LIFE Project Number

LIFE10 ENV/IT/000 389

FINAL Report

Covering the project activities from 01/09/2011 to 28/02/2015

Reporting Date

31/05/2015

LIFE+ PROJECT NAME or Acronym

INTEGREEN

Project Data

Project location	Bolzano
Project start date:	01/09/2011
Project end date:	28/02/2015
Total Project duration (in months)	42 months
Total budget	€ 1.311.810
Total eligible budget	€ 1.242.310
EU contribution:	€ 614.610
(%) of total costs	46,85%
(%) of eligible costs	49,47%

Beneficiary Data

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Instructions:

The final report must be submitted to the Commission no later than 3 months after the project end date.

One paper and one electronic version of the report is sufficient for the Commission. These documents must be sent in identical versions also to the monitoring team. The report must also be sent to the national authority.

Please refer to the Common Provisions annexed to your grant agreement for the contractual requirements concerning a final report .

1. List of contents

Acronyms

AIT: Austrian Institute of Technology – Associated Beneficiary n.3

AMAA: Advanced Microsystems for Automotive Applications

ANPR: Automatic Number Plate Recognition

ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems

AVM: Automatic Vehicle Monitoring

CALINE: CAlifornia LINE Source Dispersion Model

CBZ: Municipality of Bolzano ("Comune di Bolzano") – Coordinating Beneficiary

CIP – ICT PSP: Competitiveness and Innovation framework Programme – Information Communication Technology Policy Support Programme

COPERT: Computer Programme to calculate Emissions from Road Transport

DTM: Digital Terrain Model

EC: European Commission

EMEP: European Monitoring and Evaluation Programme

ERDF: European Regional Development Fund

FCD: Floating Car Data

FESTA: Field opErational teST support Action

FOSDEM: Free and Open Source Software Developers' European Meeting

FP7: Seventh Framework Programme

GIS: Geographic Information System

GPS: Global Positioning System

GUI: Graphical User Interface

HBEFA: Handbook Emission Factors for Road Transport

HMI: Human Machine Interface

INSPIRE: Infrastructure for Spatial Information in the European Community

IPR: Intellectual Property Rights

ITS: Intelligent Transportation Systems

JRC: Joint Research Centre of the European Commission

JSON: JavaScript Object Notation

LAN: Local Area Network

MOX: Metal Oxide Semiconductor

NGO: Non-governmental organization

OBU: On-board unit

ÖFPZ: Österreichisches Forschungs- und Prüfzentral Arsenal

OGC: Open Geospatial Consortium

PCB: Print Circuit Board

PM: Particulate Matter

POI: Point of Interest

PTC: Positive Temperature Coefficient

REST: Representation state transfer

R&D: Research and Development

RMSE: Root Mean Square Error

RPC: Remote Procedure Call

RTTI: Real-Time Travel Information

SEAP: Sustainable Energy Action Plans

SIAG: Südtiroler Informatik AG

SIRI: Service Interface for Real-Time Information

SNR: Signal-to-Noise Ratio

SOAP: Simple Object Access Protocol

TIS: Techno Innovation South Tyrol – Associated Beneficiary n.2

TPEG: Transport Protocol Experts Group

V2X: Vehicle-To-X

VDV: Verband Deutscher Verkehrsunternehmen

VKT: Vehicle Kilometers Traveled

VMS: Variable Message Signs

XFCD: eXtended Floating Car Data

2. Executive Summary

2.1 Project objectives

The objective of the INTEGREEN project is to introduce and validate a demonstrative system that is capable to provide a detailed and integrated assessment of the real-time traffic and environmental conditions, the latter ones to be intended both in terms of **air pollution levels** and **greenhouse gas emissions**. The system is primarily thought to be used in a urban scenario, even if it could be applied in more general sense even to other non-urban road environments (e.g. highways), and is going to be empirically evaluated within the city of Bolzano, an alpine city located in the north of Italy within the South Tyrol region. The added value of the INTEGREEN system is not primarily in its **enhanced monitoring capabilities**, even if the approach which is proposed is rather new at the state-of-art, and covers certain aspects such as the mobile air pollution monitoring which are still at a research stage. More specifically, the idea is to build this integrated approach by properly fusing data gathered by fixed stations and mobile units to be installed on board of existing vehicles, both capable to give indications about traffic and air pollution conditions (Figure 1). From an environmental point of view, data are used in order to feed on a real-time basis a modelling chain, which is able to estimate both the emissions generated by urban traffic and the dispersion of pollutants in the air.

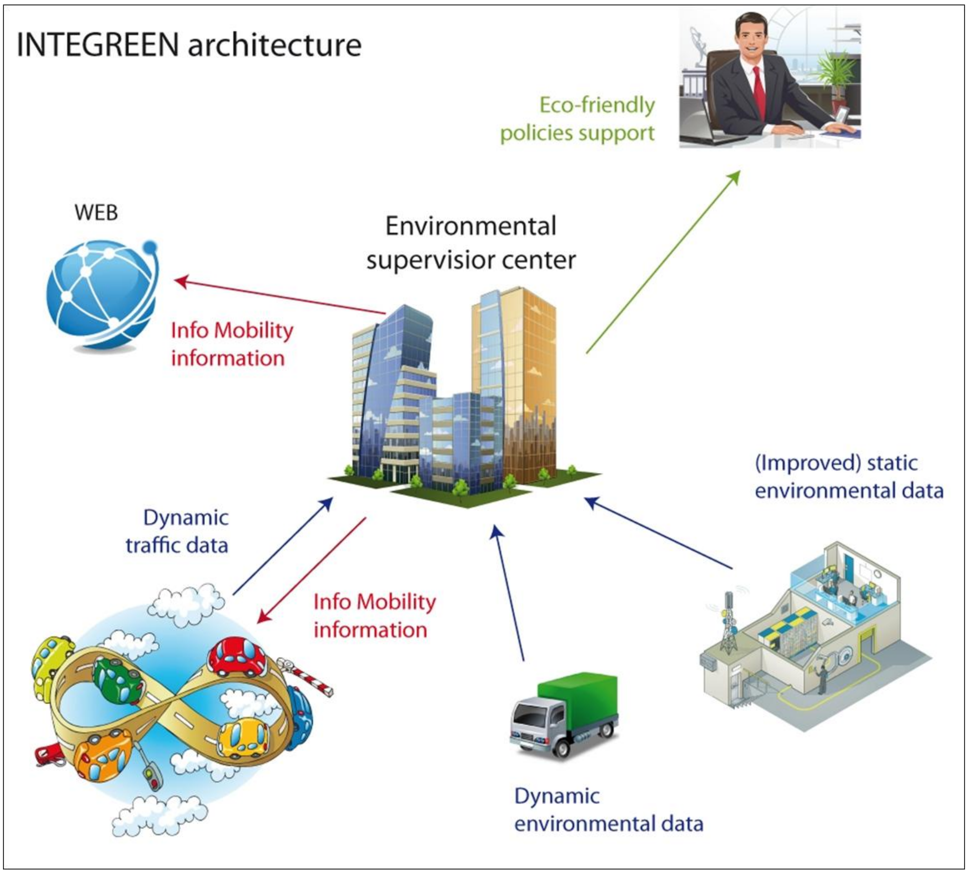

Figure 1: The high-level architecture of the INTEGREEN system.

The most important output of INTEGREEN as a system will be above all in the possible use cases that the introduction of such a monitoring instrument will be able to put into practice. In fact, traffic operators will be in the conditions to use the real-time information provided by this system in order to test and validate specific **eco-friendly traffic management policies**, such for example the dynamic and adaptive control of traffic actuators (e.g. traffic lights) or the sharing of specific real-time travel information to local end-users. In a future perspective, this system, if further exploited in direction of connected technologies, could be used in order to introduce very advanced policies and schemes, e.g. providing credits or incentives to users presenting specific "environment-friendly" attitudes. The expectation is to empirically demonstrate that these enhanced strategies are in the condition to determine a reduction of air pollutants levels as well as CO_2 emissions in the order of 15-30%, in line with the reduction potential indicated by several studies available at the state-of-art. The relevancy of this gain, if compared to the reference situation at the project start, can be further amplified by an increased **environmental education of all mobility participants**; the role of local travellers in the project is therefore of upmost importance in order to ensure that a wide and solid environmental impact can be determined thanks to the project activities.

For this reason, the project proposes a further integration approach, this time trying to complement technological with dissemination and awareness-raising actions, targeting not only the public audience as a whole but also specific focus groups such as students, driving schools and others. Thanks also to several policies and initiatives embraced in the past years by the Municipality of Bolzano in this domain, such as for example the creation of an extended bicycle road network in the city, local inhabitants have already demonstrated to have developed a real sustainable mobility culture. This has been confirmed by several modal split analysis, which have revealed the leading position of the city of Bolzano at an international perspective, with less than 40% choosing on average a private motorized vehicle for a urban trip. Given the boundary conditions explained before, the challenge that the city is trying to face is more related to the improvement of the behaviour of commuters and occasional travellers, in particular tourists. Last but not least, the INTEGREEN project aims to provide an important **contribution at European level** at different layers. First of all, the project does not only represent a direct implementation of the existing directives, e.g. Directive 2008/50/EC on ambient air quality and cleaner air for Europe; indeed, the results of this demonstrative project could be used by the European Commission in order to update and further develop the legislation and policies in different domains, including transportation one, in order to have much more integrated and accurate approaches for the joint management of traffic and environmental conditions in urban areas. On the other side, the project aims to create the basis for active cooperation and best-practice exchanges with numerous organizations at European level, and provide a reference "toolkit" in terms of documentation, tools, guidelines and other useful material for other local administrations that may be interested to replicate the INTEGREEN experience in other environments.

2.2 Key intermediate deliverables and outputs

Key intermediate deliverables and outputs produced by the project are summarized in Table 1.

Action	Deliverables	Outputs
Management	• D.1.2.1 "Initial financial report" • D.1.2.2 "First year financial report" • D.1.2.3 "Second year financial report" • D.1.2.4 "Final year financial	• Project Management Handbook. • Project accounting system with copy of the supporting documentation of all beneficiaries. • Final Cost Statements.

	report"[1]	
Requirements	• D.2.1.1 "Supervisor Centre components requirements" • D.2.2.1 "Mobile system requirements"	• In-depth analysis of baseline conditions, current environmental issues, and potential optimization margins. • Analysis of user needs and use case scenarios. • Definition of functional architecture of the system, and identification of system requirements.
System design	• D.3.1.1 "Data management unit and environmental stations front-end design" • D.3.2.2 "On board traffic and environmental monitoring unit"	• High level design of INTEGREEN system (based on standardized architecture FRAME). • Design of fixed traffic and air quality monitoring network. • Design of a low-cost system for the automatic monitoring of vehicular travel times. • Design of the mobile system components (on-board environmental / traffic monitoring units, telematics unit). • Design of the automatic elaboration tasks for the calculation of traffic conditions and air pollutants emissions and dispersion. • Design of the prototype tools and services for operators and local travellers.
System implementation and integration	• P.4.1.1: "Data management unit prototype" • "P.4.1.2: Vehicle-to-centre front-end and web interface design" • P.4.1.3: "Environmental stations front-end prototype" • P.4.1.4: "Operators centre web interface prototype" • P.4.1.5: "Public web interface prototype" • P.4.2.1: "On-board traffic monitoring unit prototype"	• Implementation of the enhanced static traffic and air quality monitoring system. • Installation of the Bluetooth detectors for the vehicular travel times calculation. • Development of the Supervisor Centre prototype and of the automatic elaboration tasks. • Development of the end-users applications. • Development of the mobile system components.

[1] Deliverables merged with the one produced in Action n.8, as already proposed in the Inception Report and approved by the EC.

	• P.4.2.2: "On-board environmental monitoring unit prototype" • P.4.2.3: "On-board telematics unit prototype" • P.4.3.1: "INTEGREEN system demonstrator"	• Integration of the mobile system components in a test vehicle. • Integration and connection of all system modules with the data center layer of the Supervisor Centre.
Test & Validation	• D.5.1.1: "On-board modules and supervisor centre test results" • D.5.2.1: "Test Bed plan and test scenarios" • D.5.2.2: "Test Bed plan validation and INTEGREEN benefits assessment" • D.5.3.1: "Quantitative impact of eco-friendly traffic policies"	• Technical verification of system components in real scenario. • Consolidation of a Test Bed plan and of an overall assessment methodology (based on standardized FESTA approach). • Quantification of the environmental gain associated to selected pilot use cases • Long-term deployment of the mobile system on a public transportation vehicle. • Preliminary testing and assessment of first "eco-policies" strategies. • Assessment of the level of fulfilment of initial users' needs. • Identification of most impacting environmental traffic policies for the city of Bolzano. • Consolidation of the project contribution to the EU policies.
Awareness-raising campaign	• Dissemination and networking activities report	• Dissemination Plan. • 5 permanent notice boards. • Project website and profiles on Facebook and Twitter. • 5 large scale events with users. • 3 press releases, 1 press conference, 2 TV / radio interviews, 20-30 presences on media channels in occasion of large scale events. • 3 local publications. • 1 teeming figure picture ("wimmelbild"). • 3 workshops. • VMSs used for educational purposes during large-scale events. • 20 meetings with target groups.

		• 9 local stakeholders active involved.
Networking & transnationality	• Dissemination and networking activities report	• 4 presentations at international conferences (with other 3 in 2015 after the project's end). • 4 networking events. • contacts with 7 EU networks. • inclusion in 2 networks. • 5 new project ideas developed.
Monitoring	• D.8.1: "Report Check Point 1" • D.8.2: "Report Check Point 2" • D.8.3: "Report Check Point 3" • D.8.4: "Report Check Point 4" • D.8.5: "Report Check Point 5"	• Definition of monitoring procedure and indicators. • Execution of five specific monitoring analysis, covering different project periods.
Audit	• D.9.1 "Audit verification certificate"	• Production of audit's certificate.
After-LIFE communication	• D.10.1 "After-LIFE communication plan"	• Production of After-LIFE communication plan

Table 1: Key deliverables and outputs of INTEGREEN.

Testing and validation activities have demonstrated that the **introduction of the first eco-friendly traffic policies** (speed detection enforcement system, traffic light cycles optimization, end-users applications has produced on average a **reduction of emission in the order of 15%**, but with higher values in case of high traffic loads. Monitoring activities have demonstrated the positive impact of the project, with an overall **reduction of traffic emissions of about 3-5%** and a **decrease in the usage of motorized modes of about 3-5%**, and a **reduction of air pollutant levels in the order of 5-10%**.

2.3 Final Report structure

The report is structured as follows. Chapter 3 provides an overall introduction to the problem targeted by INTEGREEN, and its expected longer term results. Chapter 4 covers the administrative part, with a description and an evaluation of the management system followed by the project beneficiaries. Chapter 5 illustrates in a detailed way what has been carried out in each technical and dissemination action, including an evaluation of the project implementation and an analysis of the long-term benefits. Chapter 6 covers the financial part, with a summarized presentation of the costs incurred in each cost category and in each project action. Comments about the annexed financial statements are included as well in this section. Chapters 7 and 8 indicate the list of technical and financial annexes that are delivered together with this Final Report, respectively.

3. Introduction

3.1 Background, problem and objectives

The **environmental problem** targeted by the INTEGREEN project is related to the impact that vehicular traffic has on matrix “air” within an alpine urban environment. The challenge to be addressed is twofold: on one side there is an increasing need to continuously monitor and keep under control the correlation between environment and traffic, and on the other side there is an increasing demand for mobility by citizens and foreign travellers in general. In order to respond efficiently to these opposite requirements, which tend to become more and more urgent in light of the current urbanization processes, the European Commission as well as the Italian Ministry for the Environment, Land and Sea have clearly indicated to adopt at local level a more integrated approach to urban management policies. The **hypothesis at the base of the project** is to empirically verify that through an integrated use of ITS, mixed with a set of specific awareness-raising activities, it is possible to demonstrate that greenhouse gas emissions, as well as air pollution levels can be reduced without hardly limiting the mobility of people and goods. More specifically, the idea is to demonstrate the non-negligible positive effect that certain “**soft measures**”, like for example the change in traffic lights cycles, can have on the urban environment, in particular if combined with “rewarding schemes” aiming at incentivising sustainable mobility habits. At the base of these “eco-friendly” traffic policies, there is the need to have a validated monitoring system capable to give, on a real-time basis, a quantitative overview of both traffic and environmental conditions. The proposed solutions, which is rather new at the state-of-art, is to combine fixed and mobile measurement stations capable to collect data on both the domains of interest, in order to put the premises for very detailed correlation analysis between the emitting source (traffic) and the surrounding environment. On the base of this information base, aided at central level though proper numerical models and data elaboration chains, traffic operators will be in the conditions to have a more comprehensive overview of the overall traffic situation (including its environmental impact), and to have the quantitative basis for applying on a dynamic basis specific traffic control / management policies, with the perspective to significantly reduce the time to reaction to a specific event and more ambitiously to transform reactive actions in proactive ones. In this future scenario, a crucial role is going to be played by the availability of advanced RTTI services to local travellers, who will be then in the conditions to make more efficient travel choices (not only in space but also in time and in the transport mode domain), both in the pre-trip phase and also while en-route. The final **objective** of the project is to demonstrate that in an environment like the one of the city of Bolzano, this kind of integrated and advanced approach could determine a reduction of CO_2 emissions in the order of 15-30%, depending on the level of “merging” effect that different “environmental” traffic policies and other awareness-raising activities have had.

3.2 Expected longer terms results

INTEGREEN could provide valuable inputs to the implementation, updating and development of European Union environmental policy and legislation, both in terms of novel technological solutions as well as in terms of integrated approaches for the **joint management of traffic and air pollution in an urban area**. On a local perspective, the expected result on the long term period is to demonstrate not only that INTEGREEN is technically valid, but also that is economically sustainable and in the conditions to be easily exploited in other areas.

4. Technical part

4.1. Technical actions

This part of the Final Report presents in details the technical progress, per task, of the on-going project actions which are not covered in other part of this document, namely Action n.2 (Requirements), Action n.3 (system design), Action n.4 (system implementation & integration), Action n.5 (test & validation) and Action n.8 (monitoring); the progress of Action n.6 (awareness-raising campaign) and Action n.7 (networking & trans-nationality) is presented in the following paragraph. The methodology followed by INTEGREEN for its technological implementation is the V-model engineering process, which is a quite common approach for similar ITS-oriented initiatives (Figure 2).

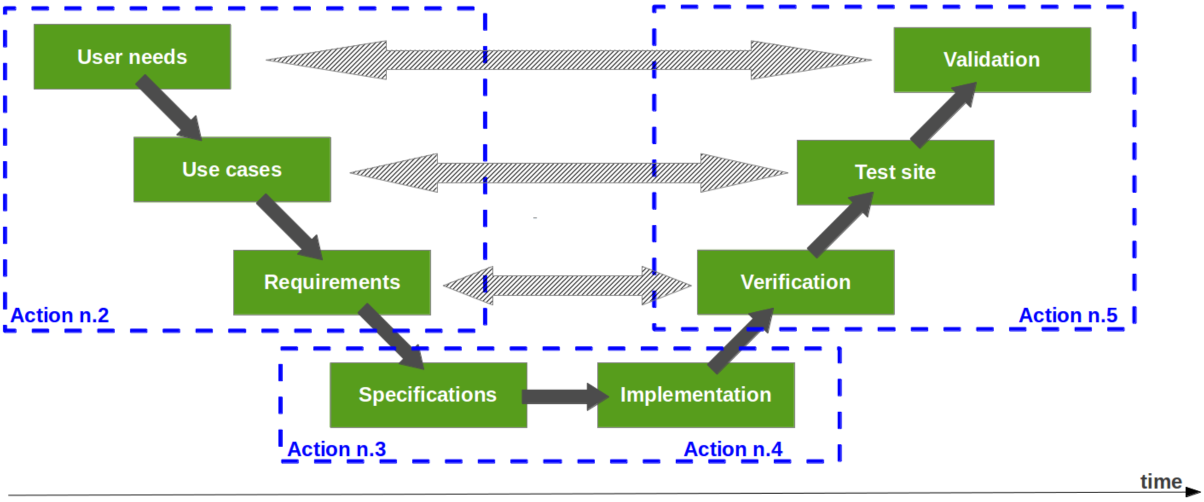

Figure 2: The V-model process followed in the technological level of the INTEGREEN project.

4.1.1 Action 2: Requirements

Expected outputs: The expected outputs of Action n.2 are a couple of reports, which have to clearly detail the set of functional and non-functional high-level requirements of the Supervisor Centre and the mobile system of the INTEGREEN architecture.

Achieved outputs: two detailed requirements' analysis, covering the first part of the V-model process presented above, were completed and documented. More specifically, the achievements obtained in each action's task have been the following.

Task 2.1 *"Supervisor Centre components"*: this task has been mainly managed by CBZ and TIS and covered the following activities:

- deep **analysis of the mobility, traffic and air pollution** in the city of Bolzano;
- extensive **investigation of the monitoring systems that are already in use** for controlling traffic and air pollution conditions in the city;
- complete **baseline assessment study**, used during the testing activities of Action n.5 as a reference for the quantification of the environmental improvements determined through INTEGREEN;
- identification of the reference **users and stakeholders** of the INTEGREEN system, and their reference needs to be addressed;

- consolidation of the set of **pre-trip and en-route inefficiencies** that have a negative environmental impact in the targeted urban scenario;
- definition of a set of reference **use cases** that could reduce the impact of the targeted inefficiencies;
- specification of the reference **high-level architecture of the INTEGREEN system**, by also taking into account the studies and the indications available in the ITS state-of-art (Figure 3);
- identification of the reference **functional and non-functional requirements** for each of the system components of the Supervisor Centre.

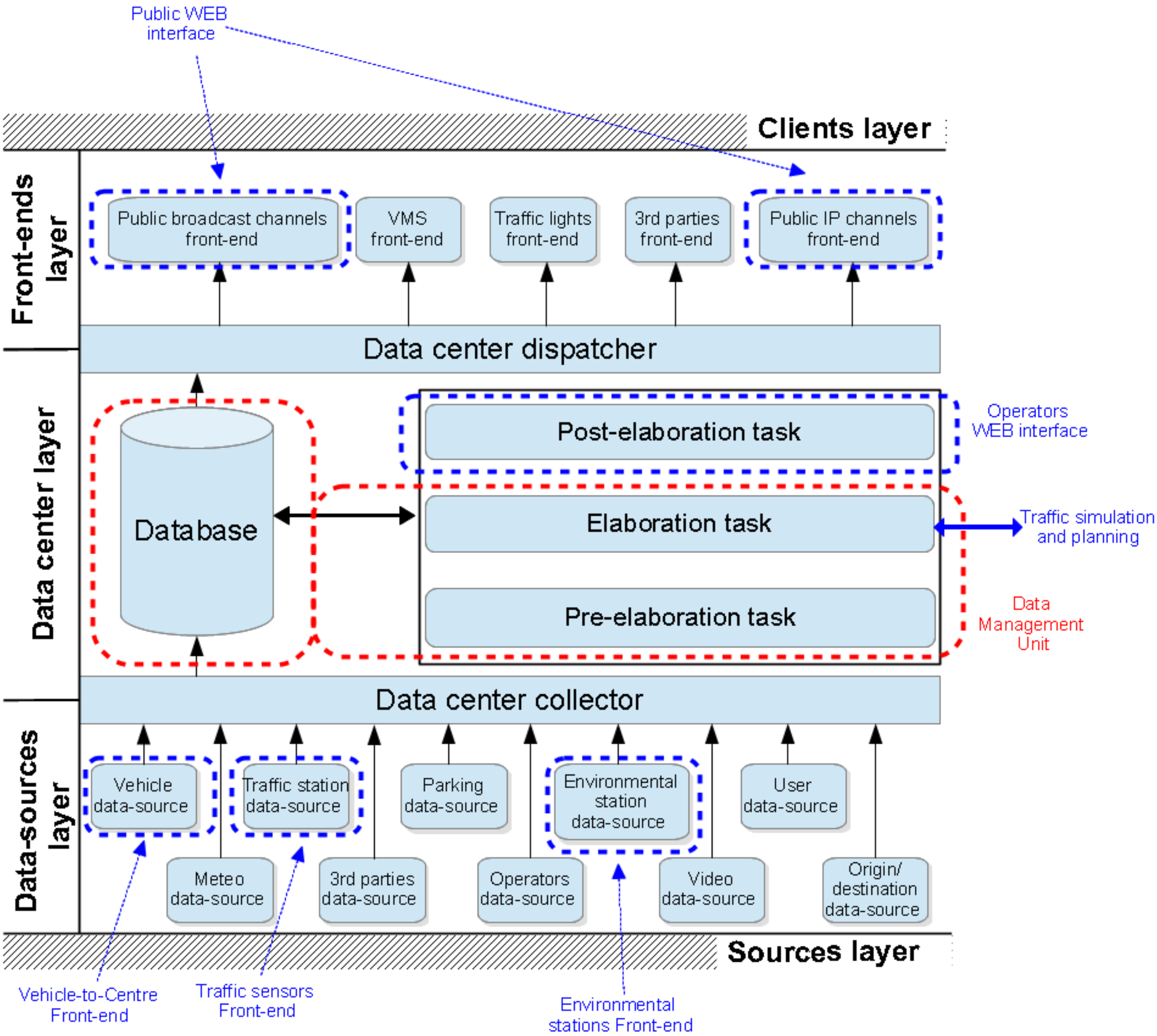

Figure 3: The specification of the high-level architecture of the INTEGREEN system.

Most relevant results can be summarized as follows:

- these studies have confirmed the presence of **relevant optimization margins** with respect to the local **environmental baseline conditions**, and the significant role that INTEGREEN can have for reducing the environmental impact produced by mobility and traffic inefficiencies in the city. The INTEGREEN system has been conceived as a **real-time aid for traffic operators** to introduce **advanced dynamic mobility**

measures, which can efficiently **complement** the **road infrastructure improvement actions** defined in the **Urban Mobility Plan 2020**;

- as far as the **air pollution level** are concerned, the historical measurements taken by the official air quality monitoring stations have offered a clear evidence of the necessity to properly manage in first place the high levels of **NO_x concentrations**. The environmental concern related to **PM levels** has strongly reduced in the last years, but this will need to be further reconsidered when the new regulations related to **$PM_{2.5}$** will enter into force;

- the **baseline assessment analysis** has mainly focused on the quantification of the real, **microscopic environmental impact** associated to **typical urban trips**, expressed in terms of produced emissions. Preliminary field measurement campaigns allowed to empirically confirm that all evaluated microscopic factors (i.e. traffic conditions, route peculiarities, driving styles, navigation factor) play an important role in the amount of CO_2 emissions produced by motorized vehicles;

- these campaigns also clearly evidenced the **strong temporal variability of traffic conditions** within the city. This was an important indication for the project implementation, since this result suggested as possible efficiency measure to foster more on **temporal navigation strategies** (i.e. recommending travellers to start their travels at a specific time) instead of **classical spatial navigation strategies** (i.e. recommending travellers the best route in the current situation).

Task 2.2 *"Mobile system"*: this task has been mainly managed by AIT in cooperation with TIS and CBZ, and covered the following activities:

- deep analysis of the state-of-art in **traffic and environmental monitoring techniques on board of mobile probes**;

- comprehensive **evaluation of all existing vehicular fleets** driving continuously in the urban area of Bolzano;

- specification of the reference **high-level architecture of the INTEGREEN mobile system**, including all the different functions that this unit must be able to perform (Figure 4);

- identification of the reference **functional and non-functional requirements** for each of the system components of the mobile system.

Most relevant results can be summarized as follows:

- this initial state-of-art investigation has confirmed on one side the **increasing maturity of mobile monitoring technologies**, in particular in the environmental domain, and on the other side the **increasing interest** in their application for **real-time environmental traffic management** purposes. This result has confirmed the novelty of the approach proposed in INTEGREEN, and the concrete opportunity to widely share and replicate this approach within other similar European areas;

- the **analysis of telematics systems deployed in existing fleets** circulating in Bolzano has confirmed that **no significant technological limitations** can jeopardize the future possibility to use these vehicles as mobile probes. A further opportunity was also identified in the car sharing service, that at the time of the analysis was still in the planning phase.

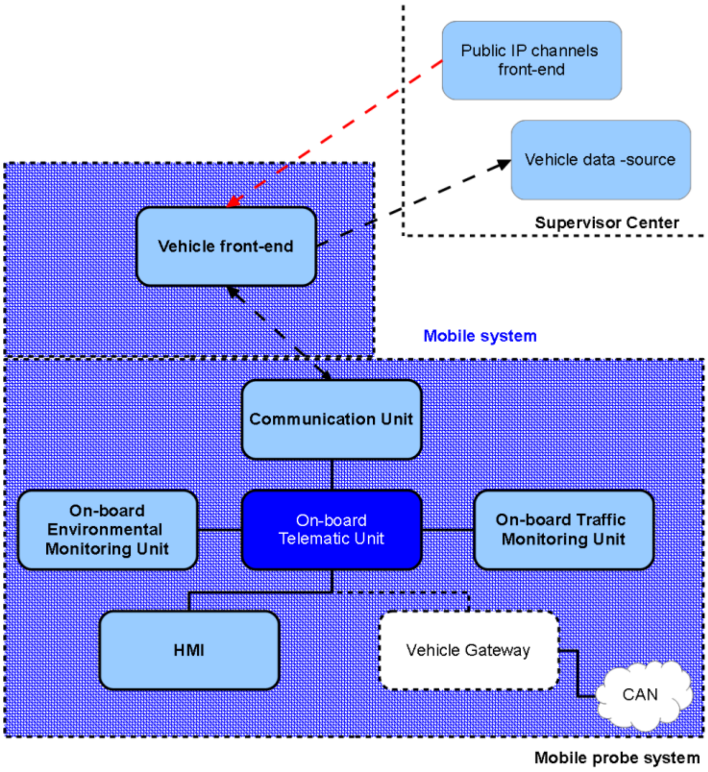

Figure 4: The specification of the high-level architecture of the INTEGREEN mobile system.

Indicators of progress: milestone M.2.1 (system requirements) has been achieved. A more detailed overview of the progress achieved by Action n.2 is given in Table 2.

Indicators		Comments	Reference report
Baseline data for starting environmental situation assessment		Completed through specific measurements analysis on the field.	D.2.1.1
Supervisors centre functional requirements ready	• Data management unit • Environmental stations front-end • Vehicle-to-centre front-end • Web interfaces	Completed based on the V-model requirements analysis process.	D.2.1.1
Mobile systems functional requirements ready	• On-board telematics unit • On-board traffic monitoring unit • On-board environmental monitoring unit	Completed based on indications coming from the early design activities (reverse engineering approach).	D.2.2.1

Table 2: Evaluation of indicators of progress for Action n.2.

Problems: no particular issue has been encountered during the execution of these activities, which have been supported and in some way extended thanks to the active cooperation not only of all project beneficiaries, but also of local stakeholders as well.

Comparison with the time schedule: the activities of this Action have been extended in light of the partner change issue that occurred at the project start. Instead of finishing at M6 (February 2012), the Action was fully completed only in M17 (January 2013). This new time schedule was shared with the EC in the Inception Report. However, thanks to the new competences brought in the project, i.e. two departments of AIT focusing respectively on the requirements analysis (Mobility Department) and on the design / implementation of the mobile system (Safety & Security Department), it has been possible to more intensively consider in the requirements analysis the indications coming from the activities of **Action n.3 (design)**, through a "**reverse engineering**" approach. This has been possible through a parallel fulfilment of Task 2.2. and Task 3.2 by the two aforementioned departments, which also supported TIS and CBZ in following a similar approach for the requirements and design activities related to the Supervisor Centre (Task 3.1). At the same time, it is worth to be mentioned how the temporal extension of this activity has made possible to better include all inputs and feedback received by users and stakeholders which have been involved in the initial dissemination and awareness-raising campaign activities. The outputs of Action n.2 have therefore reached a level of detail and initial investigation which is significantly more accurate than originally foreseen, and has allowed to speed up the following design and implementation actions.

Objectives achievability: the achievability of the objectives of this Action have been confirmed.

Outputs: the Action has produced deliverables D.2.1.1. "*Supervisor Centre components requirements*" and D.2.2.1 "*Mobile system requirements*" which were annexed to the Inception Report.

Perspectives for continuing the action after the end of the project: this Action has managed to offer a comprehensive overview of the current mobility and air pollution challenges in the city of Bolzano. All future project initiatives which will build upon INTEGREEN can use the outputs of this Action (available in complete form on the project web site) as a starting point. Preliminary investigations could be considered as a simple review or extension of these studies in light of the changed local conditions and deployments as well as the technological enhancements.

4.1.2 Action 3: System design

Expected outputs: The expected outputs of Action n.3 are four deliverables, which have to clearly present the whole set of specifications and design choices of the different components of the Supervisor Centre and the mobile system of the INTEGREEN system.

Achieved outputs: four detailed design actions, covering the specification part of the V-model process presented above, have been completed and documented. These actions include the administrative work needed for the selection of the technical sub-contractors and the purchase of the durable goods as foreseen in the project proposals. The major achievements obtained in each action's task have been the following.

Task 3.1 *"Supervisor Centre design"*. This task has been mainly managed by CBZ and TIS and produced the following outputs.

- **High-level design of the INTEGREEN system** through the European Intelligent Transport System (ITS) Framework Architecture, better known as **FRAME**. The choice of FRAME for generating a reference framework for the city of Bolzano has determined remarkable added values for the project, in particular:

- the speed-up in the future process of designing the extension of the functional capabilities of the INTEGREEN system;
- the determination of a **reference "standardized" architecture of the INTEGREEN system** that other public administrations could refer to in order to replicate this pilot experience in other similar urban environments.

The outputs produced by the FRAME tool, which are attached to deliverable D.3.1.1, are freely available for download together with the architecture itself on the project website. A graphical representation of the high-level INTEGREEN architecture mapped in FRAME is given in Figure 5.

- **Definition of the implementation choices of the Environmental Supervisor Centre** as a whole, in particular as far as the integration with the actual Traffic Control Centre of Bolzano. Different integration scenarios have been evaluated and compared, even in strict cooperation with the private company managing the hardware and software components at the centre (Famas System S.p.A.), involved in the project through an external assistance service. The final decision has been to choice a **"distributed" integration scenario**, with the Supervisor Centre to be physically implemented in the IT infrastructure of TIS and logically integrated with the Traffic Control Centre through a protected and dedicated communication channel. Several web-services have been specified in order to ensure a real-time exchange of data between the Supervisor Centre and the Traffic Control Centre.
- **Definition of the static traffic and air quality detection capabilities of the Supervisor Centre.** Based on the results of the requirements' analysis of Action n.2, the basic set of static monitoring stations has been selected, which include:
  - existing traffic stations re-arranged for the project's needs;
  - existing traffic stations already properly configured;
  - new traffic stations purchased thanks to the project, combined with air quality monitoring equipment;
  - the official air quality stations owned by the Local Agency for the Environment of the Autonomous Province of Bolzano;
  - the official meteorological station owned by the Hydrographic Office of the Autonomous Province of Bolzano.

  The position of monitoring stations has been defined according to a **reference test area** in which to concentrate all project demonstrations. This area includes the most important (and congested) urban roads of the city, residential districts and the industrial area, and virtually surrounds the A22 toll highway as well. A complete geographical overview presenting the location of all traffic and air quality static monitoring systems is given in Figure 6 and Figure 7.

  The design work covering the static monitoring components of the INTEGREEN system has moreover included:
  - the **specification of the interface with each existing station**. Two cases have been distinguished:
    - **the re-arrangement of systems already controlled by the Municipality of Bolzano**. In this case, specific works of improvements

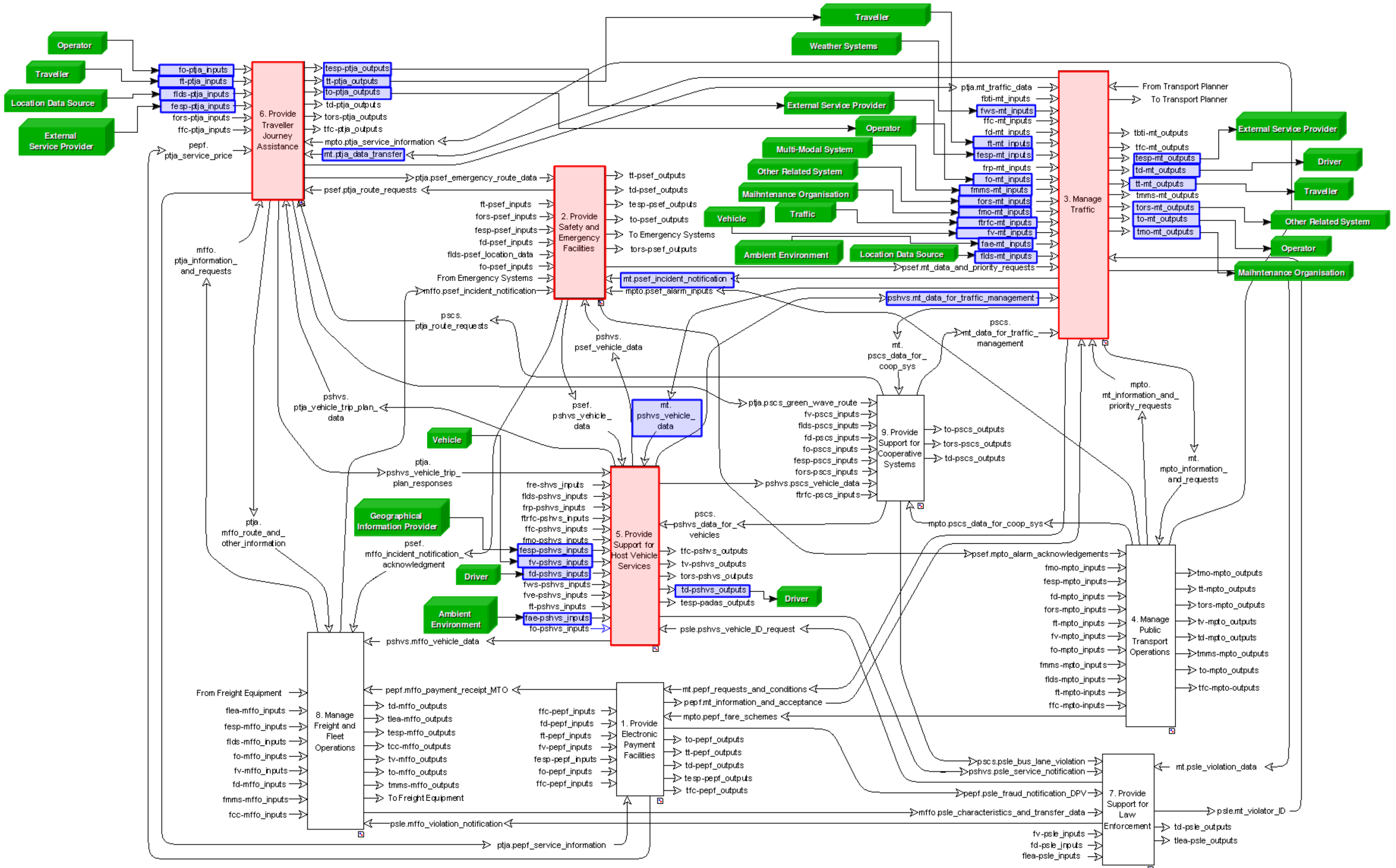

Figure 5: The high-level representation of INTEGREEN within the FRAME architecture.

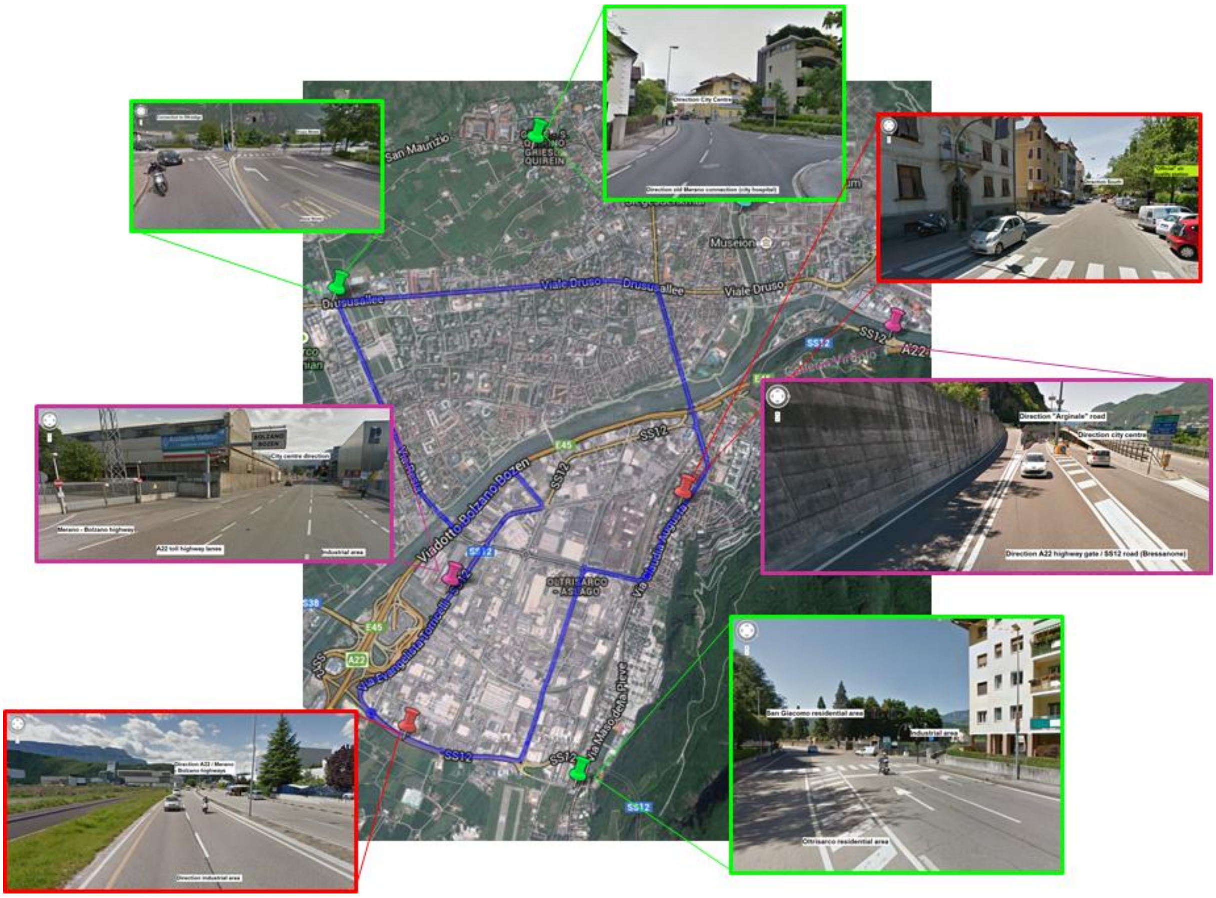

Figure 6: The map of the location of the static traffic detection points: existing traffic stations to be re-arranged (green), existing traffic stations (pink), new combined traffic and air quality stations (red).

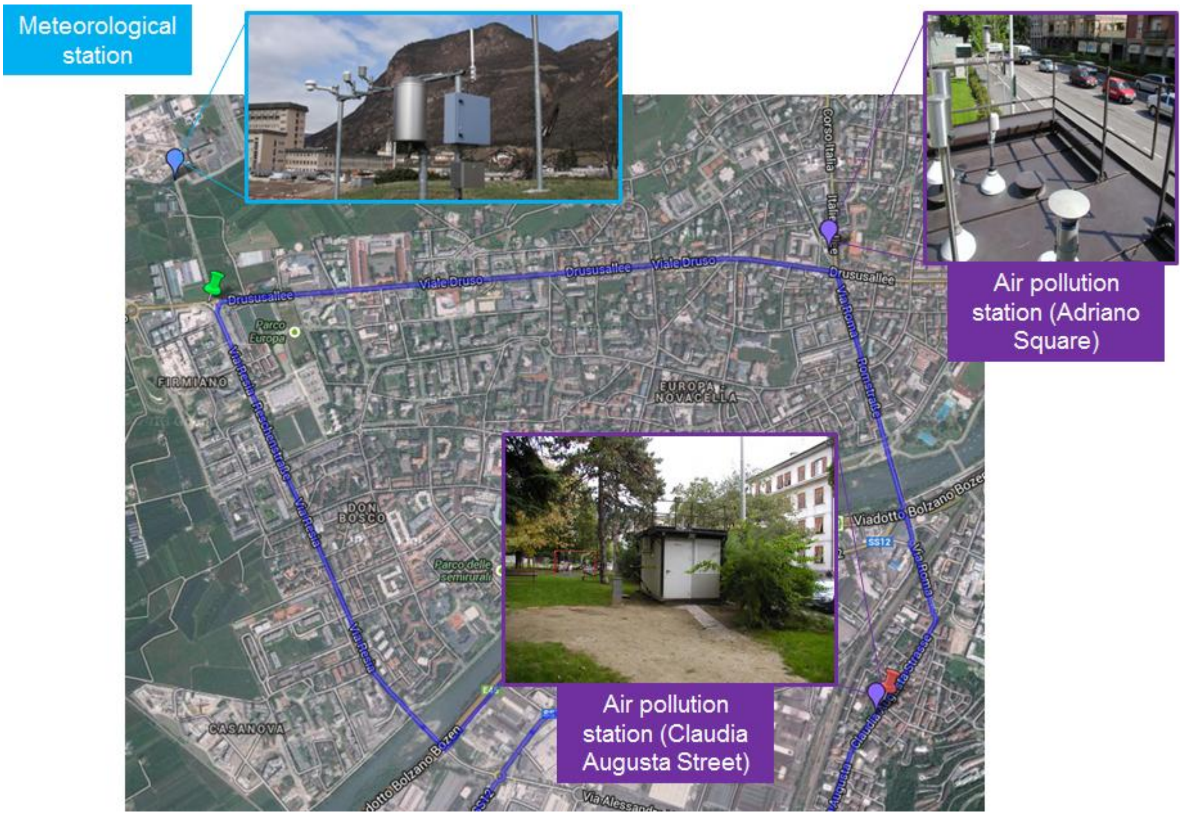

Figure 7: The map of the 3rd parties environmental stations to be integrated in the INTEGREEN system: meteorological and air pollution monitoring stations.

        - at the roadside level have been simply planned in order to guarantee more reliable monitoring performance and telematic connection;
        - **the inclusion of third parties monitoring systems**. In this case, there has been the need for specification of the new web services for the automatic exchange of the measured data;
    - the **full specification of the functionalities, performance and interface of the new monitoring systems**, that have been purchased through a public tender managed during this project phase. The **selection of air pollution monitoring technology** (thick film semiconductor-based sensors with PM detectors based on light-scattering technology) has been carried out in strict relation to the low-cost air pollution sensors analysis carried out in Task 3.2 by partner AIT for the **mobile system**: the choice of the same technology permits in fact a direct comparison between the static and mobile air pollution measurements.

- **Definition of the static vehicular travel times detection capabilities of the Supervisor Centre.** During the high-level design and planning process of the roadside monitoring units, the project has taken the opportunity to combine the conventional traffic detectors with an **additional low-cost network of non-invasive units** capable to collect data to be used for the **real-time calculation of the vehicular travel times** and eventually for making interesting **origin / destination analysis** concerning the urban trip behaviours. This detection methodology is based on a novel technique based on the idea to scan the **Bluetooth** devices which are present in the vehicles through fixed detectors. By comparing their anonymous identifiers at different locations, one could determine in quite accurate way the travel time needed for moving between two points of interests. A first prototype was internally developed and tested by TIS in late 2012, in order to evaluate the technological feasibility of this choice. The results have been so satisfactory that partners have decided to invest intensively on this system component and to take full advantage of its potential. A reference plan of the locations where to install the Bluetooth monitoring units has been subsequently defined (Figure 8). The approach is to have a couple of installations in correspondence of the outer parts of each major street covered by the reference test route, in order to have directly a complete assessment of the real-time travel times (and thus of the current congestion index) for each elementary stretch that is specifically monitored by the INTEGREEN system.

- **Definition of the interface between the mobile system and the Supervisor Centre** This activity has been mainly covered by TIS and AIT, including the selection of the reference data interchange format and the data dictionary. In the scope of this activity, the project has had the opportunity to exploit this method for the collection of further vehicular data provided by third-parties vehicles' owners. Thanks to the strict cooperation established with the public transport operator of the city **SASA** in the scope of Task 6.3, it has been possible to include in the Supervisor Centre even the **real-time information** coming from the **AVM system.** The introduction of this AVM system by SASA through own investments was carried out during the first project year, and deeply influenced by the launch of the INTEGREEN project A specific software client capable to properly receive and interpret this real-time data stream has been studied in cooperation with the external assistance company R3GIS s.r.l,.

- **Design of the "data center layer" of the Supervisor Centre and specification of the automatic elaboration tasks** for the real-time assessment of the traffic and air

Figure 8: The map of the planned installations locations of the Bluetooth monitoring units.

pollution conditions in the city. The elaboration tasks individuated for the purposes of the project have been the following (Figure 9):

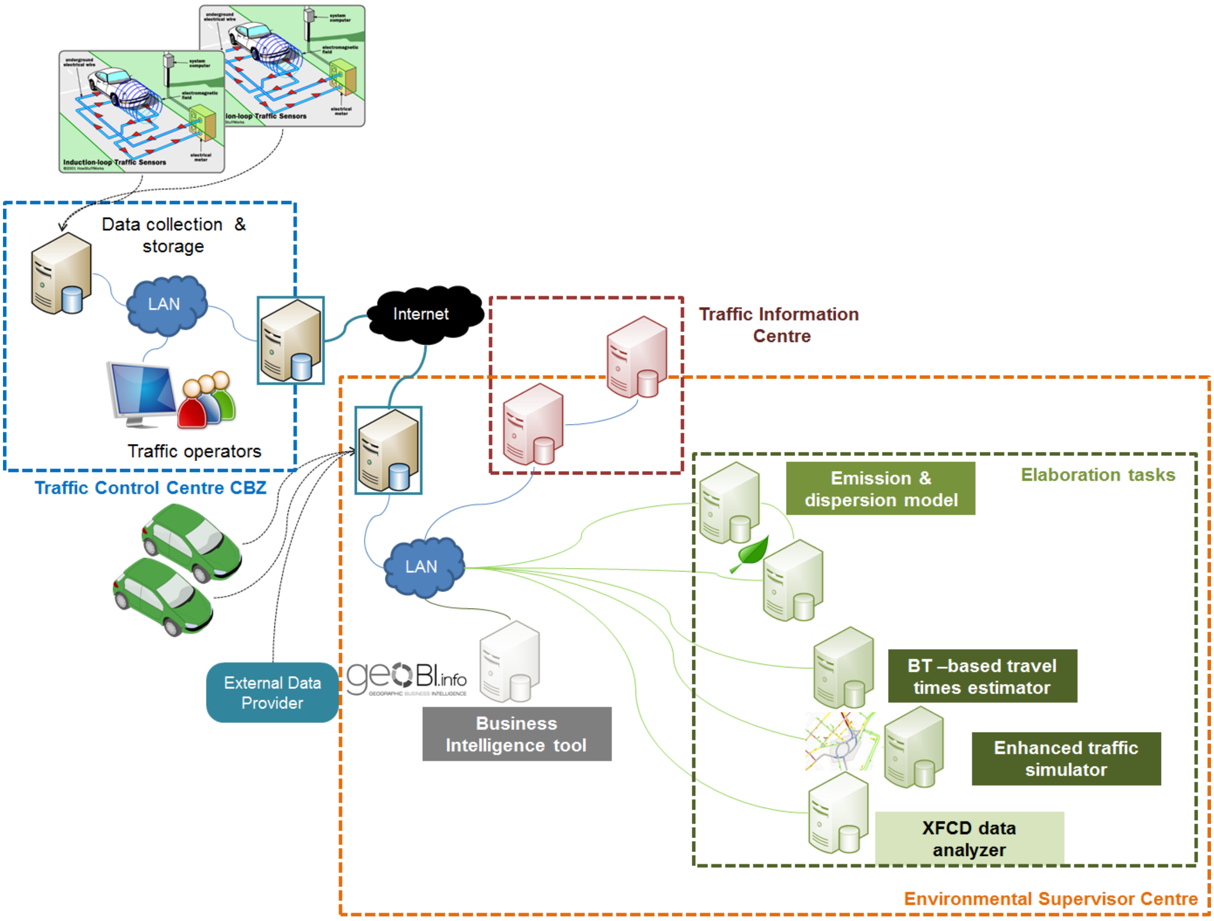

Figure 9: A graphical overview of the elaboration tasks that will be included at the Supervisor Centre.

- **Emission and dispersion model**. These models have the ability to estimate on a real-time basis the current air pollutants' emissions produced by vehicular traffic and their dispersion over the city of Bolzano, respectively. The definition of the reference environmental assessment methodology and the selection of the suitable algorithms has been carried out in cooperation with the external assistance company CISMA s.r.l.
    - The chosen **emission model** has been **COPERT**, an European standard for the road-transport emissions calculation whose reference methodology is suggested in the European guidelines "EMEP Guidebook". COPERT has been preferred to other models such as Mobile6, ARTEMIS and HBEFA because a detailed knowledge of the vehicular fleet or of the driving styles that is currently not available. The application of COPERT has been then simplified for the targeted real-time application; the complex numerical formulations at the base of the emission factors calculation have been transformed in analytic formulations. This work has been quite intense, since these formulations must be re-analysed for each vehicle class, which is characterized by a peculiar emission pattern.
    - The chosen **dispersion model** has been **CALINE**, a free and open source dispersion model developed in in California and maintained by

the California Department of Transportation. It has been preferred to other available models, in particular AUSTAL (probably the state of the art of local scale air quality dispersion model for urban areas, developed and maintained by the German Federal Environmental Agency) because of its simplicity and flexibility in adapting to peculiar situations such as urban canyons. The dispersion model runs in cascade to the emission model: obtained emission estimations' are integrated with the meteorological and air pollution data coming from the field stations as well with a reference DTM of the urban environment in order to compute a mapping of the air pollutant concentrations caused by the vehicular traffic.

- **Bluetooth-based travel times estimator and enhanced traffic simulator**. In order to properly run the above environmental elaboration chain, a detailed knowledge on the current traffic flows and average vehicle speeds of the single road stretches is needed.

  - The estimation of the **average vehicle speeds** can be obtained through a proper processing of the raw data records collected by the **Bluetooth-based travel times detection system**. <u>Novel algorithms</u> have been studied and consolidated in this phase, based on available state-of-art logics.

  - The estimation of the current traffic flows can be determined through a proper assignment of the traffic detections collected by the static monitoring stations. A <u>basic assignment scheme</u> has been studied and consolidated in this phase.

  This design activity has also investigate the technical modalities of integration of the **traffic simulation model** (PTV VISUM) that the Municipality of Bolzano already avails for offline applications only for real-time use cases. This model can in fact be able to estimate current traffic flows and average vehicle speeds over the whole network based on real-time traffic and travel times information. New concepts have been even introduced, for example the usage of the Bluetooth-based travel times detection system data for dynamically updating the origin / destination matrix, that today are typically static.

- **XFCD data analyzer**. This component is responsible of the automatic processing of the raw data delivered by the INTEGREEN mobile system. The following elaboration chain has been consolidated together with AIT for the **mobile air pollution sensors**: (i) <u>preliminary data "correction"</u> (i.e. spatial position correction, removal of the temporal shift associated to the delay introduced in the air pollution measurement system); (ii) <u>data "filtering"</u> and (iii) <u>final data "alignment"</u> (i.e. offset cancelation based on reference static air quality stations data). In the chain, different filters have been chosen, which can give a different compromise between RMSE minimization and and sudden air pollution variations management.

In order to properly manage all these complex elaborations, a proper **central data managemen**t is needed. A redundant software architecture has been specified in order to take care of the elaboration performance requirements and the real-time availability of the outputs produced by these routines. Different alternatives for the main software components have been analysed and evaluated, and a final selection has been performed. It’s important to underline the use of free and open-source tools only, and the complete avoidance of proprietary components that could determine licence costs and potential use limitations.

- **Specification of the “front-end layer” of the Supervisor Centre**. In the original perspective of the project, the idea was to create a set of simple web interfaces for the users (local travellers, traffic operators) with dedicated access to the elaborated data and information at disposal. During the requirements’ analysis, this perspective has been widely extended in the direction of creating a more complex software platform oriented to service providers, for permitting the creation of a virtual market of applications and services destined to end-users through a variety of different business models. This possibility has been taken into account since such a software platform was studied and experimentally implemented in a complementary project of CBZ and TIS, supported by ERDF funding, called “**Bolzano Traffic**”. All reference ITS standards (e.g. DATEX, TPEG, SIRI) and European initiatives were specifically investigated, and allowed the definition of a first “standardized” software platform model. The decision to use this software platform as “front-end layer” of the Supervisor Centre has determined the following design activities for INTEGREEN:
    - **extension of the software platform model**, in order to be able to publish traffic and air pollution information as well;
    - **introduction of a reference GIS stack** for the publication of the new available information even according to the requirements of the GIS domain, i.e. the guidelines of the INSPIRE directive and the specifications of OGC. This activity has been carried out in cooperation with external assistance company R3GIS s.r.l. based on the results of a previous Interreg Italy-Switzerland project called “**FreeGIS.net**”.

  The result of this design process has been the final specification of the “front-end layer”. The plan is to let service providers have controlled access to the data and information of the Supervisor Centre through a means of different standardized web services (**Errore. L'origine riferimento non è stata trovata.**).

- **Design of the web-based applications for traffic operators and local travellers**. This activity has finally covered the specification of the information to be presented to target users, the definition of the GUI and the modalities of interface with the “front-end-layer”. As far as the services for end-users is concerned, it is important to underline how in the frame of the **Bolzano Traffic** project a first set of demonstrative applications has been first introduced . These applications provide in particular: (i) **real-time parking information**; and (ii) **scheduled public transport information**. In INTEGREEN, it has been decided to widely extend this set of applications through three new services:
    - **BZTraffic**, a web application for the presentation of the **real-time traffic conditions in the city**. Based on the baseline assessment results, the choice has been to include in the application information related to temporal traffic peaks and a direct comparison with typical cycling travel times in order to further foster cycling mobility in the city.
    - **BZBus**, a web application for the presentation of the **real-time schedules of the urban public transportation service**, to be developed with the intention to increase the public transportation modal share of the city;

- o **BZAnalytics**, the **complete dashboard for traffic operators** with a user-friendly presentation of all data and information collected in the Supervisor Centre.

Task 3.2 *"Mobile system design"*. This task has been mainly managed by AIT and has been carried out in two major steps, namely (i) an initial high-level design phase, in which the high-level architecture of the mobile system has been consolidated based on the results of Action n.2, the various components of the mobile system have been functionally evaluated and investigated, and the interfaces between such components first determined; and (ii) a second detailed engineering design phase of each of the three basic units composing the mobile system. The following outputs have been produced.

- **Design of the on-board environmental monitoring unit**. A solid evaluation of the state-of-art of methods and physical principles at the base of air pollution sensing techniques has been carried out. Following sensor types have been deeply investigated in particular for mobile monitoring applications: (i) **chemo-resistive MOX sensors**, which measure changes in electrical conductivity that are directly related to variations of sensor resistivity caused by variations of gas concentrations; (iii) **electrochemical sensors**, which measure the concentration of a target gas by actively oxidizing or reducing it, and (iii) **optical gas sensors**, which take in consideration the impact that gas concentrations have on light absorption. Because of the limitation in the availability of detailed specifications, a couple of the most promising sensors available on the market has been purchased and empirically investigated. Three **pre-measurement campaigns** have been organized for this purpose during summer 2013 on the roads of Vienna. One of the most important aspects that immediately emerged after the first pre-measurement session has been the need to have a controlled air flow system able to guarantee a constant air flow over the sensors (Figure 10). These empirical evaluation session has led to the **final choice of the suitable gas sensors** for the INTEGREEN system: (i) a couple of NO_2 sensors (one based on MOX technology and one on electrochemical principles), (ii) an electrochemical O_3 sensor and (iii) a MOX CO sensor.

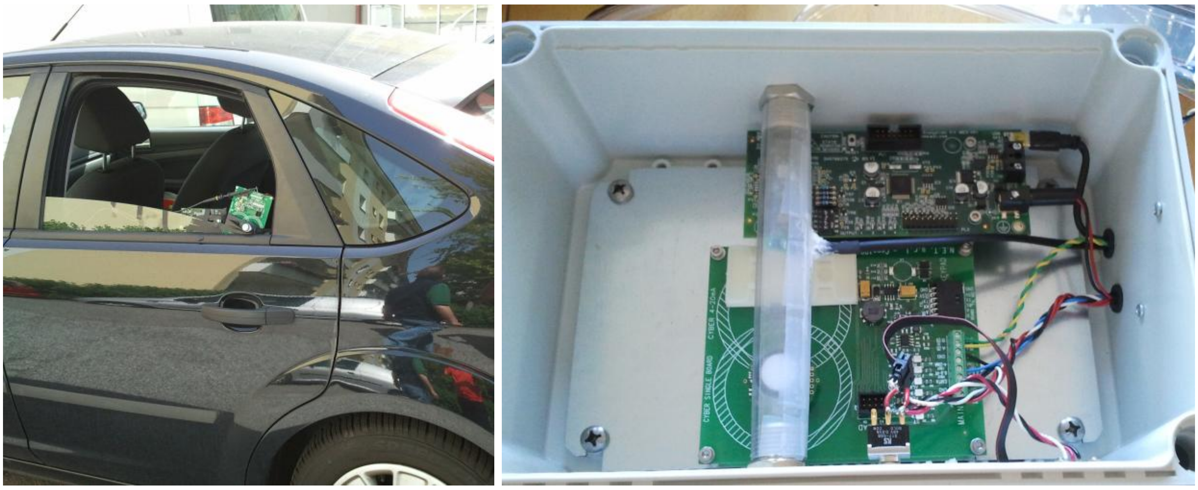

Figure 10: Preliminary field measurement campaigns with gas sensors in Vienna (on the left: first trial without air flow management system; on the right: second and third trial with controlled air flow system).

This design activity has been finally completed through the **3D detailed design of the environmental monitoring unit**, including its external interfaces. All technical specifications (including automotive ones) and business considerations have led to the solution presented in Figure 11.

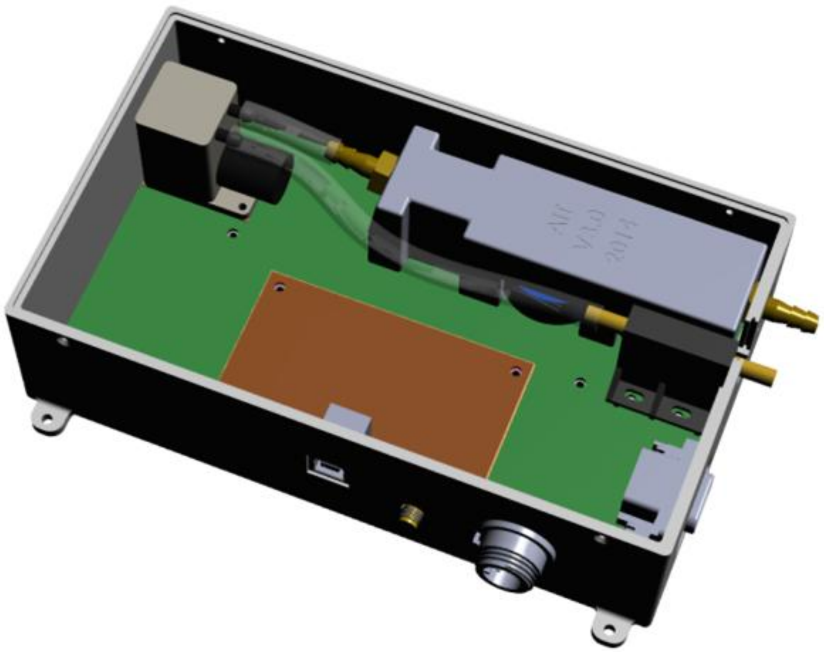

Figure 11: The final detailed design of the on-board environmental unit.

- **Design of the on-board traffic monitoring unit**. The FCD functionalities related to this component are much more mature in the state-of-art, and have permitted a less effort-demanding work of design. The novelty of the proposed solution in INTEGREEN relies in the decision to integrate in this unit **precise accelerometers** as well, which will open the doors also to specific measurement campaigns related to the correlation between fuel consumption and particular influencing driving parameters. Most of the 3D detailed design choices made for the on-board environmental unit have been applied for this unit as well, in order to have two complementary boxes with similar physical properties and just a few specific peculiarities, like for example in the interfaces capabilities.
- **Design of the on-board telematics unit**. This design activity has mainly covered the selection of the hardware components (a commercial automotive PC and a suitable HMI for the visualizing the data on-board) and the definition of the software design choices for the management of the following functions (i) real-time interface to the on-board sensors, and (ii) local data management and communication system. In order to accomplish these functions, complex software modules developed in previous R&D European projects have been re-used and properly adapted. A particular effort has been put in the design of the data transfer logic to be implemented in the mobile system. Improved communication and synchronization policies have been defined and introduced for avoiding any data losses in case of connection interruption or failure, e.g. caused by cellular network unavailability of temporary server malfunctioning.

Indicators of progress: M.3.1 (complete INTEGREEN system design) has been successfully achieved. A more detailed overview of the progress achieved by Action n.3 is given in Table 3.

Indicators		Comments	Reference report
Supervisors centre technical specifications	• Data management unit • Environmental	Fulfilled. Added values: GIS and ITS standards compliancy; software platform for service providers based on open data	D.3.1.1

Indicators		Comments	Reference report
ready	stations front-end • Vehicle-to-centre front-end • Web interfaces	approaches. New traffic monitoring technologies included (vehicular travel times). Complex elaboration modules integrated, integration with traffic simulation model evaluated.	D.3.1.2
Mobile systems technical specifications ready	• On-board telematics unit • On-board traffic monitoring unit • On-board environmental monitoring unit	Fulfilled. Added values: Advanced automotive design, integration and adaptation of software components for real-time data management developed in previous R&D projects.	D.3.2.1 D.3.2.2

Table 3: Evaluation of indicators of progress for Action n.3.

Problems: no particular technical problems have been encountered during this project phase; all technological and organizational limitations have been properly and professionally managed. This activity has only suffered of the original delay accumulated at the project start caused by the partner change issue.

Comparison with the time schedule: this action has been completely finalized on M25 (September 2013) only, instead of M14 (October 2012) as originally planned. This is related to the initial delay caused by the partner change issue and the following delay in the final availability of the outputs of Action n.2. It is important to underline that the duration of Action n.3 after the conclusion of Action n.2 has been equal to eight months (M18-M25), which is equal to what originally planned (M7-M14).

Objectives achievability: the achievability of the objectives of this Action have been confirmed.

Outputs: the Action has produced the deliverables *D.3.1.1: Data management unit and environmental stations front-end design, D.3.1.2: Vehicle-to-centre front-end and web interface design, D.3.2.1: On-board telematic unit* and *D.3.2.2: On-board traffic and environmental monitoring unit.* All these reports have been annexed to the Mid-Term Report.

Perspectives for continuing the action after the end of the project: this Action has managed to produce a first overall design of the INTEGREEN system. All future project initiatives which will build upon the INTEGREEN framework can use the outputs of this Action (available in a summarized form on the project web site) as a starting point, both for design of the extension of the functionalities of the INTEGREEN system but even for improving the design choices for some of its components on top of the new available technological developments. This will permit to significantly speed up any further design process. Moreover, the publication of the outputs of the FRAME tool will put other public administrations in the conditions to replicate or adapt the design choices of INTEGREEN in other urban environments.

4.1.3 Action 4: System implementation & integration

Expected outputs: The expected output of Action n.4 is the complete prototype of the INTEGREEN system, organized in its different components (the Supervisor Centre with connection to the mobile system demonstrator) as specified in Action n.3. The technical characteristics and functioning of the components' prototypes have to be briefly presented in the correspondent nine prototype deliverables.

Achieved outputs: The complete prototype of the INTEGREEN system has been successfully implemented, according to the design choices defined in Action n.3. The major achievements obtained in each action's task have been the following.

<u>Task 4.1 *"Supervisor Centre components implementation"*</u>: this task has been mainly managed by CBZ and TIS and produced the following outputs.

- **Implementation of the enhanced static traffic and air quality monitoring system**, which has included:
  - the development of the **telematic interface with third parties monitoring systems**, i.e. the air pollution and meteorological stations owned by the Autonomous Province of Bolzano (Figure 7);
  - the **on-site re-arrangement of the automatic traffic detectors** directly controlled by the Municipality of Bolzano, as specified in the plan presented in Figure 6;
  - the **installation and activation of the new traffic and air pollution monitoring stations** purchased through the project.

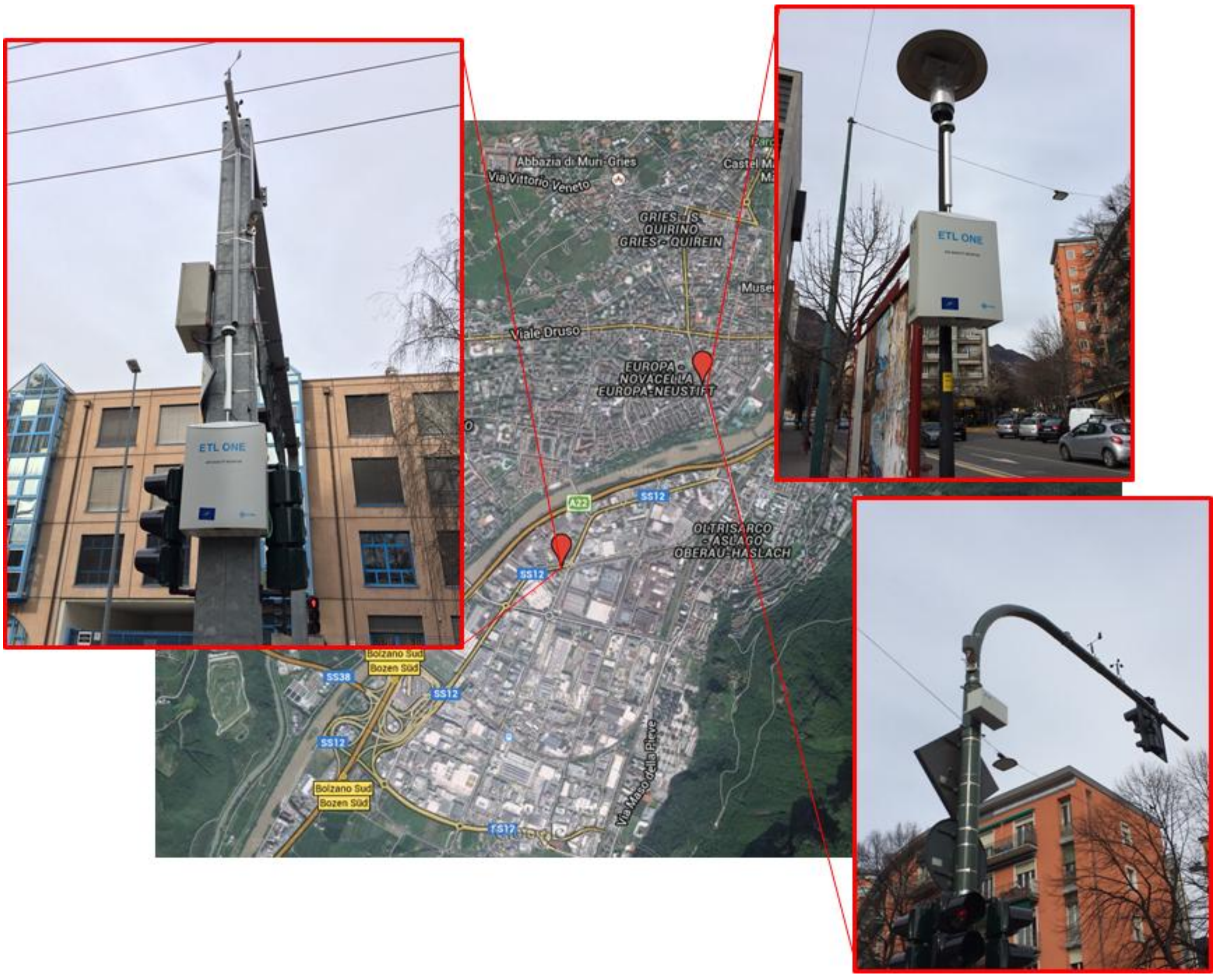

Figure 12: The new integrated traffic and air quality monitoring stations: access point linked to industrial area (left) and traffic light intersection in residential area (right).

During the implementation process, a **different installation location for the new monitoring stations** has been identified. This requirement has emerged because of the opening of urgent and unpredictable road work sites in correspondence of the chosen installation points indicated in Figure 6. Traffic and air pollution correlation analysis would have been therefore strongly affected by these disruptions, and would have led to biased and non-representative results. Different locations within the reference test area have been therefore selected, as illustrated in Figure 12:

  - one station in correspondence of an important **access point** of the city, directly linked to the **industrial area**;
  - one station in correspondence of one of the most important **traffic light intersection** of the city, located within a **densely populated residential area**.

- **Installation of the Bluetooth detectors for the vehicular travel times calculation**, as specified in the plan illustrated in Figure 8.

Figure 13: One of the roadside installation of the Bluetooth detectors.

- **Development of the Supervisor Centre prototype within a software development environment** made at disposal by TIS, with implementation of the following functionalities:
  - dedicated **communication channel** with the **Traffic Control Center of the Municipality of Bolzano**;
  - **direct interface to the third parties monitoring systems** and new monitoring implementations (Bluetooth detectors, mobile system and public transport operator AVM);
  - real-time data storage and processing;
  - enhancement of the front-end layer with "open data" publication of the measured and elaborated information, which are at disposal of third parties at the domain http://ipchannels.integreen-life.bz.it/doc/

- **Development of the automatic elaboration tasks** (traffic flows assignment model, emission and dispersion model, Bluetooth-based travel times estimator and XFCD data analyser), according to the specifications of Action n.3.

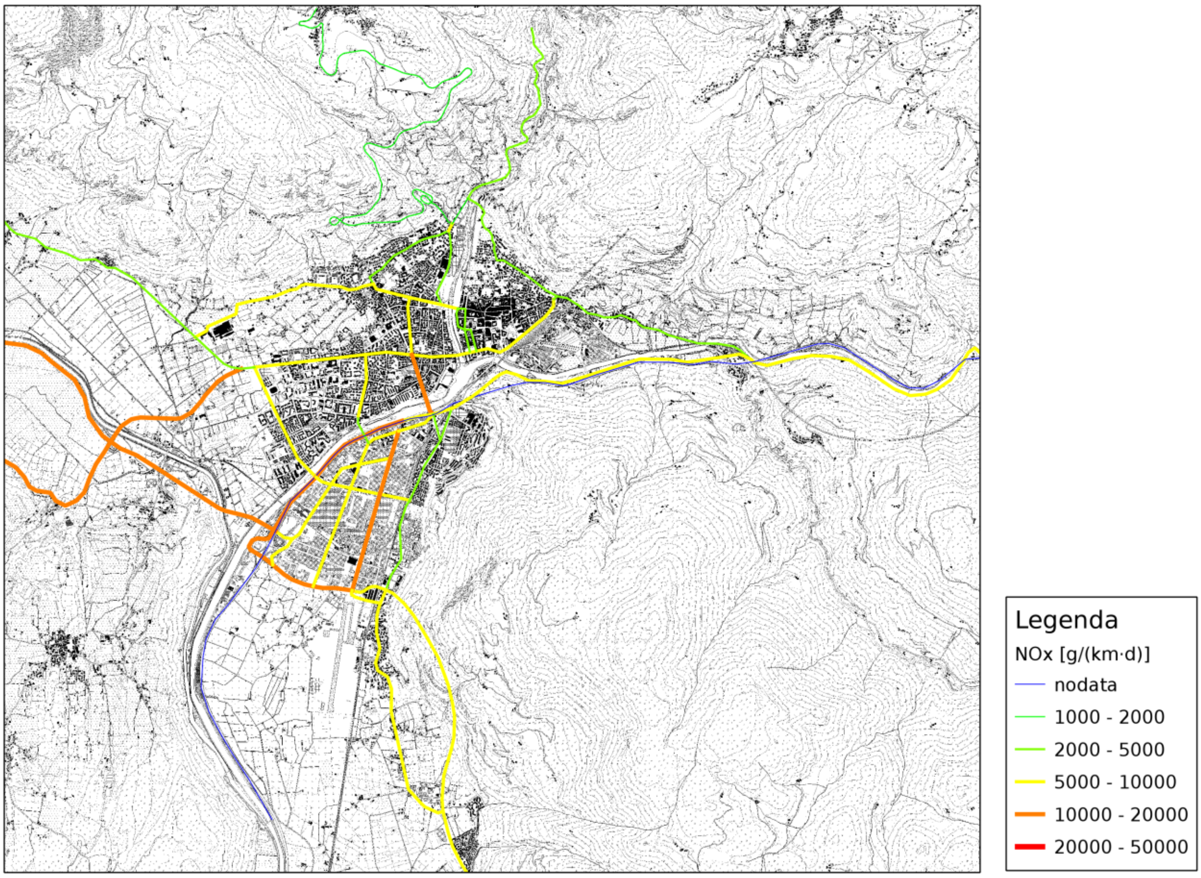

Figure 14: Example of georeferenced output generated by the emission model.

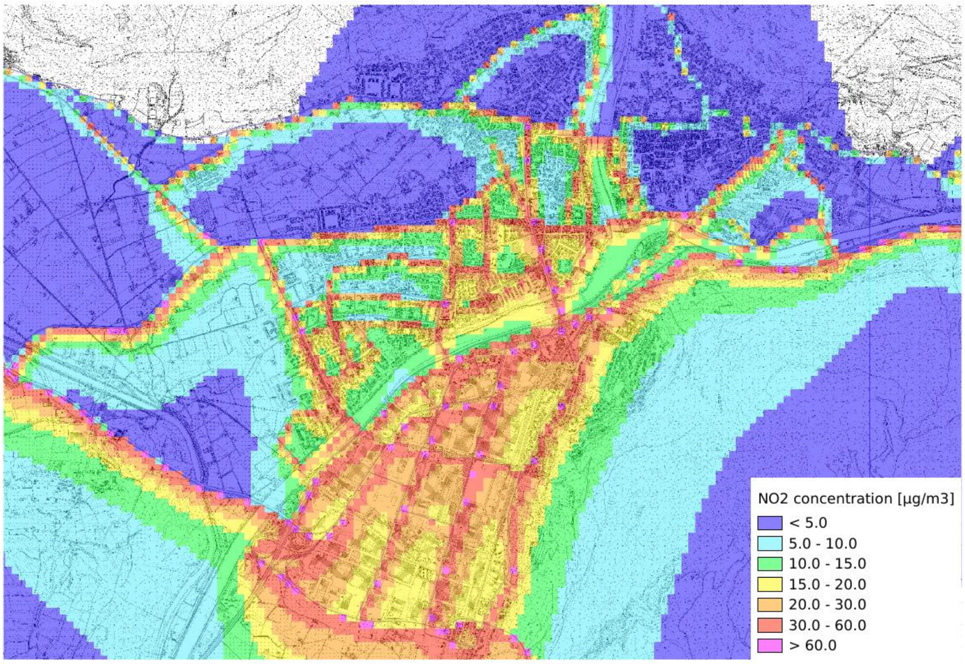

Figure 15: Example of georeferenced output generated by the dispersion model.

- **Development of the end-users applications**, more specifically:
  - **BZAnalytics**, the web-based complete dashboard, accessible by traffic operators only at the domain http://analytics.mobility.bz.it. Expert users can use the map view to get a real-time assessment of the traffic and air quality

conditions in the city, and use the plot view to get more in detail of current and historical data.

- **BZBus**, the web-based application presenting the real-time positions of the urban buses, that local travellers can freely access at http://bus.bz.it;
- **BZTraffic** the web-based application presenting the real-time vehicular travel times in the test area of the project, with a direct comparison with typical cycling times, that local travellers can freely access at http://traffic.bz.it.

All these applications have been developed in HTML5 language, so that presented contents can be properly visualized through any Internet-connected device.

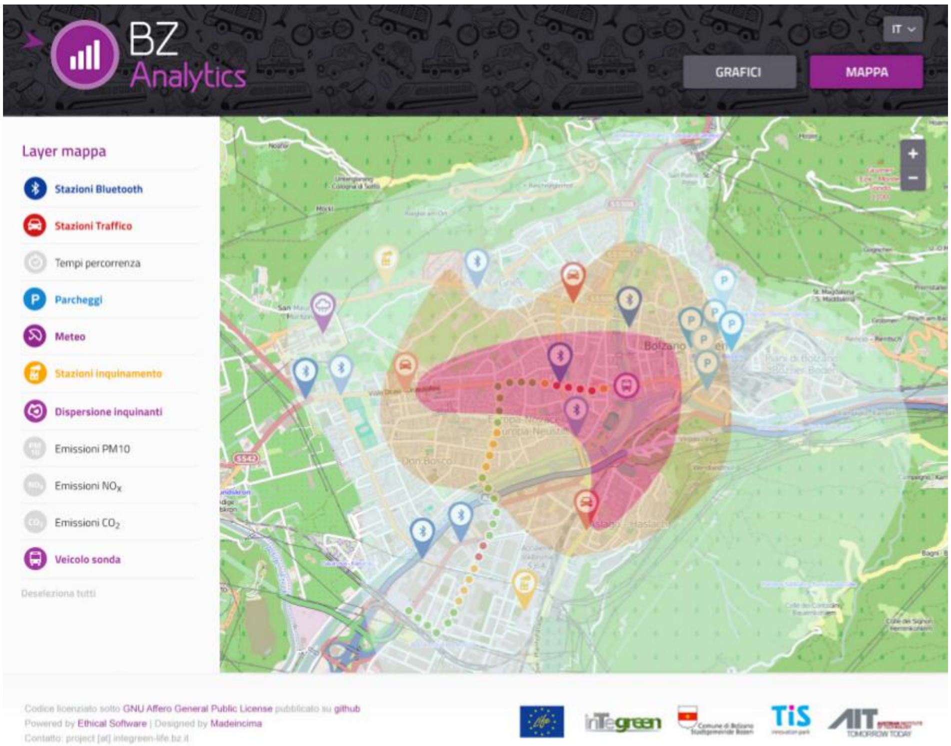

Figure 16: Example of complete overview of traffic and air quality conditions through the BZAnalytics application.

Task 4.2 *"Mobile system implementation"*: this task has been mainly managed by AIT and produced as output a first, consolidated prototype of all the on-board units (traffic and environmental monitoring units and telematic unit). Two complete mobile system demonstrators have been developed. The implementation process for the traffic and monitoring units has followed this workflow:

- **electronic design phase**, in which the right components have been selected and the design of the schematic diagram was performed;
- **PCB layout design and production**, in which the PCB layout has been finalized and produced in cooperation with external specialized companies;
- **component purchase activity**, in which the final electric components needed for the final mounting phase have been selected and bought. This process has been quite challenging for the environmental monitoring unit, since not all the components were available on the market. The missing components have been therefore internally produced, like for example the air guide block for the gas sensors. This activity has been carried out in parallel during the external PCB production;

- **electronic component mounting**, in which the purchased equipment has been mounted on the PCB. This process has been carried out in part internally, and in part in partnership with external suppliers for the most critical mounting activities;
- **labelling and testing of the mounted PCBs**, in which the PCBs have been labelled in order to avoid any problem of components mix-up, and tested in order to check the power consumption, the communication interfaces and the sensor outputs;
- **final housing and integration activity**, in which the on-board components have been housed in a box. Because of the physical dimension of the unit, it has been necessary to design an ad-hoc housing and produce it through a 3D printer owned by AIT.

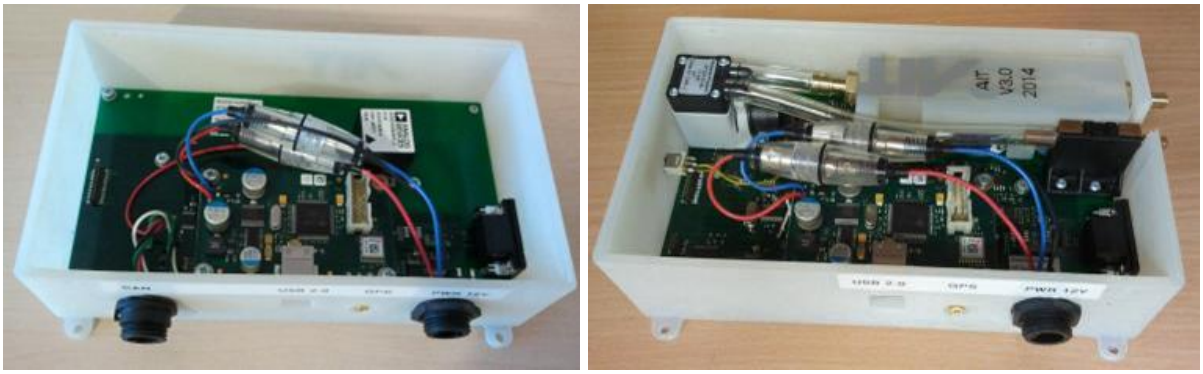

Figure 17: The on-board monitoring units prototypes: traffic (left side) and environmental (right side).

The two monitoring units are managed through an **on-board telematics unit**, implemented in two different hardware solutions (one for each developed prototype). One prototype has more an experimental profile, with the capabilities to test even very advanced functionalities (in particular as far as the kinematics of the vehicle is concerned); the second prototype is a simpler and more end-user oriented solution, thought to be used with minimum intervention by the driver. The novel monitoring units are directly connected to this on-board component, where raw measurements are first gathered. Specific software elements specified in Action n.3 have been developed in order to guarantee a proper reading of the data and the real-time remote data delivery to the server components of the INTEGREEN system, which have been already dimensioned with the purpose to manage large vehicles' fleets. On board, it is possible to check the functioning of the mobile system demonstrator through a professional automotive display, which could also be used, together with other on-board mobile connected devices, to have a direct access to the end-users services made at disposal by the INTEGREEN system.

Task 4.3 *"System integration"*: this task has been mainly managed by AIT together with TIS, and has focused on the final integration of the different system developments. Two different integration processes have been completed:

- **the integration of all on-board modules within one single mobile system demonstrator**, and its **deployment in a properly equipped test vehicle**. Different integration sessions have been organized in the final stage of Action n.4. First of all, separated on-board modules have been jointly tested first in laboratory and then on a test vehicle of AIT for first technical verification checks. Only in a second phase the single mobile system demonstrator has been developed and finally tested both as a laboratory mock-up as well as a complete prototype installed in the test vehicle. This process has permitted to significantly reduce the number of potential technical issues that one may encounter during such a complex automotive integration phase.

Preliminary communication tests have been included as well in order to smooth as much as possible the following component validation sessions scheduled in Task 5.1.

Figure 18: The integration of the on-board modules within one single mobile system demonstrator.

- **the integration of all modules at the data center layer of the Supervisor Centre**, with the launch of the full real-time operative chain. In this phase, all data sources have been linked to the external data providers, and have permitted to start storing the received data on a continuous basis. The developed elaboration algorithms have been subsequently linked to the database, and periodically executed in order to generate fresh processed outputs. Finally, the front-end layer has been linked to the core of the system in order to permit end-users applications to present the real-time measurements and elaborations. This process has been carried out on a step-by-step basis, by integrating available components at different stages. In this way, it has been possible to consolidate the functionalities of the Supervisor Centre in a smoother way, and significantly reduce the complexity related to the integration of all these software components in a real-time operating environment.

Indicators of progress: milestone M.4.1 (components development) has been successfully achieved. A more detailed overview of the progress achieved is given in Table 4.

Indicators		Comments	Reference report
Supervisors centre subsystems prototype ready	• Data management unit • Environmental stations front-end • Vehicle-to-centre front-end • Web interfaces	All Supervisor Centre components prototypes available. The number of expected components / functionalities is wider than the one planned at the project start (e.g. the implementation of the connection with the AVM system of the public transport operator).	P.4.1.1 P4.1.3 P.4.1.2 P.4.1.4/5
Mobile systems subsystems prototype ready	• On-board telematics unit • On-board traffic monitoring unit • On-board environmental monitoring unit	All mobile system components prototypes available. Sensing units have been properly calibrated.	P.4.2.3 P.4.2.1 P.4.2.2
Integration of new components at Mobility Centre		Real-time interface with Traffic Control Centre has been established.	P.4.3.1

Indicators	Comments	Reference report
Mobile system components installed on test vehicles	Final mobile system demonstrator developed and successfully deployed on a test vehicle owned by AIT.	P.4.3.1

Table 4: Evaluation of indicators of progress for Action n.4.

Problems: the INTEGREEN system manages (directly and indirectly) a number of roadside installations which is much higher than the original expectation (e.g. the Bluetooth stations for the real-time evaluation of the travel times on specific urban roads). This process has therefore needed a time period longer than originally planned. However, thanks to the high scalability and exploitability character of the INTEGREEN system, as well as the iterative integration process followed, it has been possible to **ensure the availability of first consolidated versions of the entire system prototype already at an early stage**, without affecting the execution of the final field operations tests. It is important to underline that this kind of situation will be in the near future quite common, since it is expected that the number of ITS roadside implementations will continuously increase even after the project. This situation has therefore represented an additional test for specifically assessing in practice the scalability and exploitability of the INTEGREEN system as a whole.

Comparison with the time schedule: this action has been completely finalized on M37 (September 2014) only, instead of M30 (February 2014) as originally planned. This is related in part to the initial delay caused by the partner change issue and the following delay in the final availability of the outputs of Actions n.2 and n.3, and in part to the larger implementation activities. Thanks to the hard work of partners and the strict cooperation with external assistance providers and stakeholders, during this phase it has been possible to recover most of the accumulated delay. It is in fact important to underline that the duration of Action n.4 after the conclusion of Action n.3 has been equal to twelve months (M25-M37), four months lower to what originally planned (M14-M30).

Objectives achievability: the achievability of the objectives of this Action have been confirmed.

Outputs: the Action has produced all expected prototypes, which are documented in the following prototype deliverables: P.4.1.1: *Data management unit prototype,* P.4.1.2: *Vehicle-to-centre front-end and web interface design,* P.4.1.3: *Environmental stations front-end prototype,* P.4.1.4: *Operators centre web interface prototype,* P.4.1.5: *Public web interface prototype,* P.4.2.1: *On-board traffic monitoring unit prototype,* P.4.2.2: *On-board environmental monitoring unit prototype,* P.4.2.3: *On-board telematics unit prototype* and P.4.3.1: *INTEGREEN system demonstrator*. A first version of these deliverables have been already annexed to the Mid-Term Report. A second and final version of this list of reports is now annexed to this Final Report.

Perspectives for continuing the action after the end of the project: the INTEGREEN system has been developed as a **scalable framework** that can be easily extended in terms of (i) new monitoring stations providing data types that are already managed by the system or that have not been included yet; (ii) new offline and online elaboration tasks that can produce new aggregated outputs on the base of the plenty of data and information now available; and (iii) new front-end capabilities that can offer the possibility to continuously develop more and more efficient services to end-users, including traffic operators. The perspectives for continuing this development action after the end of the project go mainly in two different directions.

- On one side, there is the opportunity to continuously **improve the current implementation developed for the Municipality of Bolzano**. Activities in this direction have already been planned. Thanks to the funding received within the **FP7 SINFONIA** project (ref.: http://www.sinfonia-smartcities.eu), the Mobility Office of the Municipality of Bolzano has in plan to significantly improve the monitoring capabilities of the actual INTEGREEN system, as illustrated in Figure 19 (in blue the new Bluetooth detectors, in red the new traffic detectors, in brown new VMS presenting current travel times information, in green new bicycle counters; other installations are related to the public street lighting system). Additional financial support is ensured by the **Italian Ministry of the Environment**, which will allow to further strengthen the static traffic and air pollution monitoring network. The choice of the monitoring technologies and locations is completely based on what has been started in the INTEGREEN project. All this new data, which will be available in the two-year period 2015-2016, will be integrated in the new Supervisor Centre, and will increase the accuracy and the scope of the actual elaboration tasks, e.g. its emission and dispersion capabilities. This work will be mainly carried in cooperation between CBZ and TIS.

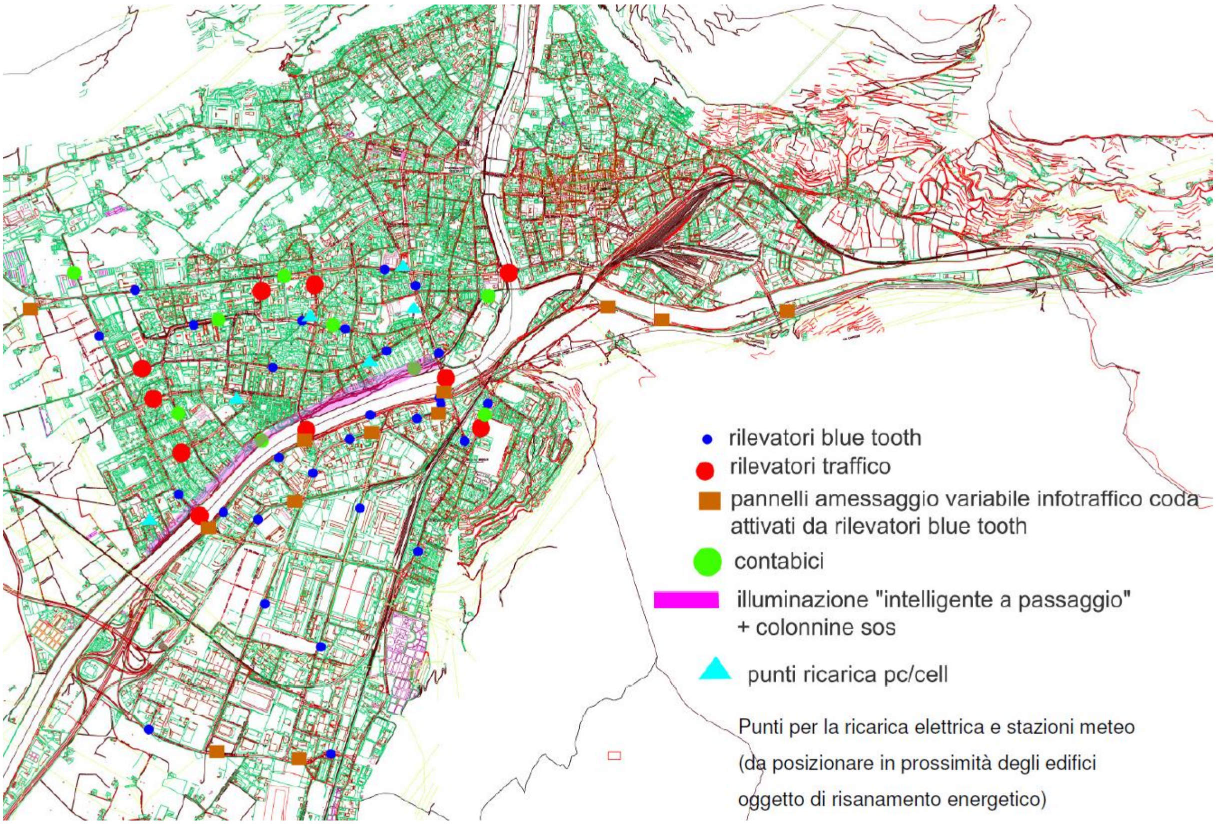

Figure 19: The future installations planned in the scope of the FP7 project "SINFONIA".

- On the other side, there is the opportunity to start using the INTEGREEN system as a generic "**big data infostructure**" capable of properly managing together data generated from different sectors. From this point of view INTEGREEN has already managed to implement a first step in this direction, by integrating together traffic and air pollution information. The possibility that the Municipality of Bolzano aims to exploit in the short term future is to use the Supervisor Centre of INTEGREEN as a platform for all public data, starting in particular from those related to the electricity grid and the water supply network. TIS has moreover received requests by local stakeholders to use the INTEGREEN system in order to host additional real-time information such as the status of the **charging points of electric vehicles**, or the **availability of bikes and cars of public sharing services**. Part of this implementation is moreover in use in the scope of the **LIFE11 ENV/IT/000002 CLEAN-ROADS** project in order to share with local travellers real-time information related to the **road conditions in the Province of Trento**.

As far as the perspectives for continuing the implementation of the **mobile system** after the end of the project, the next steps are slightly different. A non-negligible effort is still needed in order to **turn the INTEGREEN prototype into a commercially viable product** that can be used for **large-scale deployments**. The results obtained in the scope of this project are however very promising, since they have confirmed the feasibility of collecting useful air quality data through low cost mobile probes. AIT will therefore cooperate with TIS in order to put the preconditions for a know-how transfer from research to industry and the development of this new business. Last but not least, it is important to underline the fact that in the scope of the project many local companies have been involved as **external assistance service providers**, which have had a significant role during the design, implementation and testing of the various components of the INTEGREEN system. Thanks to their involvement in the project, they have had the opportunity to develop **new products or services** or improve the one they already have on the market. This will ensure the flourishing of an ecosystem of partners that by working together will be able to continuously improve the performance of this first prototype implementation and transfer this knowledge to other interested parties.

4.1.4 Action 5: Test & Validation

Expected outputs: The expected output of Action n.5 is the final empirical verification of the INTEGREEN system within the city of Bolzano, with an initial assessment of the ecological impacts associated to different experimental traffic planning strategies. The final outcome is in particular the definition of guidelines for the large scale implementation of the such dynamic measures, that can be deployed with reasonable effort on top of the new INTEGREEN system.

Achieved outputs: The complete prototype of the INTEGREEN system has been successfully tested in the final phase of the project. The system has demonstrated its capability to identify and evaluate on a real-time basis clear correlations between traffic and environmental conditions. In particular, the functionality offered by the mobile system to identify air pollution hotspots has revealed to be unique and is now a completely new knowledge that can support the activities of local air pollution experts as well. The validation and exploitation horizon of the field operational tests has been significantly extended thanks to the cooperation of the urban public transportation operator and the car sharing operator, who have permitted to use existing vehicles for long mobile monitoring sessions. At present, however, it is still quite difficult in practice to properly manage critical situations in advance, since the INTEGREEN system does at present not provide any tools for predicting certain hotspot situations.

The test activities have moreover confirmed the expected ability of the INTEGREEN system of quantitatively assessing the impact of new traffic strategies. First experiments that have been organized, in particular the installation of speed detectors and the public release of the end-users applications, have demonstrated the achievability of the target of 15-30% emissions reduction set in the project proposal. Emissions reduction potential can be even higher under certain particular conditions of high mobility demand. Unfortunately, it has not been possible to include in this assessment process the evaluation of the impact associated to improved eco-driving behaviour by public transportation vehicles' drivers, as supposed in the Mid-Term

Report. Empirical results obtained on the field, coupled with the novel indications provided by research and pilot initiatives around the world, have permitted to identify the most promising solutions for improving the environmental footprint of the urban traffic in the city of Bolzano. The major achievements obtained in each action's task have been the following.

Task 5.1 *"Component test"*: this task has been mainly managed by TIS and AIT and produced the following outputs.

- **Technical verification of the Supervisor Centre components**, according to the technical requirements defined in Action n.2. This verification check has been the first step of the component testing phase, and immediately performed once the "core" components of the Supervisor Centre have been integrated together and fed with fresh real-time data.
- **Technical verification of the reliability of the elaboration tasks**. This verification has mainly concentrated on the validation of the elaborated travel times computed on top of the detections collected by the Bluetooth-based monitoring system, since this data is explicitly or implicitly used in all present elaborations. Complex algorithms have been continuously refined in order to improve the accuracy of this output, which has demonstrated to be sufficiently reliable and precise. The main current limit observed is related to the intrinsic nature of the monitoring process, since it can not be excluded that in particular time intervals the most likely travel pattern from point A to B is not the shortest path. As a consequence of this, isolated travel times peaks are sometimes generated, which however are not representative of the current traffic load. This issue is not particularly important, since it is statistically uncommon and in most of the cases properly recoverable.
- **Technical verification of the proper integration between mobile system and Supervisor Centre**. This has been one of the most important activity during the whole technical execution of the project, that could have been in the condition, if not properly managed, to determine several negative impacts on the achievability of the project's objectives. This potential risk has been successfully avoided thanks to several simulation communication test sessions organized already during the implementation phase that have significantly smoothed the issues encountered during the final validation sessions carried out on the field. The verification of this integration process has been completed during three different component test sessions in Bolzano:
    - **component test session n.1 (February 2014)**, in which the first prototype of the mobile system has been deployed on a test car of AIT and for the first time connected to the Supervisor Centre while driving on a road (Figure 20). During this session the XFCD analyser in charge of automatically elaborate the mobile air pollution data has been finally calibrated and later implemented at the Supervisor Centre.
    - **component test session n.2 (May 2014)**, in which the low-cost air pollution sensors have been finally validated with respect to the official air quality measurements taken by the official monitoring stations. More specifically, the mobile system has been left active near the station for several hours. Recorded data have been used to pre-process the raw measurements already within the on-board unit, so that transmitted values are already available for further elaborations and analysis.

Figure 20: Component test session n.1: the first mobile system prototype installed in a test car of AIT.

- **component test session n.3 (June 2014)**, in which the final prototype of the mobile system has been deployed on a properly equipped car sharing vehicle (Figure 21). This testing activity has represented the last moment of technical verification of the whole system.

Figure 21: Component test session n.3: the final mobile system prototype installed in a car sharing vehicle.

It is important to underline that no detailed field tests combining the mobile system (with a precise portable air pollution measurement system based on optical techniques has been carried out. This is mainly due to the fact that current products available on the market have demonstrated to be not easily available, especially for short rental periods. The limited time (and residual budget) at disposal have therefore induced partners to concentrate on the final testing activities, and to postpone this additional comparison study to the near future, when hopefully both monitoring systems will have a higher level of maturity and commercial viability.

Task 5.2 *"Outdoor urban tests"*: this task has been mainly managed by CBZ with the active cooperation of TIS and AIT and produced the following outputs.

- **Consolidation of the Test Bed plan and of the overall assessment methodology**. The final validation process has been a specification of the V-model approach followed in the entire technical development of the INTEGREEN system (**Errore. L'origine riferimento non è stata trovata.**). An important added value for the scientific relevancy of the project has been the choice to follow the guidelines indicated by "Field opErational teSt supporT Action" (**FESTA**), a reference "standardized" methodology for the fulfilment of field operational test of ITS in Europe. The Test Bed plan has been structured in different testing and validation phases, namely:
  - **a first phase** ("*test site phase*"), focused on the verification of the proper fulfilment of the use case scenarios proposed during the requirements analysis of Action n.2. The aim is to empirically demonstrate the benefits of the INTEGREEN system in selected situations ("pilot use cases") and to quantify the potential associated environmental gain;
  - a **second phase** ("*validation phase*"), concentrated on the field verification of the ecological benefits of different experimental traffic planning strategies.
- **Potential quantification of the environmental gain associated to the selected pilot use cases**, namely:
  - pilot use case 1: **local citizens** planning an internal trip;
  - pilot use case 2: **tourists** planning to visit the city;
  - pilot use case 3: **commuters** planning to enter the city;

- o pilot use case 4: **traffic operators** evaluating real-time information.

More specifically, the quantification of the environmental gain has been determined by considering the data and the information collected by the INTEGREEN system during specific case studies, in which particular circumstances have been observed (e.g. bad weather conditions, high demand of commuters or tourists, etc.). Patterns related to different user categories have been individuated by properly matching data, e.g. by analysing the particular time interval of the day or the occupancy rate of the parking areas, which has revealed to be a very good indicator for indicating the degree of current tourist demand. Obtained results are summarized in Table 55.

Pilot use case	Potential environmental gain estimated
Pilot use case 1	Emissions generated during peak hours increase of 5-10%, which can arrive up to 20% in case of rainy days. These emissions can be avoided through the execution of a trip at a different time (typically in less than one hour) or a selection of different transport mode. In such conditions, an e-bicycle is typically faster than a car. During rainy days, the choice of a bus using the application BZBus can lead to similar travel times compared to car.
Pilot use case 2	The arrival of tourists can have more negative impacts during rainy days in summer than in occasion of big events like the Christmas market. Measured travel times have revealed to nearly double during hours when the traffic load is not maximum. A sustainable trip choice to reach the center (train, park & ride) influenced by a combined use of all applications can determine in such conditions a reduction of travel time of about 15%.
Pilot use case 3	Bad weather conditions have revealed to influence significantly travel times during peak commuting hours, when people arrive into the city to start working. Experienced travel times can nearly double. Local increase of emissions are in the order of 15-20% for NO_X and 20-25% for CO_2. The combination with the opening of the Christmas market does however not further affect this negative externality.
Pilot use case 4	The INTEGREEN monitoring system has confirmed its added value in terms of integrated analysis of the real-time conditions. The “integration” value is to be intended both in the capability to combine fixed and mobile measurements, and to evaluate together the current situation of traffic and air pollution.

Table 5: Potential environmental gain estimated for selected pilot use cases.

- **Long-term deployment of the mobile system prototype on a public transportation vehicle**. This operation has been finalized in October 2014, in strict cooperation with the public transportation operator and other local stakeholders (Figure 22). The chosen test vehicle has been one of the fuel cell vehicles currently in testing operation in the city in the scope of the EU-funded project “CHIC” (http://chic-project.eu). Such a vehicle has been selected for two reasons: (i) it drives once every two days always on the same bus line, which has given the opportunity to collect a large quantity of data related to the same target area; (ii) it offers a comfortable time and space for maintenance activities on the unit if required. The mobile system installed on the test vehicle has been a second prototype unit, technically identical to the one validated in the previous task.

Figure 22: The long-term deployment of the mobile system prototype on a public transportation vehicle.

From the analysis of this big amount of data it has been possible to recognize several situations of air pollution hotspots, which can be explained as a function of a high transit of pollutant vehicles, a situation of localized traffic jam, or external pollutant factors.

- **Preliminary testing and assessment of first "eco-policies" strategies**, namely:
    - a **speed detection enforcement system**, introduced in correspondence of the opening of the Christmas market 2014. This strategy has been widely discussed and conceived with the political governance of the city. The purpose of this testing strategy has been mainly to induce drivers to respect the admitted speed limit of 40 [km/h] in the city. The testing activities of the INTEGREEN project have moreover offered the occasion to quantitatively evaluate the environmental impact of such a measure as well. This is the reason why most of the detectors have been placed on road stretches monitored by Bluetooth detectors. The evaluation of the impact of this strategy has been focused on two significant urban routes (Figure 23), by comparing average travel patterns observed in the weeks before the installation and the weeks immediately after their introduction. Results have been surprisingly positive: on the monitored roads, **the reduction of pollutant emissions has been estimated in the order of 10%** (**Errore. L'origine riferimento non è stata trovata.**). This effect is directly linked to the lowering of the traffic load and the effective reduction of speeding patterns, with some positive effects on the congestion phenomena as well. No significant increase in other neighbouring roads has been observed. Longer-term analysis have however confirmed the necessity to continuously support the enforcement activities, in order to maintain constant such impact.
    - the **optimization of certain traffic light cycles**, introduced in at the beginning of 2015. The Municipality of Bolzano has already decided to introduce a new system for the automatic management of traffic lights based on real-time traffic detections. Initial tests with an "improved" traffic light positioned on one of the route with the speed detectors installed (Druso Street) have demonstrated to contribute for **further reducing emissions of 1%-2%.** However, much higher improvements are expected once the system will be deployed on a series of consecutive traffic lights. <u>Together with the speed enforcement system, this</u>

policy has demonstrated to improve vehicular travel times of 5% and emissions in the order of 10-12%;

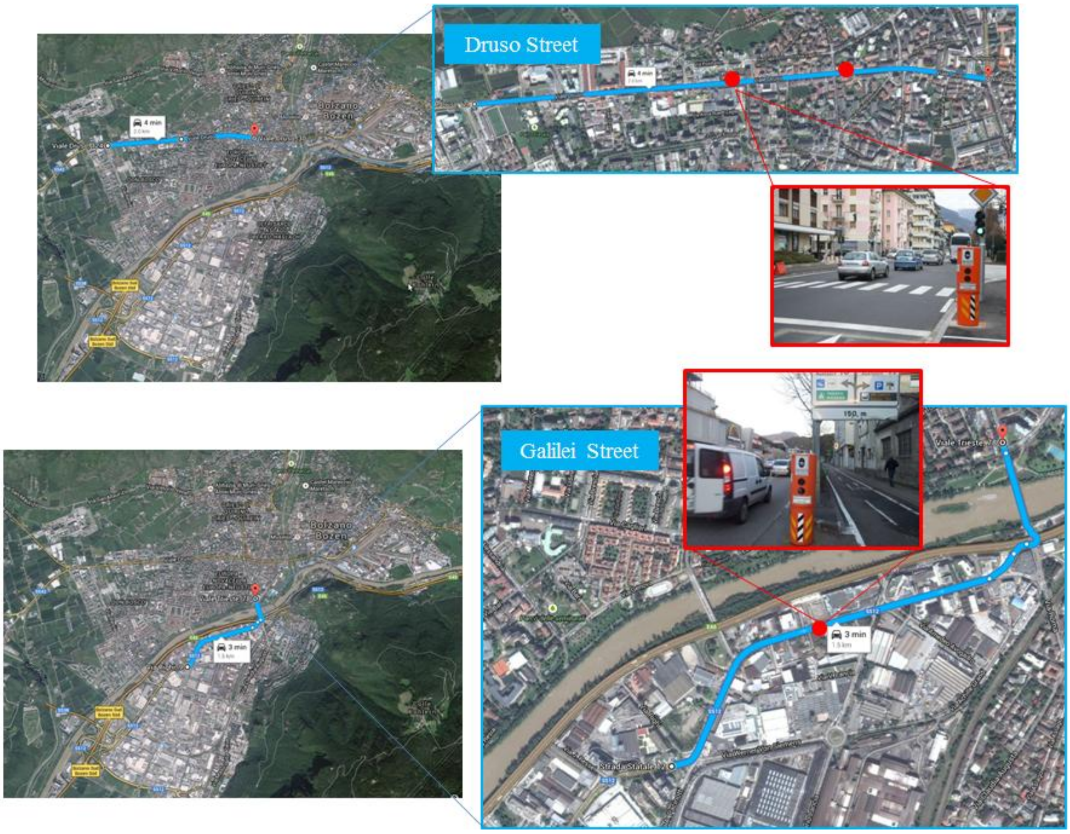

Figure 23: The urban routes in which the speed detection eco-friendly strategy has been implemented and evaluated.

- the **public launch of the end-users applications**, which has taken place in the last project months. Little improvements have been observed yet, since the penetration in the usage of these applications is still low (about 300-500 accesses every week), with the necessity to further promote them. The added value of this policy is in particular in a **better limitation of negative externalities caused by e.g. bad weather conditions**, as indicated by the results of the pilot use cases assessment. **The total reduction of emissions observed is in the order of 15-20%** on the routes considered in the analysis.

- **Assessment of the level of fulfilment of the user needs identified at the project start.** This final evaluation analysis has been carried out by directly evaluating the feedback received by the traffic operators and through a user questionnaire, launched together with the end-users application services and compiled by about 100 people soon. The initial level of acceptance to the new services is certainly good, with the best comments received for the application BZBus. Travellers have revealed that they will use them in particular during certain events negatively affecting normal urban mobility conditions. Important suggestions on how to improve the quality and the effectiveness of the services have been received as well.

Task 5.3 *"Eco-friendly traffic policies"*: this task has been mainly managed by CBZ with the active cooperation of TIS and AIT and produced the following outputs.

- **Consolidation of the most promising urban environmental traffic policies available at the state-of-art.** Preliminary studies carried during the requirements process analysis have been updated with the purpose to potential environmental benefits associated to specific traffic strategies. Results from the most relevant international research and innovation projects have been combined with significant pilot initiatives carried out in European cities. The outputs of this investigation are summarized in Table 6.

Eco-friendly traffic policy class	Target	Potential environmental benefit
Speed management	Control vehicular speeds in order to ensure that the quantity of emissions is minimum.	Emissions reduction in the order of 10-15%, air pollution concentrations of 2-8%.
Traffic control	Optimize the regulation at signalized intersections.	Initial "automation" of traffic lights can determine a reduction of traffic emissions up to 30%. Additional benefits up to further 20% are possible through new cooperative approaches based on direct communications traffic lights – driver.
Urban navigation	Optimize the distribution of vehicular traffic over the road network.	Limited environmental improvements (in the order of 5% emission reductions, obtained in particular in case of heavy traffic).
Mobility management	Influence the mobility demand of people and goods so that the efficiency in the usage of the road network and the mobility services is maximum.	Emissions savings can be potentially huge (even more than 20%) if policies determine modal split changes. The highest benefits can be obtained during traffic congestion situations. Measures which are linked to novel Low Emission Zones concepts can have direct impacts on air pollution concentrations, in the order of 5% or even more.
Driving management	Improve the driving styles so that the environmental footprint of a motorized urban trip is minimized	Highest improvements are in urban surroundings in correspondence of traffic lights, and can be responsible for emission savings in the order of 20%. The improvement is however much more greater if the initial driving style is very inefficient.

Table 6: Eco-friendly traffic policies categories and potential environmental benefits.

- **Identification of the eco-friendly traffic policies to be deployed in the city of Bolzano.** The results of the outdoor urban tests, as illustrated in the matrix of Table 7 have empirically revealed that some classes of interventions have a higher impact than others, and that the environmental benefit is strictly related to the load of urban traffic.

Eco-friendly traffic policy class	Impact with low traffic load	Impact with high traffic load
Speed management	Medium	Medium
Traffic control	Medium	High

Urban navigation	Low	Medium
Mobility management	High	High
Driving management	Medium	Medium

Table 7: Eco-friendly traffic policies categories: potential of improvement in the city of Bolzano.

On the base of these assessment results, the following package of policies has been identified for short-term implementation.

- **Large scale installation of speed detectors**, which have already given proof of their important contribution. Detectors must cover all significant road stretches of the city (in order to avoid that most of drivers deviate on uncontrolled urban routes) and guarantee their proper effect on the long-term period by continuously maintain the initial level of control and enforcement policies.
- **Introduction of advanced coordinated traffic lights signalling plans**, dependent not only by local traffic detections but also on current air pollution levels and meteorological conditions as well. This is in ambitious policy, not deployable in Bolzano with reasonable effort thanks to the INTEGREEN system, which promises to significantly reduce the environmental impact at traffic intersections in particular in case of situations of high traffic load (e.g. high tourist demand, bad weather, etc.).
- **Further improvement and promotion of the advanced services destined to local travellers**, which will be used to promote more and more intelligent mobility choices by occasional and non-occasional users. Services must be improved in order to provide in an easier way the recommendation for the best trip in Bolzano based on the current conditions. Most of the efficiency is in the time and mode of a travel, less on the selection of the route. A politic of incentives must be moreover be introduced, such as e.g. for non-entering in the city during peak hours, or the change of the prices of the parking areas in the city according to current load for accessing the historical city centre.
- **Introduction of an advanced Low-Emission Zone concept**, that aims to dynamically manage the transit of high pollutant vehicles (in particular, heavy ones) to and across the city. The idea is to manage restrictions in a non-fixed way, depending on the current (and possibly forecasted) traffic and air quality conditions in the city.

- **Consolidation of the contribution to the implementation of new EU policies in the field of air pollution and urban transport.** INTEGREEN represents a local effort to implement the EU policies in the field of sustainable urban transport and the management of air pollution issues. The main added value of the project is that it is one of the attempts at European level to approach the traffic and the environmental community by creating a unique system capable to measure both conditions on a real-time basis. The project supports even the idea to include some new technologies like the mobile system prototype for detecting the localized presence of air pollution peaks. From a transportation point of view, the INTEGREEN system represents an interesting solution for quantitatively assess the performance of the selected traffic strategies, with the opportunity to significantly improve the monitoring capabilities concerning the level of achievement of reference EU targets.

Indicators of progress: Expected action outputs have been achieved, as illustrated in Table 8.

Indicators		Comments	Reference report
Components tests completed	• Mobile system • Supervisor Centre	Component test sessions successfully completed. No final test session with mobile air pollution measurement system has been carried out. Mobile air pollution sensors have been calibrated by comparing measured values with official air quality measurements.	D.5.1.1
Operative evaluation plan released for INTEGREEN framework validation and environmental benefits assessment		Test Bed plan available, based on the standardized FESTA methodology.	D.5.2.1
Definition of operative plan and environmental gain quantification		The INTEGREEN system has demonstrated its ability to be used as a monitoring tool to detect peaks in traffic / air pollution conditions and to measure the environmental impact of selected traffic policies. The potential benefit has been assessed with reference a set of pilot use cases, analysed in specific case studies. A first set of eco-friendly traffic policies has been experimented and quantitatively evaluated.	D.5.2.2
Urban environment traffic policies selection		The most promising policies for the city of Bolzano has been individuated, based on the results of the field test sessions and the indications available at the state-of-art. Contributions to the improvement of the EU policies have been consolidated.	D.5.3.1

Table 8: Evaluation of indicators of progress for Action n.5.

Problems no technical or organizational issue has compromised the expected fulfilment of the field operational tests. The only critical aspects which have emerged have been the ones illustrated in the Mid-Term Report, namely:

- **availability of portable reference mobile air pollution monitoring systems**. Experience has demonstrated that at present it is very difficult to have at disposal precise mobile air pollution measurement systems to be used as reference instrument. The availability is low, the effort for the on-site calibration is high, and the costs for such activity are not negligible. Partners have therefore decided to not carry out this calibration sessions, and to follow the countermeasure already identified to calibrate the mobile system air pollution sensors through long static measurement sessions near the official air quality stations of the city.
- **impossibility to involve public transportation drivers for eco-driving tests because of conflicts with trade unions**. Unfortunately, no agreement has been found between the urban public transportation operator and the trade unions for the definition of how savings produced by improved eco-driving behaviour of bus drivers could be distributed between the company and the drivers themselves. Therefore, no eco-driving measures have been inserted in the final Test Bed plan.

Comparison with the time schedule: the Action has been fully completed in correspondence of the project's end. The months at disposal for the final test and validation activities have revealed to be sufficient for properly completing all activities as originally scheduled.

Objectives achievability: the achievability of the objectives has been confirmed, as well as the environmental and operational targets set in the proposal, as indicated in Table 9.

Expected target	Achieved target
Availability of information about environmental conditions from once a day to 3-5 samples per hour	At present it is possible to have air pollution data from static stations every 15 minutes (4 samples per hour) and to have real-time data from the mobile system deployed on the public transportation vehicle. Each point of the covered route is monitored once every hour.
Time to react after an extraordinary traffic / environmental event will decrease of 30-50%	The time to react after an extraordinary traffic event has slightly reduced, since traffic operators can immediately detect the presence of peak situations through the system of video cameras they have in use. The most important target achieved has been the possibility to reduce to time to reaction after an environmental event. On average, this time has reduced of more than 50%.
Ability to prevent critical situations is increased of 30-50%	This target has been confirmed, i.e. about the 30-50% of critical situations can be somehow identified in advance. Quantified travel time or air pollution patterns can be used to see the trends and recognize the occurrence of possible extraordinary events.
Update times of traffic and ecology plans will decrease of a factor 1/3 (a plan every four month)	Actually, thanks to the INTEGREEN system, it is possible to make an instantaneous photography of the traffic / air pollution of the city, with a time resolution of even less than one hour. It is confirmed the possibility to reduce the time for update of local plans up to 3-4 months.
Project impact on road transport related emissions estimated in the order 15-30%	All together, the implementation of the eco-friendly traffic policies have demonstrated on average to reduce the traffic emissions in the order of **15-20%.** These percentages are higher in case of high traffic load, situations which are revealing to occur less frequently as a demonstration of the enhanced stability obtained by the local mobility system.

Table 9: Comparison between expected and achieved project's target.

Outputs: the Action has produced the deliverables D.5.1.1: *On-board modules and supervisor centre test results*, D.5.2.1: *Test Bed plan and test scenarios*, D.5.2.2: *Test Bed plan validation and INTEGREEN benefits assessment* and D.5.3.1: *Quantitative impact of eco-friendly traffic policies*. All these reports are annexed to this Final Report.

Perspectives for continuing the action after the end of the project: the perspectives for continuing the action after the end of the project are clear, and can be summarized as follows.

- **Continuous evaluation of the performance of the monitoring stations and the elaboration tasks**, with the opportunity to check respectively:

  - the appearance of possible calibration issues related to drift phenomena of the sensors, which must be properly compensated;
  - the possibility to further improve the performance and the accuracy of the elaborated outputs.

- **Introduction of the new eco-friendly traffic policies** which have been identified, and quantitative assessment of their environmental impact. In particular, the very next step will be to increase the integration level between the Supervisor Centre with the new traffic lights system and the traffic simulation model. The traffic lights system will provide additional traffic data at the intersections, and implement automatic logics based on the current traffic and air pollution conditions. The traffic simulation model will become an online model and directly feed the emission and dispersion modelling chain developed in INTEGREEN.
- **Further introduction of the instruments and tools developed by INTEGREEN within the daily activities of traffic operators**, with the perspectives to improve the efficiency of the actual set of procedures to be followed in case of specific traffic / air pollution issue.

4.1.5 Action 8: Monitoring

Expected output: The expected output of Action n.8 is the verification of the time and financial progress of the project activities, as well an assessment of the environmental improvements observed during their execution.

Achieved outputs: The envisaged monitoring activities have been successfully completed. The major achievements obtained in each action's task have been the following.

Task 8.1 *"Monitoring the project progress"*: this task has mainly covered the internal monitoring of the technical and financial progress evaluation by project partners, in particular by TIS (who is in charge of the daily project management of the project) with CBZ, the Coordinating Beneficiary of the project. This activity has been carried out smoothly and without any particular issues in light of the project management structure and the internal monitoring tools prepared and defined at the project's start, and thanks to the internal procedures that beneficiaries have agreed to follow. Most of the strategic decisions taken by the internal management board (e.g. temporal planning of the technical implementation phases of the project, test bed activities planning, component test session organization, etc.) have been possible thanks to this internal efficient monitoring framework that it has been possible to create and maintain.

Task 8.2 *"Monitoring the environmental improvements in the project"*: this task has been mainly managed by CBZ and TIS, and produced the following outputs.

- **Definition of the monitoring procedure and indicators**, which have been introduced in order to evaluate the reduction of the environmental impact of traffic and the improvement of the sustainable mobility habits of the local travellers.

  The reduction of the environmental impact of traffic has been monitored by continuously analysing:

  - the official traffic data in correspondence of the entry points of the city, in particular by evaluating the share of the most pollutant vehicles (i.e. heavy vehicles) and the occurrence of congestion phenomena;
  - the official air pollution data measured by the air quality stations of the city;

- the estimated amount of emissions generated by local traffic, measured in the first part of the project through the detailed CO_2 emissions inventory monitoring assessments carried out by CBZ in partnership with the local research center EURAC in the scope of the process of SEAP definition. In the final stage of the project, the INTEGREEN emission model has been directly used as a monitoring tool, and applied by considering in input the official traffic data.

The improvement of the sustainable mobility habits of the local travellers has been investigated through complementary surveys and studies carried out or commissioned by CBZ or other local stakeholders such as the Autonomous Province of Bolzano. Main indicators for the evaluation have been the modal split and the average number of travels per person.

- **Execution of five specific monitoring analysis over the periods**: (i) September 2011 – February 2012; (ii) March 2012 – October 2012; (iii) November 2012 – August 2013; (iv) September 2013 – February 2014; and (v) March 2014 – February 2015. All periods were compared with the data collected during the previous year. The most relevant results that have been obtained through this set of analysis can be summarized as follows:
  - **Traffic levels**. All monitoring periods have revealed a general trend in the reduction of vehicular transits in correspondence of the entry points of the city of Bolzano, in particular as far as the private non-commercial traffic is concerned. The estimated reduction is in the order of 3%. Generated traffic emissions have been reduced with the same order of magnitude.
  - **Air pollution levels**. According to an ex-ante / ex-post analysis of the concentrations of air pollution in the city, **levels of NO_2 have decreased in the order of 5-10%**. In particular, situations of heavy pollutions are now much less frequent in the city .
  - **Greenhouse gas emissions**. thanks to the new emission monitoring capabilities of the INTEGREEN system, CBZ has decided together with EURAC to introduce a novel methodology for the assessment of the emissions caused by traffic. The new analysis have revealed that urban traffic counts only for 17% of the whole CO_2 emissions (instead of 31% estimated with the initial territorial approach), as graphically reported in Figure 24.
  - **Mobility habits**. The results of a wide survey commissioned by the Municipality of Bolzano in year 2013 have revealed how **the percentage of motorized travel choices in the city is continuously decreasing, from 37% to 34%** (Figure 25). Further social research studies carried out by the Institute for Alpine Environment of EURAC have on the other side revealed how the air pollution problem is still quite perceived by the local population (about 57% of about 1.000 interviewed citizens has expressed to be quite or a lot disturbed by the air pollution conditions in the its residential area).

Problems: no particular issue has been encountered during the execution of these activities, which have been supported and in some way extended thanks to the active cooperation not only of all project beneficiaries, but also of local stakeholders as well.

Comparison with the time schedule: the activities have been completed in line with the original temporal plan.

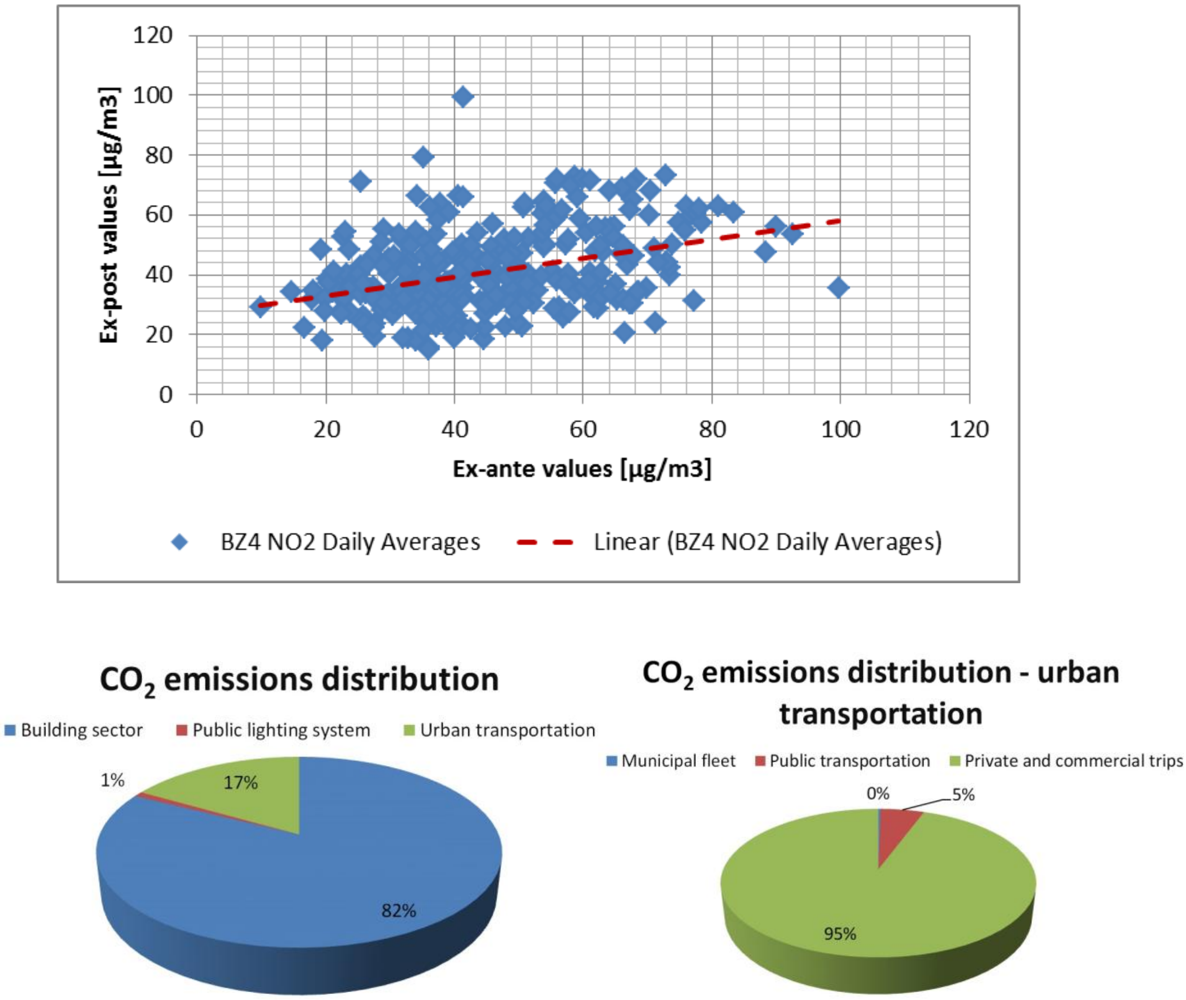

Figure 24: Results from environmental monitoring assessment – ex-ante / ex-post air pollution levels and impact of urban traffic on CO_2 emissions.

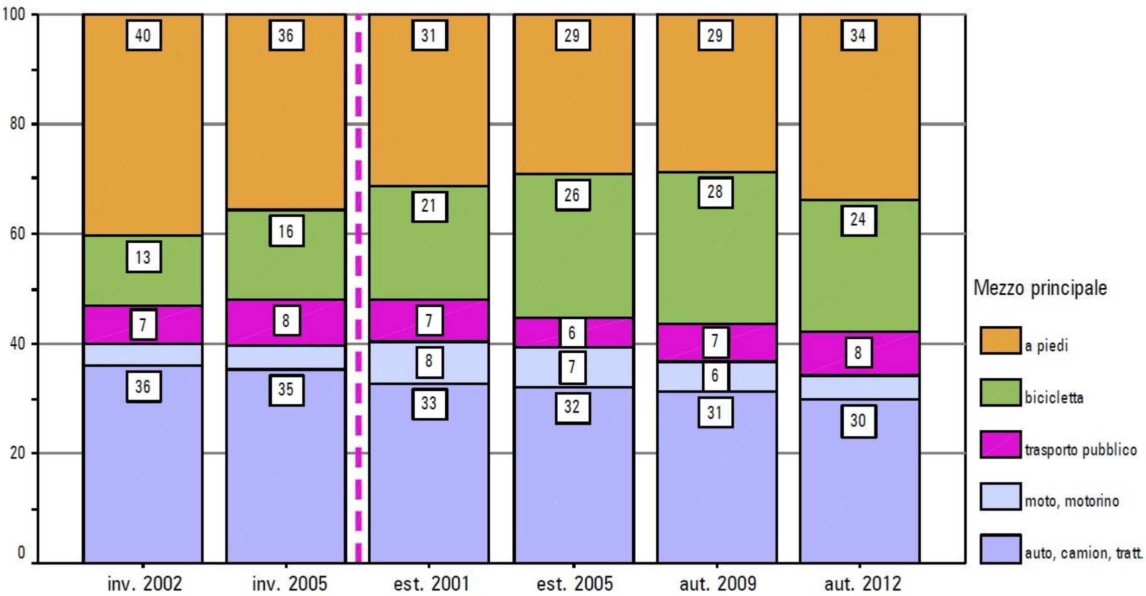

Figure 25: Results from environmental monitoring assessment – new modal split situation.

Indicators of progress: not applied to Action n.8

Objectives achievability: the achievability of the objectives of this Action have been confirmed.

Outputs: the Action has produced the deliverables D.8.1: *Report Check Point 1;* D.8.2: *Report Check Point 2;* D.8.3: *Report Check Point 3;* D.8.4: *Report Check Point 4* and D.8.5: *Report Check Point 5*. Deliverable D.8.1 was already submitted as annex of the Inception Report. D.8.2 and D.8.3 have been annexed to the Mid-Term Report, while D.8.4 and D.8.5 are delivered together with this Final Report.

Perspectives for continuing the action after the end of the project: this monitoring activity will be regularly carried out in the future on top of the INTEGREEN system, which can be used as a monitoring tool, too (as envisaged at the project start) in order to check the environmental improvements associated to the introduction of new measures and strategies. The proposed monitoring methodology will be significantly enhanced and new indicators will be introduced on the base of the new available set of data. An additional perspective is to integrate the INTEGREEN emission model within the emissions inventory monitoring toolbox of the city. Such an integration process has been already kicked-off.

4.1.6 Overview of temporal execution of project activities

The effective temporal execution of project activities is illustrated in the Gantt diagram of Figure 26. The timing of the actions have followed the plan indicated in the Mid-Term Report, except for Action n.4 which has taken one month more to be finalized.

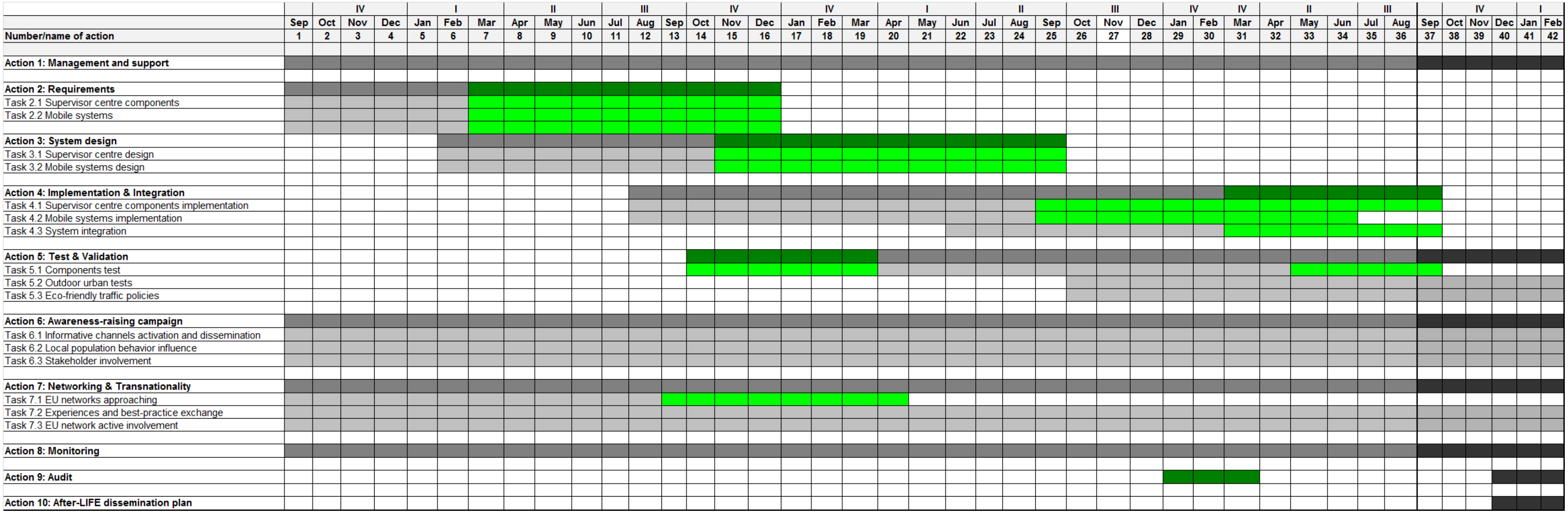

Figure 26: Effective Gantt diagram related to the project activities.

4.2 Dissemination actions

4.2.1 Objectives

One of the annexes of the Inception Report delivered to the EC has been the **dissemination plan**. In this document, many elements have been consolidated in order to prepare the local and international dissemination campaign planned by the project. In particular:

- the **target groups have been identified** (i.e. local population – including tourists, local stakeholders and EU networks and stakeholders) and the objectives of the dissemination strategy addressing each of them have been consolidated;
- the **different phases of the dissemination, networking and awareness-raising activities have been defined**:
    - a start-up period, with the preparation and activation of several dissemination and awareness-raising products and channels and the creation of early contacts with local and EU stakeholders;
    - an intermediate period, with the execution of the awareness-raising campaign to be performed in the target area of Bolzano and the consolidation of the synergies and partnerships with stakeholders;
    - a final period, with the execution of final dissemination and networking activities, aiming on one side at actively involving local travellers in the final validation tests of INTEGREEN and on the other side at promoting the adoption of the approach proposed by the INTEGREEN projects at international level.

Given the limited capabilities of the project in terms of time and budget, during the preparation of the awareness-raising campaign it has been decided to **limit the activities on a set of very specific focus groups**. If properly individuated, these groups could act as natural "multipliers" of the messages and concepts conveyed by the project, and thus spread them on a large scale and on the long-term period. The selected focus groups have been:

- **schools, both high and primary ones**. The older students are in the condition to better understand the project (even from a technical point of view) and determine an immediate impact on the social welfare, since they are near to the driving license period. Young children are a very interesting group since by addressing them it is possible to positively influence their parents as well.
- **professional drivers**. By influencing travellers who have the necessity to make a lot of VKT, it would be possible to have very large environmental impacts, and probably create the conditions for indirectly impacting non-professional drivers as well.
- **tourists**, since they represent a key driver for reducing the observed mobility inefficiencies;
- **citizens** presenting both a certain economical wealth and a positive perception towards sustainable mobility concepts, since they could act as reference models for the local society.

The objectives of these specific awareness raising activities are, in an order of ambition:

1. Create **information** about basic sustainable mobility concepts (e.g. "transport modes", "eco-driving", "multi-modality", etc.).

2. Create **awareness** – the user starts to assess the inefficiencies in his/her travel choices and styles.
3. Create the **desire of being informed** – the user starts to evaluate possible alternatives that must be however supported by an informative base (e.g. the one provided by INTEGREEN).
4. Create a travel behaviour **change.**

4.2.2 Dissemination: overview per activity

Task 6.1 *"Informative channels activation and dissemination"* and task 6.2 "*Local population behaviour influence*": a large set of local dissemination and awareness-raising activities mainly coordinated by CBZ and TIS has been carried out, beyond the original set of initiatives indicated in the project proposal. All the dissemination channels have been properly activated and consolidated, and are used in order to continuously promote the project even after its conclusion. Many awareness-raising initiatives have been completed in the last project year, together with the final launch of the INTEGREEN system prototype.

The **project web site** (www.integreen-life.bz.it) has been continuously improved in terms of graphical layout and amount of news, information and technical details. Since the second semester of 2012, at least 500 people visit the website every month, and about 44% of visitors are new ones. In 2014, the number of visits has significantly increased, up to an average of 1.500 accesses per month. In the period February 2012 – February 2015, about 19.000 visits have been counted, with about 8.000 unique visitors.

In order to improve the relationship with especially the local community, partners then decided to open in November 2012 a **Facebook** and **Twitter profile** as well. The potential of these channels has not been fully exploited yet, and the results of the first promotion campaigns on these channels has been quite disappointing. Numbers demonstrate that no critical mass has been built on these networks. The experience has shown that is particularly difficult to have a significant appearance on these networks since the amount of information and contents shared by the users is very high. Moreover, users seem to prefer to use social networks mainly for trivial purposes only. More specific studies and additional (and much higher) investments should be experimented after the project conclusion in order find the proper key for a real large-scale involvement of users within these virtual networks.

In order to give proper visibility among those citizens who are still unfamiliar with digital technologies, a set of **permanent notice boards** has been installed in three locations in the city (Figure 27), and afterwards replaced after some vandalism problems occurred during a huge event hosted by the city ("*adunata nazionale degli alpini*" – national assembly of the Italian alpine troopers) in May 2012. Dissemination activities have been moreover supported with the distribution of about 3.000 **flyers** and 1.000 **stickers fostering eco-travelling**.

One of the most relevant dissemination outputs produced has been a **teeming figure picture** (better known with German term "*wimmelbild*"), a graphical illustration very dense of details in which partners have tried to combine reference project use cases and eco-friendly traffic management concepts together with absurd, comic and also typical inefficiency situations (Figure 28). This product, chosen in place of the project video because of its broader flexibility and variety of use, has concretely supported the specific awareness-raising activities carried out together with focus groups, in particular the students of the high schools.

Figure 27: One of the project notice board with teeming figure picture.

Figure 28: The INTEGREEN teeming figure picture.

Large-scale awareness-raising activities have culminated in particular in correspondence of a series of important **public events**, in which the INTEGREEN project has presented the addressed environmental challenges and the proposed countermeasures. The most impacting initiatives have been in particular:

- the organization of a project stand during the **Innovation Festival 2012** (September 27th - 28th -29th), in which local citizens and visitors had the opportunity to enter in contact with the project by empirically testing the eco-driving concepts through a proper simulator (Figure 29). The best eco-drivers were awarded with gadgets, and a lot of project stickers were distributed to children. The festival was attended by about 25.000 visitors, and the INTEGREEN stand got a huge visibility on the local media.

Figure 29: The INTEGREEN stand with eco-driving simulator during the Innovation Festival 2012.

- the large scale distribution of INTEGREEN material during a big event fostering local sustainable mobility habits, namely "***Bolzano in bici 2013***", organized by the Municipality of Bolzano on September 22nd 2013 during the European Mobility Week 2013.The event, attended by several thousands of citizens, was for the first time promoted during all the week through the VMSs, in order to further foster the mobility habits change of motorized drivers.
- the organization of a project stand during the **Long Night of Research 2014** (September 26th – 27th), in which local citizens and visitors had the opportunity to get in direct touch with the main implementations of the project (e.g. the mobile system and the Bluetooth detector) and to see the first results of the measurement sessions on board of a car sharing vehicle (Figure 30). Users had the opportunity to deepen this environmental problem and were fostered to provide their own contribution to it by improving their mobility choices. The event was attended by about 12-14.000 visitors.

Figure 30: The awareness-raising activities during the "Long Night of Research 2014" event.

- the organization of a **final roadshow for journalists** on February 27th 2014, in which invited representatives of local media operators (TV, radios, newspapers) had the opportunity to make a drive on a test car of beneficiary AIT with the mobile system in function. Journalists could check air pollutions levels in the different roads and remained significantly impressed by the added value of the INTEGREEN system as a whole. The project and the targeted environmental problem had large visibility on all media channels, with an estimated coverage of about half of the entire city population.

Media activities have been completed by **two radio interviews, one additional press release** and **a press conference** organized for the final launch of the end-users applications. Thanks to the active cooperation with local stakeholders, specific targeted awareness-raising activities with the identified target groups (schools, professional drivers, tourists and selected types of citizens) have been completed, and have put the conditions for a large set of after-LIFE initiatives. These activities are summarized in Table 10.

Target group	Awareness-raising activity completed
Students	Initial meetings with students have been organized by TIS and CBZ already in 2013, both in schools and at TIS. In 2014, the project staff had three sessions of meeting with more than 100 students coming from seven different high schools. In these working groups, project staff has tried to work with students in the organization of specific initiatives to be proposed in primary schools. A common and detailed work plan has been finalized at the end of activities. Its implementation has been not carried out yet, but will be promoted on a large scale basis in direct cooperation with the local schools organizations and other interested stakeholders.
Professional drivers	An active working group with the urban public transportation operator (SASA) and a local excellence centre on safe driving (Safety Park) has been created in the scope of the project. Thanks to this, an increased awareness about the added value of eco-driving has been consolidated; the local demand and offer for eco-driving courses has been improved. Unfortunately, no concrete actions like the organization of a demonstrative eco-driving training course have been completed yet, in light of the actual conflicts with trade unions already mentioned in Action n.5.
Tourists	An active working group with reference tourist organizations (in particular the Tourist Agency of the city of Bolzano) has been established. Thanks to this, the interest for new services to tourists with real-time information about current access conditions in the city has been created and consolidated. The developed prototype applications have been already promoted by these stakeholders to tourists, with immediate visible effects on the reduction of seasonable events. The working group has moreover already identified a set of more efficient actions and measures to be carried out after the project in order to inform tourists more timely.
Citizens	Sustainable mobility concepts, fostered by ICT/ITS technologies, have been discussed in a series of public meetings organized by CBZ. The most relevant one has taken place on November 27th 2014, during a political meeting open to the discussion of local citizens. These awareness-raising activities have been completed by the cooperation with selected stakeholders in the targeted promotion of the end-users applications, as for example CNA/SHV, the local association of artisan businesses.

Table 10: Targeted awareness-raising activities summary.

Finally, a set of dissemination activities have been organized in order to support the stakeholder involvement and networking activities which are more specifically targeted by Task 6.3 and the tasks of Action n.7. After the **first workshop** organized on June 27th 2012 with the intention to give an initial presentation of INTEGREEN, a **second local event** has been organized on June 24th 2014, in which a public presentation of the first implemented components of the system have been given and international best-practices have been discussed. Strict contacts have been established with other LIFE projects, namely the projects LIFE09 ENV/IT/092 "**OPERA**" and LIFE+11 ENV/IT/015 "**PERHT**". The **final third workshop** has been organized on February 24th 2015, with the presentation of the final results obtained in the INTEGREEN project.

The international visibility of the project has been finally strengthened by a set of **technical publications and presentations at important congresses**. Four project presentations have been organized in occasion of different international congresses. Project results will be moreover presented in other three conferences in 2015. Three local publications destined mainly to local citizens have been prepared and published in the first part of the project; more will follow in the after LIFE period. INTEGREEN has been finally mentioned in a couple of other national and international publications, including the report "**LIFE and Air Quality**" (2014).

Task 6.3 *"Stakeholders involvement*": one of the most promising results achieved has been the establishment of a strong commitment by several local stakeholders in the development and exploitation of INTEGREEN. All this set of contacts was mainly established in occasion of the first project workshop, and then strengthened through specific working groups. The list of local stakeholders with which the most relevant active synergies have been activated can be summarized as follows:

- SASA, the **urban public transportation operator**, and the **car sharing operator**, which have put at disposal their vehicles for the field operational tests of INTEGREEN, and are interested in further deploying the mobile system prototype;
- the **Local Agency for the Environment**, which has not only given an important support in the technical implementation of the project, but is willing to exploit similar actions even on the highway section crossing the city;
- the organization "**Autostrade del Brennero S.p.A.**", responsible of the management and maintenance of the A22 highway, which has started a similar research project in partnership with the **Environmental Engineering Faculty of the University of Trento** for a better understanding of the correlation between traffic conditions and air pollutions in correspondence of specific stretches of the A22 highway, including the one transiting over the urban area of Bolzano. Project partners and these stakeholders have activated a joint working group with a sharing of data, results and lessons learnt. Together with the Local Agency for the Environment, it has been decided to develop a **new joint LIFE proposal** called "**BrennerLEC**", presented on the LIFE 2014 call;
- the **Institute for Renewable Energies of EURAC**, which is supporting various offices of the Municipality of Bolzano (including the Mobility Office) in the definition of a SEAP in light of its adhesion to the Covenant of Mayors, and is performing detailed CO_2 emissions inventory monitoring assessments;
- the local NGO **Ecoistituto Alto Adige**, with which several joint awareness-raising activities will be started in the next future in the city of Bolzano;

- the **Business Location Südtirol** (BLS), who has been committed by the **Mobility Department of the Province of Bolzano** in cooperation with its **Mobility Agency** to introduce a long-term strategy towards a completely decarbonized mobility system in South Tyrol. INTEGREEN has given an important demonstration of the important role that ITS technologies will have for this kind of evolution. This new awareness is significantly influencing the selection of the actions and measures to be started in the next years at regional scale.

It is finally worth to be mentioned the strict cooperation that the project is having with the **LIFE+10 ENV/IT/000002 "CLEAN-ROADS"**, coordinated by the Autonomous Province of Trento, in light of the participation as Associated Beneficiary of TIS in both projects. Joint networking events with these selected stakeholders have been organized in order to strengthen the existing cooperation, one in correspondence of the best-practice exchange organized in the city of Vienna during the 4th Plenary Meeting (see Action 7.2), and a more recent one in occasion of the 5th Plenary Meeting held in Bolzano (**Errore. L'origine riferimento non è stata trovata.**).

Task 7.1 "*EU networks approaching*" and task 7.3 *"EU networks active involvement*": thanks to various national and international networking activities it has been possible to create an important international visibility to INTEGREEN. The most important and significant activity in this direction has probably been the participation to the **LIFE+ Platform Meeting** organized by the Astrale Monitoring Team in Berlin on November 21st – 22nd, 2013, in which the project had the opportunity on one side to present and discuss the INTEGREEN approach to a large number of international technical experts, and on the other side to get valuable inputs and information about other on-going LIFE+ initiatives targeting clean and sustainable mobility around Europe (Figure 31). The meeting was attended by key representatives of the EC as well, with which it has been possible to share the local lessons learnt and to exchange important considerations about the development of improved policies at European level.

Other relevant networking activities are those that project partners are performing within relevant networks such as **CIVITAS**, **ELTIS**, **EPOMM**, **ECOWEB** and others. An international visibility to the project actions and outputs is still on-going, and will continue even after the project's end. The Municipality of Bolzano has increased its weight in the CIVITAS network, and has been involved in the preparation of a new ambitious CIVITAS proposal which could capitalize most of the INTEGREEN experience. The number of new international project ideas developed is very high and varied; from one side, they aim to investigate the possibility to use the INTEGREEN system for other mobility applications, and on the other side they are willing to implement new eco-friendly traffic policies concept. The most relevant output is from this point of view the **LIFE proposal** "**DIANA**", presented on the call 2014, which aims to demonstrate a new concept of low emission zone in Bolzano. Other relevant networking activities are those carried out in the scope of the networks in which the project has been presented (e.g. **ERTICO**, the partnership for the promotion of ITS in Europe) and in which beneficiaries are involved, e.g. the ***European Automotive Research Partners Association*** (**EARPA**). The experience gained in INTEGREEN is providing value inputs to the vision and positioning of the members of this association.

Task 7.2 *"Experiences and best-practice exchange*": many new cooperation channels have been established with other European cities. A particular synergy has been developed with Austrian partners and organizations, thanks in particular to the networking work done by AIT. During the **4th Plenary Meeting** organized in **Vienna**, instead than in Bolzano, the internal project meeting was coupled with (i) a networking event between invited Italian and Austrian stakeholders and (ii) a demonstration session in which all the invited organizations had the unique opportunity to experience on a real car the future capabilities of cooperative mobility scenarios based on V2X communications, and to visit the Traffic Management Centre of the ASFINAG highways (Figure 32). Thanks to this best-practice exchange, it has been possible for stakeholders to extend their local perspectives and to create the basis for future important international partnerships, also beyond the scope of INTEGREEN.

Figure 31: The LIFE+ Platform Meeting organized by the Astrale Monitoring Team (November 21st – 22nd 2013, Berlin).

A second relevant best-practice exchange has been organized in partnership with the **Italian Ministry for the Environment** (LIFE+ National Focal Point) and the Office of the Public Function of the Presidency of the Council of Ministers. A delegation of important policy makers, representatives of various public administrations in the **Italian regions of the Convergence Objective** (i.e. Campania, Calabria, Puglia and Sicily) was received on January 23rd 2014 by the Municipality of Bolzano, TIS and other local organizations (including the Province of Bolzano) with the intention of presenting the local policies and actions for environment protection and for addressing climate changes. A third important best-practice exchange has been completed on August 7th 2014, at the presence of a **Finnish delegation** visiting the city of Bolzano. It has been nice to see how even the **city of Helsinki**, one of the

Figure 32: The visit to the Traffic Control Centre of ASFINAG held in occasion of the 4th Plenary Meeting (April 12th 2014, Vienna).

best cities in the world as far as the sustainable mobility promotion is concerned, could get useful inputs from a small city like Bolzano.
During the last project year, project partners have consolidated different national and international contacts, even with **North America**, where contacts with the local authorities of **Chicago** are in place. This international networking has had its peak during the second international workshop, with a specific best-practice exchange session with the **city of Graz**, a pilot city of the EU FP7 project "**CARBOTRAF**", coordinated by AIT, and the **city of Treviso**, in which the **LIFE+ PERHT** project is taking place. Last but not least, CBZ has had an active role in the European Biking Cities campaign coordinated by the international LIFE+ project "**CLEAN AIR**", and has shared its huge experience in cycling promotion with the European cities of **Brighton-Hove**, **Mannheim**, **Potsdam**, **Strasbourg** and **Vitoria-Gasteiz**.

Expected vs achieved results. A summary of all dissemination and networking results, compared with the ones indicated in the project proposal, are summarized in Table 11. Most of the actions' outputs has been overcome thanks in particular to the active involvement of local stakeholders, who have permitted to significantly extend the scope of the dissemination and networking opportunities of INTEGREEN. The international dimension of the project has been furthermore amplified by the entrance of beneficiary AIT in the consortium.

Expected results	Achieved results
Dissemination Plan	Dissemination Plan made available at the project start and further improved during the project.
Permanent notice boards	5 permanent notice boards, later substituted by other 3 boards after vandalism phenomena.
Project website	Active project website, enriched by Facebook and Twitter channels.
Production of 3-5 press conferences / articles, TV / radio interviews	1 press conference, 2 TV / radio interviews, 1 "isolated" press release, 2 press releases in occasion of workshops, 1 press release in occasion of project public demonstration, 20-30 presences on media channels in occasion of large scale public events.
Production of at least one technical article	3 local publications, 4 presentations at international conferences (+3 in 2015 after the project conclusion).
Production of a project video	1 teeming figure picture ("wimmelbild").
Organization of three workshops and two networking events	3 workshops and 4 networking events (2 combined with workshops).
Use of VMSs for education purposes	VMSs usage has been limited only during periods in which big sustainable mobility events have been organized.
Promotion of "eco-driving" and "sustainable mobility events in at least	The project and its addressed concepts have been promoted in 5 public events.

three public events	
Organization of 3-5 meetings in schools and consumer association	8 meetings with schools, 12 meetings with consumers' associations.
Active involvement of local stakeholders for the adoption of novel policies towards sustainable mobility, the sharing and the assessment of the INTEGREEN validation results, the organization of the awareness-raising campaign and the exploitation of the project's results	Active cooperation with 9 local stakeholders.
Approaching of at least five EU networks active in the field of sustainable urban transports	Active contacts with 7 EU networks.
Inclusion of INTEGREEN partners into into at least two EU networks	Project beneficiaries are included in 2 EU networks.
Active influence on at least three existing projects and the creation of at least three new project ideas	Influence on 2 existing projects and creation of 3 new project ideas very strictly related to the city of Bolzano and 2 additional one related to the broader application of the INTEGREEN system. Cooperation evaluated but not deployed in other two project proposals.
After-LIFE communication plan	After-LIFE communication plan defined, with a very detailed list of activities to be carried out with local stakeholders as well.

Table 11: Expected vs. achieved dissemination and networking results.

Problems: no particular issue has been encountered during the execution of these activities, which have been on the contrary significantly extended. The only critical point has been the reduction of the involvement activities of professional drivers. The feedback and comments received have been always very positive, at demonstration that the set of activities launched has been going on the right way for a new level of users and stakeholders' engagement.

Comparison with the time schedule: the activities have been completed in line with the original temporal plan.

Outputs: <u>The full details of all dissemination and networking activities are given in the attached report, which was not planned in the initial work programme</u>. An integration of such document already submitted with the Mid-Term Report is delivered together with this Final Report.

4.3 Evaluation of Project Implementation

<u>Methodology applied</u>. Several considerations can be made concerning the impact of the adopted methodology with which the work program was initially conceived, and the cost effectiveness of each single initiative taken to support its technical, organizational or dissemination achievements. The first consideration is related to the **proper integration of technical and non-technical actions** while executing a project with similar ambitious targets and complexity. It has revealed important to create an active involvement of the target audience already from the project start, in order to create the conditions on one side for developing external significant partnerships which could improve the scope and the outcomes of the project, and on the other side for a behavioral change which could be then maximized when the demonstrative system is implemented and available for use.

A second consideration is related to the **technical implementation** of the project only. By following a specific, consolidated methodology for the execution of all technical actions (i.e. the V-model which has been presented several times in this report) it has been possible to smooth and reduce the complexities related to this process, and above all to minimize the integration risks which are quite common in similar developments. Moreover, partners have experienced the added value of actively involving local industry partners (mainly small or medium enterprises, which represent the majority of the companies located in South Tyrol) in the implementation of the specific project tasks and taking advantage of their specific competences in a specific field of interest. Through a proper integration of these different knowledge, enriched through the inputs coming from the heterogeneous point of views of project beneficiaries (public administration, research institute and innovation centre), it has not only been possible to significantly enrich the technical value of the project, but also create the basis for pushing local investments in research and development activities and for opening new market opportunities, even in cooperation through business partnerships. This is also a powerful way to multiply the dissemination effects among specialized experts, who are in contact with these private organizations.

The third consideration is about multiplying the mobility behavioral changes effects through the **organization of specific dissemination and awareness-raising activities destined on certain focus groups**. It is unthinkable with limited temporal and budget constraints think to address all possible targets which characterize a local mobility system. Theoretical studies, confirmed by practice, have demonstrated that large effects can be induced if certain awareness-raising actions are in the conditions to change the perspective of certain key focus groups, who could then by imitated by other categories who consider them as reference model to follow. Another important key element is again the creation of intelligent partnerships with stakeholders and/or initiatives that have already managed to create a significant critical mass of users: in this way further activities organized in the scope of a limited project as INTEGREEN could take benefit of all this background work and be organized with acceptable investments in terms of effort and money. Last but not least, is the "*gamification*" element, i.e. the idea to transfer concepts and messages or foster specific travel habits in a funny way, without imposing anything from on high but just making leverage on the pleasure to make a specific action and/or the competition to be better than another user in doing a specific task. This was noticed in particular during the eco-driving demonstration organized during the Innovation Festival 2012 event through an ad-hoc simulator. A similar huge interest and impact, also on local media, would have been impossible without such an interactive instrument.

Comparison between the results achieved against the objectives of each project Action: this has been analyzed in the description of the activities of each project action. It is to be underlined how in most of the cases project achievements have overcome initial expectations, despite the issues encountered at the project start. The potential for exploitation is clear and incredibly high and various.

Visibility of project results. The targeted environmental impact has been mostly already observed as a function of the various involvement activities of the users and the introduction of the first eco-friendly policies. Reduction in traffic levels, reduction in percentage of motorized trips in the city, containment of the levels of air pollutants, are all indicators that the path is directed in the right way. The expectation is however that more noticeable improvements will be possible in the short future, when the knowledge of traffic and air pollutions conditions will increase, the tools and services will fully enter the daily routine of operators and travelers, and new dynamic policies will be introduced based on this continuously enhanced base knowledge.

Other relevant lessons learnt up in the scope of the INTEGREEN experience have been the following:

- the **partner change issue** has passed from being a big problem at the project start, with significant delays in the activation of the project activities, in a big opportunity to extend the scope and the geographical character of the project. Even the most critical problem could become a remarkable opportunity, if properly and timely addressed;
- it is important to follow a **recursive and dynamic approach** when managing the different phases of such a **complex technical implementation**. In this way, it has been possible to anticipate the availability of a reference system implementation, and to gradually extend its capabilities and features once the design choices become more specific and definitive. The advantage of this approach is the intrinsic scalability and continuous improvability of such a solution, which could continue even after the project's end thanks also to the innovation "loop" induced by the project;
- it is important to create a **strong commitment of local stakeholders** already in the first phases of the project. In this way, the opportunities for further expanding and exploiting a system can significantly increase, and the impact on the target audience can be strengthened and amplified.

4.4 Analysis of long-term benefits

1. **Environmental benefits.**
   a. **Quantitative analysis**. By implementing the selected eco-friendly traffic policies, the reduction of emissions generated by urban traffic can be in the order of up 50%. A reduction of air pollution levels could also be obtained, with a realistic expectation of decrease of about 5-10% with respect today average values.
   b. **Contribution to EU policies**. On the other hand, INTEGREEN has demonstrated its potential for actively supporting the implementation of the EU Environment Action Programme and the further development of the EU legislative framework the in terms of (i) more accurate monitoring system capable to jointly measure traffic and air pollution conditions directly at the emission source (i.e. the road), and thus the possibility to exactly assess the environmental impact of a specific measure / policy; (ii) specific evaluations about the localized presence of air pollution peaks through the low-cost mobile probe, and thus enhance the comprehension of the dispersion phenomena near these linear sources; and (iii) integrated real-time traffic / air pollution conditions assessment, which could significantly influence and improve not only the way urban traffic is typically managed and controlled, but also the traffic-related policies which are typically proposed by air quality experts in order to face the pollution issues facing the urban environments. INTEGREEN could thus represent a very valuable instrument for further approaching the traffic and the environmental communities.

2. **Long-term benefits and sustainability.**
    a. **Environmental**. Environmental challenges addressed can be efficiently contrasted on top of the INTEGREEN system, if properly exploited and applied on large scale. The inclusion of real-time information related to other sources of emissions as well precise indications of short-term forecasted conditions will have an increasing role in order to properly address peak situations. Historical data about which traffic policy has had which effect in which conditions will also provide a unique base for improving the efficiency of future actions and decisions.
    b. **Economic**. The proposed solutions of INTEGREEN are economically very interesting, since most of them are based on extremely cheap and off-the-shelf hardware and software, with interesting business opportunities for new or existing local companies. The use of free and open source solutions does not put into question issues related to possible licensing costs.
    c. **Social**. Long-term benefits will be possible only if a social innovation process will continue as carried out in INTEGREEN, with a deep and committed involvement work of both key stakeholders and local travelers as well. Modal split in Bolzano is already excellent, but through the introduction of a market of RTTI applications travelers will also have the possibility to further improve their travel decision choices, in particular in correspondence of particular contextual events which may alter the stability of the local transportation system. The maintenance of such ecosystem of end-users applications by local service providers is therefore crucial and connected to the previous point, and promises to foster further structural improvements of the whole mobility system in Bolzano This will ensure increasing levels of quality of life and health, the creation of new and qualified jobs fostered by an increasingly appealing habitat for small and medium companies, and the integration of people with different cultures and walk of life.
    d. **Continuation of the project actions**. Project partners have put most of their effort in guaranteeing that the demonstrative system developed in INTEGREEN could be easily exploitable on large scale. This could be carried out by project beneficiaries in cooperation with local stakeholders and private companies already involved in the project. Project actions will continue in part in the direction to put "in production" the most relevant features and measures developed on top of INTEGREEN, in part in the direction of expanding the system on the whole urban area and even beyond it, and finally in the direction of continuing investigating new and more advanced solutions for further reducing the environmental impact of traffic. All these technical activities will have to be coupled with the awareness-raising activities indicated in the After-LIFE dissemination plan.

Replicability, demonstration, transferability, cooperation. Technically, INTEGREEN as a system has demonstrated its potential for being easily replicated in other similar urban areas. In reality, in the last years, many public administrations have started to introduce air pollution measurements for traffic management purposes. Tools and approaches developed in the project could enrich the local experiences which have already started. Not only: through the intense cooperation with the local industry, it has been possible to give a great impulse for commercial applications and components that could support the deployment of similar systems. The wide use of open source software solutions and cost-effective hardware devices has given the possibility to significantly reduce the barriers for the large scale penetration of the various innovations brought by INTEGREEN. The strategy has been therefore to invest more on the local knowledge, rather than on (closed) physical equipment or devices: in this way the further development of INTEGREEN could be ensured thanks to the new abilities that the project has contributed to produce. Moreover, the new transnational character of the consortium has opened the doors to an internationalization of the project, which will allow to facilitate the transferability of the lessons learnt in Bolzano not only at a regional and inter-regional level, but also in other European countries and areas.

Best practice lessons. Project beneficiaries have actively taken advantage of different best-practices among Europe. On the other side, it has been interesting to observe how contacted EU leading cities in the field of sustainable mobility like Helsinki are following with interests the local experience carried out in the city of Bolzano. In a future project experience, the focus will be on best-practices covering both technological and social measures inside the same set of actions, like proposed by INTEGREEN, since the acquired certainty is that this is the key for generating large environmental impacts.

Innovation and demonstration value. The results of the test and validation activities have confirmed the high innovation value of INTEGREEN as a concept. The possibility to have an enhanced monitoring system capable of jointly measuring traffic and air pollution conditions directly at the emission source, identifying the localized presence of air pollution peaks and performing integrated real-time traffic / air pollution conditions assessment has a unique value for the city, and represents a best-practice that can be very significant for the whole European community. The demonstration performed in the project is very valuable for decision-makers at different levels in the public governance, since they will be more and more in the conditions to understand what could be impact of performing actions like the one suggested in INTEGREEN in the urban environment they are managing. The EU funding has had a crucial role for the execution of this project initiative, and will be moreover very important in supporting project beneficiaries in developing a new generation of policies, technologies and tools based on the results of INTEGREEN.

Long term indicators of the project success. The methodology that INTEGREEN has proposed for monitoring the environmental improvements during the project's execution (i.e. monitoring of traffic and air pollution levels, greenhouse gas emissions, mobility habits and others) can be considered also for evaluating the project success in the long-term period. The new set of data collected through INTEGREEN will moreover allow for much more detailed assessment of the specific situations occurred in the city under certain conditions.

5. Annexes

The Final Report is completed with a series of annexes which provide lots of details concerning the administrative, technical and dissemination implementation of the project. The electronic version of all this documentation include all annexes that were already submitted through the Inception Report and the Mid-Term Report. A specific overview of each single annex is given in the paragraphs below.

5.1 Technical annexes

The delivery of the technical annexes is summarized in Table 12. Most of the deliverables are published on the project website (http://www.integreen-life.bz.it/approfondimenti-tecnologici)

Deliverable	Comment	Reference Report
D.2.1.1 Supervisor Centre components requirements	Final version.	Inception Report
D.2.2.1 Mobile system requirements	Final version.	Inception Report
D.3.1.1 Data management unit and environmental stations front-end	Final version. Contains specific design annexes (e.g. outputs of FRAME design process)	Mid-Term Report
D.3.1.2 Vehicle-to-centre front-end and web interfaces design	Final version.	Mid-Term Report
D.3.2.1 On-board telematics unit	Final version.	Mid-Term Report
D.3.2.2 On-board traffic and environmental monitoring unit	Final version.	Mid-Term Report
P.4.1.1 Data management unit prototype	Prototype description documents. Version 1 is submitted with the Mid-Term Report and the final version with the Final Report.	Mid-Term Report (v1) Final Report (v2)
P.4.1.2 Vehicle-to-centre front-end prototype		
P4.1.3 Environmental stations front-end prototype		
P4.1.4 Operators centre web interface prototype		
P4.1.5 Public web interface prototype		
P.4.2.1 On-board traffic monitoring unit prototype		
P.4.2.2 On-board environmental monitoring unit prototype		
P.4.2.3 On-board telematic unit prototype		
P.4.3.1 INTEGREEN system demonstrator		
D.5.1.1 On-board modules and supervisor centre test results	Final version expected.	Final Report
D.5.2.1 Test Bed plan and test scenarios	Final version expected.	Final Report
D.5.2.2 Test Bed validation and INTEGREEN benefits	Final version expected.	Final Report

Deliverable	Comment	Reference Report
assessment		
D.5.3.1 Quantitative impact of eco-friendly traffic policies	Final version expected.	Final Report
D8.1 Report Check Point 1	Final version.	Inception Report
D8.2 Report Check Point 2	Final version.	Mid-Term Report
D8.3 Report Check Point 3	Final version.	Mid-Term Report
D8.4 Report Check Point 4	Final version expected.	Final Report
D8.5 Report Check Point 5	Final version expected.	Final Report
D9.1 Audit verification certificate	Final version expected.	Final Report
D10.1 After-LIFE communication plan	Final version expected.	Final Report

Table 12: Technical annexes list.

5.2 Dissemination annexes

5.2.1 Layman's report

The Layman's report is delivered together with this Final Report. The report is available in English and in the mother tongues spoken in South Tyrol, namely Italian and German.

5.2.2 After-LIFE Communication plan

The After-LIFE Communication plan is delivered together with this Final Report, and contains a detailed plan on how the project will be promoted at local and international level.

5.2.3 Other dissemination annexes

A comprehensive indication of all dissemination annexes is given in Table 13.

Annex	Comment	Reference Report
Dissemination Plan	-	Inception Report
Dissemination Mid-Term Report	Annex presenting in detail all dissemination activities carried out in the period covered by the Mid-Term Report	Mid-Term Report
Notice board	Poster and images of the notice board installation	Inception Report (poster); Mid-Term Report (new notice boards installations photos)
Flyer	-	Inception Report
Stickers fostering eco-travelling	-	Inception Report
First workshop material	Presentations, participants' list, photos, press release	Inception Report
Local publications	Copy of three publications appeared on local magazines	Inception Report
Press release	Official communication to the press, newspapers articles.	Mid-Term Report (with updates through the Final Report)
Teeming figure picture	-	Mid-Term Report

Annex	Comment	Reference Report
Public events material	Photos of five main public events (Klimamobility 2011,Innovation Festival 2012, Bolzano in bici 2013, Long Night of Research 2014 and journalists' roadshow 2015)	Inception Report (first two events); Mid-Term Report (third event); Final Report (final events)
Congresses presentations and technical papers	Project presentations and paper proceedings at international conferences	Mid-Term Report (with updates through the Final Report)
Networking events and best-practice exchange material	Various material related to four main networking and best-practice exchange events (best-practice exchange in Vienna, networking event at 5th Plenary Meeting, best-practice exchange with Italian regions of the Convergence Objective and LIFE+ Platform Meeting on Urban Mobility)	Mid-Term Report
Second workshop and final event material	Presentations, participants' list, photos, press release	Final Report
Final dissemination activities / demonstrations	Various material presenting final dissemination activities / demonstrations (including final further dissemination outputs)	Final Report
Dissemination Final Report	Annex presenting in detail all dissemination activities carried out in the project	Final Report

Table 13: Dissemination annexes list.