2.5 3rd parties Data Source

ID	3PDS_1
Name	Data type
Description	Each single received data must be linkable to one of the following categories: • traffic; • parking; • air pollution / emissions; • general events; • roadworks: • accidents; • road conditions; • public transport; • others.
Type	Functional
Priority	Must
Verification analysis	This DS has been implemented for the transfer of data with the Traffic Control Centre of the city of Bolzano. A specific web service makes an association between station and station type. Following categories are available: traffic; weather; traffic + weather; air pollution; bicycle detector.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 60: Verification of requirement 3PDS_1 (data type).

ID	3PDS_2
Name	Data aggregation
Description	The data-source must be able to properly aggregate the data depending on (i) reference category and (ii) time delivery modalities defined by the 3rd parties sources.
Type	Functional
Priority	Must
Verification analysis	The DS is capable to aggregate the data according to the station type, based on what has been reported for requirement 3PDS_1. The time delivery modalities are based on the measurement performance of the different monitoring stations.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 61: Verification of requirement 3PDS_2 (data aggregation).

ID	3PDS_3
Name	3rd parties source authentication and authorization
Description	The data-source must recognize and authorize each external 3rd parties source.
Type	Non-functional
Priority	Must
Verification analysis	In order to get the data from the Traffic Control Centre of the city of

	Bolzano, the IT department of the Municipality of Bolzano has opened an exception in the firewall for the trusted IPs associated to the 3PDS. In this way, the requirement for authentication and authorization is automatically fulfilled.
Reference prototype deliverable	P.4.1.3
Verification result	FULLFILLED
Relevancy of issue	NONE

Table 62: Verification of requirement 3PDS_3 (3rd parties source authentication and authorization).

ID	3PDS_4
Name	Standard data transfer
Description	The data provided by each 3rd parties source must be exposed with a standard data exchange protocol (e.g. DATEX II, SIRI, VDV, etc.).
Type	Interface
Priority	Must
Verification analysis	The data are not transferred through a standard ITS protocol yet, but using documented SOAP web services. A DATEX II could be however very simple added if a direct communication with another TMC would be needed.
Reference prototype deliverable	P.4.1.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 63: Verification of requirement 3PDS_4 (standard data transfer).

2.2.6 Other Data Sources

During the process of definition of the requirements, additional data sources were originally identified, namely:

- **Traffic Station Data Source**, i.e. a specific entity for the collection of traffic data from detectors, including a reference of speed and vehicle type. This data source has been not implemented since the available traffic data are transferred through the third-parties DS. In the future, however, this component could be implemented in order to automatically retrieve e.g. the data at disposal of the Province of Bolzano, in particular the ones that are used for the monitoring analysis of Action n.8 [6].

- **User Data Source**, i.e. a specific entity capable to collect all the users notification concerning traffic disruptions. Despite the public availability in Bolzano of the Co-Cities applications, which could provide the possibility for local travelers to provide such a feedback, this kind of service has not been implemented yet, but will introduced only in a second stage when a critical mass of users using the available end-users applications will be created.

- **Operators Data Source**, i.e. a specific entity in charge of putting authorized personnel of the Municipality of Bolzano to introduce information related to roadworks and general city events. This software application has not been developed yet since such an activity has been already covered by another office of the Municipality of Bolzano, responsible of the management of all geodata. The plan is therefore to

introduce this new data source (probably to be renamed in e.g. “public road spaces occupation DS”) once this new software of the Municipality of Bolzano will enter in complete function.

- **Video Data Source**, i.e. a specific entity capable to collect the automatic notification coming from video cameras. At present, this functionality has not been implemented in the video surveillance system of the city of Bolzano, so such notifications are at present not available. Similar installations are however in planning, so the implementation of such a DS is to be taken in consideration in the short future.

2.3 Front-ends Layer

ID	FEL_1
Name	Output information delivery requests
Description	Any front-end must be able to be contacted by one or more specific and supported external clients wanting to have access to certain validated information available at the Data Center Layer.
Type	Functional
Priority	Must
Verification analysis	The front-ends that have been developed provide this functionality
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 64: Verification of requirement FEL_1 (output information delivery requests).

ID	FEL_2
Name	Front-ends isolation
Description	Any front-end must be an independent entity with respect to the other front-ends and the Data Center Dispatcher.
Type	Functional
Priority	Must
Verification analysis	The front-ends are independent software entities which just share common functions and libraries
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 65: Verification of requirement FEL_2 (front-ends isolation).

ID	FEL_3
Name	Incoming requests pre-validation
Description	Any front-end must drop all received requests that are formatted in a different manner as expected.
Type	Functional
Priority	Must
Verification analysis	The requests to front-ends must be specified as indicated in the indicated guidelines, otherwise it is dropped and an error message is returned.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 66: Verification of requirement FEL_3 (incoming requests pre-validation).

ID	FEL_4
Name	Front-end requests forwarding service
Description	Any front-end must forward to the Database only those requests concerning data that it has the role to access.
Type	Functional
Priority	Must
Verification analysis	The front-ends are designed in a way to be able to request certain data types only.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 67: Verification of requirement FEL_4 (front-end requests forwarding service).

ID	FEL_5
Name	Front-end output information forwarding service
Description	Any front-end must forward to the end-user client the reply to its request which is generated by the Database and received through the Data Center Dispatcher.
Type	Functional
Priority	Must
Verification analysis	The front-ends have implemented this major functionality.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 68: Verification of requirement FEL_5 (front-end output information forwarding service).

ID	FEL_6
Name	Clients requests management
Description	Any front-end must process the different clients requests in the same manner, i.e. through all the same processing steps, and independently from the client identity.
Type	Non functional
Priority	Must
Verification analysis	The front-ends make no distinctions between different client applications.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 69: Verification of requirement FEL_6 (clients requests management).

ID	FEL_7
Name	Security management
Description	Any front-end must have sufficient capabilities to prevent any improper use of the resources and any malicious attacks (e.g. denial-of-service).
Type	Non functional
Priority	Must
Verification analysis	The front-ends have not implemented yet logics in order to guarantee the proper security of the overall front-end layer.
Reference prototype deliverable	P.4.1.4

Verification result	NOT FULFILLED
Relevancy of issue	MINOR

Table 70: Verification of requirement FEL_7 (security management).

ID	FEL_8
Name	Authentication capability
Description	Any front-end must be able to authenticate itself with the Data Center Dispatcher
Type	Non functional
Priority	Must
Verification analysis	The front-ends do not authenticate with the Data Center Dispatcher since they are both executed in a protected software environment.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 71: Verification of requirement FEL_8 (authentication capability).

ID	FEL_9
Name	Client identification
Description	Any front-end should be identified by the Data Center Dispatcher by coupling the client's request with its own identifier.
Type	Non functional
Priority	Should
Verification analysis	An association between front-end and client's request is made by the Data Center Dispatcher.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 72: Verification of requirement FEL_9 (client identification).

ID	FEL_10
Name	Client interoperability
Description	Any front-end must expose a standard interface and use well defined and documented protocols to interact with the end-user clients.
Type	Interface
Priority	Must
Verification analysis	The front-end expose standard and documented interfaces, by making extensive use of widespread protocols and standards.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 73: Verification of requirement FEL_10 (client interoperability).

ID	FEL_11
Name	Scalability
Description	Any front-end must be implemented in such a way so that it can be easily scaled as a function of the amount of incoming requests.
Type	Performance
Priority	Must

Verification analysis	The capabilities of each front-end can be dynamically scaled as a function of the volumes of incoming requests.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 74: Verification of requirement FEL_11 (scalability).

ID	FEL_12
Name	Elaboration time
Description	Assuming that the connection between front-end and client is sufficiently stable and broadband, the total amount of time which is needed by the system to reply to a request of an end-user client must be compliant with the user's expectation, i.e. at maximum 5 [s].
Type	Performance
Priority	Must
Verification analysis	This requirements is fully satisfied in case of real-time data download. When historical data is requested, the duration for the retrieval of the information can be obviously longer, as a function of the amplitude of the data requested.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 75: Verification of requirement FEL_12 (elaboration time).

2.3.1 Public IP (and broadcast channels) front-end

The public IP channels front-end has been developed as a set of specialized front-ends, that are responsible for the retrieval of very specific data types. At present, the public broadcast channels front-end has not been included, since no contacts with any broadcast operator has been developed in the scope of the project. Particular front-ends implementing the specific requirements associated to this system components can be however simply implemented on top of the front-end layer that has been developed in the scope of the project.

ID	PICF_1
Name	Data and information type
Description	The Public IP Channels Front-End must have access through the Data Center Dispatcher to all type of data and information managed by the Data Center Layer (traffic / environmental, current / historical, etc.) but only to the one which is validated and elaborated, i.e. which have passed through all elaboration chain.
Type	Functional
Priority	Must
Verification analysis	The set of front-ends can have access to all validated data and information of the Data Center Layer, according to the data "visibility" they have.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 76: Verification of requirement PICF_1 (data and information type).

ID	PICF_2
Name	Data and information formatting and forwarding service
Description	The Public IP Channels Front-End must be able to receive on-demand and/or periodic requests coming from the external clients, get the validated data and information from the Supervisor Centre through the Data Center Dispatcher, and finally format and deliver it accordingly, all this by using well defined interfaces (i.e., web-services).
Type	Functional
Priority	Must
Verification analysis	The set of front-ends fully implement such data delivery mechanism.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 77: Verification of requirement PICF_2 (data and information formatting and forwarding service).

ID	PICF_3
Name	Exploitation opportunities
Description	The Public IP Channels Front-End must be not only the end-point for third parties services deployed as websites and smartphone applications, but also be in charge of publishing the validated data according to the open data approach.
Type	Functional
Priority	Must
Verification analysis	The set of front-ends are fully in line with the open data approach followed by the project..
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 78: Verification of requirement PICF_3 (exploitation opportunities).

ID	PICF_4
Name	Standard communication protocols
Description	The Public IP Channels Front-End must support standard web communication languages (e.g. XML) and be able to support one or more communication protocols used for the distribution of info-mobility information over an IP channel, like for example TPEG-ML.
Type	Non functional
Priority	Must
Verification analysis	The set of front-ends make use of standard web communication language (JSON) but are not compliant with ITS data publication standards.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 79: Verification of requirement PICF_4 (standard communication protocols).

ID	PICF_5
Name	Open data distribution license
Description	The Public IP Channels Front-End must release the data according to a well-defined open data license.
Type	Non functional

Priority	Must
Verification analysis	The process for the choice of the open data license is still on-going.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 80: Verification of requirement PICF_5 (open data distribution license).

2.3.2 Connection with Traffic Control Centre traffic lights and VMS management subsystems

During the requirements' process, it was planned to create automatic interfaces between the Supervisor Centre and the current software executed at the Traffic Control Centre responsible for the management of the traffic lights and the Variable Message Signs. During the design and implementation phase of the project, it was decided for the moment not to include this part of system actuation in the Supervisor Centre, and to leave to traffic operators the task to use these available software for implementing the traffic strategies based on the outputs offered by this novel system.

3 Elaboration tasks verification

3.1 Common data center tasks

ID	DCT_1
Name	System capability
Description	The Data Center Tasks must: • elaborate the data stored in the database in order to calculate the current (or historical) traffic and air pollution conditions within the monitored area of the city; • be able to perform the actuation strategies defined and inserted within the system by the operators.
Type	Functional
Priority	Must
Verification analysis	The Data Center Tasks fully implement the first point, while the second point has not been included in the system capabilities yet. The actuation strategies are manually introduced by the operators as at the project start.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 81: Verification of requirement DCT_1 (system capability).

ID	DCT_2
Name	Outputs storing capabilities
Description	Any Data Center Task must be able to store its generated outputs in the database.
Type	Functional
Priority	Must
Verification analysis	Elaborated outputs are stored in separate tables.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 82: Verification of requirement DCT_2 (outputs storing capabilities).

ID	DCT_3
Name	Data accessibility
Description	Any task must be able to access all the kind of data that are needed to carry out its elaboration task.
Type	Non functional
Priority	Must
Verification analysis	Data Center Tasks can access all data stored in the database.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 83: Verification of requirement DCT_3 (data accessibility).

ID	DCT_4
Name	Task triggering

Description	Depending on the purpose, the execution of each task must be triggered: ● **periodically**, in the case the objective is to automatically produce an update of the previously calculated outputs (i.e. current traffic / environmental conditions); ● **on-demand**, in the case the objective is to manually activate a particular elaboration on the data or an actuation on the traffic control systems.
Type	Non functional
Priority	Must
Verification analysis	At present all elaboration tasks are executed automatically in a periodic way. It is also possible to launch specific elaboration routines through the "on-demand" approach, but at present there is no GUI for the traffic operator that can permit to configure and launch the requested on-demand task.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 84: Verification of requirement DCT_4 (task triggering).

ID	DCT_5
Name	Warning generation management
Description	Any task should be able to fire a warning in case of need to the Database as well as to the Supervisor Centre operators.
Type	Non functional
Priority	Should
Verification analysis	At present there is no automatic warning generation functionality implemented.
Reference prototype deliverable	P.4.1.1
Verification result	NOT FULFILLED
Relevancy of issue	MINOR

Table 85: Verification of requirement DCT_5 (warning generation management).

ID	DCT_6
Name	Interface mandatory constraints
Description	The Data Center Tasks must interact only with the Database. No interaction must be possible with the other components of the system architecture.
Type	Interface
Priority	Must
Verification analysis	The Data Center Tasks interact only with the database only.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 86: Verification of requirement DCT_6 (interface mandatory constraints).

ID	DCT_7
Name	Interface optional extensions
Description	The Data Center Tasks could optionally interact, in a future system elaboration expansion, with trusted elaboration tools i.e. in the case of traffic elaborations, with a traffic simulation tool.

Type	Interface
Priority	Could
Verification analysis	It will be rather simple to integrate the Data Center Layer with a trusted elaboration tool, even following a complete cloud computing environment.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 87: Verification of requirement DCT_7 (interface optional extensions).

3.2 Common (pre)/(post)-elaboration tasks

ID	PreET_1
Name	Calibration problems discovery
Description	The Pre-Elaboration Task must pre-process all the data stored in the Database in order to find out outlayers and unreliable data, e.g. acquired by a data source which is out of calibration. This data must be properly marked and must be excluded from the elaboration chain. A warning must be fired, following the principle of requirement DCT_5.
Type	Functional
Priority	Must
Verification analysis	This requirement has been partially fulfilled. Pre-validation logics have been designed and developed for the automatic elaboration of the travel times data collected by the Bluetooth system, whereas at present there no is automatic process for the discovery of outliers in the set of environmental data.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 88: Verification of requirement PreET_1 (calibration problems discovery).

ID	PreET_2
Name	Malfunctioning problems discovery
Description	The Pre-Elaboration Task should be able to analyze the sources status and to discover any malfunction occurrence in the source. The malfunctioning problem should be signaled through a proper warning, following the principle of requirement DCT_5.
Type	Functional
Priority	Should
Verification analysis	The level of fulfillment of this requirements is directly linked to the level of development indicated for requirement PreET_1.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 89: Verification of requirement PreET_2 (malfunctioning problems discovery).

ID	PreET_3
Name	Triggering
Description	The Pre-Elaboration Task must be triggered periodically, as soon as there is a data record update in the database coming from the Data Center Collector.

Type	Non functional
Priority	Must
Verification analysis	Implemented pre-elaboration tasks are triggered periodically, synchronized with elaboration tasks.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 90: Verification of requirement PreET_3 (triggering).

ID	ET_1
Name	Elaboration outputs format
Description	The Elaboration Task must produce geo-spatial outputs.
Type	Functional
Priority	Must
Verification analysis	The output of each elaboration tasks are geo-referenced data records or maps.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 91: Verification of requirement ET_1 (elaboration outputs format).

ID	ET_4
Name	On-demand outputs
Description	The Elaboration Task must have routines to be started on-demand which return statistics on the past traffic/ environmental conditions over the monitored routes (e.g. the average daily traffic profile over a route section, the average daily emission profile over a route section, etc.).
Type	Functional
Priority	Must
Verification analysis	Such routines are not implemented in a way that can be automatically called by a traffic operator through its dedicated interface, but are however indirectly possible by requesting the available data and post-process it manually.
Reference prototype deliverable	P.4.1.1
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 92: Verification of requirement ET_4 (on-demand outputs).

ID	ET_5
Name	Data processing capabilities
Description	The Elaboration Task should be enriched by available algorithms, libraries, software tools in order to process the pre-validated data as expected and in the given time constraints.
Type	Functional
Priority	Must
Verification analysis	Elaboration tasks, where necessary, are enriched by algorithms, libraries and software tools available at the state-of-art.
Reference prototype deliverable	P.4.1.1
Verification result	FULFILLED

Relevancy of issue	NONE

Table 93: Verification of requirement ET_5 (data processing capabilities).

ID	PostET_1
Name	Elaboration outputs post-validation
Description	The periodic elaboration outputs must be presented at the operator and, where necessary, receive a post-validation by an authorized operator of the Supervisor Centre before they are published to the front-ends layer.
Type	Functional
Priority	Must
Verification analysis	Elaboration outputs are only presented to the operator. No post-validation is currently managed by the system, data and information are automatically published.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 94: Verification of requirement PostET_1 (elaboration outputs post-validation).

ID	PostET_2
Name	On-demand routines management
Description	The operator must be able to start the on-demand routines described in requirement ET_4.
Type	Functional
Priority	Must
Verification analysis	At present the interface destined to the operator does not offer the ability to manage the launch of on-demand routines.
Reference prototype deliverable	P.4.1.4
Verification result	NOT FULFILLED
Relevancy of issue	MINOR

Table 95: Verification of requirement PostET_2 (on-demand routines management).

ID	PostET_3
Name	Eco-friendly traffic policies actuation capability
Description	The operator must have the possibility to dynamically and remotely actuate specific eco-friendly traffic policies, which can include, among the others: • a change of the cycle of one or more traffic lights; • a change in the variable speed limits; • a change in the circulation permissions over specific routes; • a change in the travel choices of mobility participants (e.g. incentives to take specific routes within the city, or to choose alternatives in combination with other travel means); In particular, the operator must have the possibility: • to define one or more modifications in the cycle of one or more traffic lights and to send this new regulations to the traffic lights control system through its front-end; • to insert the textual messages to be displayed over the VMSs; • to introduce manual messages and recommendations to be delivered to the traveler over the public broadcast- and IP channels front-ends; • to introduce manual warnings to be delivered to other traffic control centers through the 3rd parties front-end.

Type	Functional
Priority	Must
Verification analysis	The calibration of the selected eco-friendly traffic policies is directly executed through the existing software controlling the traffic lights and the VMS, and not managed automatically by the Supervisor Centre.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 96: Verification of requirement PostET_3 (eco-friendly traffic policies actuation capability).

ID	PostET_4
Name	Traffic lights center warnings visualization
Description	The operator must be able to receive and visualize eventual warnings coming from the traffic lights centre concerning the application of a specific dynamic regulation.
Type	Functional
Priority	Must
Verification analysis	Such warnings are available in the software managing directly the single traffic lights.
Reference prototype deliverable	P.4.1.4
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 97: Verification of requirement PostET_4 (traffic lights center warnings visualization).

ID	PostET_5
Name	Graphical operator interface
Description	The operator must avail of a user-friendly graphical interface in order to easily perform the operations described in the previous requirements.
Type	Non-functional
Priority	Must
Verification analysis	The traffic operators avail of the dedicated application BZAnalytics which allow them to visualize the current traffic and environmental situation in the city and to implement the eco-friendly policies on top of the actuation systems executed at the Traffic Control Centre.
Reference prototype deliverable	P.4.1.4
Verification result	FULFILLED
Relevancy of issue	NONE

Table 98: Verification of requirement PostET_5 (graphical operator interface).

3.3 Bluetooth-based travel times estimator

ID	ET_2
Name	Traffic elaboration – periodical outputs
Description	On a periodical basis, the traffic-related routines must produce as final output an update for: • a four-class classification of the current traffic conditions of the monitored road network (“low”, “medium”, “high”, “congested”); • a short-term prediction (i.e. over one hour) of the traffic conditions, to be elaborated as in the point before, based on a comparison between current and historical data.

Type	Functional
Priority	Must
Verification analysis	This requirement has been implemented not as an elaboration task in the Data Center Layer, but as an “external task” associated to the BZTraffic application
Reference prototype deliverable	P.4.1.1 – P.4.1.5
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 99: Verification of requirement ET_2 (traffic elaboration – periodical outputs).

ID	ET_6
Name	Traffic elaboration outputs – spatial resolution
Description	The spatial resolution of traffic elaboration outputs must be at maximum 100 [m], i.e. a classification label must be assigned to each elementary road section which must have this value as maximum extension.
Type	Performance
Priority	Must
Verification analysis	The spatial resolution of the system is equivalent to the spatial extension of the links which have been defined on top of the Bluetooth detectors. The average length of each link is about 1 [km].
Reference prototype deliverable	P.4.1.1 – P.4.1.5
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 100: Verification of requirement ET_6 (traffic data elaboration outputs – spatial resolution).

3.4 Emission and dispersion model

ID	ET_3
Name	Environmental elaboration – periodical outputs
Description	On a periodical basis, the environmental-related routines must produce as final output an update for: • an emission map for: ❖ air pollutants (NO_x, CO, PM_{10}); ❖ fuel consumption; ❖ greenhouse gases (CO_2); • a dispersion map, which presents the traffic-induced air pollutants concentration over the city.
Type	Functional
Priority	Must
Verification analysis	The emission and dispersion models generate exactly these outputs. An emission map for much more pollutants is in reality generated.
Reference prototype deliverable	P.4.1.1 – P.4.1.5
Verification result	FULFILLED
Relevancy of issue	NONE

Table 101: Verification of requirement ET_3 (environmental elaboration – periodical outputs).

ID	ET_7
Name	Environmental elaboration outputs – spatial resolution
Description	The spatial resolution of environmental elaboration outputs must be at maximum:

	• 100 [m] for the emission map, since it is primarily calculated on the base of traffic data for each elementary road section; • 100 [m] for the dispersion map, which is intended as maximum horizontal spacing for each elementary cell of the map grid.
Type	Performance
Priority	Must
Verification analysis	The spatial resolution of the emission model is equivalent to the length of the elementary road archs of the network which is considered in the calculation. The average length is about 100 [m]. The spatial resolution of the dispersion model is equivalent to the dimension of each elementary cell in which the computation is performed. In this case the obtained resolution is equivalent to 50 [m].
Reference prototype deliverable	P.4.1.1 – P.4.1.5
Verification result	FULFILLED
Relevancy of issue	NONE

Table 102: Verification of requirement ET_7 (environmental data elaboration outputs – spatial resolution).

4 Mobile system integration verification

ID	OBEU_1
Name	Environmental sensors
Description	The environmental data unit has to deliver at least pollutant sensor data composing of: • NO_2 • O_3
Type	Functional
Priority	Must
Verification analysis	The on-board environmental unit is characterized by the presence, among others, of such air pollution sensors.
Reference prototype deliverable	P.4.2.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 103: Verification of requirement OBEU_1 (environmental sensors).

ID	OBEU_2
Name	Meteorological sensors
Description	The environmental data unit has to deliver meteorological data, related in particular to the following parameters: • air temperature; • humidity.
Type	Functional
Priority	Must
Verification analysis	The on-board environmental unit includes meteorological sensors as well, which however refer to the conditions inside the unit.
Reference prototype deliverable	P.4.2.2
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 104: Verification of requirement OBEU_2 (meteorological sensors).

ID	OBEU_3
Name	Environmental sensors plus
Description	The environmental data unit can deliver additional pollutant sensor data: • NO_X • PM_{10} • VOC • CO • SO_2
Type	Functional
Priority	Could
Verification analysis	The only additional pollutant cover from the above list is CO. Other air pollutants are at present not considered in the actual mobile system implementation
Reference prototype deliverable	P.4.2.2
Verification result	PARTIALLY FULFILLED
Relevancy of issue	MINOR

Table 105: Verification of requirement OBEU_3 (environmental sensors plus).

ID	OBEU_4
Name	Environmental sensor quality
Description	The pollutant and meteorological sensors together with the first data stream filtering should deliver additional quality and accuracy information.
Type	Functional
Priority	Should
Verification analysis	The on-board environmental unit provides additional information related to the quality and accuracy of the delivered measurements.
Reference prototype deliverable	P.4.2.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 106: Verification of requirement OBEU_4 (environmental sensor quality).

ID	OBTU_1
Name	Kinematic sensors
Description	The on-board traffic monitoring unit has to deliver at least GPS sensor data composing of: • position; • heading ; • speed.
Type	Functional
Priority	Must
Verification analysis	The on-board traffic unit is capable of providing this kinematic information.
Reference prototype deliverable	P.4.2.1
Verification result	FULFILLED
Relevancy of issue	NONE

Table 107: Verification of requirement OBTU_1 (kinematic sensors).

ID	OBTU_2
Name	Kinematic sensors plus
Description	The traffic data unit must also deliver acceleration sensor data
Type	Functional
Priority	Must
Verification analysis	The on-board traffic unit can provide advanced acceleration data in the three dimensions.
Reference prototype deliverable	P.4.2.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 108: Verification of requirement OBTU_2 (kinematic sensors plus).

ID	OBTU_3
Name	Kinematic sensor quality
Description	The GPS and acceleration sensor together with the first data stream filtering should deliver additional quality and accuracy information.
Type	Functional
Priority	Must
Verification analysis	The on-board environmental unit provides additional information related to the quality and accuracy of traffic-related measurements.

Reference prototype deliverable	P.4.2.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 109: Verification of requirement OBTU_3 (kinematic sensors quality).

ID	OBU_1
Name	Computing capacity
Description	The CPU of the on-board telematic unit requires enough computing capacity to accomplish the following tasks: • the control of the attached units; • the basic map matching and filtering of the data stream from the traffic and environmental units; • the processing of the communication protocols; • the preparation of the data to be displayed as well as the interaction with the HMI.
Type	Functional
Priority	Must
Verification analysis	The on-board telematic unit covers all functionalities included in this requirement. Basic map matching techniques have been considered for this application.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 110: Verification of requirement OBU_1 (computing capacity).

ID	OBU_2
Name	Storage capacity
Description	The on-board telematic unit must be equipped with enough memory to backup the recorded data of the traffic and environmental unit for at least 15 minutes.
Type	Performance
Priority	Must
Verification analysis	The on-board telematic unit can store a backup with is much greater than simply 15 [minutes] of measurements.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 111: Verification of requirement OBU_2 (storage capacity).

ID	OBU_3
Name	Storage capacity (optional)
Description	Further memory allocation must be considered in the case the on-board telematic unit needs to store basic map representations.
Type	Performance
Priority	Could
Verification analysis	Since basic map matching techniques have been considered in the project, no need for further memory allocation has been needed.
Reference prototype deliverable	P.4.2.3
Verification result	NOT FULFILLED

Relevancy of issue	NONE

Table 112: Verification of requirement OBU_3 (storage capacity (optional)).

ID	CU_1
Name	Communication technology
Description	The communication unit must apply standard communication technologies such as 2G, 3G, WLAN (802.11) and Bluetooth
Type	Non functional
Priority	Must
Verification analysis	The on-board telematic unit communicates with the server side of the INTEGREEN system through 3G.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 113: Verification of requirement CU_1 (communication technology).

ID	CU_2
Name	Communication protocols
Description	The communication unit must apply standard communication protocols, e.g.: • XML, GPRS (generic data) • UMTS, CALM (traffic data)
Type	Non functional
Priority	Must
Verification analysis	The on-board telematic unit communicates with the server side using standard communication protocols.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 114: Verification of requirement CU_2 (communication protocols).

ID	CU_3
Name	Communication load
Description	The communication between the mobile probe system and the receiving vehicle front-end has to transfer: • traffic data (position, heading, velocity and acceleration) with an update frequency of 5 [s]; • environmental data (air pollutants and meteorological data) with an update frequency of 60 [s];
Type	Performance
Priority	Must
Verification analysis	The update frequency of traffic and environmental data is the same, and has been dimensioned in the order of 1 [minute]. Data samples are recorded and transmitted every 1 [s].
Reference prototype deliverable	P.4.2.3
Verification result	PARTIALLY FULFILLED
Relevancy of issue	NONE

Table 115: Verification of requirement CU_3 (communication load).

ID	HMI_1
Name	HMI - Information content
Description	The human machine interface has to provide functionalities to display: • the status of the INTEGREEN mobile probe system, including basic analyses and configuration capabilities; • the information provided by the Supervisor Center;
Type	Functional
Priority	Must
Verification analysis	Through the on-board HMI, it is possible to check on-board both the dataset measured by the mobile system and the information published by the Supervisor Centre though the different available end-users interfaces.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 116: Verification of requirement HMI_1 (HMI – information content).

ID	HMI_2
Name	GUI - Information content
Description	The graphical user interface of the mobile subsystem has to provide functionalities to display elementary map representations including the current position.
Type	Functional
Priority	Could
Verification analysis	Through the application BZAnalytics such requirement has been fulfilled.
Reference prototype deliverable	P.4.2.3
Verification result	FULFILLED
Relevancy of issue	NONE

Table 117: Verification of requirement HMI_2 (GUI – information content).

4.1 Vehicle Data Source

ID	VeDS_1
Name	Data type – position and timestamp
Description	Each single generated data record delivered to the vehicle data-source must contain one or more fields related to the correspondent acquisition position of the mobile probe. The position must be characterized in terms of: • coordinates (referred to a standard spatial reference system); • heading (which is the compass direction toward which the mobile probe is moving); • timestamp.
Type	Functional
Priority	Must
Verification analysis	Every data record is enriched by the position information provided by the on-board GPS system.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 118: Verification of requirement VeDS_1 (data type – position and timestamp).

ID	VeDS_2
Name	Traffic data type
Description	Each single generated data record delivered to the vehicle data-source must contain one or more fields related to the cinematic status of the mobile probe. The cinematic status must be characterized in terms of: • 1D speed; • 3D acceleration.
Type	Functional
Priority	Must
Verification analysis	Mobile system data packets contain information about 1D speed and 3D acceleration.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 119: Verification of requirement VeDS_2 (traffic data type).

ID	VeDS_3
Name	Environmental data type
Description	Each single generated data record delivered to the vehicle data-source must contain one or more fields related to the air pollutant levels monitored by the mobile probe. The air pollutants to be monitored must be: • NO_X; • O_3. Together with these air pollutants it is mandatory to monitor the following meteorological parameters: • air temperature; • humidity;
Type	Functional
Priority	Must
Verification analysis	Mobile system data packets contain these environmental parameters.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 120: Verification of requirement VeDS_3 (environmental data type).

ID	VeDS_4
Name	Data type – position (optional)
Description	Each single generated data record delivered to the vehicle data-source should contain some optional fields related to the accuracy of the acquired position (e.g. quality of the signal acquired by the satellite navigation receiver, number of available satellites, etc.).
Type	Functional
Priority	Should
Verification analysis	Mobile system data packets contain additional information related to the accuracy of the GPS signal.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 121: Verification of requirement VeDS_4 (data type – position (optional)).

ID	VeDS_5
Name	Environmental data type (optional)
Description	Each single generated data record delivered to the vehicle data-source should contain some optional fields related to the air pollutant levels monitored by the mobile probe. The optional air pollutants levels to be monitored must be: • CO; • PM_x; • BC.
Type	Functional
Priority	Should
Verification analysis	Mobile system data packets contain additional CO measurements..
Reference prototype deliverable	P.4.1.2
Verification result	PARTIALLY FULFILLED
Relevancy of issue	NONE

Table 122: Verification of requirement VeDS_5 (environmental data type (optional)).

ID	VeDS_6
Name	Data frequency update
Description	The maximum time interval between two consecutive generated data packets delivered to the vehicle data-source must be 5 minutes.
Type	Functional
Priority	Should
Verification analysis	Mobile system data packets are delivered to the vehicle data source on average once every minute.
Reference prototype deliverable	P.4.1.2
Verification result	FULFILLED
Relevancy of issue	NONE

Table 123: Verification of requirement VeDS_6 (data frequency update).

Conclusions

This report has presented the results of the technical verification of the proper fulfillment of the list of requirements defined in the scope of Action n.2, which are graphically summarized in Table 124 and Table 125. Most relevant issues cover non-functional aspects of the system, which can be properly solved with minor effort in the steps needed to bring the system into a production phase. In other cases, the missed fulfillment of the requirements are related to the technical deviations which have been necessary to follow during the design and implementation phase of the project.

Most relevant issues identified are the following:

- the decision of the **open data licenses** to be applied to the new data sets available;
- the implementation of **authentication mechanisms** in order to improve the security of the system, in particular if deployed in other production environments;
- the reduced capabilities of the current **Environmental Data Source** implementation, since most of the functionalities have been integrated in the 3rd Parties Data Source;
- the reduced capabilities of the **O/D Data Source** implementation, which at present is only linked to the Bluetooth travel times monitoring system;
- the **pre-elaboration capabilities** of the system in terms, which are not fully developed yet;
- the **traffic elaboration capabilities**, which have a spatial resolution lower than indicated (an aspect which could be improved once new data will be at disposal of the Supervisor Centre);
- the possibility for an authorized user to launch **on-demand routines** in order to have certain elaboration outputs applied to historical data;
- the possibility for the Supervisor Centre to be automatically linked to the **actuation systems of the Traffic Control Centre** (the workflow is at present managed in a manual way);
- the limited **map matching capabilities** of the mobile system, which could be however further improved in future system developments.

Components	ID	Name	Type	Priority	Verification Result	Issue Relevancy
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		
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		
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		
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	F	S		

		generated data		
	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	
Public IP channels front-end	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 124: Requirements verification summary (Supervisor Centre).

Components	ID	Name	Type	Priority	Verification Result	Issue Relevancy
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 125: Requirements verification summary (mobile system).

Bibliography

[1] INTEGREEN consortium, „D.2.1.1 "Supervisor Centre components requirements",“ 2012.

[2] INTEGREEN consortium, „D.2.2.1: Mobile system requirements,“ 2012.

[3] INTEGREEN consortium, „D.5.2.1 "Test Bed plan and test scenarios",“ 2015.

[4] INTEGREEN consortium, „D.5.2.2. Test Bed validation and INTEGREEN benefits assessment,“ 2015.

[5] INTEGREEN consortium, „D.5.3.1: Quantitative impact of eco-friendly traffic policies,“ 2015.

[6] INTEGREEN consortium, „D8.1 Report Check Point 1,“ 2013.

[7] INTEGREEN consortium, „D.5.1.1: On-board modules and Supervisor Centre test results,“ 2015.

[8] INTEGREEN consortium, „P.4.3.1 "INTEGREEN system demonstrator",“ 2015.