LIFE+10 ENV/IT/000389

INTEGREEN

Action 4: Implementation & Integration

P.4.3.1

INTEGREEN system demonstrator

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

Document history

Date	Document Author(s)	Document Contribution
31/03/14	Roberto Cavaliere, Paolo Valleri, Stefano Seppi (TIS), Reinhard Kloibhofer, Wolfgang Ponweiser (AIT)	First document version submitted to the EC
31/05/15	Reinhard Kloibhofer,Franco Fresolone (AIT), Roberto Cavaliere (TIS)	Second and final document version submitted to the EC.

Dissemination level: CO[1]

Delivery month: M45

Status: submitted to the EC

[1] **PU** = Public; **CO** = Confidential (for members of the consortium only, including the European Commission); **RE** = Restricted, i.e. only a selected target of stakeholders defined by project consortium and validated by European Commission can access to the document. The final dissemination level will be defined in cooperation between the INTEGREEN consortium and the European Commission.

Table of Contents

Table of Figures

1 Introduction

The Implementation phase follows directly the design specification phase and it relies on the V-model approach as show here below in Figure 1.

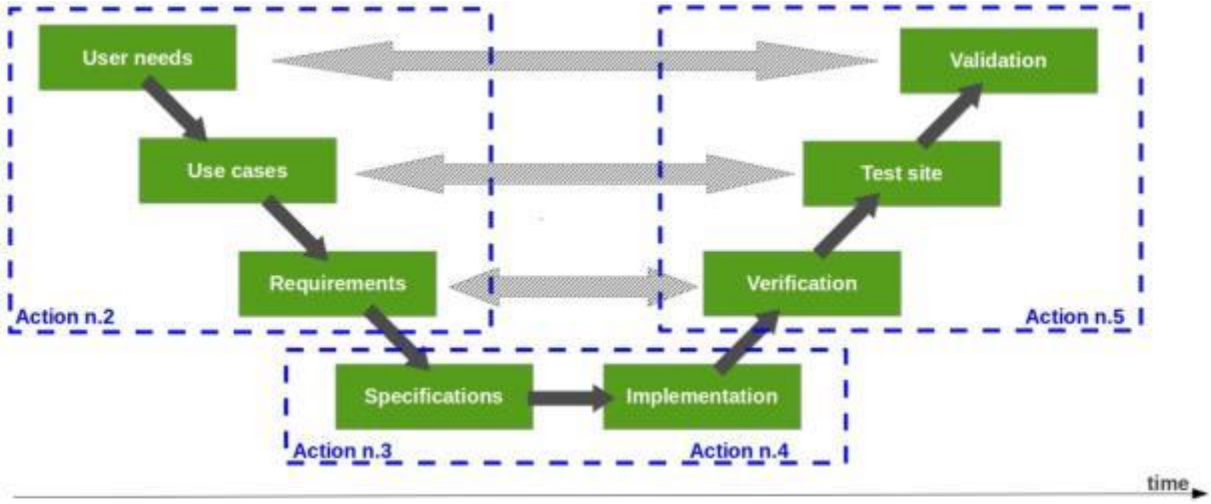

Figure 1: The V-model approach applied in the INTEGREEN project

The Implementation and Integration action aims primarily at producing the physical prototypes for the INTEGREEN Systems and mount them in their final production environment. It is executed after the Design phase which is the main input to this Action as it can be seen in Figure 1.

1.1 Purpose of the document

This document deliverable P.4.3.1 is the last AIT deliverables of Action 4: Implementation and Integration. AIT is the responsible beneficiary for the activities in Action 4 and directly responsible for the execution of Task 4.2 Mobile systems implementation as well as for the execution of Task 4.3 System integration. The execution of Task 4.1 Supervisory Centre component implementation is under the responsibility of beneficiary TIS.

In this document deliverable the activities of Task 4.3 are described, which cover mainly the integration of the mobile system prototype in selected test vehicles.

2 Mobile system demonstrator integration in AIT demo vehicle

This chapter briefly presents the first integration phase of the mobile system, in which the prototype of this system has been installed inside the AIT demo vehicle. The complete system prototype (including connection with Supervisor Centre through the vehicle data source) was finally tested on the field in February 2014 in Bolzano.

2.1 On-board units integration

For the first on-board system integration, it was decided to place all units (including telematic one) in the rear luggage compartment (Figure 2) of the AIT test vehicle. It is important to underline that the red component is a unit which is not part of the INTEGREEN Mobile System. The units are connected as specified in the deliverables of Action n.3, Task 3.2 [1].

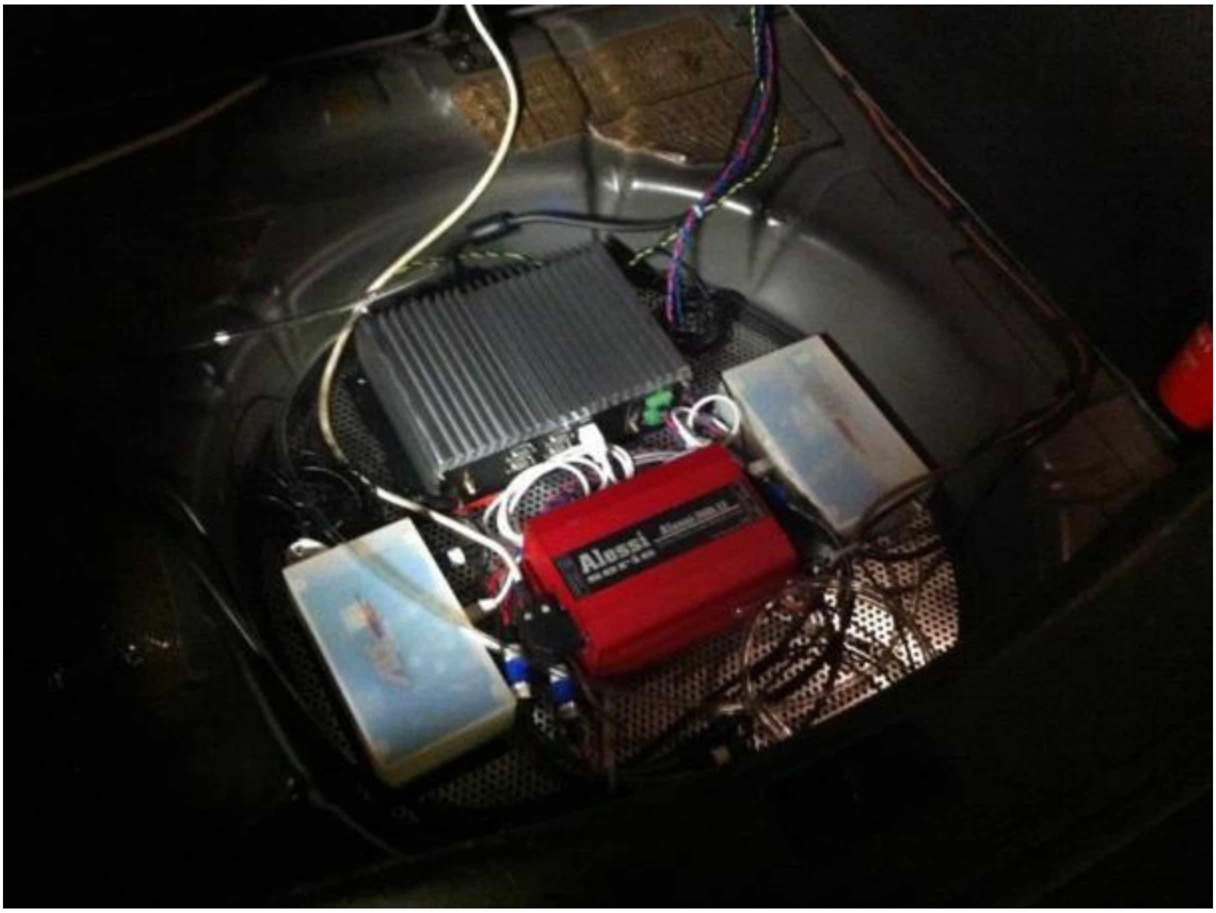

Figure 2: Integration of the on-board units in the AIT demo vehicle

The three main units can be distinguished:

- The white box on the left side is the traffic monitoring unit
- The white box on the right side is the environmental monitoring unit

- The black/silver box behind is the telematic unit

Electrical connections to the vehicle are:

- Power supply (battery and ignition)
- CAN-bus connection.

2.2 Air tube and antennas integration

The air tube which is needed in order to collect the air samples for the measurements by the on-board environmental unit is placed in correspondence of the rear glass of the luggage compartment (Figure 3). This is considered the most efficient position since it allows a minimum impact on the vehicle and the air can be inhaled in the opposite driving direction of the vehicle. The GPS receiver and 3G/4G antennas are placed in the rear part of the roof.

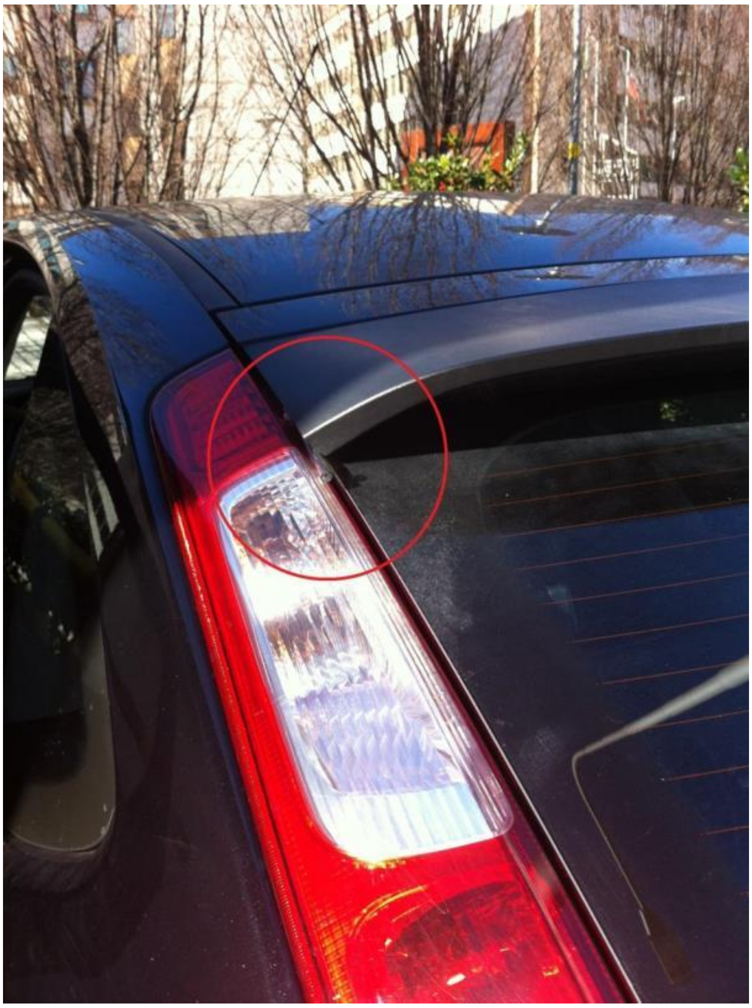

Figure 3: Integration of the air tube in the AIT demo vehicle

2.3 HMI and Operator interface

Finally, the connection with the operator HMI is covered through a serial connection with the telematics unit. The cable has been laid on the floor corner in order to minimize the inconvenience of the passengers. Keyboard and mouse are connected to this unit through a wireless short range communication, i.e. Bluetooth. Through the HMI the operator can check on a real-time basis the functioning of all the deployed units and take the proper countermeasure in case an issue takes place.

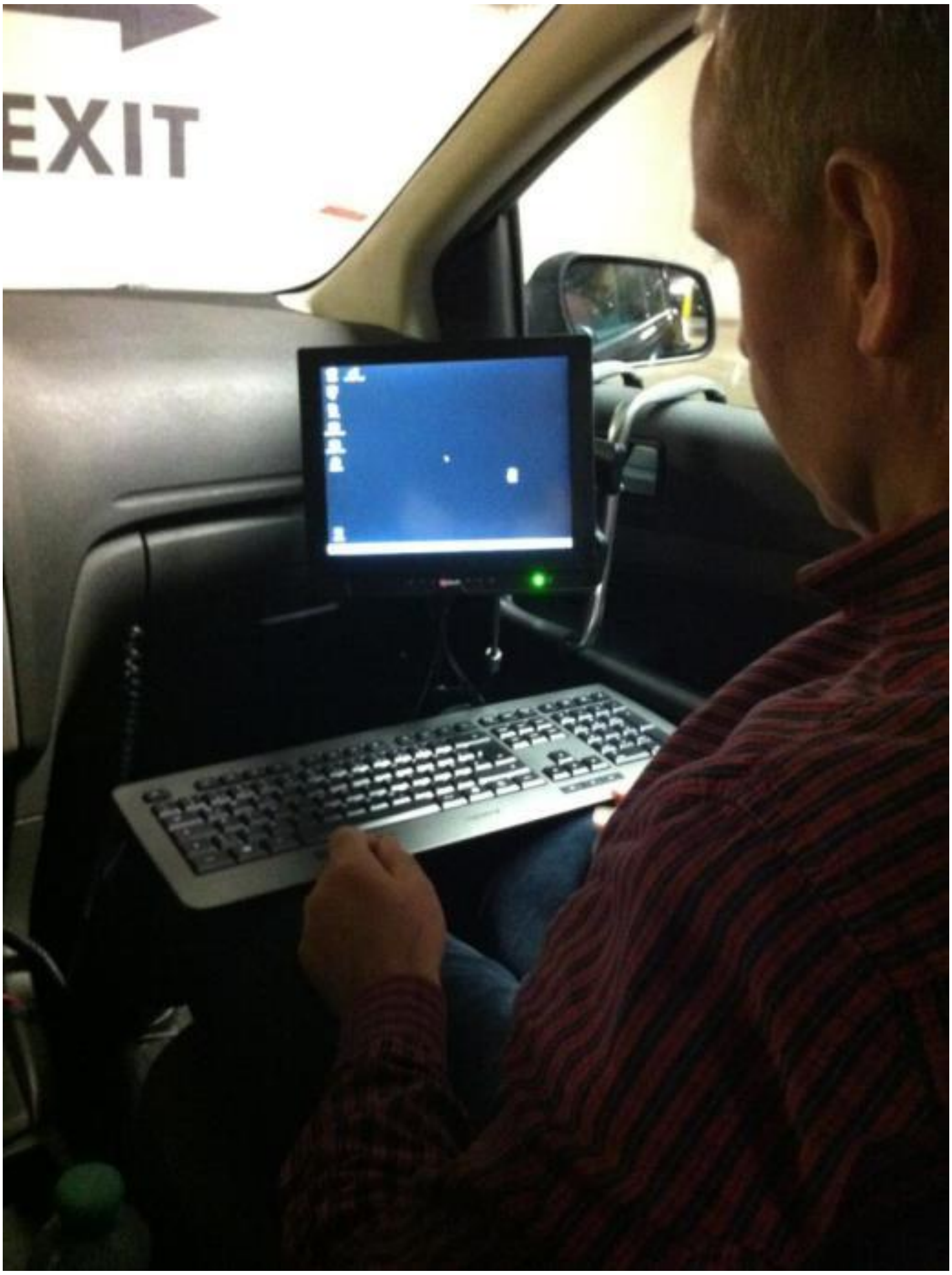

Figure 4: Integration of the operator HMI in the demo vehicle.

2.4 Empirical results from first integration activities

The first field session that was organized with the purpose to verify the integration level between the mobile system and the Supervisor Centre was organized during the 5th Plenary Meeting, organized during the days February 12th -13th.

The objective of this preliminary field test session has been twofold:

- **verification of the entire communication chain** between mobile system and Supervisor Centre, with the intention to identify aspects to be optimized;

- **verification of the behavior and performance of the first mobile system OBUs**, in particular of the on-board environmental unit and the low-cost sensors installed on it, as illustrated in Chapter 2 of P.4.3.1 [2].

The test session has been organized with the aim to cover different use cases, including static measurements sessions near fixed air quality stations (Figure 5) and mobile measurements on selected routes, including the INTEGREEN monitored road, tunnels and the A22 highway.

Figure 5: Static measurement sessions of the mobile system during the first mobile system integration phase.

These measurements have allowed to properly calibrate the air pollution sensors, in order to generate post-processed values that can be directly comparable with the ones obtained through the fixed reference stations. Part of these computations have been included in the on-board telematic unit and in part in the XFCD data analyzer [3].

The results of this first empirical test session are graphically presented in the map of Figure 6. The measurements have demonstrated the spatial variability of air pollution (NO_2) concentrations, as well as directly link to roads in which the impact of heavy vehicles and stop&go situations is more remarkable.

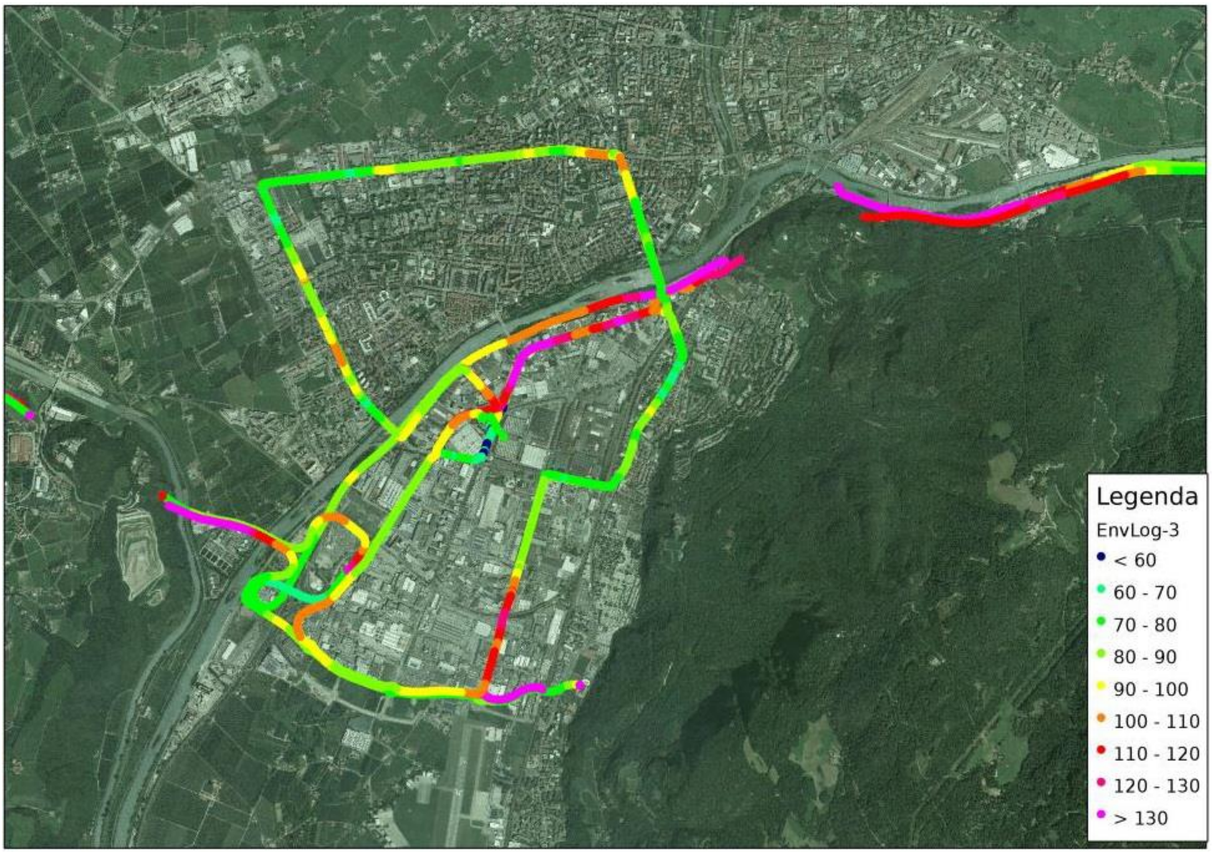

Figure 6: Results of first driving sessions with the mobile system integrated within the AIT test vehicle.

3 Mobile system integration in a car sharing demo vehicle

On the base of the important milestone reached during the first empirical integration session, the following efforts were concentrated on integrate all components of the mobile system in one single “box” that could be easily installed on third-parties vehicles. Based on the availability and interest of local stakeholders, the decision was to test the installation of the mobile system on board of a car sharing vehicle (solution for specific test measurements sessions) and on board of a public transportation vehicle (longer term solution providing the capability to test the reference use cases addressed by the project).

Figure 7: Preliminary integration evaluation meeting with car sharing operator.

To integrate the mobile system in a vehicle less equipped than the AIT car a compact box with the two monitoring units and the telematic unit with all necessary connections was finally developed (see Figure 8). On the lower left side the connections for the traffic monitoring unit, on the lower right side the connections for the environmental monitoring unit and on the upper side the connections of the telematic unit can be seen. All cable connections are protected through the handle on the left and right side of the compact box.

The car sharing company provided the power supply connectors in the vehicle in the rear luggage compartment. The details of the installation of the “compact” mobile system with all connections (power supply and air tube) are show in the following figures.

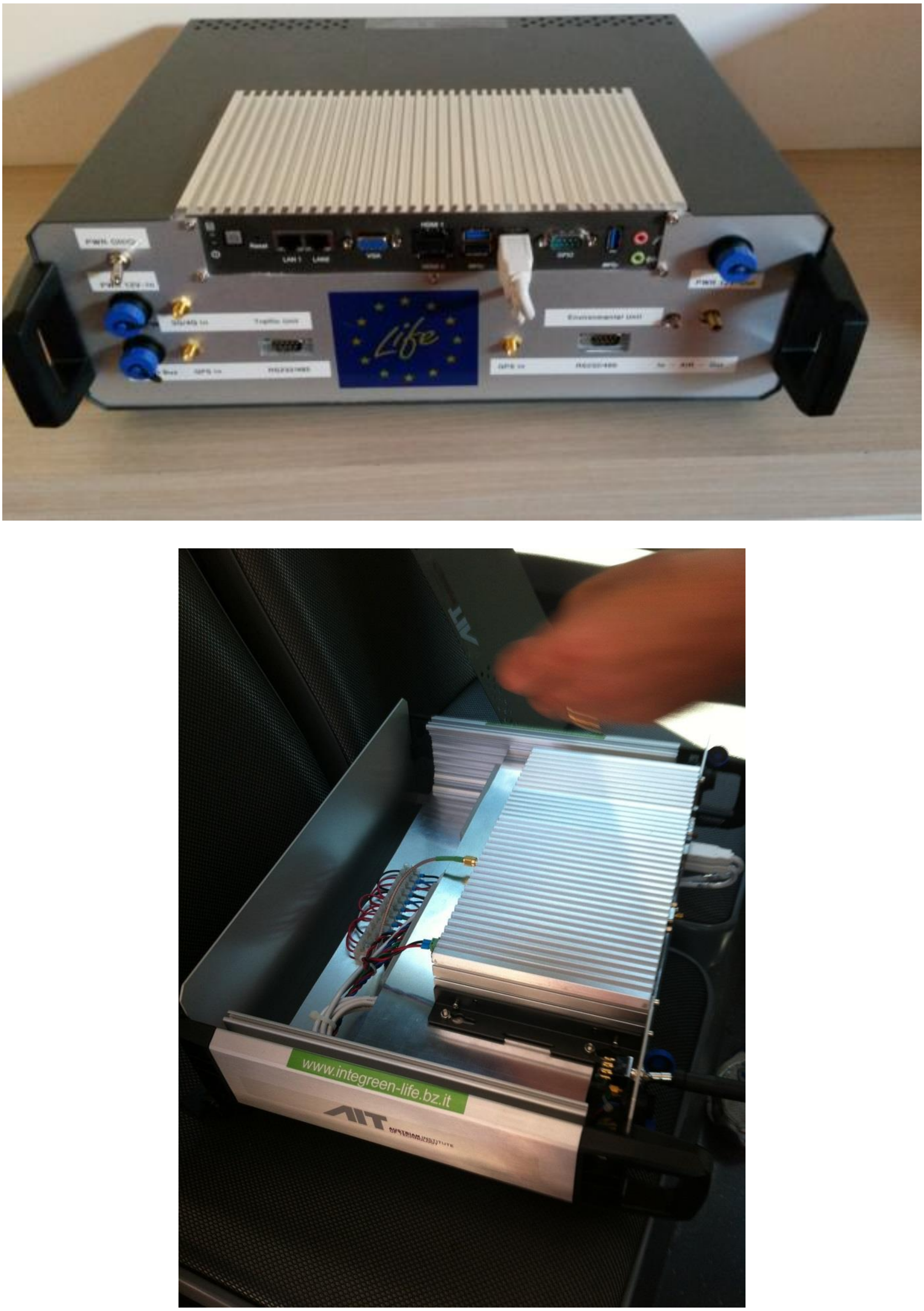

Figure 8: Compact Mobile System for use in different vehicles.

Figure 9: Mobile System in the car sharing vehicle

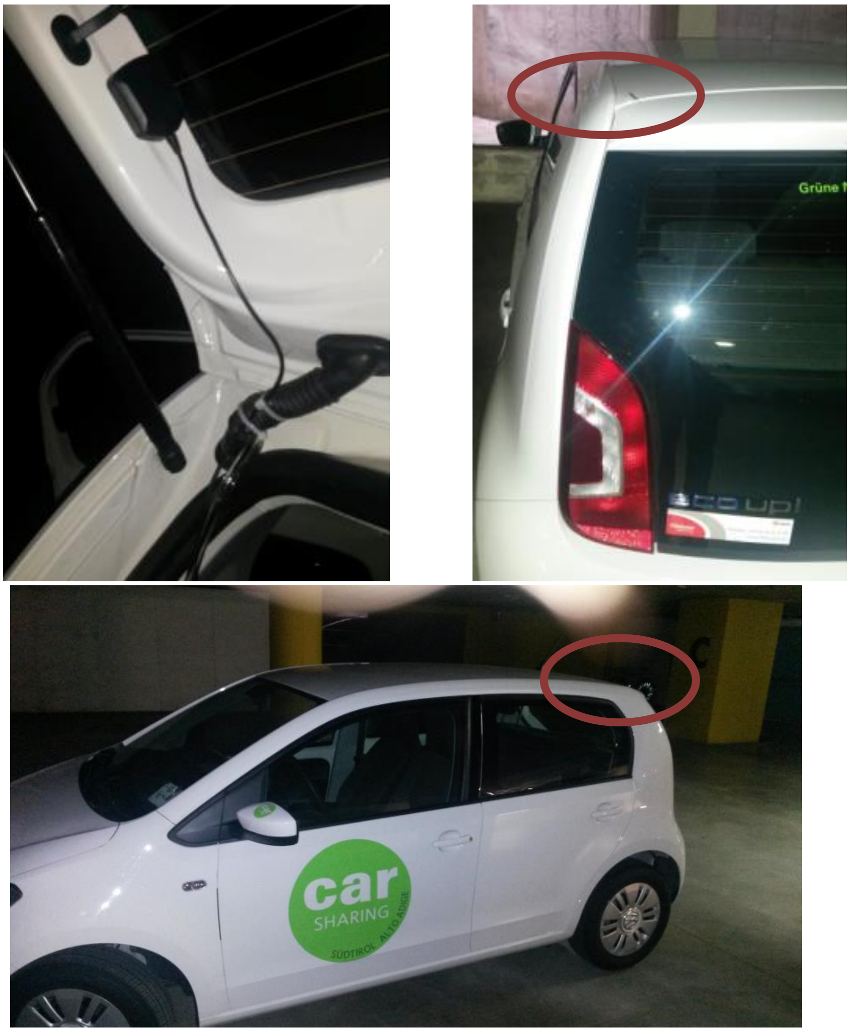

Figure 10: Position of GPS antenna and air tube

For the first test a display was used to control if the system worked correctly. For the proper test drives the display was not necessary because the primary elaboration and the real time data transfer were working automatically.

3.1 Empirical results from second integration activities

The integration of the mobile system in the car sharing vehicle has also been the occasion to further test the communication chain and the XFCD analyser. Results of driving sessions are presented in .

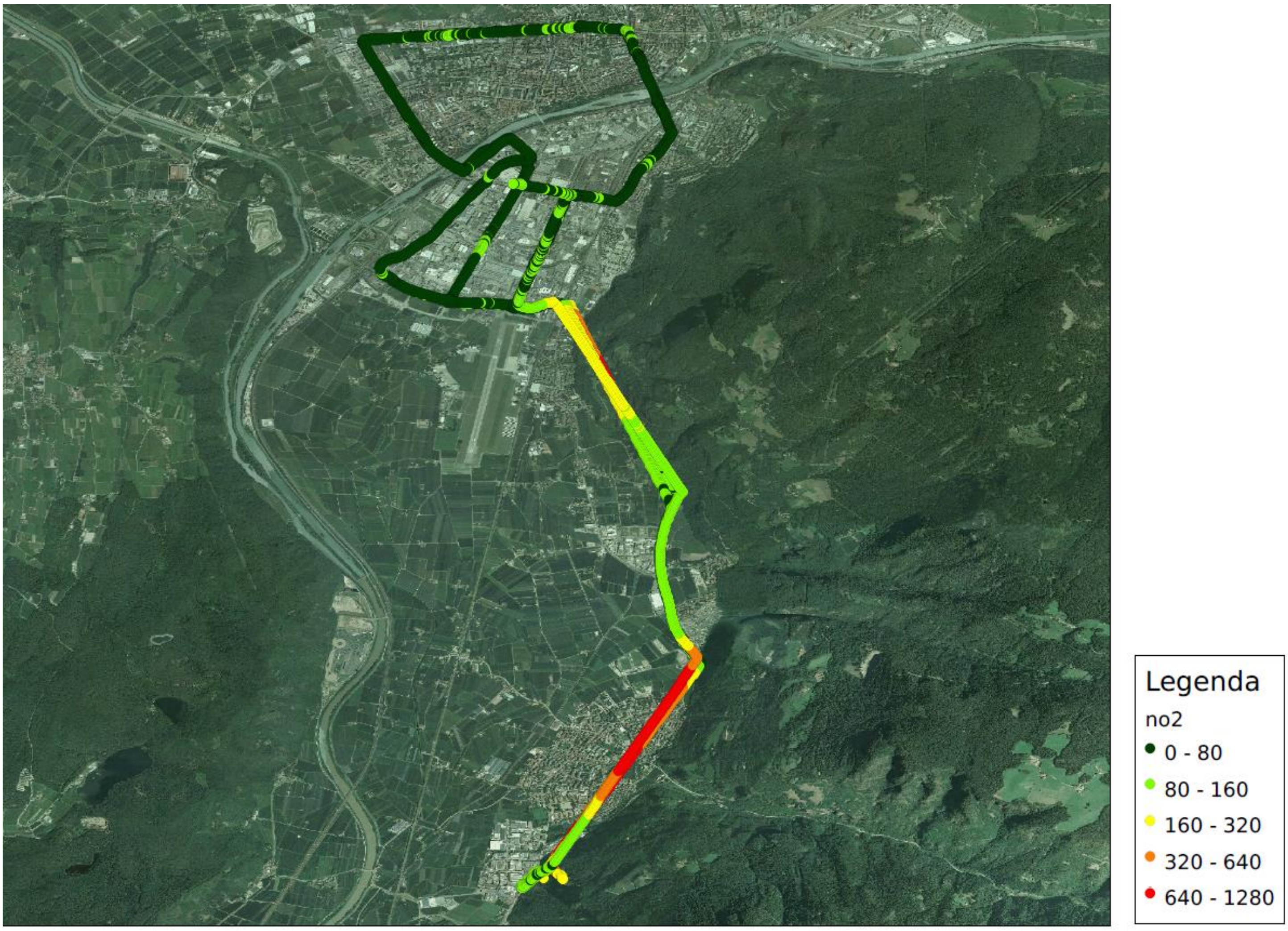

Figure 11: Results of second driving sessions with the mobile system integrated within a car sharing vehicle.

Tests were mainly concentrated in tunnels, since the objective of these investigations has mainly been to understand how quick the system when passing from areas with very high pollution concentrations to areas with “normal” levels (and viceversa), and how stable could the measurements if taken at a short temporal distance one from each other. The plot of Figure 12, which indicates the measurements taken in a series two tunnels at a distance of less than one hour, confirm the capability of the system to be in particular a very useful instrument to detect areas with high pollution levels in a very fast way. Since the temporal resolution of the measurement unit is high, the price to be paid for that is in terms of accuracy and precision of the collected data.

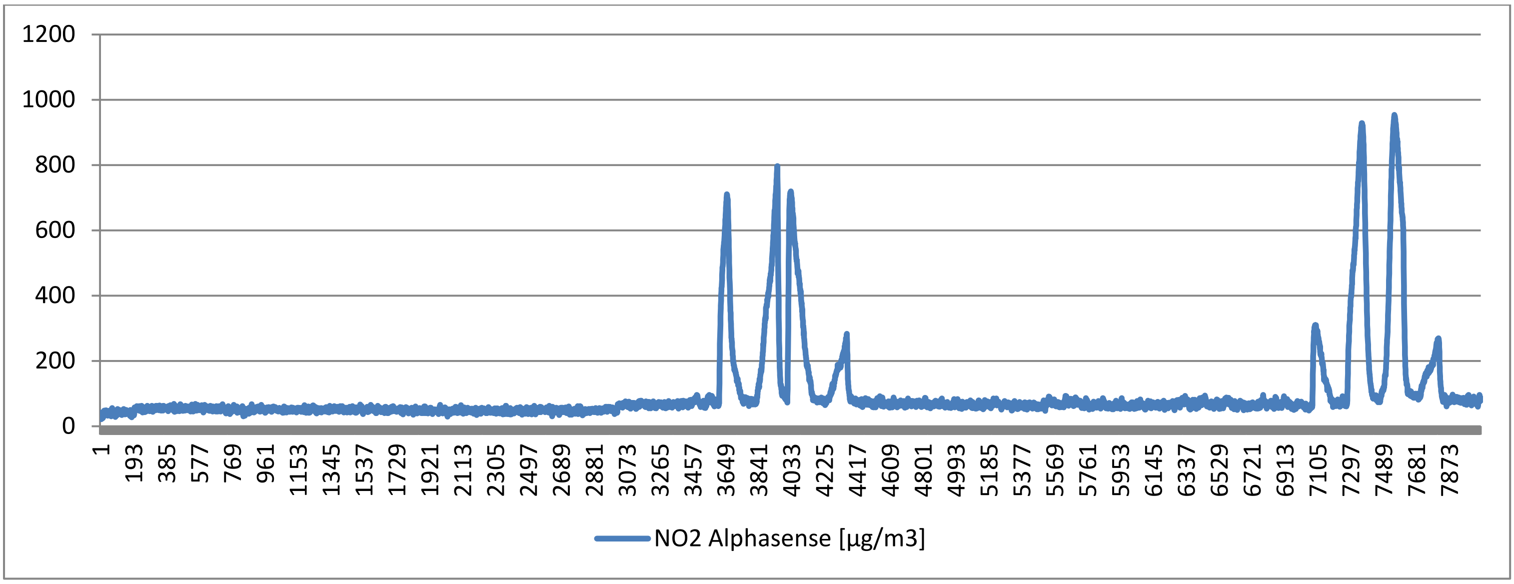

Figure 12: Post processed air pollution values in correspondence of road tunnels.

Further driving sessions with the car sharing vehicle were carried out by TIS in September 2014. Most interesting results are shown in the following air pollution maps, which confirm the preliminary indications obtained during the first driving tests.

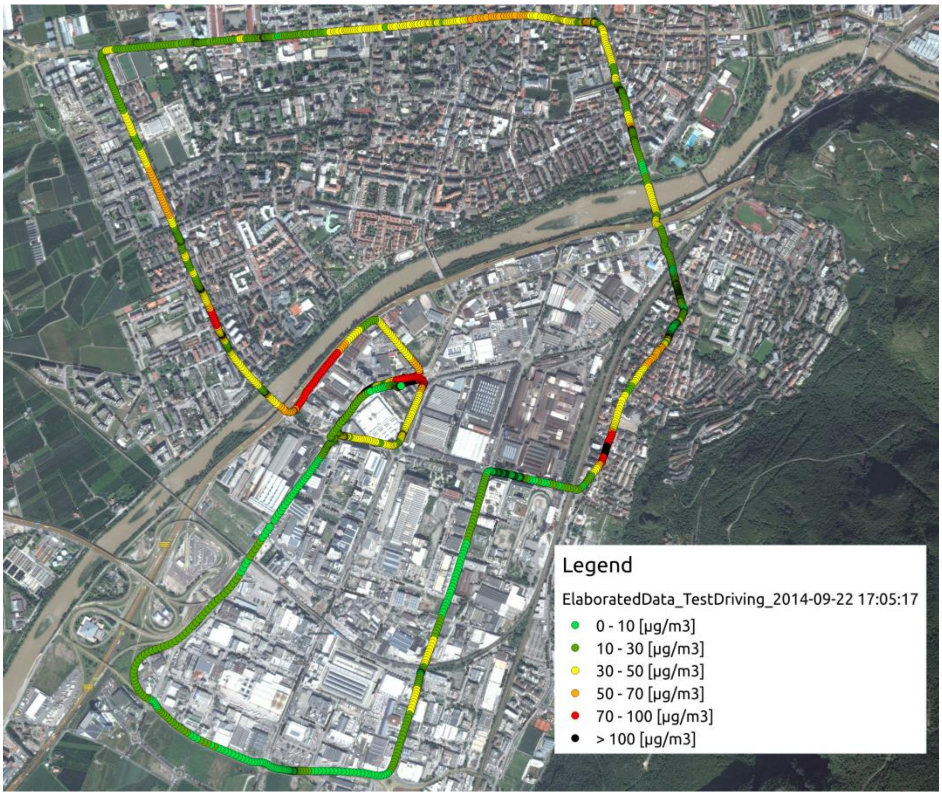

Figure 13: Post processed air pollution values (driving test 1 September 22nd).

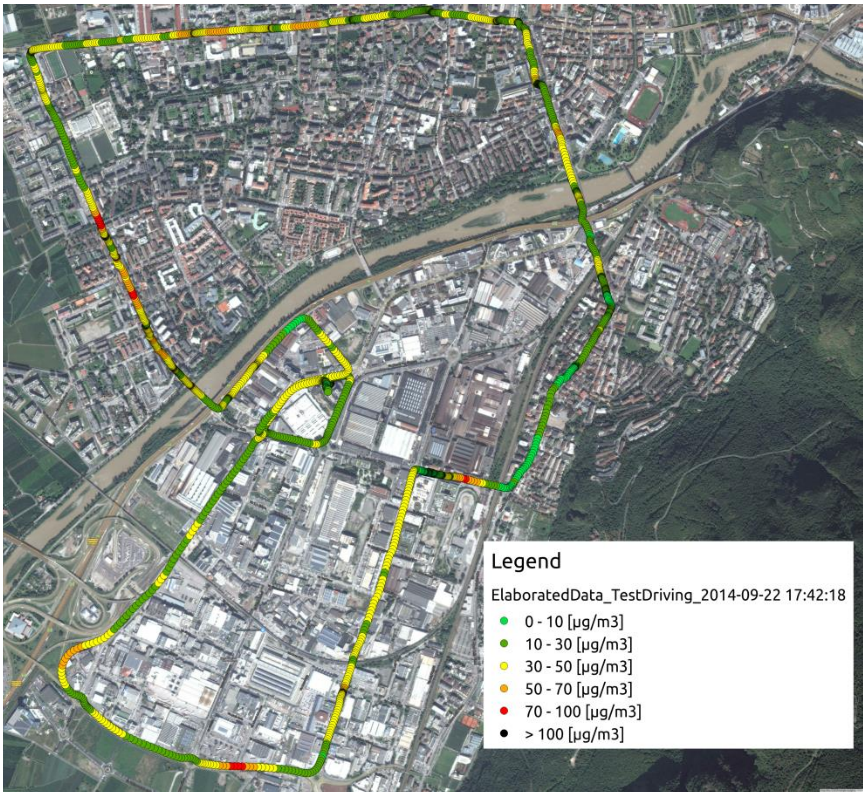

Figure 14: Post processed air pollution values (driving test 2 September 22nd).

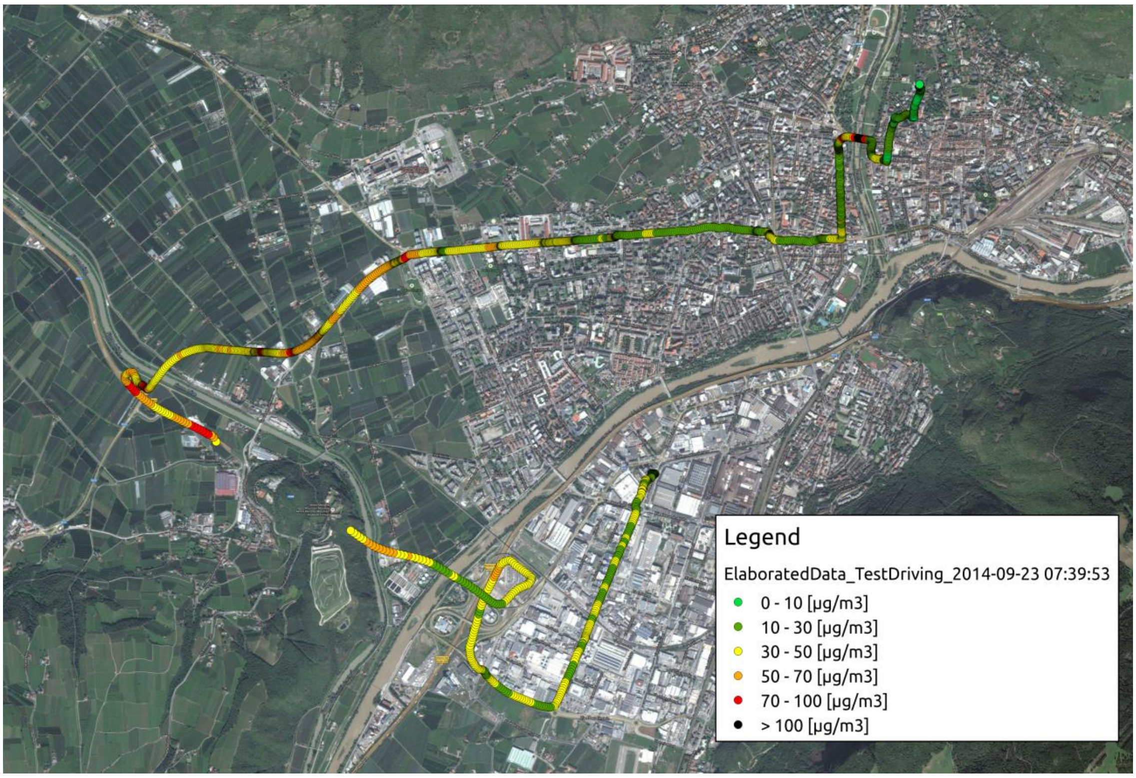

Figure 15: Post processed air pollution values (driving test 3 September 23rd).

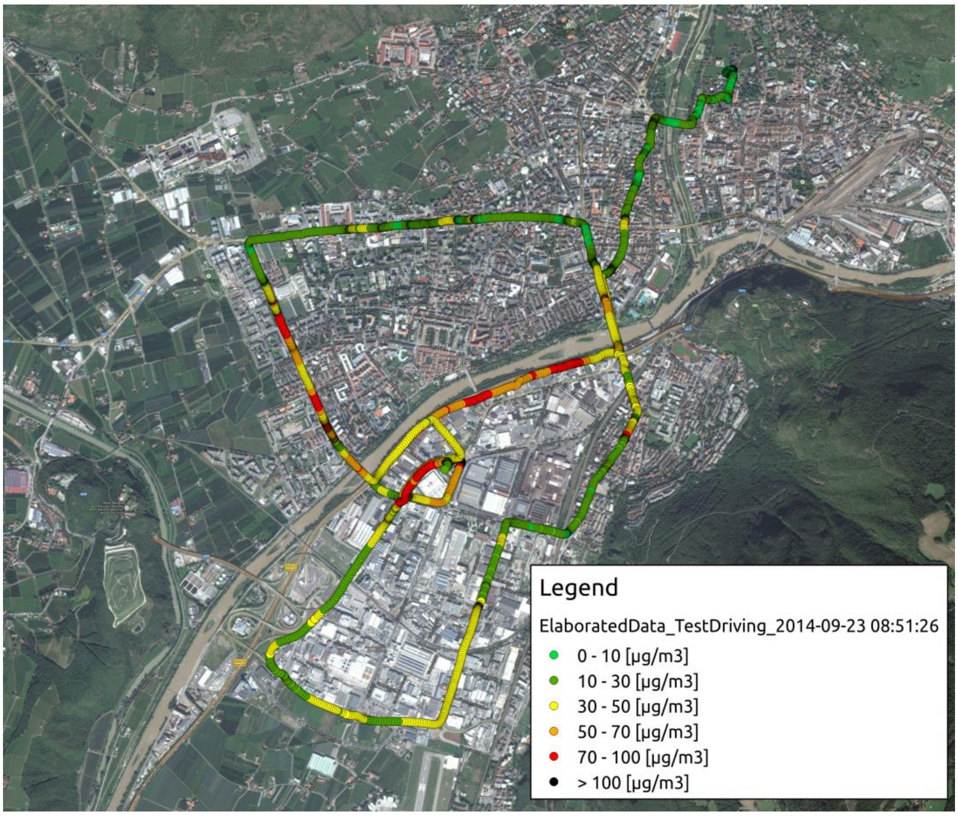

Figure 16: Post processed air pollution values (driving test 4 September 23rd).

4 Mobile system integration on SASA bus

The final installation of the Mobile System was on the test vehicle put at disposal by SASA, a fuel cell bus purchased in the scope of the EU project "CHIC".Preliminary meetings with SASA started already in February 2014 in order to define in a very specific way how the mobile system coul be mounted in the SASA bus.

Figure 17: Preliminary integration evaluation meeting with SASA.

An optimum place for the mobile system was found above the passenger seats as indicated in Figure 19 and Figure 18. In this place the GPS receiver and the 3G/4G modem have a good reception and the cable for the power supply could be mounted in a simple way. A specific mechanical support for the placement of the unit was prepared by SASA. An existing vent grill near the driver seat has been used for the aspiration of the air inlet (see Figure 20).

Figure 18: Mobile System mounted in the SASA bus.

Figure 19: Mounting place of the Mobile System in the SASA bus

Figure 20: Position of air tube in the SAS-bus

Different to the test system in the AIT and car sharing vehicle, in the SASA bus all operations that are in charge of the mobile system had to be fully automatic. This means that once the driver turns on the vehicle engine, the mobile system should start automatically its monitoring activities, without need of any manual intervention by the on-board personnel. After switching off the bus engine the mobile system should go in a low power mode not to discharge the bus battery. These measures have the objectives of minimizing as much as possible the complications that this activity could have on the normal public transport service.

Therefore a specific **power control system** was developed. This power control system is powered from the 12 V continues power supply. The 12 V ignition line is used as input to indicate the status of the bus. The telematic unit cannot be switched-on or off immediately but needs a switch-on time and a switch-off time. In this way the power control system needs two timers (switch-on time and switch-off time). Four states of the power control system can be distinguished:

1. Off: Mobile System in low power mode
2. Switch-On: use of switch-on timer
3. On: Mobile System is working and collecting data
4. Switch-Off: use of switch-off timer

The power control system has been working fine in general, but unfortunately the telematic unit sometimes started after the Switch-Off procedure by itself. This rare failure is due to the high impedance push-button of the telematic unit for switching-on and switching-off and could not be resolved in a perfect way within the project time. However, some manual interventions were necessary in this test phase but the data collection worked without problems and different measurement results could be achieved. This final installation was finalized in October 2014, allowing for the collection of data covering four different months.

4.1 Empirical results from third integration activities

The possibility to collect an incredible amount of air pollution data has been very useful for the final validation of the INTEGREEN system, as better illustrated in D.5.2.2 [4]. An additional advantage has been the possibility to collect a lot of measurements on the same routes, since this special bus travels only on a specific public transportation line in the city. In the following plots several exemplary maps of the ones that are automatically produced by the INTEGREEN system are presented. Please note that **values are here reported erroneously as [µg/m^3], but in reality values are expressed in [ppb]**.

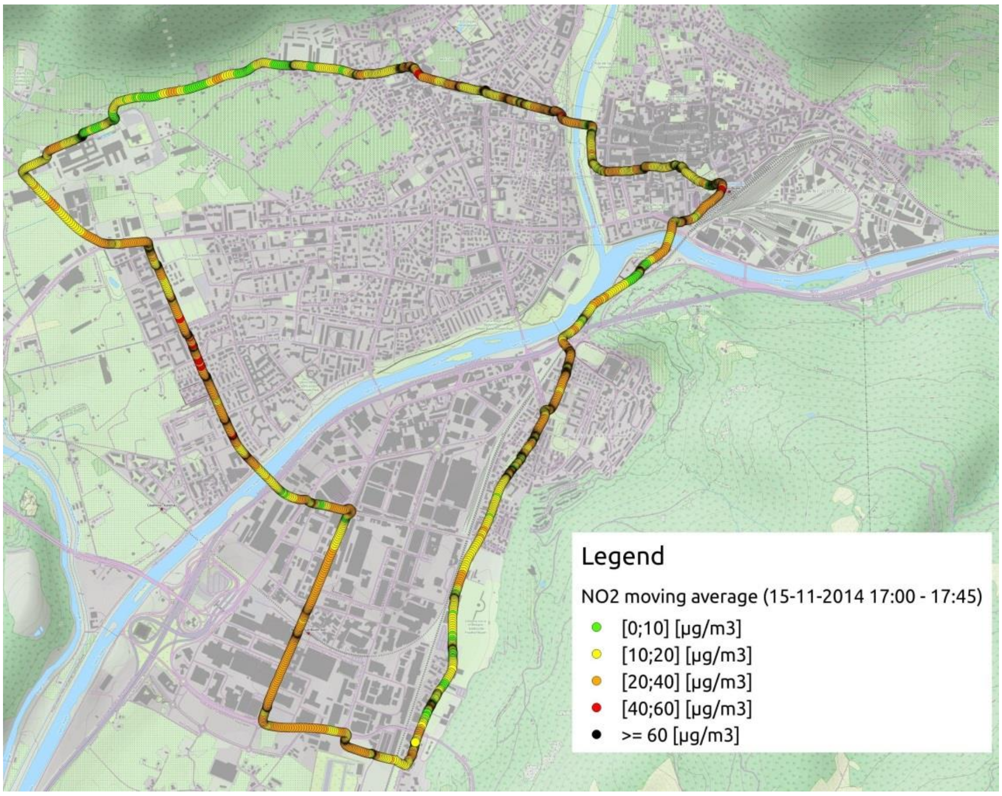

Figure 21: Post processed air pollution values (SASA driving test 1 November 15th).

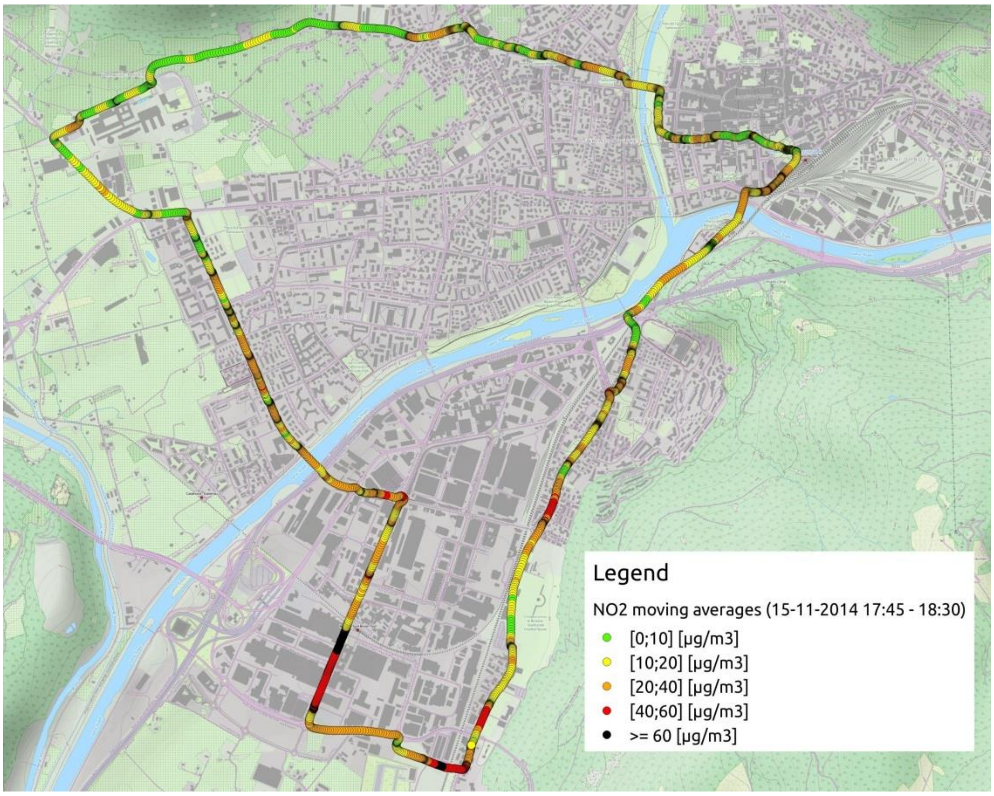

Figure 22: Post processed air pollution values (SASA driving test 2 November 15th).

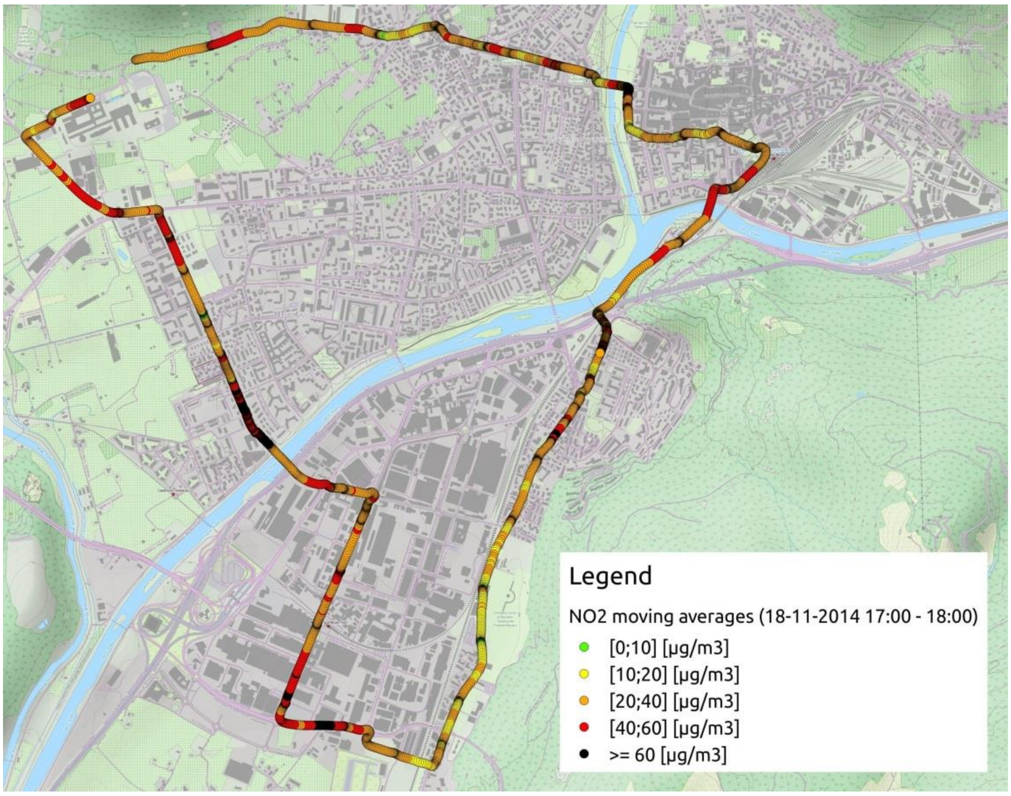

Figure 23: Post processed air pollution values (SASA driving test 3 November 18th).

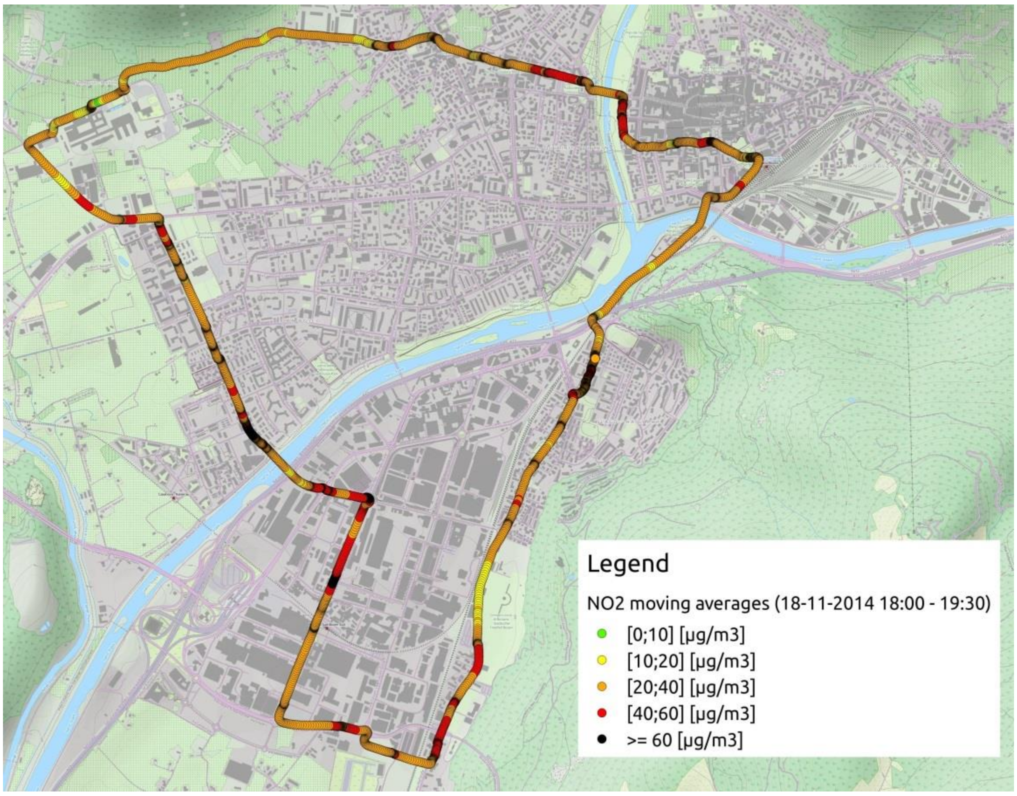

Figure 24: Post processed air pollution values (SASA driving test 4 November 18th).

5 Parallel Test of Mobile systems

A final test of the mobile systems was performed to verify the deviation of the measurement results of one mobile system to the second one.

5.1 Setup of the Parallel Test

For this test the AIT mobile probe (first mounted in the way described in chapter 2) was built in an equivalent compact box like the TIS mobile systems (first described in chapter 3). Now both mobile systems were mounted in the AIT test vehicle in such a way that the aspiration tube first goes to the inlet of the TIS mobile systems, the air outlet of the TIS mobile systems is connected with a short tube to the inlet of the AIT mobile systems. So both systems have the same measurement air but with a very short delay (2-3 seconds). The setup is shown in Figure 25.

Figure 25: Two Mobile Systems with the same measurement air

5.2 Results of the Parallel Test

A comparison of the measurement results of the two mobile systems is shown in Figure 26. This field measurement was executed in the city of Bolzano with drive routes through different tunnels (two very high and three lower peaks in the measurement result). The peaks in the tunnels were clearly measured from both systems. But also the very low peaks around 51000 [s] and near 56700 [s] are detected from both systems.

What we see is that the calibration of the two systems is not perfect, especially for the offset. In the INTEGREEN project the main objective of the mobile sensors is to detect hot spots caused by traffic and this is possible with both of the two mobile systems.

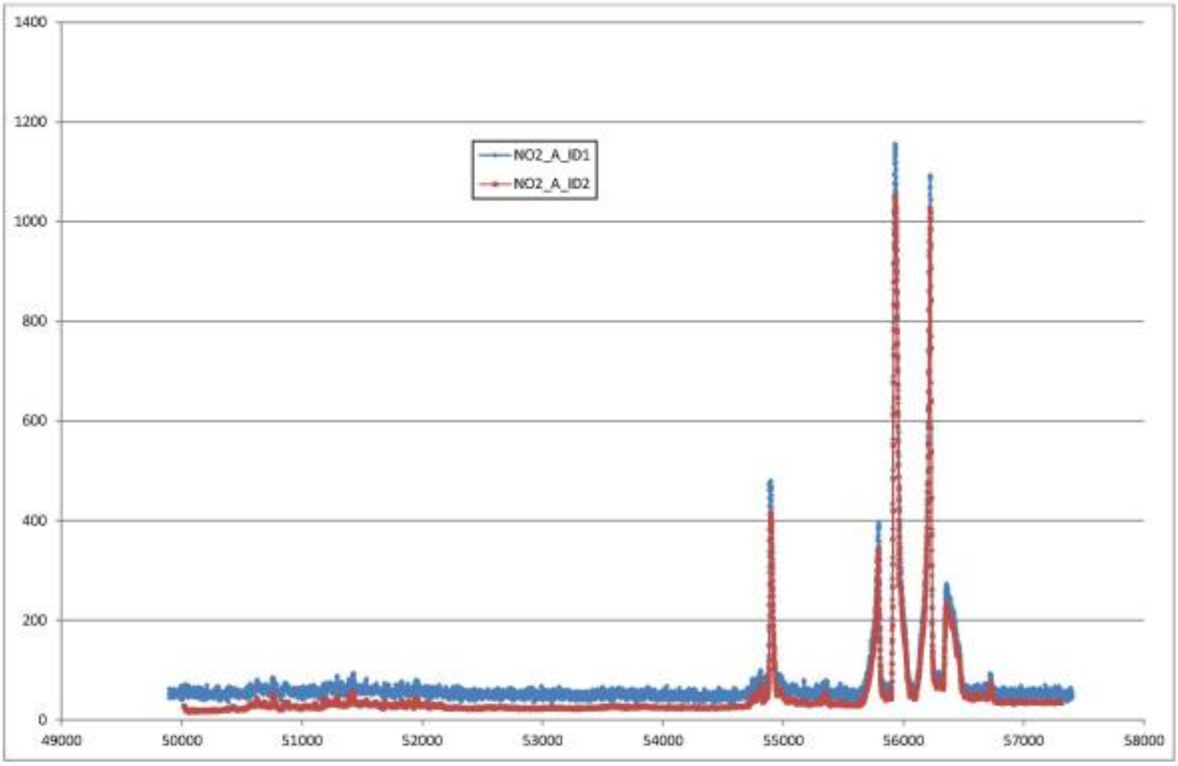

Figure 26: Comparison of air pollution measurements taken by the two mobile systems “in series”.

Conclusions

The integration activities of the INTEGREEN mobile system have been executed on different vehicles. First the system was mounted in the AIT test vehicle with the distributed unites in the trunk of the vehicle and different field tests were conducted.

In a second phase, all units of the mobile system were integrated in a compact enclosure box with all connectors on one side. So the system can be mounted and dismounted in a simple way in a vehicle. This compact box was first mounted in a low emission car sharing vehicle, and second in a fuel cell powered bus from the company SASA. For this latter integration a fully automatic power-on and power-off system was built. In this set-up many field tests on the bus route were performed and actively considered during the final activities of Action n.5.

Finally a combined test with two INTEGREEN mobile systems was executed to compare the measurement results of two different systems using the same measurement air.

An incredible amount of mobile system data has been therefore collected in the last project year, as demonstrated in some air pollution maps included in this document.

The mobile systems worked very well during the different installations, only a small problem with the automatic switch-on and switch-off mechanism could not be resolved completely. Therefore a few manual interventions were necessary.

The operation of the mobile probe was successfully tested in the INTEGREEN project. The next steps should be a further miniaturisation of the system with a fast power-on and power-off functionality. Also the calibration should be improved for a use of a real measurement device rather than a detector of zones with higher pollution.

Bibliography

[1] INTEGREEN consortium, „D.3.1.2 "Vehicle-to-centre front-end and web interfaces design",“ 2014.

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

[3] INTEGREEN consortium, „P.4.1.1 "Data management unit prototype",“ 2014.

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