LIFE+10 ENV/IT/000389

INTEGREEN

Action 5: Testing & Validation

D.5.2.2

Test Bed validation and INTEGREEN benefits assessment

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)

Città di Bolzano
Stadt Bozen

TIS innovation park

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

Document history

Date	Document Author(s)	Document Contribution
31/05/15	Ivan Moroder, Brunella Franchini (CBZ), Roberto Cavaliere (TIS)	Document finalization

Dissemination level: PU[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

Table of Tables

1 Introduction

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

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

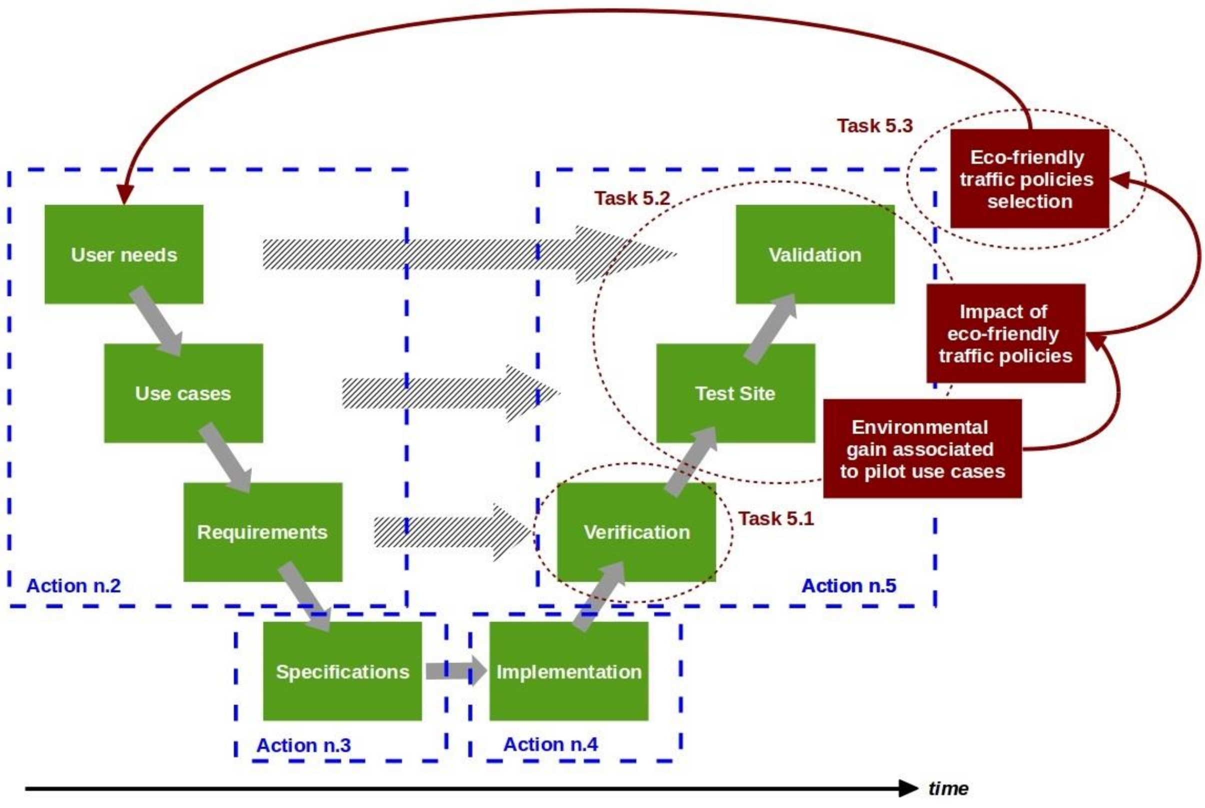

Figure 1: The V-model methodology followed in the technical implementation of the project and a graphical presentation of Action n.5 activities.

Action n.5 is organized in three different tasks:

- **Task 5.1** ("components tests"), in which system components are technically analyzed in order to verify that original system requirements are properly fulfilled.
- **Task 5.2** ("outdoor urban tests"), in which the INTEGREEN system is used empirically

within the city of Bolzano to quantify the environmental impact associated to a set of initial eco-friendly traffic policies introduced in the final part of the project, in particular by:

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

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

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

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

1.1 Purpose of the document

The implementation of the activities of Action n.5 is governed by the Test Bed plan presented in deliverable D.5.2.1 [1]. The purpose of this document is to present the assessment results obtained thanks to the empirical test use of the INTEGREEN system. The amount of collected data is impressive, so the choice has been to focus on the most significant results only.

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

1.2 Document structure

This deliverable is structured as follows. In Chapter 2 the local environmental gain associated to the set of "pilot use cases" is analyzed. Potential benefits are compared to the preliminary hypothesis and the performance indicators quantified during the test bed planning. Chapter 3 presents the pilot experience and the results associated to the introduction of a certain number of eco-friendly traffic policies, which have been selected in strict cooperation with the political governance of the city. Finally, Chapter 4 completes a preliminary assessment of the current level of satisfaction of the user needs identified at the project start. This has been aided by a questionnaire organized in correspondence of the launch of the end-users applications destined to local travelers.

2 Preliminary INTEGREEN benefits assessment

2.1 Pilot Use Case 1 evaluation: local citizens planning an internal trip

Pilot use case 1 is related to the evaluation of a set of use scenarios in which local citizens plan to carry out an internal O/D trip in different conditions: using a motorized vehicle (i.e. a car) compared to another sustainable transport means, in case traffic conditions are “normal” (i.e. day with no rainy precipitations) or “heavy” ((i.e. day with rainy precipitations). This pilot use case has been fully evaluated on top of a significant case study identified on the road stretch Galilei Street, the main connection in the city from the industrial zone to the residential areas of the city and its center (Figure 2).

Figure 2: Pilot use case 1: an overview of the road stretch considered for the analysis (Galilei Street).

This road is monitored by the INTEGREEN system by a couple of Bluetooth detector, at a distance of about 1.47 [km]. The speed limit is 40 [km/h], which means that the theoretical minimum travel time a car can experience is about 130 [s] (Figure 3). The road can be traveled in one direction and is characterized by two / three lanes. A series of consecutive traffic lights control the flowing of traffic. The access to Roma Bridge is managed by a two lanes roundabout.

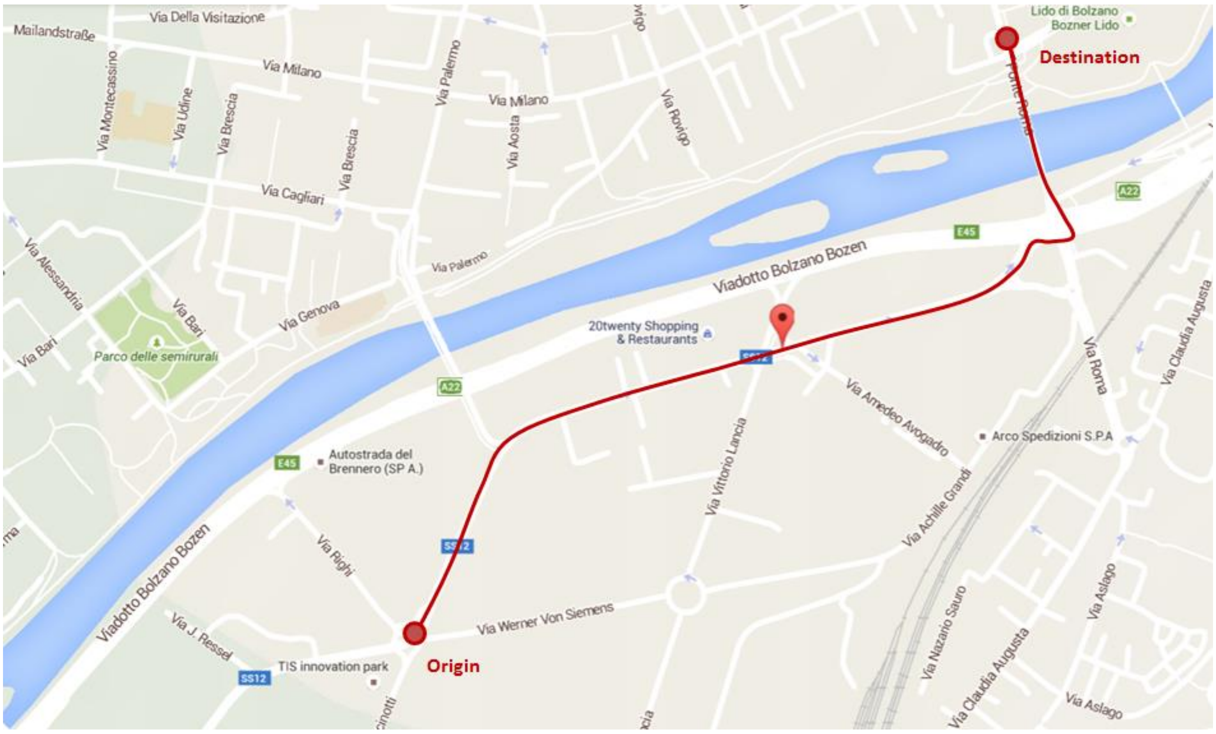

Figure 3: Pilot use case 1: the map of the road stretch considered for the analysis (Galilei Street).

The days evaluated for the quantification of the potential environmental gain associated to these pilot use case are those of the week 45 of year 2014 (November 3rd – 9th). This week was in fact characterized by two intense consecutive days of rainy precipitation, i.e. November 5th (Wednesday) and 6th (Thursday), as indicated in Table 1.

Day	Cumulated Precipitation [mm]
03/11/2014	0,0
04/11/2014	1,3
05/11/2014	66,9
06/11/2014	52,7
07/11/2014	0,8
08/11/2014	1,3
09/11/2014	0,1

Table 1: Pilot use case 1: cumulated precipitation of the days considered in the case study.

More details of the precipitation patterns are given in Figure 4. On the horizontal axis, the hour of the day is reported, starting from November 3rd up to November 9th. As it is possible to see, the precipitation event started in the night between November 4th - 5th.

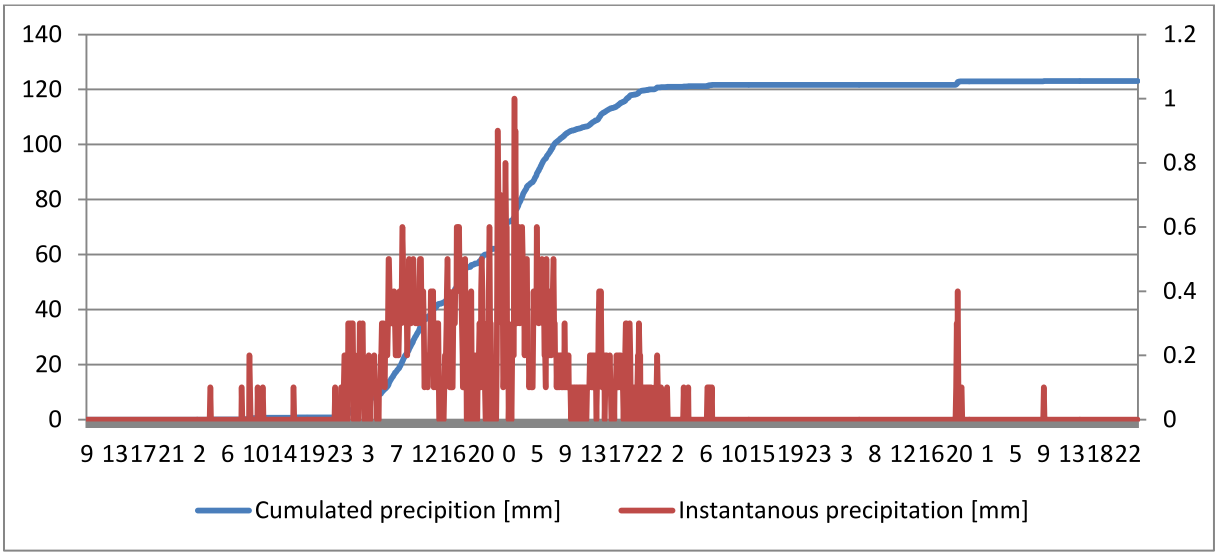

Figure 4: Pilot use case 1: details of rainy precipitation patterns during the days considered in the case study.

The presence of heavy rain has had an effect of amplifying travel times conditions during peak hours, in particular in the evening, as presented in Figure 5.

According to the plan defined in D.5.2.1 [1], these two days can be considered as" rainy days with heavy traffic", while the others days of the week are to be considered "non-rainy days with normal traffic conditions" (Table 2). The trip improvement is considered in the time axis, and not in the spatial one. Travel times measured and emissions calculated on this road stretch can be therefore be analysed in order to verify the hypothesis associated to this pilot use case (Table 3).

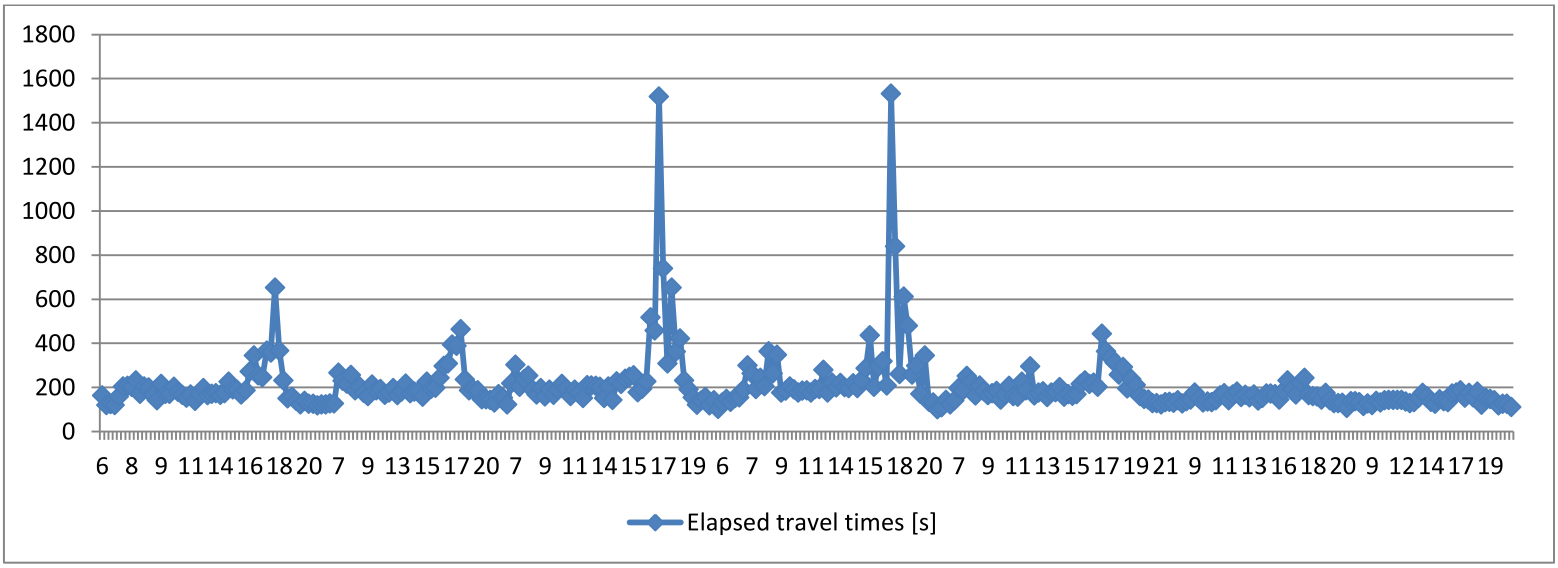

Figure 5: Pilot use case 1: elapsed times observed during the days considered in the case study.

ID	Weather / traffic	Trip / routing improvement
US_1.1 US_1.3	Rainy day with heavy traffic (November 5th – 6th)	Trip improvement (routing plan adaptation) Modal improvement (bus is preferred to car)
US_1.2 US_1.4	Non-rainy day with normal traffic conditions (November 3rd – 4th)	Trip improvement (routing plan adaptation) Modal improvement (bicycle is preferred to car)

Table 2: List of pilot use scenarios associated to pilot use case 1.

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

Table 3: Hypothesis associated to scenarios associated to pilot use case 1.

2.1.1 Use Scenarios related to non-rainy day with normal traffic

During conditions of normal traffic, at peak hours measured travel times are typically in the interval between 400-600 [s] (6-10 [minutes]), i.e. 2-3 times more than average travel times during the rest of the day. The position of the peak is more or less identical, and located in the time interval between 5:00 – 6:00 PM. What can change from day to day is the amplitude of the travel time peak and the duration of these heavier traffic conditions, which in general is in the order of 45 – 60 [minutes]. In some cases, the increasing trend reveals the start of this peak hour time (as on November 4th), while in others the trend is more difficult to identify since it presents a more fluctuating behaviour (as on November 3rd).

What is however interesting to observe is that after the peak travel times conditions return

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

very quickly to normal patterns. This observation is in line also with the baseline data collected during the requirement analysis [4].

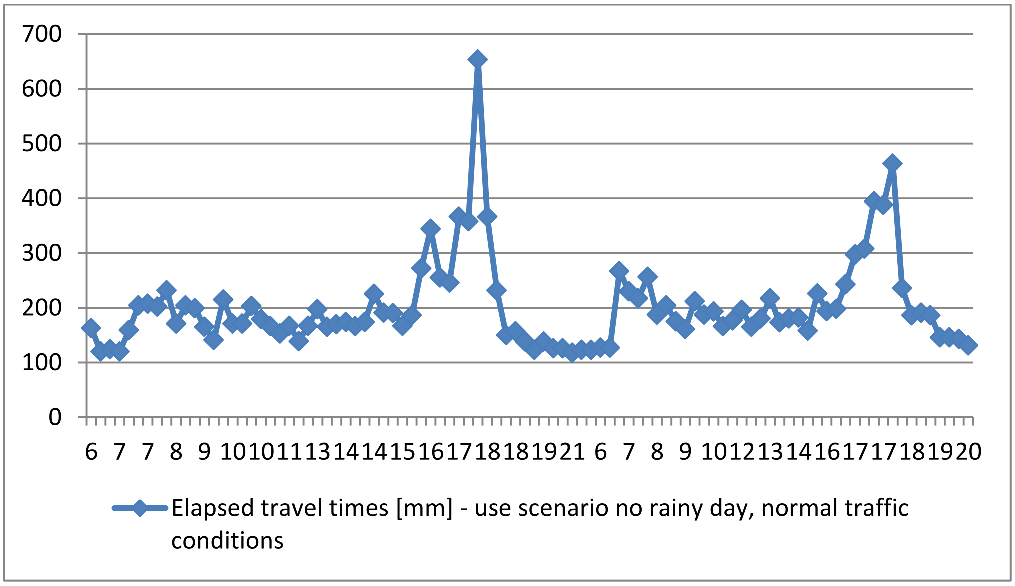

Figure 6: Pilot use case 1: elapsed times observed during the non-rainy days considered in the case study.

By starting a trip 15-30 minutes before the interval of maximum travel time, the travel time can be reduced in the order of 15% with respect to the worst case scenario. By starting a trip 15-30 minutes after a peak hour, the travel time can be reduced even more, in some cases up to 30-40%. Thanks to the BZTraffic application, one can check this data, compare actual with historical travel times and get a rough indication of when the peak hour will occur. The reference hypothesis is therefore confirmed, even taking in consideration the empirical limitations in the use of the application in real use case scenarios.

What about the possibility to compare these travel times with those of an e-bicycle? This comparison is absolutely possible on the case study road, since there is a dedicated bicycle path parallel to this road.

By assuming a reasonable average speed of 15 [km/h], the travel time is about 6 [min], or 360 [s]. During peak hours period, the trip duration by e-bicycle confirms to be lower than by car, and this without considering the time needed for searching a parking lot and arriving at the destination point. The reference hypothesis is therefore confirmed.

The verification of the emissions reduction has been carried out by considering the NO_X and CO_2 emissions estimates obtained on November 4th through the real-time INTEGREEN emission model [5], reported in Table 4.

The appearance of the peak in travel times conditions during normal situations associated to non-rainy precipitation is responsible for an increase of the emissions in the order of 5-10%. The reference hypothesis is therefore confirmed.

Period of the day	NO_X emissions [g/km/h]	CO_2 emissions [g/km/h]	NO_X emissions reduction	CO_2 emissions reduction
4:00 PM	463	192.252	11,2%	11,4%
5:00 PM	522	216.888	-	-
6:00 PM	485	201.788	7,2%	7,0%

Table 4: Emissions estimates associated to pilot use case 1 (non-rainy conditions).

2.1.2 Use Scenarios related to rainy day with heavy traffic

During conditions of heavy traffic caused by bad weather, at peak hours measured travel times are typically in the interval between 600-800 [s] (10-13 [minutes]), i.e. about the double of what is typically experienced during non-rainy days. Moreover, these conditions can lead to severe but limited traffic jam conditions, in which peak can arrive up to 1600 [s] (about 25 [minutes]).

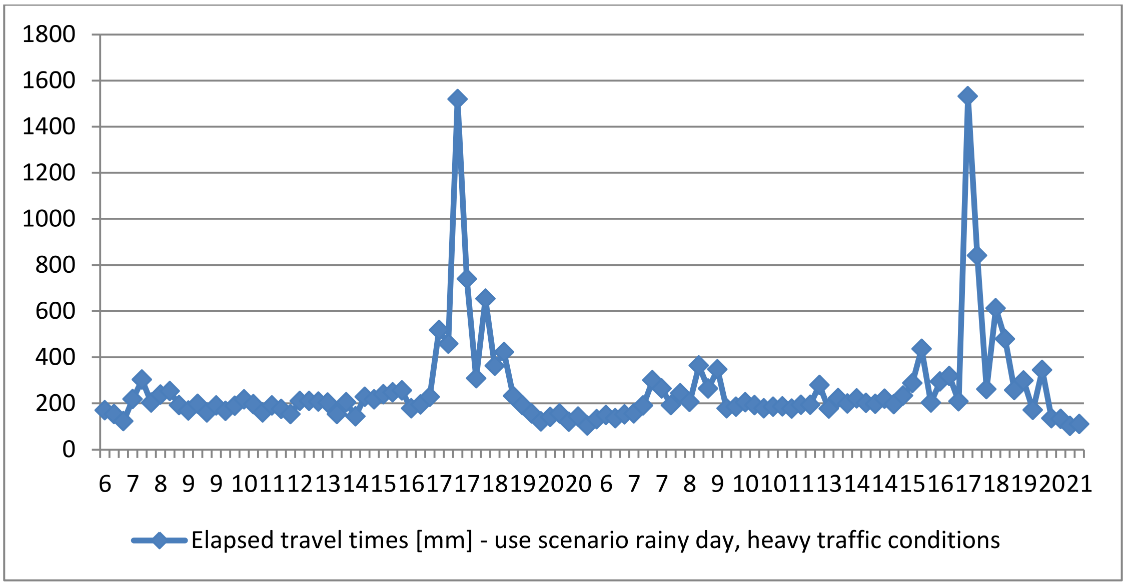

Figure 7: Pilot use case 1: elapsed times observed during the rainy days considered in the case study.

The position of the peak is slightly anticipated (15-30 [minutes]) to what is observed during non-rainy days, probably in relation to the willing of drivers to avoid the peak time. The duration of these heavy traffic conditions is much more longer, and cover the period 4:00 – 7:00 AM. The anticipation of travel time patterns revealing the appearance of such heavy traffic conditions is hard to be identified, based on historical data.

During exceptional conditions caused by bad weathers, drivers can experience very high travel times associated to traffic jams, which can be in the order of 50% more of what measured in the time interval before and after. The decision to postpone the car trip in the queue of the period with heavy traffic conditions, can produce significant travel times savings, typically in the order of 30% (travel times from about 600 [s] to 400 [s]. Thanks to the BZTraffic application, one can check the current real-time traffic conditions, and decide when to optimally start a trip also base on the historical travel times. The reference hypothesis is therefore confirmed.

What about the possibility to compare these travel times with those one could experience by taking a bus? Unfortunately such a comparison is difficult to be carried out on this case study road, since the only bus driving on it is the line n.6, which however takes another route to connect the industrial area to the residential districts of the city (Figure 8).

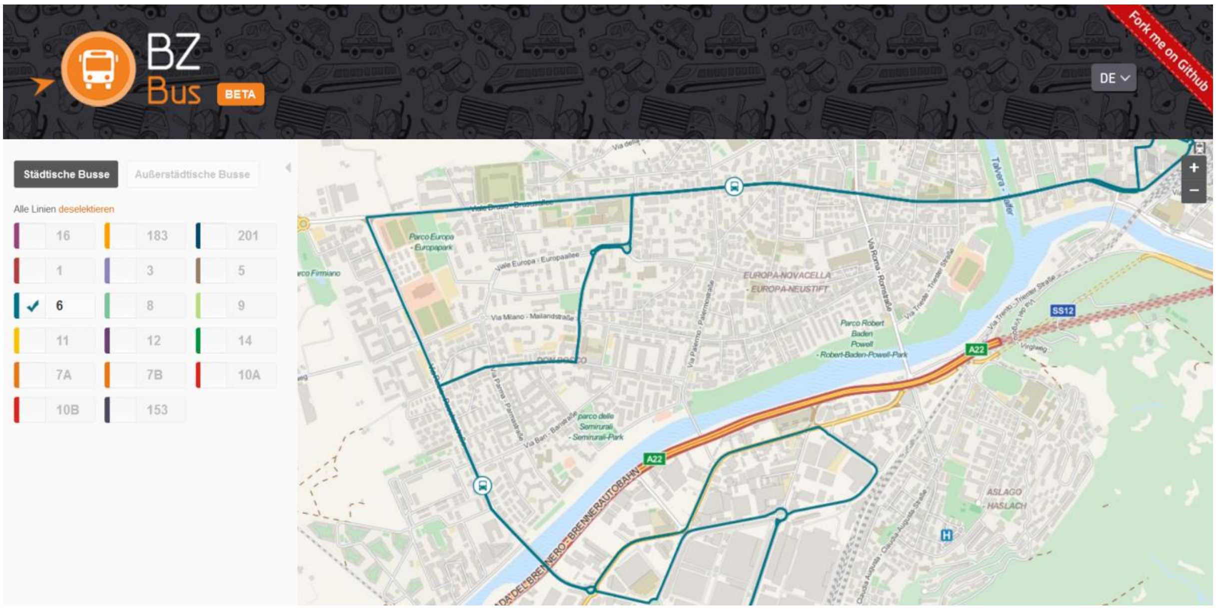

Figure 8: Pilot use case 1: reference bus line considered for comparison.

The frequency on this line is 30 [minutes]. The official time by bus needed to join the headquarters of TIS (starting point of the monitored road stretch) with Adriano Square (intersection between Roma and Druso Streets) is 15 [minutes], passing through Resia Street.

By considering the fact that in Druso Street dedicated bus lanes are available (i.e. private vehicles do not influence the travel times of the public transportation vehicle), and that travel times measured on that route during that days were in the order of 5-6 [minutes], in certain conditions of traffic jam over the case study road Galilei Street, bus is a more competitive alternative to reach a reference destination point located in Adriano Square. A user can experience such an improvement by evaluating in detail the passage of a bus through the BZBus application, and minimizing his / her waiting time at the bus stop.

The verification of the emissions reduction has been carried out by considering the NO_X and CO_2 emissions estimates obtained on both days through the real-time INTEGREEN emission model, reported in the following tables. It is interesting to observe, as stated before, how the peak in the emissions has been observed for the second rainy day one hour before.

Period of the day	NO_X emissions [g/km/h]	CO_2 emissions [g/km/h]	NO_X emissions reduction	CO_2 emissions reduction
4:00 PM	439	181.713	18,6%	18,8%
5:00 PM	539	223.759	-	-
6:00 PM	505	209.631	6,3%	6,3%

Table 5: Emissions estimates associated to pilot use case 1 (rainy conditions, November 5th 2014).

Period of the day	NO_X emissions [g/km/h]	CO_2 emissions [g/km/h]	NO_X emissions reduction	CO_2 emissions reduction
4:00 PM	636	264.742	-	-
5:00 PM	568	236.193	10,6%	10,8%
6:00 PM	551	229.352	13,3%	13,4%

Table 6: Emissions estimates associated to pilot use case 1 (rainy conditions, November 6^{h} 2014).

The appearance of the higher peak in travel times conditions during heavy traffic situations associated to rainy precipitation is responsible for an increase of the emissions in the order of 5-20% with respect to what is observed the hour after and before. A similar increase is noticeable if emissions associated to the peak of rainy days are compared to the ones estimated during non-rainy days. The reference hypothesis is therefore confirmed.

2.2 Pilot Use Case 2 evaluation: tourists planning to visit the city

Pilot use case 2 is related to the evaluation of a set of use scenarios in which local traffic conditions are strongly influenced by an increase of the mobility demand from external centroids, in particular related to tourists wanting to access the city in order to visit it. Different use scenarios have been taken into account in this analysis: bad weather conditions and the presence of tourist events in the city center, more specifically the Christmas market.

This pilot use case has been fully evaluated on top of a significant case study identified on the road stretch Druso Street, one of the main road access to the city centre directly connected to the Oltradige Valley and the Merano-Bolzano ("MEBO") expressway (Figure 9). This road is monitored by the INTEGREEN system by a couple of Bluetooth detector, at a distance of about 1.97 [km]. The speed limit is 40 [km/h], which means that the theoretical minimum travel time a car can experience is about 180 [s] (Figure 10***Figure 3***). The road can be traveled in two directions and is characterized by two lanes and a new dedicated bus lane in the direction city centre.

Figure 9: Pilot use case 2: an overview of the road stretch considered for the analysis (Druso Street).

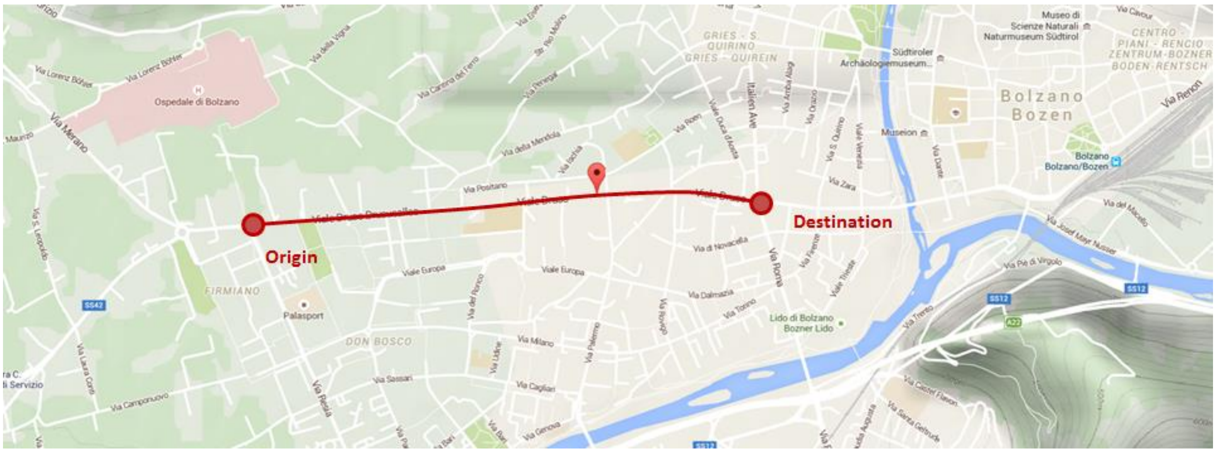

Figure 10: Pilot use case 2: the map of the road stretch considered for the analysis (Druso Street in direction city centre).

The days evaluated for the quantification of the potential environmental gain associated to this pilot use case are related to two different periods:

- **week 35 of year 2014** (August 25th – 31st), in which high tourist flows were observed, but in presence of little precipitation events;
- **week 48 of year 2014** (November 24th – December 4th), in which high tourist flows were observed, in correspondence of the opening of the Christmas market and with cases of heavy precipitation events;

It is important to underline that the second period considered in the analysis is related to the last week without speed detectors on this route, which have been used in the application of the eco-friendly policy presented in the next chapter.

The characterization of these case studies is determined by the precipitation patterns and the parking occupancy trends, which have revealed to be a good indicator for individuating such peaks of tourist (or more generally speaking "occasional") demand, as illustrated in the figures below.

In Figure 11 and Figure 12, the data cover the period from the night between August 24th - 25th to the night between August 31st – September 1st. During the night, the occupancy percentage is automatically set to 100% (equivalent to 932 free slots, the total maximum nominal capacity). The days with high tourist arrivals have been August 26th and August 30th, while short periods of precipitation events have been observed only during the night between August 29th and August 30th and during the evening of August 31st. Please observe that high flow of tourist of August 30th could be influenced by this meteorological perturbation.

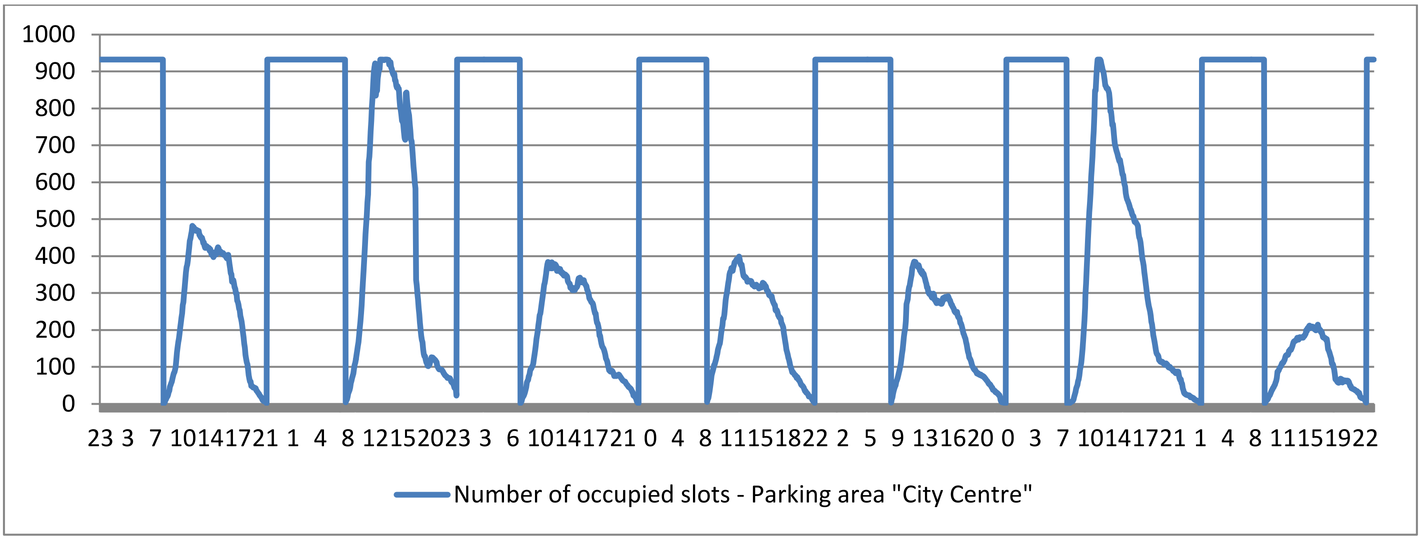

Figure 11: Pilot use case 2: parking slots occupancy during week 35/2014 at parking area "City Centre".

In Figure 13 and Figure 14***Figure 12***, the data cover the period from the night between November 23rd - 24th to the night between December 3rd – 4th. The days with high tourist arrivals have been in this case November 29th and November 30th (the first weekend with the Christmas market open – the official start was on November 27th). An intense precipitation event has been observed during December 1st, which however started the day before.

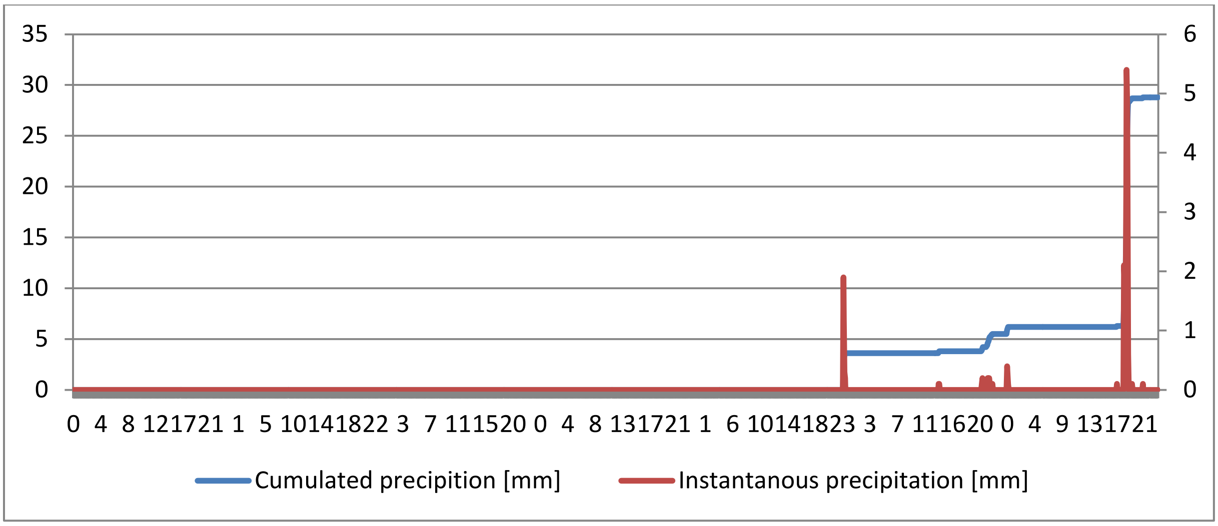

Figure 12: Pilot use case 2: precipitation patterns during week 35/2014.

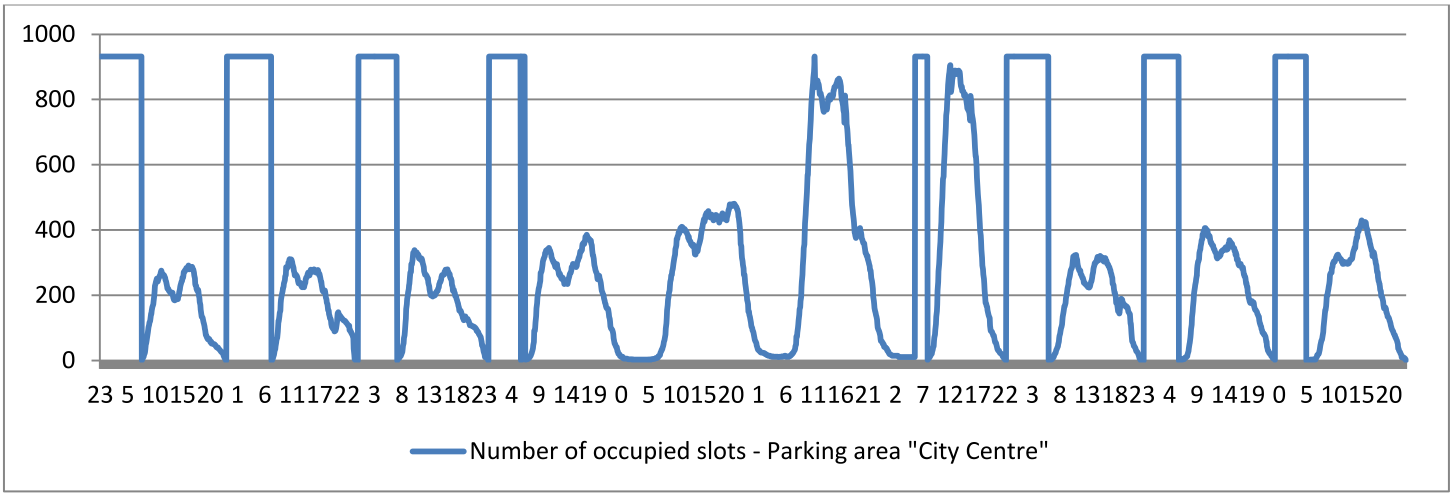

Figure 13: Pilot use case 2: parking slots occupancy during week 48/2014 at parking area "City Centre".

Day	Cumulated Precipitation [mm]
25/08/2014	0,0
26/08/2014	0,0
27/08/2014	0,0
28/08/2014	0,0

29/08/2014	3,6
30/08/2014	1,9
31/08/2014	23,3

Table 7: Pilot use case 2: cumulated precipitation during week 35/2014.

Day	Cumulated Precipitation [mm]
24/11/2014	0,0
25/11/2014	0,0
26/11/2014	0,0
27/11/2014	0,2
28/11/2014	1,9
29/11/2014	0,0
30/11/2014	2,9
01/12/2014	20,0
02/12/2014	0,3
03/12/2014	0,2

Table 8: Pilot use case 2: cumulated precipitation during week 48/2014.

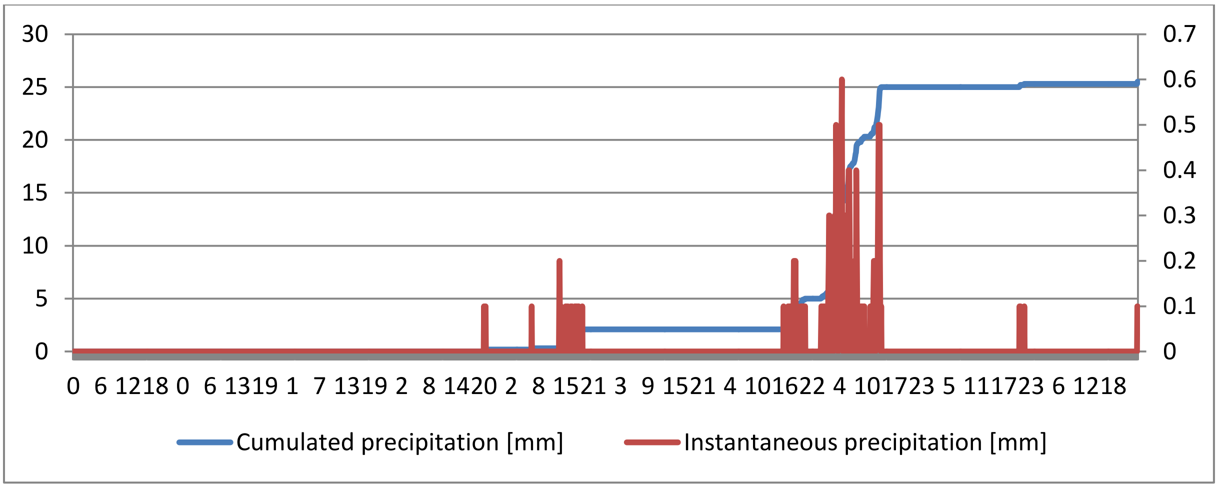

Figure 14: Pilot use case 2: precipitation patterns during week 48/2014.

The presence of high tourist flows has had an effect of extraordinarily amplifying travel times conditions, as presented in the elapsed times associated to the two specific cases in Figure 15 and Figure 16. During the August period, the data covering the period November 25th -30th (starting from 3:00 PM) reveal the presence of a traffic jam on August 30th. During the November period, the data covering the period November 24th – December 3rd (but with a "hole" for November 25th) reveal the presence of several interesting conditions, but with a clear traffic jam during the morning of December 1st.

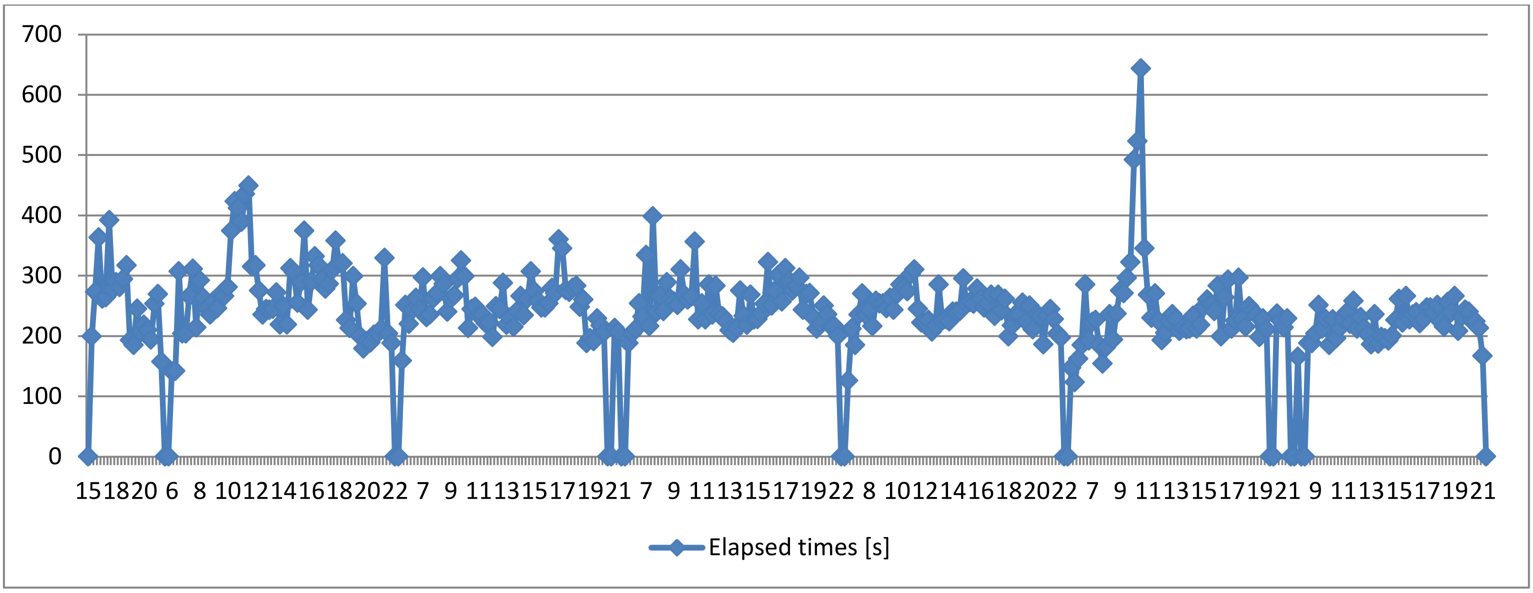

Figure 15: Pilot use case 2: elapsed times observed during week 35/2014 considered in the case study.

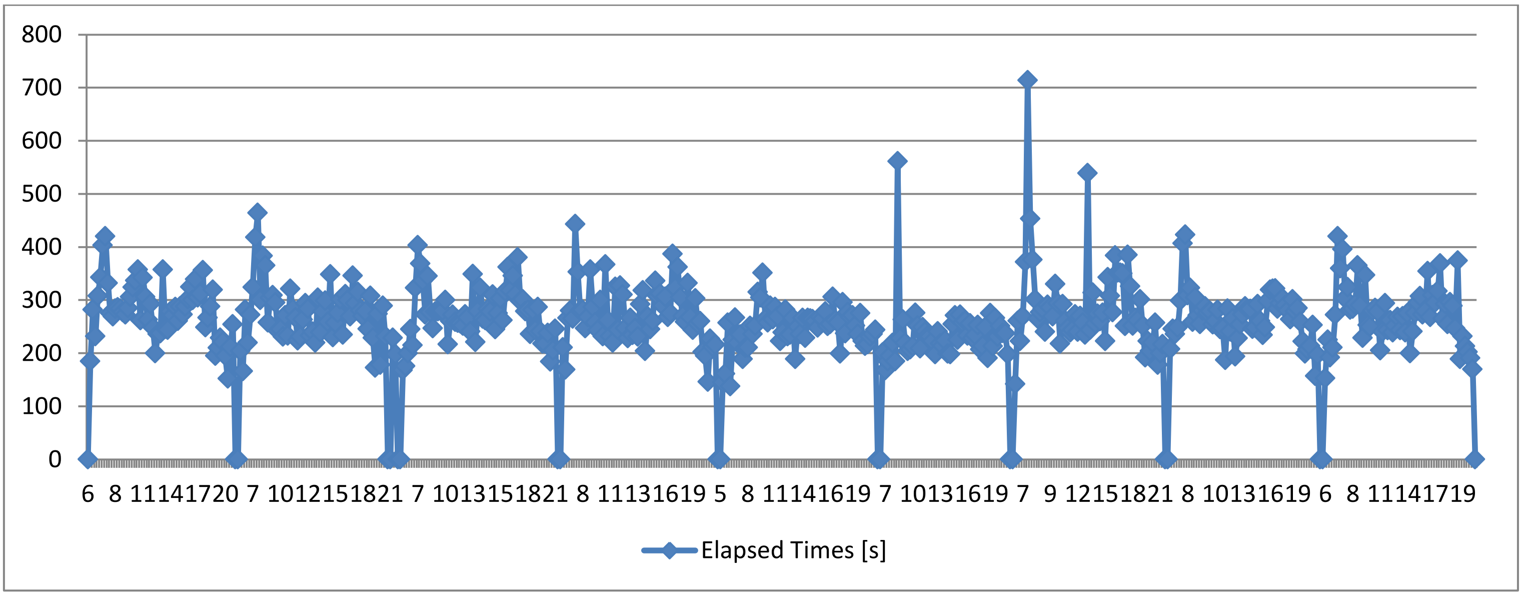

Figure 16: Pilot use case 2: elapsed times observed during week 48/2014 considered in the case study.

According to the plan defined in D.5.2.1 [1], days with high tourist flows have been distinguished according to the weather conditions and the presence of not of the Christmas market opened (Table 9 and Table 10). It is important to underline that the use scenario takes in consideration not only the effective presence of a precipitation event, but also influence of bad meteorological conditions e.g. during the evening / night before to induce tourists to visit the city. In these tables, expected optimization margins defined during the Test Bed plan have been reported as well.

ID	Weather / traffic	Trip / routing improvement	Hypothesis
US_2.3 US_2.4	Rainy day with heavy traffic (August 30th)	Arrival by train at Bolzano South rail station and last mile by bus Arrival by car at Fiera Parking rail station and last mile by bus	Travel time with the alternative travel mode is improved by 15% (bus option) and by 10% (alternative parking option)
US_2.1 US_2.2	Non-rainy day with normal traffic conditions (August 26th)	Arrival by train at Bolzano South rail station and last mile by bus Arrival by car at Fiera Parking rail station and last mile by bus	Travel time with the alternative travel mode is comparable to the one by car only

Table 9: List of pilot use scenarios associated to pilot use case 2 (Non-Christmas market).

ID	Weather / traffic	Trip / routing improvement	Hypothesis
US_2.7 US_2.8	Rainy day with heavy traffic (November 30th)	Arrival by train at Bolzano South rail station and last mile by bus Arrival by car at Fiera Parking rail station and last mile by bus	Travel time with the alternative travel mode is improved by 30% (bus option) and by 20% (alternative parking option)
US_2.5 US_2.6	Non-rainy day with normal traffic conditions (November 29th)	Arrival by train at Bolzano South rail station and last mile by bus Arrival by car at Fiera Parking rail station and last mile by bus	Travel time with the alternative travel mode is improved by 20% (bus option) and by 10% (alternative parking option)

Table 10: List of pilot use scenarios associated to pilot use case 2 (Christmas market).

2.2.1 Use Scenarios related to non-Christmas market period

In normal conditions, travel times are typically in the interval between 300-350 [s] (5-6 [minutes]). When weather conditions are good, the Christmas market is not open but high flows of tourists come to visit the city center, travel times can arrive to up 450 [s] (7.5 [minutes]), i.e. up to 30% more. It is also interesting to observe that the position of these travel times peak is not located during the typical morning and afternoon periods, in which a high number of commuters carries out their trip from and to home. In this particular case, the peak is located at about 10:00 – 11:00 AM (Figure 17). The duration of this intense flow of traffic has been in this particular case about 60 [minutes].

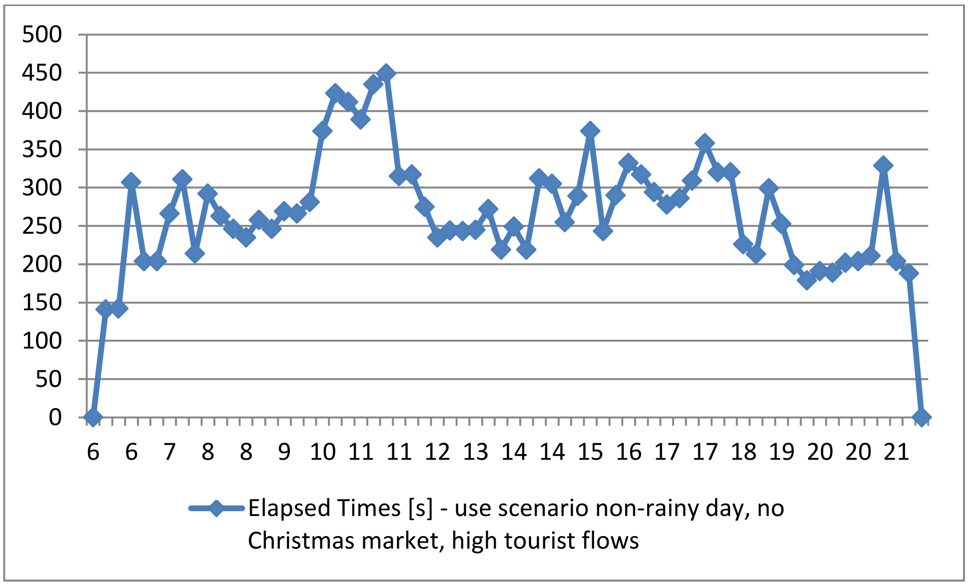

Figure 17: Pilot use case 2 elapsed times observed during the non-rainy / non-Christmas market / high tourist arrivals days considered in the case study.

During normal conditions, associated with good weather conditions and in absence of the Christmas market, the arrivals of tourists in the city can determine an increase of travel times of about 30%. To travel by car on the monitored route, it takes about 7-8 [minutes]; to arrive to the city center, in such traffic conditions it can take additional 15 [minutes]. The alternative travel options (train & bus; park & ride) can provide comparable similar experienced travel times, since the average time to reach the city center by bus from the parking area “Fiera” is about 15 [minutes] through line 10B, which is characterized by a frequency of 10 [minutes] (Figure 18). A traveller can evaluate such alternatives on a real-time basis by properly using all three applications.

During bad weather conditions, the travel times patterns are very similar in time and duration but its amplitude is further amplified by local travellers who decide to switch to car because of the meteorological conditions. In such situation, the peak of travel time can exceed 600 [s], i.e. 10 [minutes] (Figure 19).

Figure 18: Pilot use case 2: alternative P&R option (park in "Fiera" parking area, and direct bus connection to the city centre through a low-traffic route)

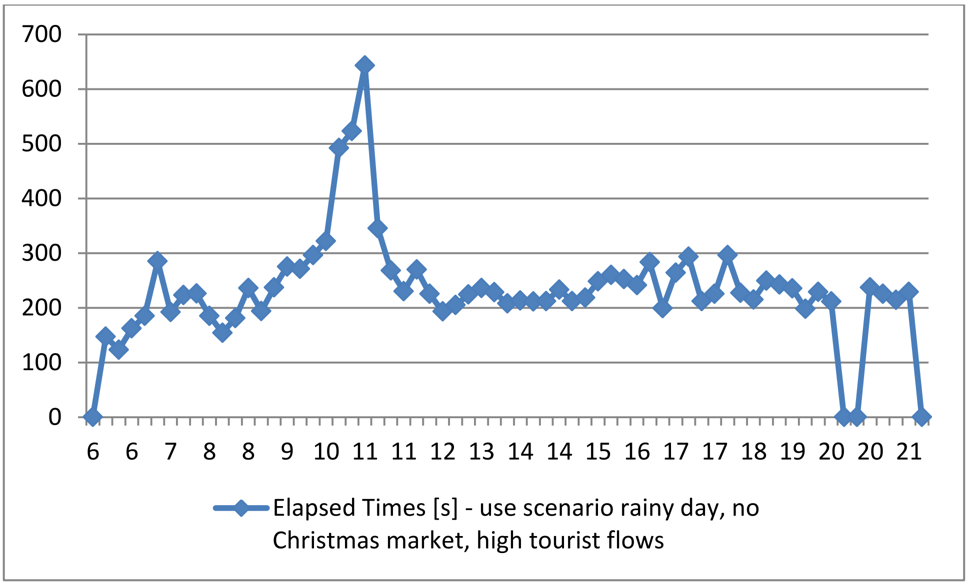

Figure 19: Pilot use case 2 elapsed times observed during the rainy / non-Christmas market / high tourist arrivals days considered in the case study.

During rainy conditions, but in absence of the Christmas market, the arrivals of tourists in the city can nearly double travel times to reach the city center. To travel by car on the monitored route, it can take about 10 [minutes]; to arrive to the city center, in such traffic conditions it can take additional 20 [minutes]. The alternative travel options (train & bus; park & ride) can provide a reduction of travel times of about 15%, since the average time to reach the city center by bus from the parking area “Fiera” is about 15 [minutes] through line 10B, which is characterized by a frequency of 10 [minutes]: a trip can therefore last about on average 25 [minutes], five less than driving by car to the city centre. A traveller can evaluate such alternatives on a real-time basis by properly using all three applications.

2.2.2 Use Scenarios related to Christmas market period

When weather conditions are good, the Christmas market is open and high flows of tourists come to visit the city center, differently to what was originally expected travel times patterns have been comparable to a working day. It is however important to remember that the analysed use case refers to a Saturday (November 29^{th}) and a Sunday (November 30^{th}), when the load of traffic is typically slightly lower than the other days of the week, with travel times that do not exceed the value of 300 [s] (5 [minutes]). The arrival of tourists has determined a limited and short increase of travel times at about 9:00 AM of 15% (Figure 20).

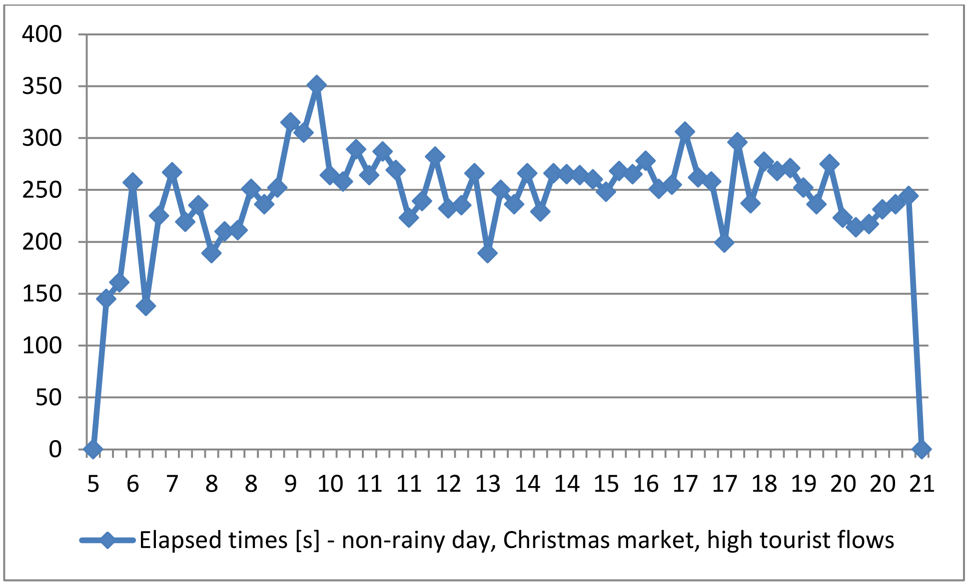

Figure 20: Pilot use case 2 elapsed times observed during the non-rainy / Christmas market / high tourist arrivals days considered in the case study.

This result can be associated to the fact that during the Christmas market many tourists are already used to take the option P&R or to arrive in the city center directly by train. The entrance of motorized vehicles in the city has taken place without significant disruptions.

During good weather conditions and with the Christmas market opened, the arrivals of tourists in the city can determine an increase of travel times of about 15% with reference working days with normal traffic demand. To travel by car on the monitored route, it takes about 5-6 [minutes]; to arrive to the city center, in such traffic conditions it can take additional 10-12 [minutes]. The alternative travel options (train & bus; park & ride) can provide comparable similar experienced travel times, as indicated in the previous use case scenarios. A traveller can evaluate such alternatives on a real-time basis by properly using all three applications.

During bad weather conditions occurred on the day after, no significant disruptions have been observed. This could be related to the fact that most of the visitors were already in the city. (Figure 21***Figure 19***).

During bad weather conditions and with the Christmas market opened, no siginificant disruptions to normal traffic conditions have been observed. To travel by car on the monitored route, it can take less than 5 [minutes]; to arrive to the city center, in such traffic conditions it can take additional 10 [minutes]. The alternative travel options (train & bus; park & ride) can provide a travel times experience slightly longer.

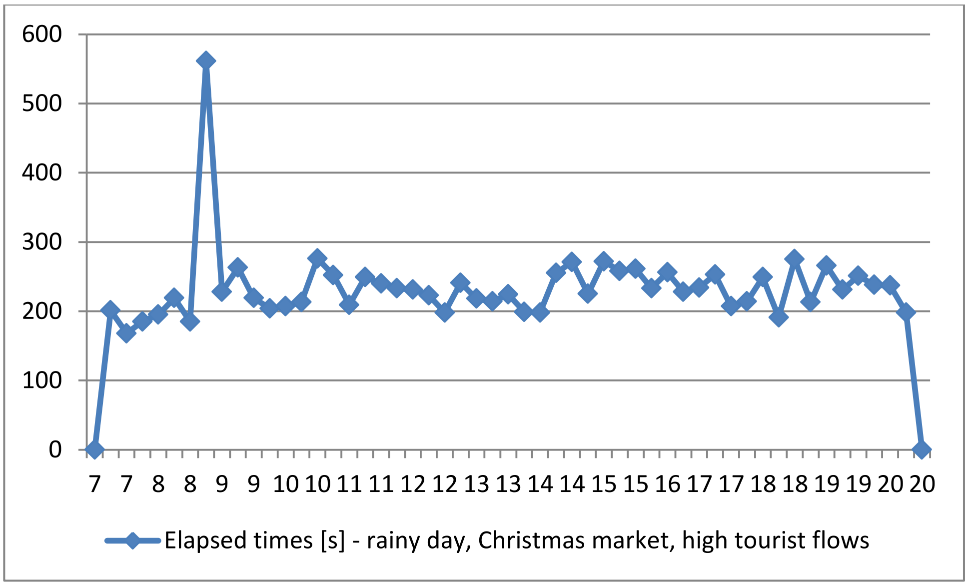

Figure 21: Pilot use case 2 elapsed times observed during the rainy / Christmas market / high tourist arrivals days considered in the case study.

2.3 Pilot Use Case 3 evaluation: commuters planning to enter the city

Pilot use case 3 is related to the evaluation of a set of use scenarios in which traffic conditions are strongly influenced by the choice of local commuters to take the car to join their working place. Different use scenarios have been taken into account in this analysis: bad weather conditions and the presence of tourists to visit the Christmas market.

This pilot use case has been fully evaluated again on the road stretch **Druso Street**, already considered for the evaluation of pilot use case 2.

The days evaluated for the quantification of the potential environmental gain associated to this pilot use case are related to two different periods, one of them already investigated in pilot use case 2 (but with a detailed investigation of other days):

- **week 45 of year 2014** (November 3rd – 9th), in which the impact of bad weather conditions only has been considered;
- **week 48 of year 2014** (November 24th – December 4th), in which the impact of both bad weather conditions and Christmas market opened has been considered;

The precipitation patterns occurred during week 45/2014 are presented in Figure 22. Intense precipitation events have taken place in particular on November 5th – 6th.

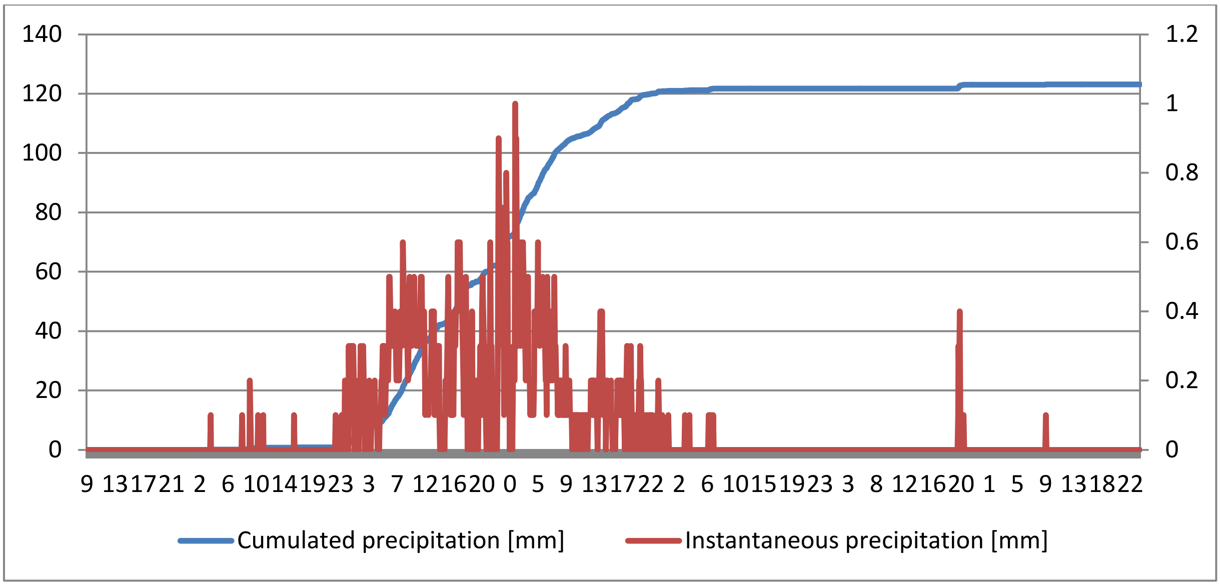

Figure 22: Pilot use case 3: precipitation patterns during week 45/2014.

Day	Cumulated Precipitation [mm]
03/11/2014	0,0
04/11/2014	1,3
05/11/2014	66,9
06/11/2014	52,7
07/11/2014	0,8
08/11/2014	1,3

09/11/2014	0,1

Table 11: Pilot use case 3: cumulated precipitation during week 45/2014.

The presence of bad weather conditions has had an effect of extraordinarily amplifying travel times conditions, as presented in the elapsed times associated to the specific cases of week 45/204 (Figure 23).

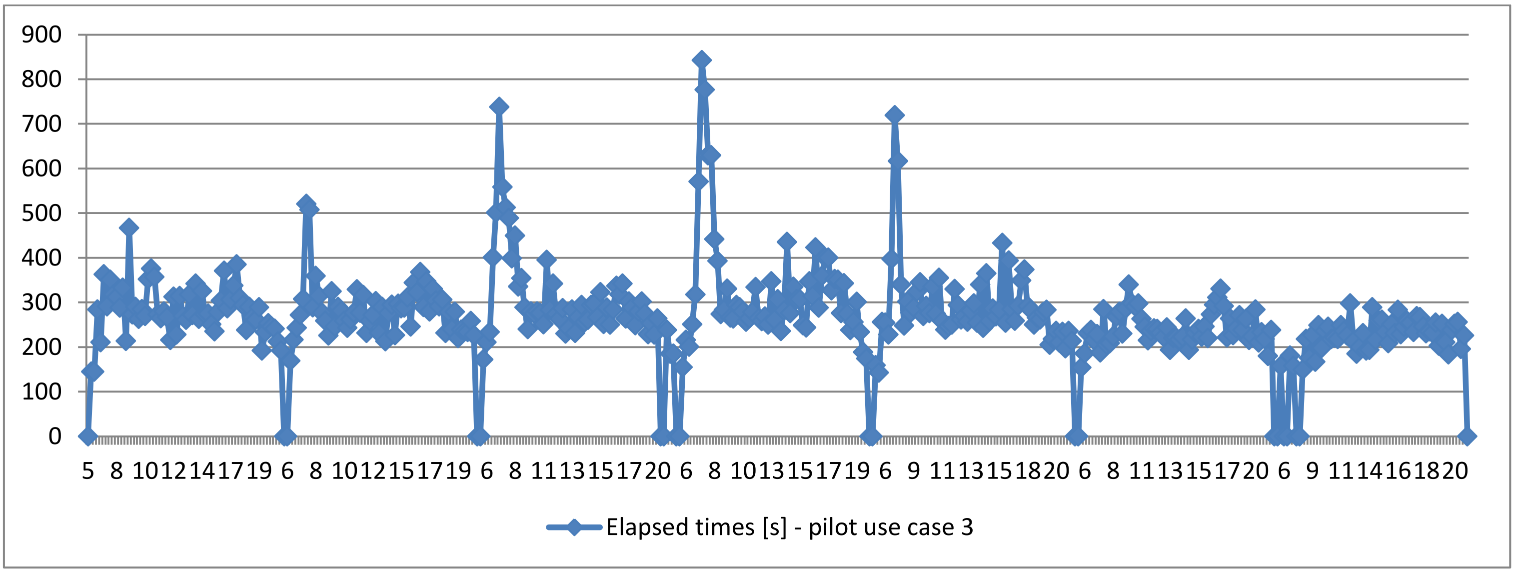

Figure 23: Pilot use case 3: elapsed times observed during week 45/2014 considered in the case study.

According to the plan defined in D.5.2.1 [1], days with peaks in the number of commuters traveling a motorized vehicles have been distinguished according to the weather conditions and the presence of not of the Christmas market opened (Table 12 and Table 13). In these tables, expected optimization margins defined during the Test Bed plan have been reported as well.

ID	Weather / traffic	Trip / routing improvement	Hypothesis
US_3.2	Rainy day with heavy traffic (November 5th-6th)	Temporal routing improvement	Travel times improved up to 30%. CO_2 emissions reduced up to 20%.
US_3.1	Non-rainy day with normal traffic conditions (November 3rd - 4th)	Temporal routing improvement	Travel times improved up to 15%. CO_2 emissions reduced up to 10%.

Table 12: List of pilot use scenarios associated to pilot use case 3 (Non-Christmas market).

ID	Weather / traffic	Trip / routing improvement	Hypothesis
US_3.4	Rainy day with heavy traffic (December 1st)	Temporal routing improvement	Travel times improved up to 35%. CO_2 emissions reduced up to 25%.
US_3.3	Non-rainy day with normal traffic conditions (December 2nd - 3rd)	Temporal routing improvement	Travel times improved up to 15%. CO_2 emissions reduced up to 10%.

Table 13: List of pilot use scenarios associated to pilot use case 3 (Christmas market).

2.3.1 Use Scenarios related to non-Christmas market period

During conditions of normal traffic, at peak hours measured travel times are typically in the order of 500 [s] (about 8 [minutes]), about 25% more than maximum travel times measured on average during the rest of the day. The position of the peak is in this case located in the morning period, in the time interval between 7:00 – 9:00 PM. This is something normal since in this analysis only the travel direction "city centre" has been considered, therefore, the peak in the afternoon is not visible.

During bad weather conditions, these peak phenomena are much more amplified, and can determine travel times in the order of more than 800 [s] (about 13 [minutes]), which means 50% more than the maximum travel times measured on average during non-peak hours in days without intense precipitation.

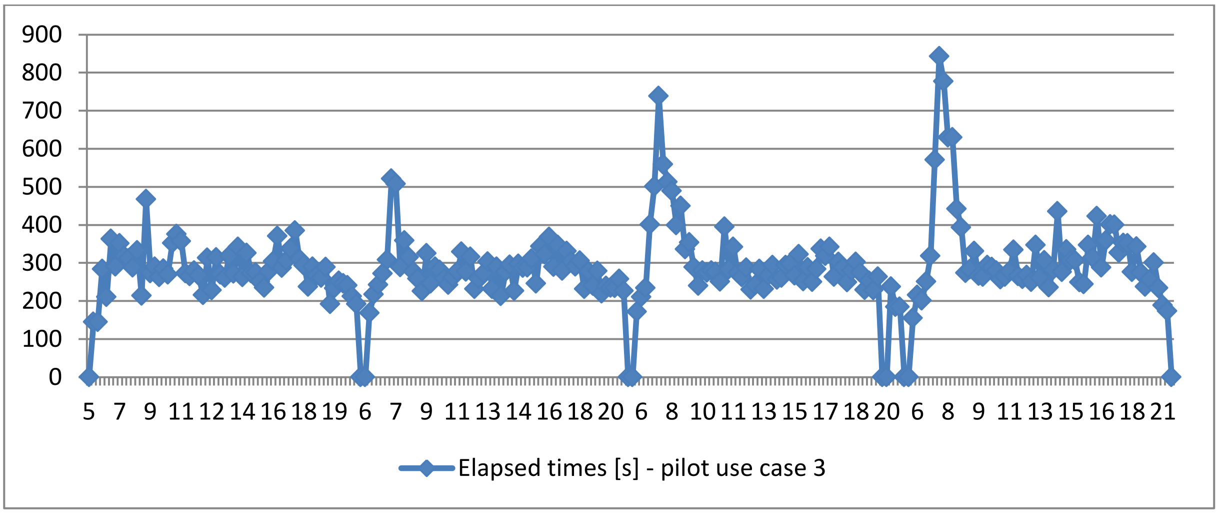

Figure 24: Pilot use case 3: elapsed times observed during the non-Christmas market days considered in the case study.

In absence of precipitation, by starting a trip 15-30 minutes before the interval of maximum travel time, the travel time can be reduced in the order of 25%. In presence of intense precipitation, the travel time reduction potential can be greater, up to 2 times, but the start of the trip must be furthermore anticipated.

The verification of the emissions reduction has been carried out by considering the average NO_X and CO_2 emissions estimates obtained on the two couples of days in which the two use scenarios have been detected. Emissions estimates derived from the real-time INTEGREEN emission model [5] are reported in Table 14.

Period of the day	NO_X emissions [g/km/h]	CO_2 emissions [g/km/h]	NO_X emissions reduction	CO_2 emissions reduction
7:00 AM	679	335.217	19,7%	28,3%
8:00 AM	754	366.817	21.8%	32.4%
9:00 AM	625	280.417	1,7%	2,1%

Table 14: Emissions estimates associated to pilot use case 3 (rainy days, non-Christmas market).

The increase of the peak in travel times conditions associated to local commuters travels during rainy precipitation is responsible for an increase of the emissions in the order of 20% for NO_X and 30% for CO_2. By properly selecting the departure time with the application BZTraffic, it is possible to generate a reduction of the emissions estimated for use scenario US_3.1 in 10% NO_X and 10-15% CO_2, and for use scenario US_3.2 in 15-20% NO_X and 20-25% CO_2.

2.3.2 Use Scenarios related to Christmas market period

By comparing the same use scenarios during days in which the Christmas market was open, travel times patterns have demonstrated to be very similar, without any further significant increase or amplification of these negative externalities. During the rainy day of December 1st, the maximum travel time measured has been about 700 [s], so comparable to what was observed in a similar use case but without Christmas market opened. Moreover, the increase in travel times has been in this case “only” the 40%, and not 50% as previously estimated. Similarly, during days without intense precipitation, maximum travel times during the peak hours have remained under acceptable conditions, i.e. about 400 [s], which means 100 [s] than what observed without Christmas market opened! This probably reveals that local citizens and travellers are already used to change their mobility habits during this period accordingly, with the effect of having overall traffic conditions which are more efficient than in other periods of the year.

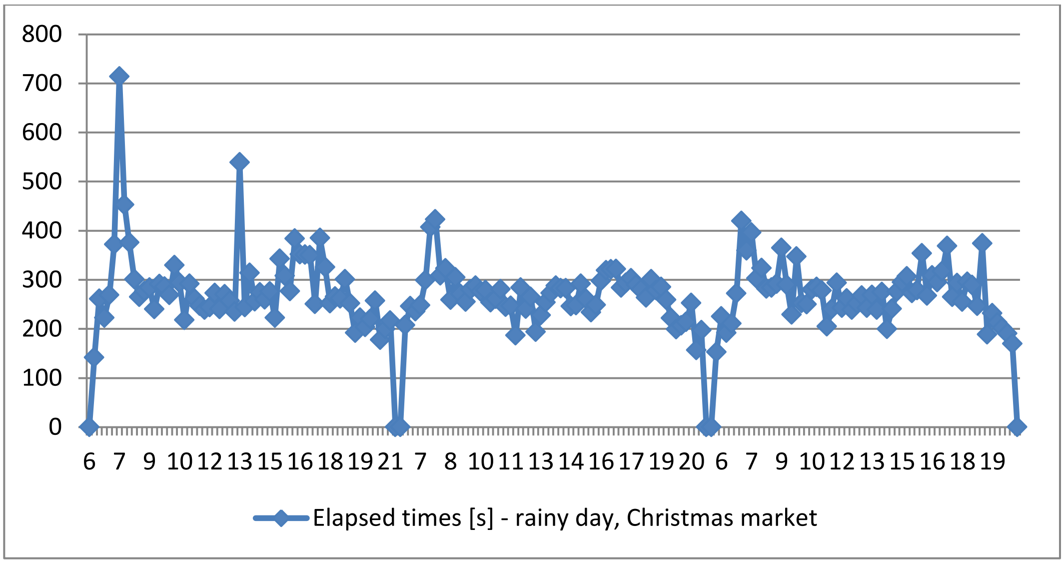

Figure 25: Pilot use case 3: elapsed times observed during the Christmas market days considered in the case study.

It is important however to remember that the heaviest traffic disruptions historically associated to the Christmas market are located in other periods of December, so these results may be affected by a level of mobility demand which is not the greatest as possible.

During the Christmas market, travel times during peak commuting periods have revealed to be not further amplified with respect to non-Christmas market periods: in absence of precipitation, by starting a trip 15-30 minutes before the interval of maximum travel time, the travel time can be reduced in the order of 10-20%. In presence of intense precipitation, the travel time reduction potential can be greater, up to 75%.

The verification of the emissions reduction has been carried out by considering the average NO_X and CO_2 emissions estimates obtained on the days in which the two use scenarios have been detected. Emissions estimates derived from the real-time INTEGREEN emission model [5] are reported in Table 15***Table 14***.

Period of the day	NO_X emissions [g/km/h]	CO_2 emissions [g/km/h]	NO_X emissions reduction	CO_2 emissions reduction
7:00 AM	594	280.265	8,4%	11,7%
8:00 AM	637	286.996	3.8%	3.9%
9:00 AM	521	231.517	-11,8%	-12,2%

Table 15: Emissions estimates associated to pilot use case 3 (rainy days, Christmas market).

The increase of the peak in travel times conditions associated to local commuters travels during rainy precipitation is responsible for an increase of the emissions in the order of 10% for both NO_X and CO_2 but only for the time interval in which the increased peak times are detected. By properly selecting the departure time with the application BZTraffic, it is possible to generate a reduction of the emissions estimated for use scenario US_3.3 in 10-15% and for use scenario US_3.4 in 15-20%.

2.4 Pilot Use Case 4 evaluation: traffic operators evaluating real-time information

Pilot use case 4 is related to the evaluation of the benefits associated to the activities of traffic operators, in particular in terms of ability to properly detect issues related to traffic jams or air pollution peaks, according to the use case scenarios identified in D.5.2.1 and briefly summarized in Table 16. Table 17 presents moreover the expected improvements to be observed.

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

Table 16: List of pilot use scenarios associated to pilot use case 4.

ID	Description	Hypothesis
US_4.1	Traffic officer controlling traffic / air quality levels in normal traffic / air quality conditions	Traffic officer can take under control traffic / air quality conditions with an update time lower than 15 [minutes]
US_4.2	Traffic officer controlling traffic / air quality levels in traffic jam conditions	The ability of traffic officer to anticipate traffic jam conditions is increased up to 30%, i.e. in 30% of traffic jams situations traffic officers are able to identify an abnormal travel time pattern.
US_4.3	Traffic officer controlling traffic / air quality levels in air pollution peak conditions	Traffic officer are able to detect air pollution hotspots associated to urban traffic, and manage traffic as a consequence of this information.

Table 17: Hypothesis associated to scenarios associated to pilot use case 4.

As far as the control of traffic patterns is concerned, these situations can be immediately identified by considering the case studies evaluated for the previous pilot use case. Moreover, traffic officers can combine this information with the set of environmental data and information at disposal, i.e.:

- **fixed air pollution measurements**, available every 15 [minutes] from the new roadside installations and every 60 [minutes] from the official air quality stations of the city;
- **mobile air pollution measurements**, which thanks to the long-term deployment on the public transportation vehicle [6] are available every day on the route of the line 10 with a delay of a couple of minutes and with a return time over the same monitored point of about 60 [minutes];
- **emission and dispersion models outputs**, which are available with a time frequency of 60 [minutes].

In order to demonstrate such integrated monitoring capability, and the possibility to take evidence of the environmental impacts of traffic, the expected benefits associated to the aforementioned hypothesis are demonstrated through the further investigation of two case studies:

- **analysis of the air pollution levels during the traffic jams of November 3rd on Druso Street through the fixed monitoring stations** (evaluated in pilot use case 3);
- **analysis of the air pollution levels during a traffic jam observed in January 2015 during a big fair in the industrial zone through the mobile monitoring station**.

2.4.1 Use Scenario related to fixed air quality monitoring

Figure 27**Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates the official levels of NO_2, expressed in [μg/m^3] transmitted by the official monitoring stations of the city. The station BZ4 is positioned very near at the end of the road stretch considered in the analysis, while station BZ5 is located quite far from it, in a different area of the city (Figure 27).

The levels of air pollution are typically correlated, and measurements quite similar. The reason for that is the fact that main source of pollution considered by the two monitoring stations are common (e.g. the A22 highway). In some cases, however, the difference between patterns and measurements is not-negligible, and can indicate the presence of local air pollution hotspots determined by very specific sources. In the considered case study, it is very clear the air pollution hotspot detected by the station BZ4 only on November 3rd in the morning, after the traffic peak previously analyzed. Amplified traffic jams are not typically associated to amplified air pollution peaks, but more likely one of the main causes of air pollution concentrations which are typically higher than the average, in particular during meteorological conditions in which the dispersion phenomena are more difficult.

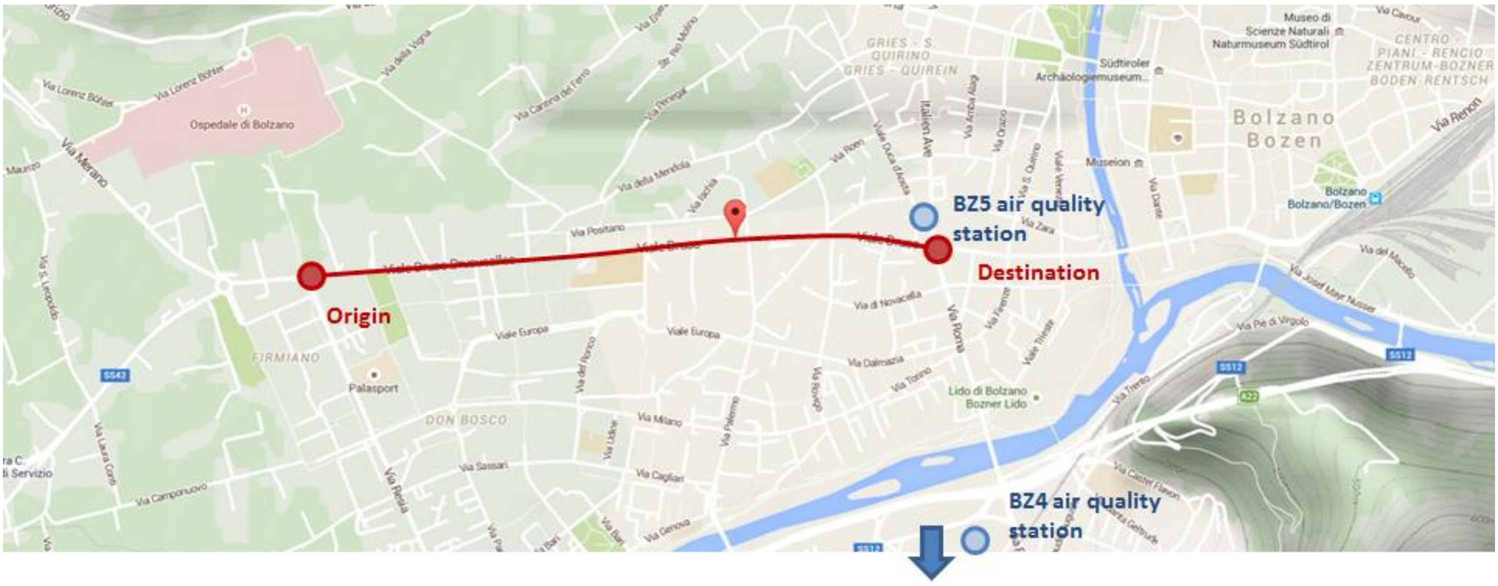

Figure 26: Pilot use case 4: Druso Street and the position of the official air quality stations.

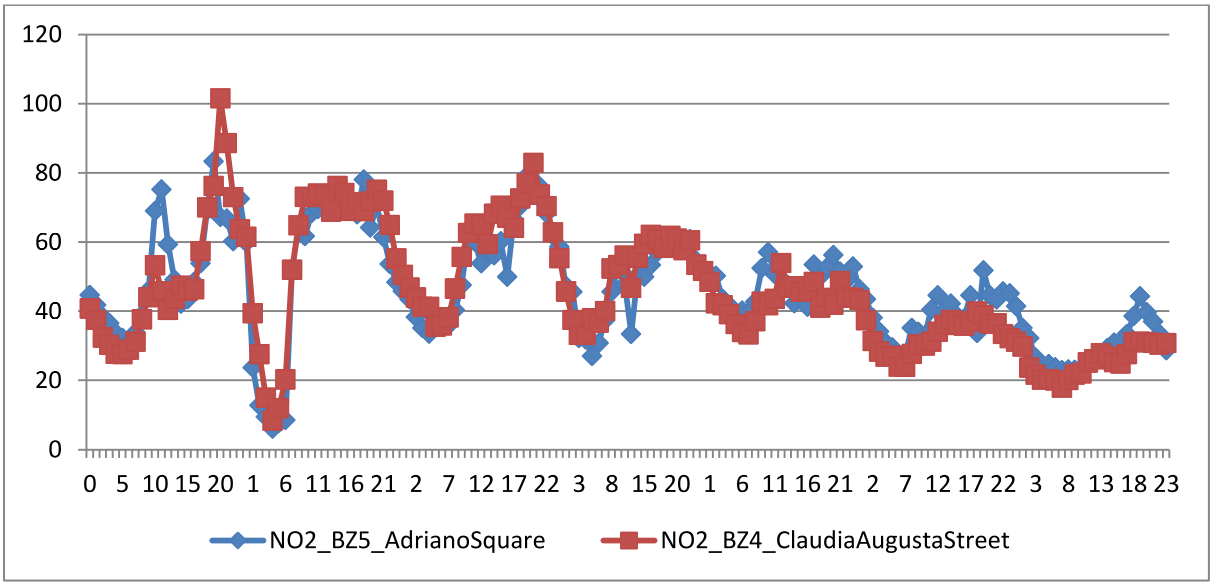

Figure 27: Real-time evaluation of the environmental impact of traffic disruptions.

During normal or heavy traffic conditions, traffic operators can quantitatively monitor the evolution of the traffic / air pollution situation with a time frequency of about 15 minutes. In about 60-70% of the cases, based on historical patterns, they are also in the condition to estimate the evolution of traffic conditions and continuously check if urban traffic is the direct responsible for certain air pollution peaks.

2.4.2 Use Scenario related to mobile air quality monitoring

The second reference situation is completely new in this report and therefore must be properly introduced. The use case scenario relates in particular to the opening of the Klimahouse fair, the biggest commercial event taking place in the fair of Bolzano with four days of exhibitions, demonstrations and tours (Figure 28). In 2015, the fair has taken place during the days January 29th – 30th – 31st and February 1st.

Figure 28: The Klimahouse fair in Bolzano.

The fair of Bolzano, which hosts this event, is not far from one of the Bluetooth monitored routes of the INTEGREEN system. The distance between the detectors, as indicated in the map of Figure 29, is about 0.7 [km]. The speed limit is 50 [km/h], which means that the theoretical minimum travel time a car can experience is about 50 [s]. The road can be traveled in two directions and is characterized by two lanes for each direction travel. This road is important for the city since it provides a direct connection to the MEBO expressway and the A22 highway, and during peak hours intense traffic jams can occur (Figure 30).

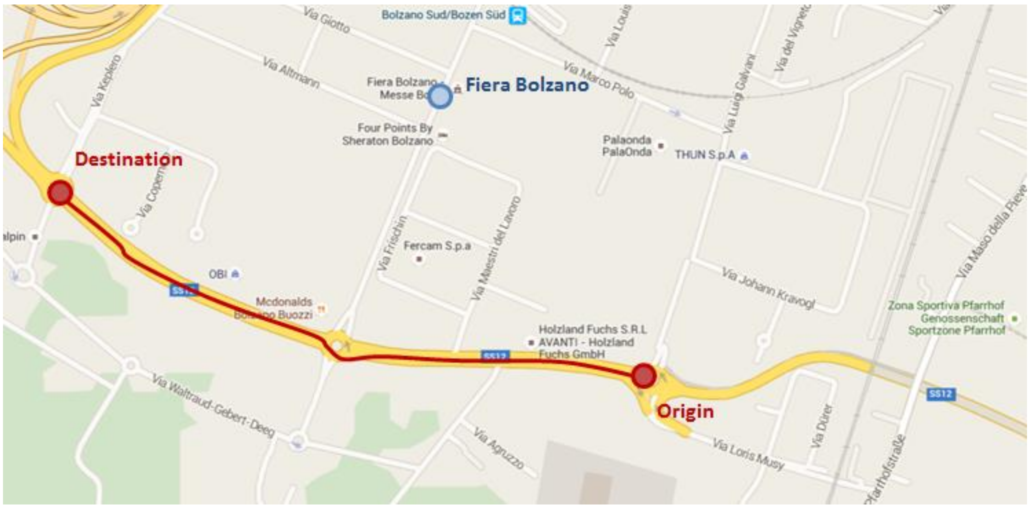

Figure 29: Pilot use case 4: the case study road for the evaluation of the impact of the Klimahouse fair.

Figure 30: *Pilot use case 4: the case study road "Einstein Street" during a traffic jam.*

Measured travel times during normal conditions are in the order of 80 – 100 [s], as demonstrated by the empirical values collected during January 22nd, i.e. one week before the start of the fair.

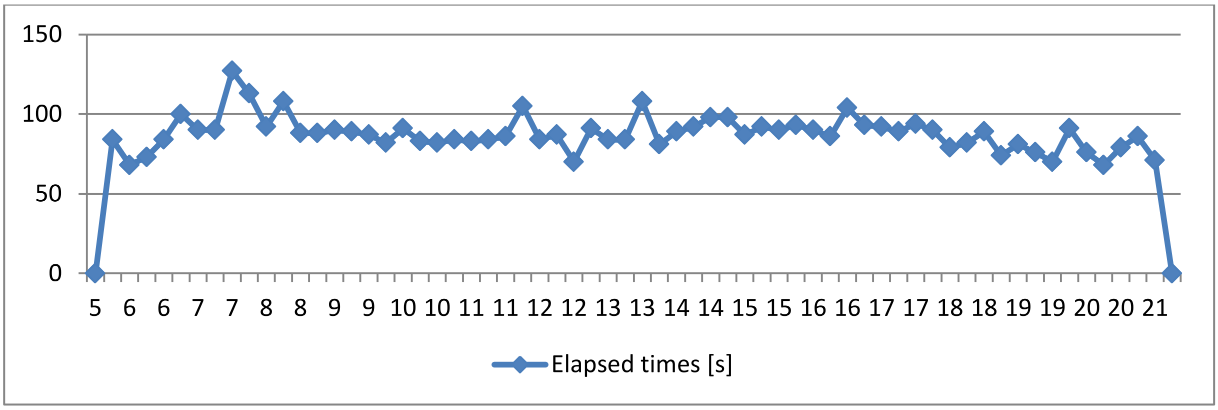

Figure 31: Pilot use case 4: reference elapsed times during "normal conditions".

During the fair, several traffic disruptions have been noticed, in particular during the afternoon period in which a lot of commuters take the way back to home. Figure 32 presents the elapsed times measured during the days January 28th –30th. At is possible to see, during the first two days of event travel times have reached peaks in the order of 700-800 [s], i.e. 7-8 times more than normal conditions. Such heavy traffic conditions have moreover survived for about 2-3 hours, in the interval 4:00 – 7:00 PM.

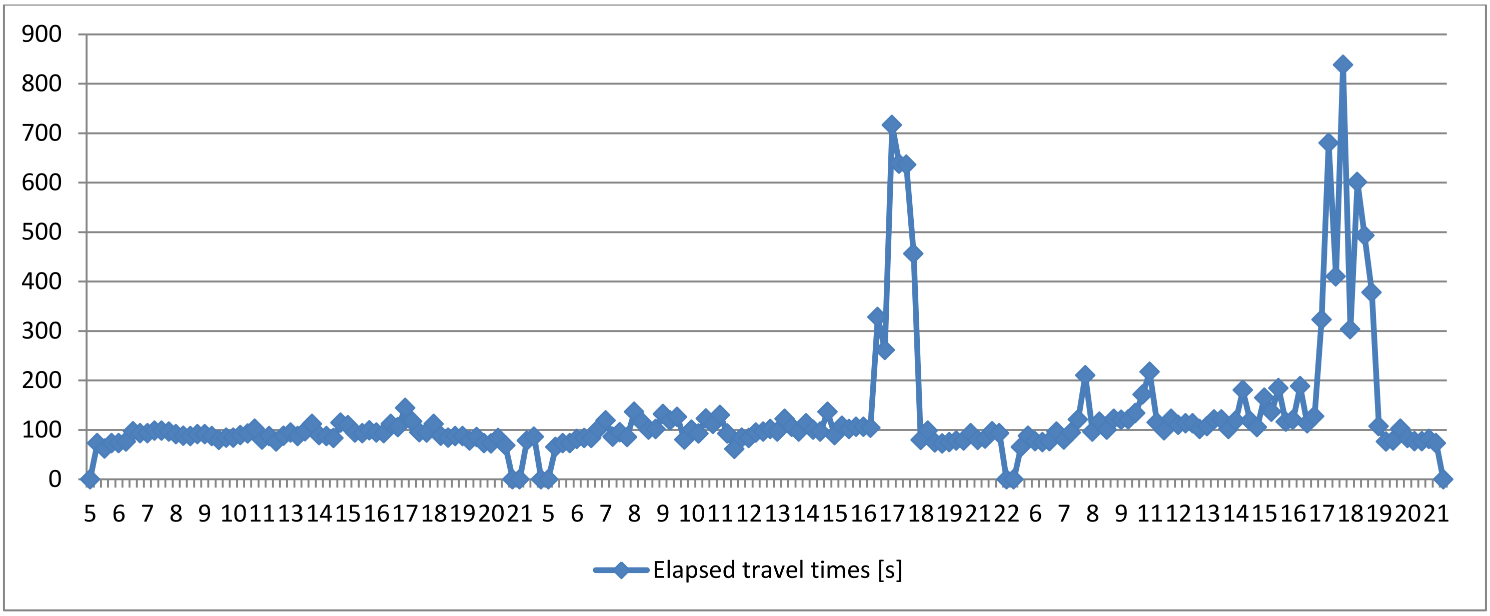

Figure 32: Pilot use case 4: reference elapsed times during the Klimahouse fair.

By observing the official NO_2 measurements, expressed in [µg/m^3], it is possible to see that on January 29th a certain increase of the concentration of this air pollutant has occurred, with both values in the order of 80 [µg/m^3] in the late afternoon (Figure 33).

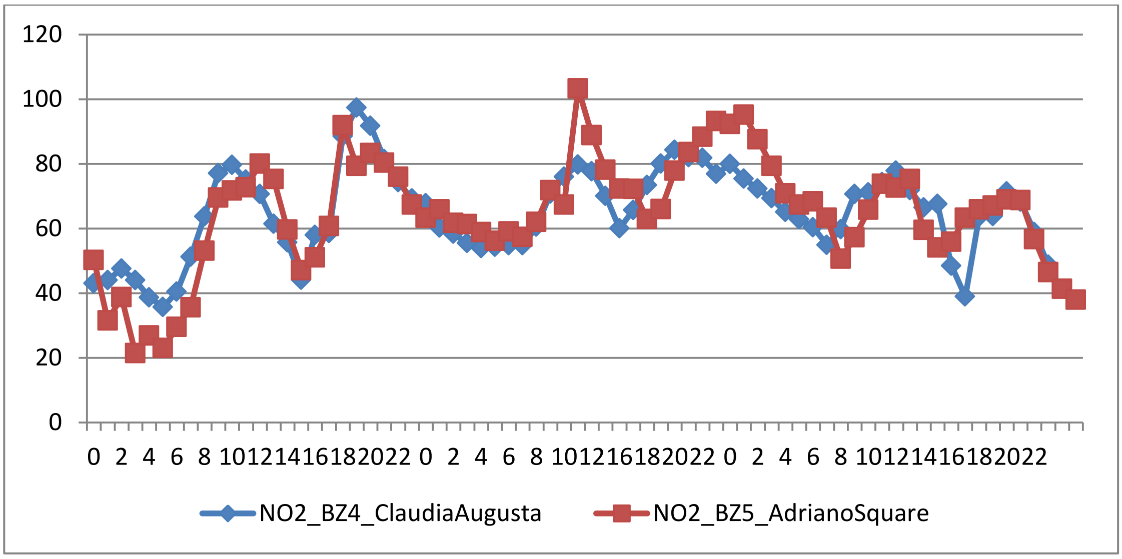

Figure 33: Pilot use case 4: reference fixed air quality measurements during the Klimahouse fair.

The contribution to air pollution has been confirmed by the mobile air pollution measurements taken by the on-board system mounted on the public transportation vehicle, which has passed through the road stretch analyzed during the peak hour (Figure 34).

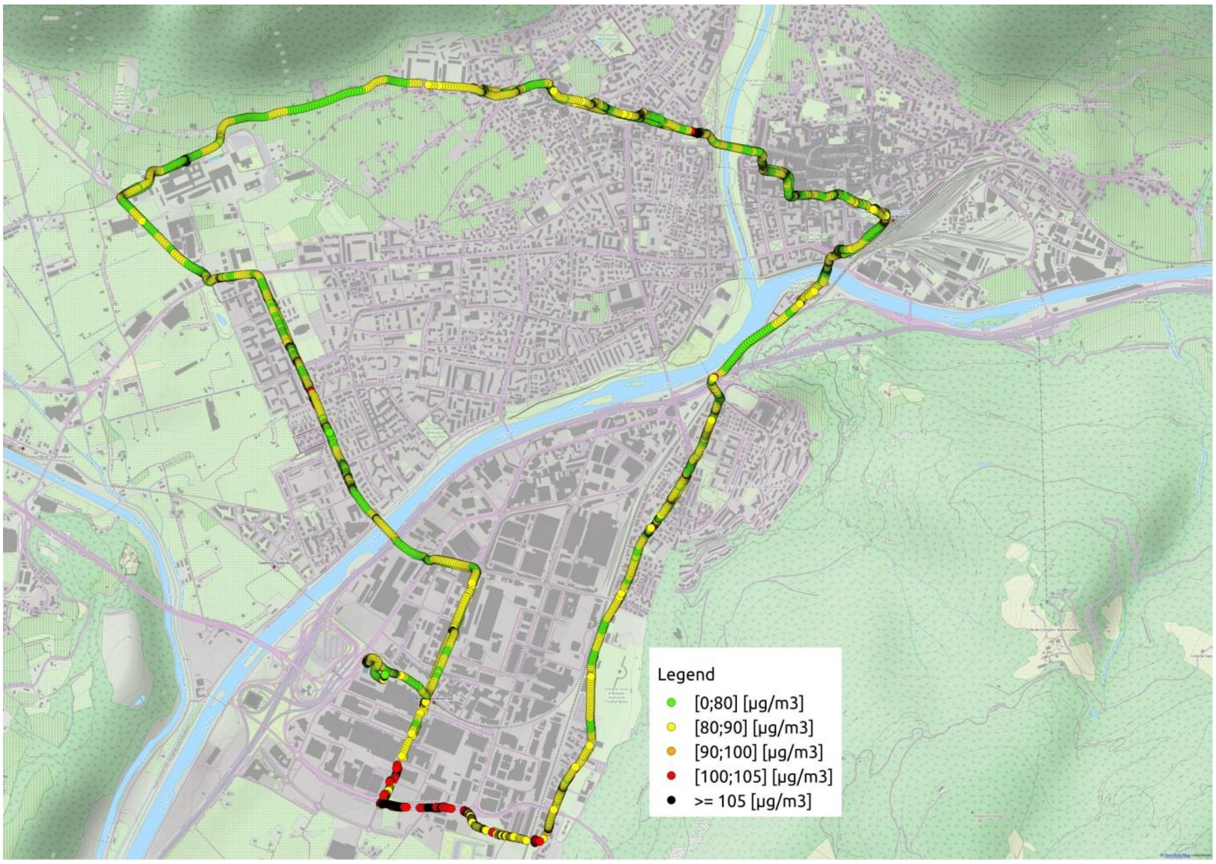

Figure 34: Pilot use case 4: mobile air quality measurements during the Klimahouse fair.

For more information related to the final deployment activities of the mobile system demonstrator, please refer to P.4.3.1 [6].

The monitored air pollution concentrations on the case study road and near the fair have been in the order of 100 [µg/m^3], in line with the static air pollution measurements.

Thanks to the integrated monitoring capabilities of INTEGREEN (fixed and mobile, traffic and air pollution), traffic operators can dynamically detect the presence of traffic jams and/or air pollution peaks and manage traffic according to the detected patterns.

3 Eco-policies benefits assessment

The last part of the testing and validation of the INTEGREEN system is related to the initial test of a selected set of eco-friendly traffic policies, identified during the planning of the Test Bed [1], as reported in Table 18.

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

Table 18: List of eco-friendly traffic policies associated to pilot use case 5.

The evaluation of these eco-friendly traffic policies has been concentrated on the road stretch associated to **Druso Street**, already considered for the assessment of pilot use case 2.

Unfortunately, due to conflicts with trade unions related to the definition of how savings produced by improved eco-driving behaviour of bus drivers could be distributed between the company and the drivers themselves, policy EP_5 could not be including in the real-testing phase. The introduction of the eco-friendly traffic policies has followed the basic plan defined in D.5.2.1, but with the small difference that measures have been introduced more gradually in order to check their combined effects even on a longer term. For this reason, the chosen temporal planning has been the one indicated in Figure 35. The policy EP_4 has been included in the analysis but never applied, since in the last months **no significant congestion** in the city has registered, with the necessity to use the Variable Message Signs to better deviate traffic flows within the road network. For this reason, the impact of this policy will be evaluated by analysing some historical cases in which VMS messages have been used in order to inform that all parking areas of the city were completely full, and to take the bus in order to join it.

The updated hypothesis associated to friendly traffic policies associated to pilot use case 5 are summarized in Table 19.

ID	Description	Hypothesis
Eco-policy 1	Speed detectors installed in Druso Street	Vehicular travel times are reduced up to 5%, CO_2 emissions and pollutants levels up to 3%. Pilot results will lead the Municipality of Bolzano to better understand how to best use this measure.
Eco-policy 2	Traffic light phases adapted in Druso / Resia Streets	Vehicular travel times are reduced as a whole within the affected roads up to 15%, CO_2 emissions and pollutants levels up to 8%. Pilot results will lead the Municipality of Bolzano to better understand how to best use this measure.
Eco-policy 3	End-users apps public launched	End-users apps determine an increase in the public transport modal share of up 3%. Vehicular travel times are reduced as a whole within the affected roads up to 10%, CO_2 emissions and pollutants levels up to 7%. The majority of users (at least 70%) consider usability of the applications as "high", while it is expected to have a non-negligible share of users (at least 30%) revealing to be willing even to pay a little fee for certain RTTI services.

Table 19: Hypothesis associated to scenarios associated to pilot use case 5.

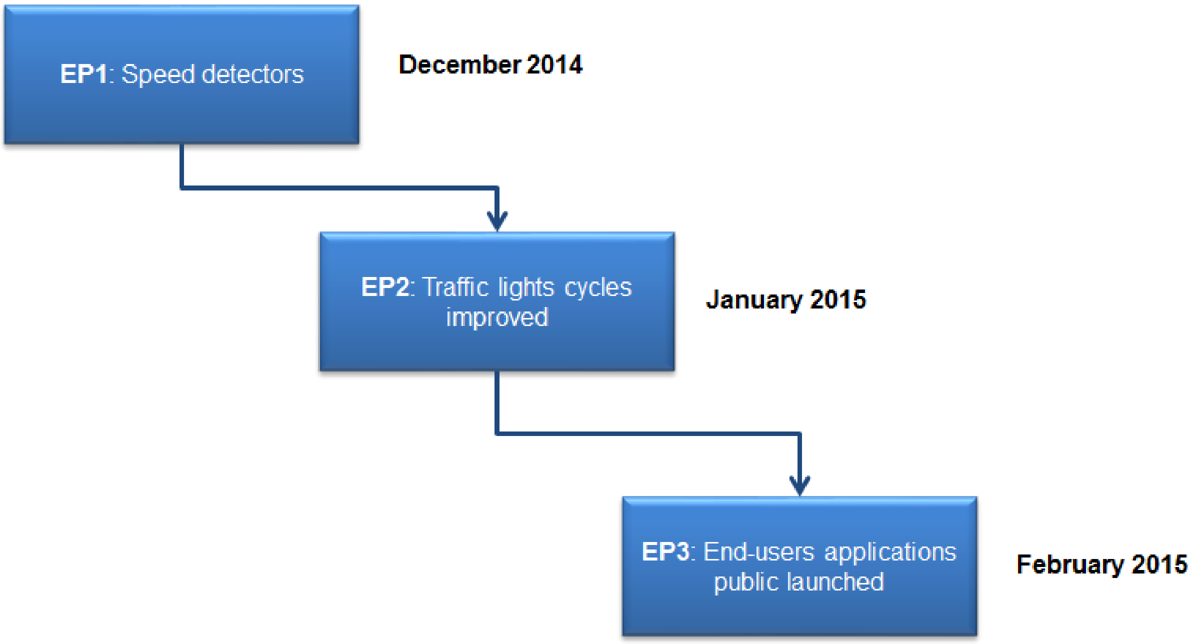

Figure 35: Temporal planning in the introduction of the tested eco-friendly traffic policies.

3.1 Eco-policy 1: speed detection enforcement system

The first measure introduced has been the installation of a set of **speed enforcement detectors** in certain points of the city. This measure has been heavily discussed and evaluated in strict cooperation with the political governance of the city, and has been proposed with the main willing to reduce vehicular speeds and hopefully give an answer to the increasing number of accidents involving both motorized vehicles and vulnerable road users. The INTEGREEN project has taken advantage of this initiative of the Municipality of Bolzano in order to check its environmental impact as well, since as confirmed by D.5.3.1 speed management policies, if properly organized, are among the most-effective policies ones from an environmental point of view.

Eight detectors have been installed on December 4th 2014, as indicated in Figure 36. It is not a case that five of these detectors have been placed on the road stretches monitored by the INTEGREEN system: three on Druso Street, one in Galilei Street and one in Claudia Augusta Street.

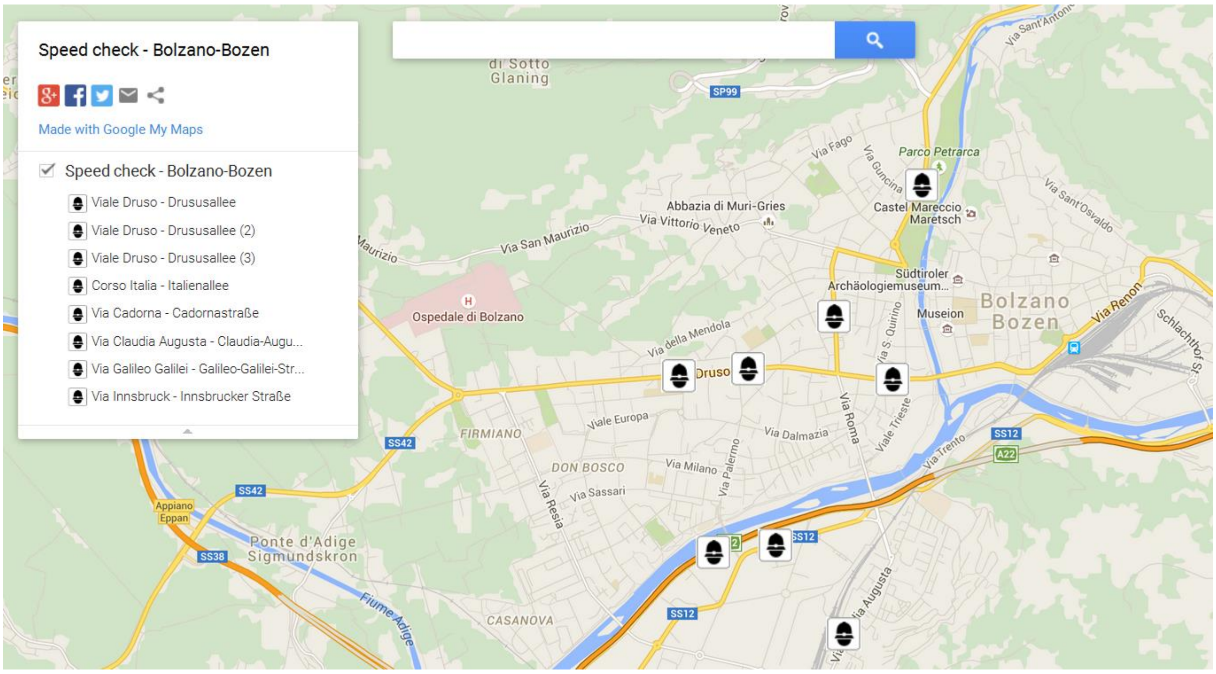

Figure 36: The map of the speed enforcement detectors installed in the city of Bolzano.

The ex-ante and ex-post assessment of the impact of this eco-friendly traffic policy has been therefore concentrated on two case study roads (Figure 37):

- **Druso Street**, which is as already mentioned the area where all eco-friendly traffic policies are evaluated;
- **Galilei Street**, in order to check if the number of the detectors installed and the different road peculiarities (.g. traffic control policies, traffic demand and load, etc.) have determined a significantly traffic / environmental impact.

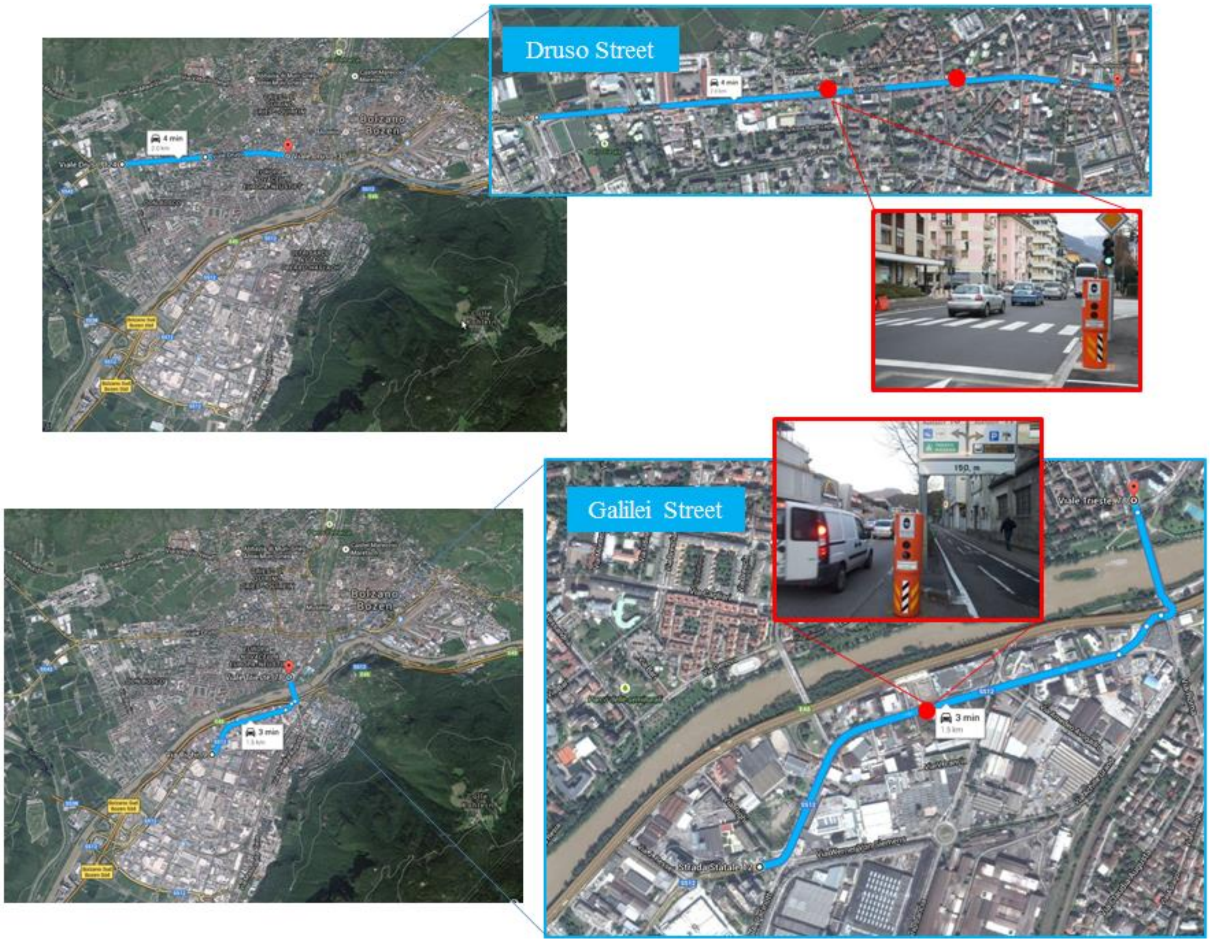

Figure 37: The details of the speed detectors installations considered in the testing & validation activities of INTEGREEN.

In order to evaluate the impact of this policy, considered travel times data on these monitored roads have covered the period August 19th 2014 – January 3rd 2015. In this way, the travel times observed during the previous three months have been compared to what has been observed up to one month after the introduction of this policy. The ex-post period is smaller basically for two reasons: (i) in order to evaluate the short-term impact of this measure, in order to understand if drivers have immediately changed their driving habits; and (ii) in January policy EP_2 has been launched.

The results are presented and discussed in the following pages, in which many plots and tables of the obtained results are reported with reference the following links.

- **Druso Street (direction city centre);**
- **Druso Street (direction city suburbs);**
- **Galilei Street.**

Druso Street (direction city centre)

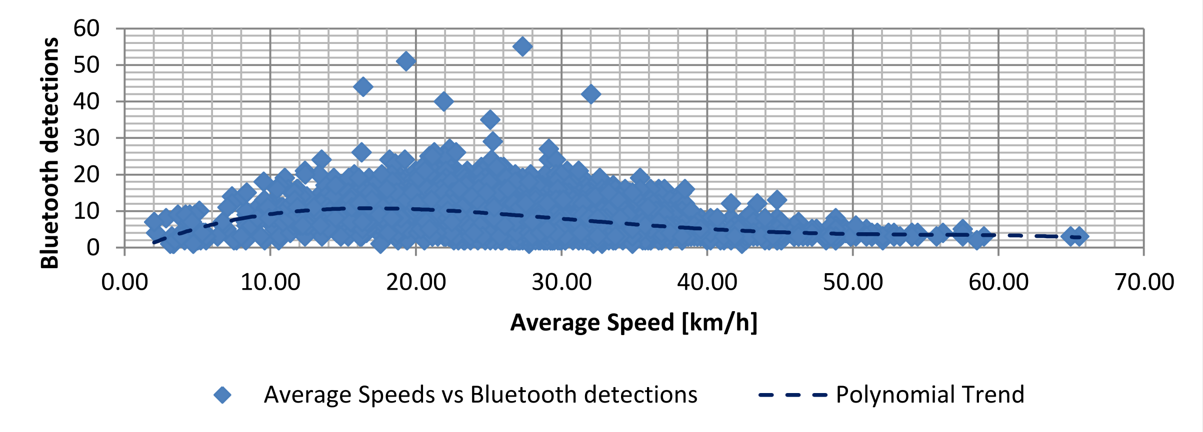

Figure 38: The overall traffic patterns observed on Druso Street (direction city centre).

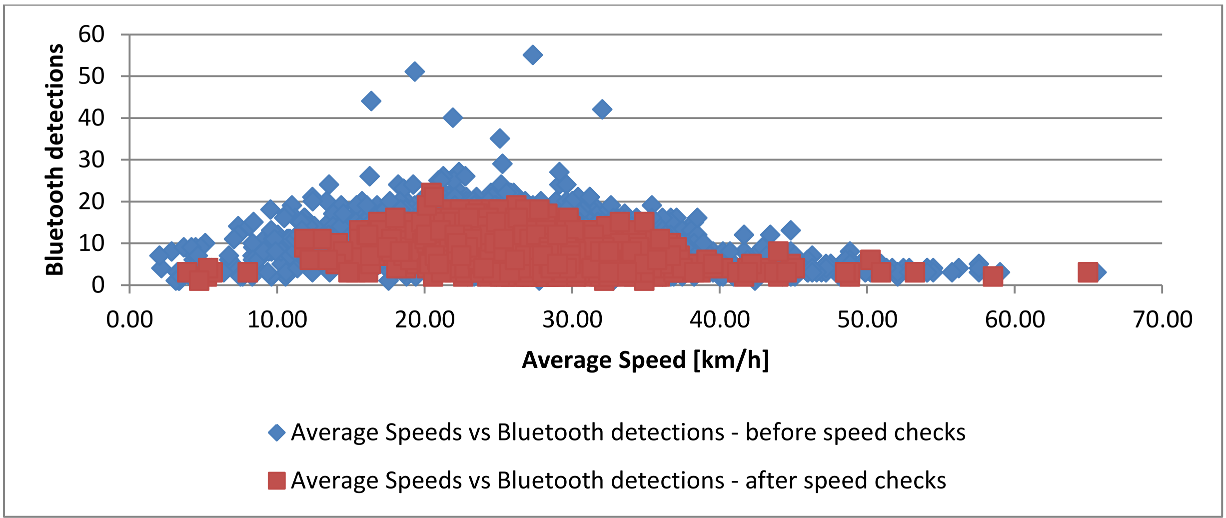

Figure 39: The ex-ante / ex-post traffic patterns observed on Druso Street (direction city centre).

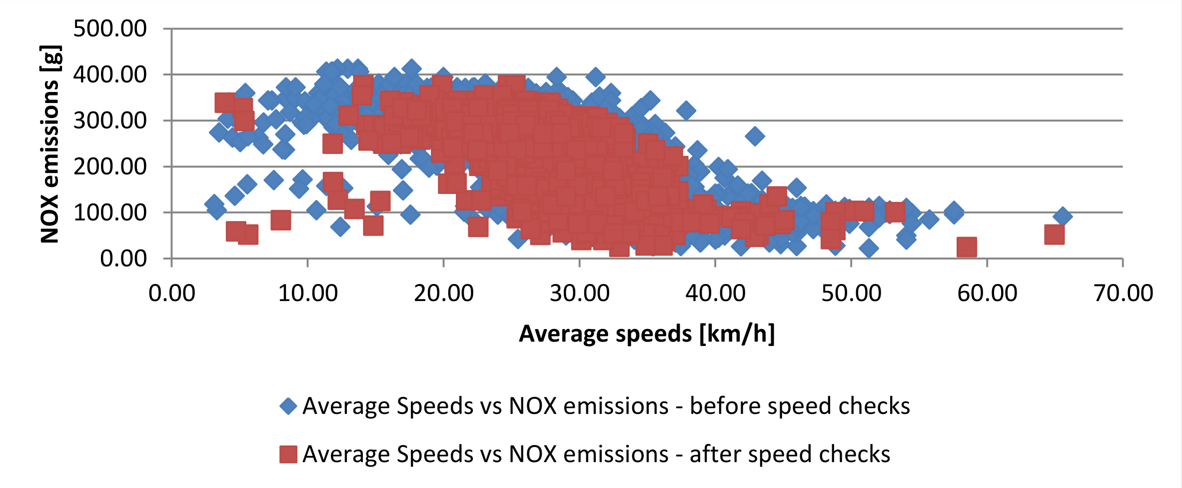

Figure 40: The ex-ante / ex-post environmental impact observed on Druso Street (direction city centre).

Druso Street (direction city suburbs)

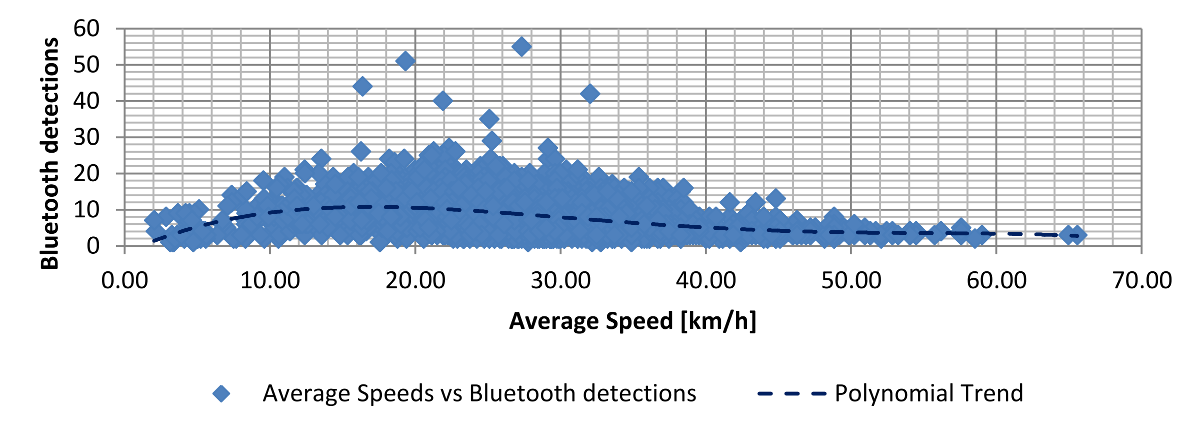

Figure 41: The overall traffic patterns observed on Druso Street (direction city suburbs).

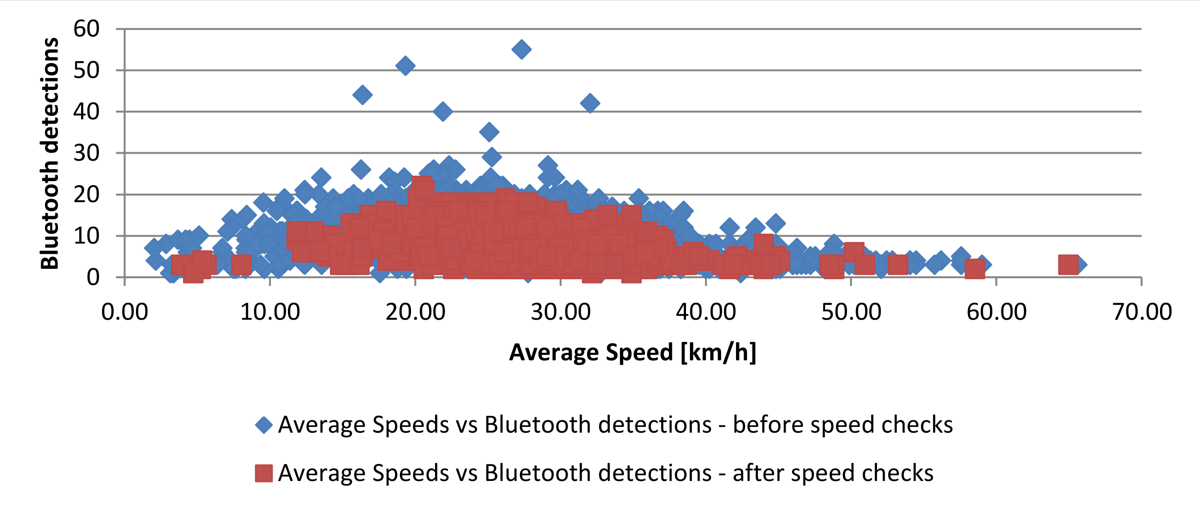

Figure 42: The ex-ante / ex-post traffic patterns observed on Druso Street (direction city suburbs).

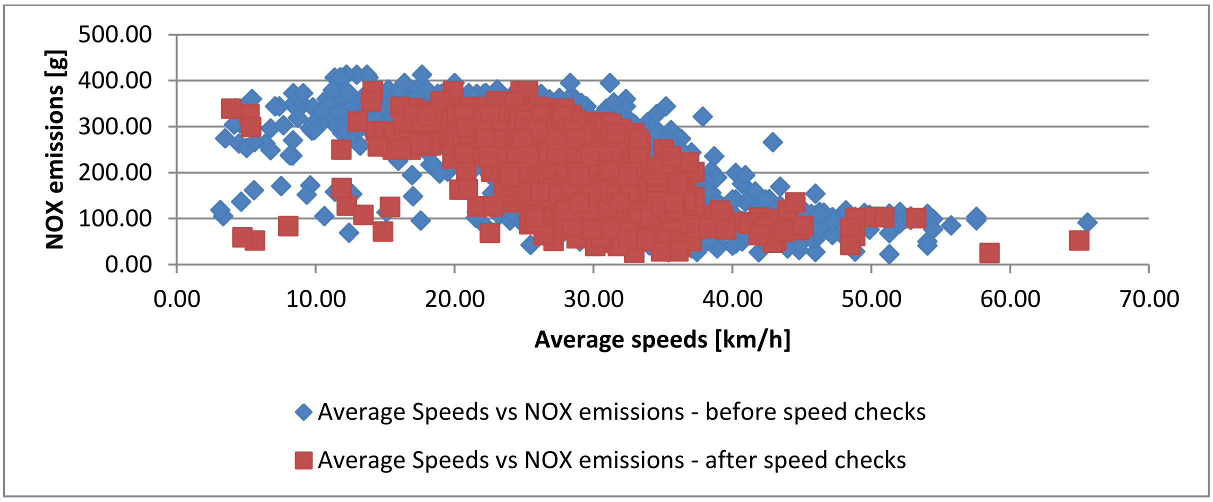

Figure 43: The ex-ante / ex-post environmental impact observed on Druso Street (direction city suburbs).

Galilei Street

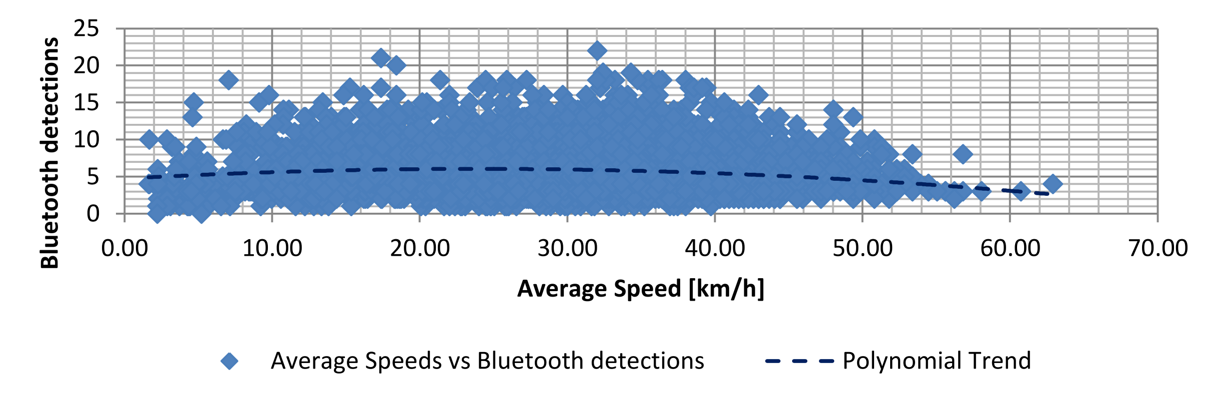

Figure 44: The overall traffic patterns observed on Galilei Street.

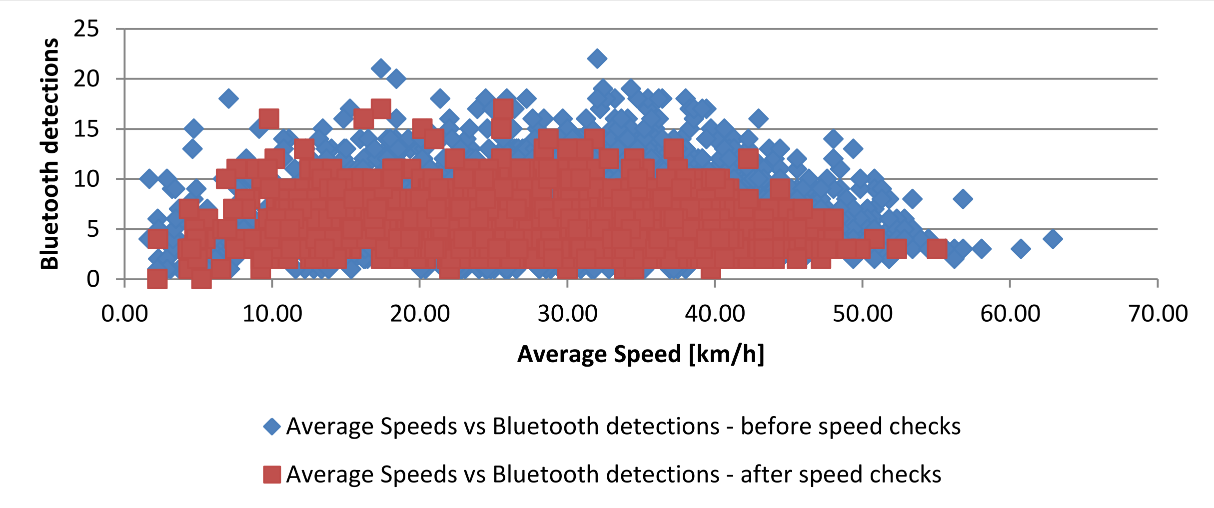

Figure 45: The ex-ante / ex-post traffic patterns observed on Galilei Street.

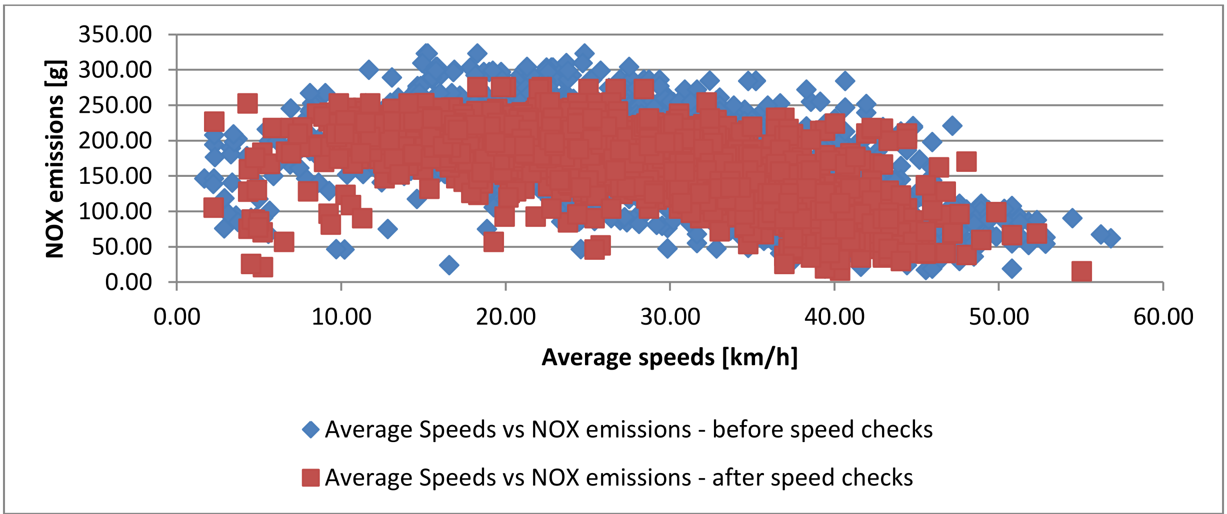

Figure 46: The ex-ante / ex-post environmental impact observed on Galilei Street.

Key Performance Indicators	Druso Street (direction city centre)	Druso Street (direction city suburbs)	Galilei Street
Average speed	+ 2 %	0 %	- 10 %
Nr. of vehicular detections	- 12 %	- 16 %	- 11 %
Nr. of congestion records	- 0.7 %	- 0.5 %	+ 1.8 %
Nr. of speeding records	- 1.4 %	- 3.5 %	- 6.7 %
PM_{10} emissions	- 9 %	- 9 %	- 3 %
NO_X emissions	- 9 %	- 8 %	- 3 %
CO_2 emissions	- 10 %	- 10 %	- 4 %

Table 20: Summary of the impact associated to the eco-friendly policy EP_1.

As summarized in Table 20, the impact of this measure has been slightly higher in Druso Street than in Galilei Street. Speed detectors have influenced only in part the average speeds and number of speeding records, i.e. elementary intervals in which the estimated average speed is greater than the admitted speed limit. The greatest influence has been in terms of reduction of vehicular detections, and as a consequence of air pollutants and greenhouse gases emissions. So it must be considered the issue that many drivers have decided to take alternative routes in order to enter the city, in which such detectors are not installed. In order to avoid such negative externality, all major routes should be controlled in the future. These results have confirmed state-of-art analysis reported in D.5.3.1, in which it is recommended to combine speed management policies with enforcement approaches in order to be environmentally effective.

As far as the impact on air pollution concentration is concerned, the following plots presents some correlation analysis between emitted pollutants and measured concentrations. In Figure 47 estimated emissions related to Druso Street have been compared to the NO_2 measurements taken by the air quality station BZ5 (Adriano Square) while Figure 48 presents the correlation results between the estimated emissions related to Galilei Street with the NO_2 measurements taken by the air quality station BZ4 (Claudia Augusta Street). No significant improvements have been observed, since in the period in which tested traffic policies have been tested other dominant sources of pollution (e.g. domestic heating) are responsible for the high levels of pollution.

The eco-friendly traffic policy EP_1 (speed enforcement detectors) has produced in the short term period the following impacts: (i) little increase of vehicular travel times of up to 10%; and (ii) reduction of emissions in the order of 5-10%. No immediate effects on the concentration levels of air pollution have been observed, since the winter months in which the policies have been introduced are mainly dominated by other sources of pollution.

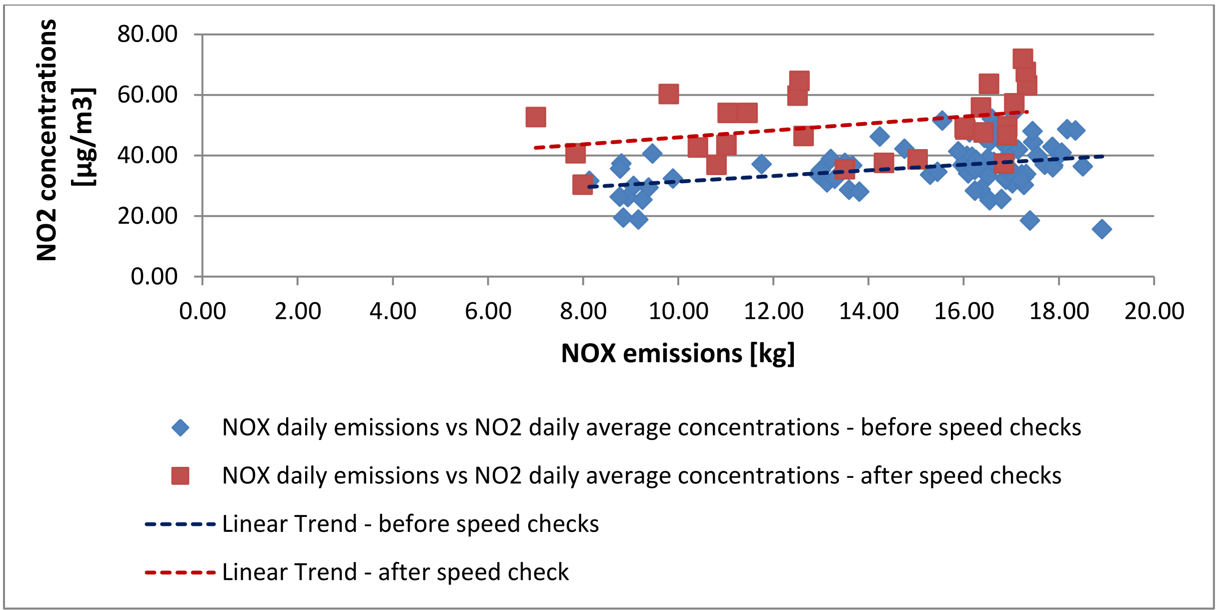

Figure 47: The correlation between emissions estimated on Druso Street and air pollution concentrations measured by the station BZ5 (Adriano Square).

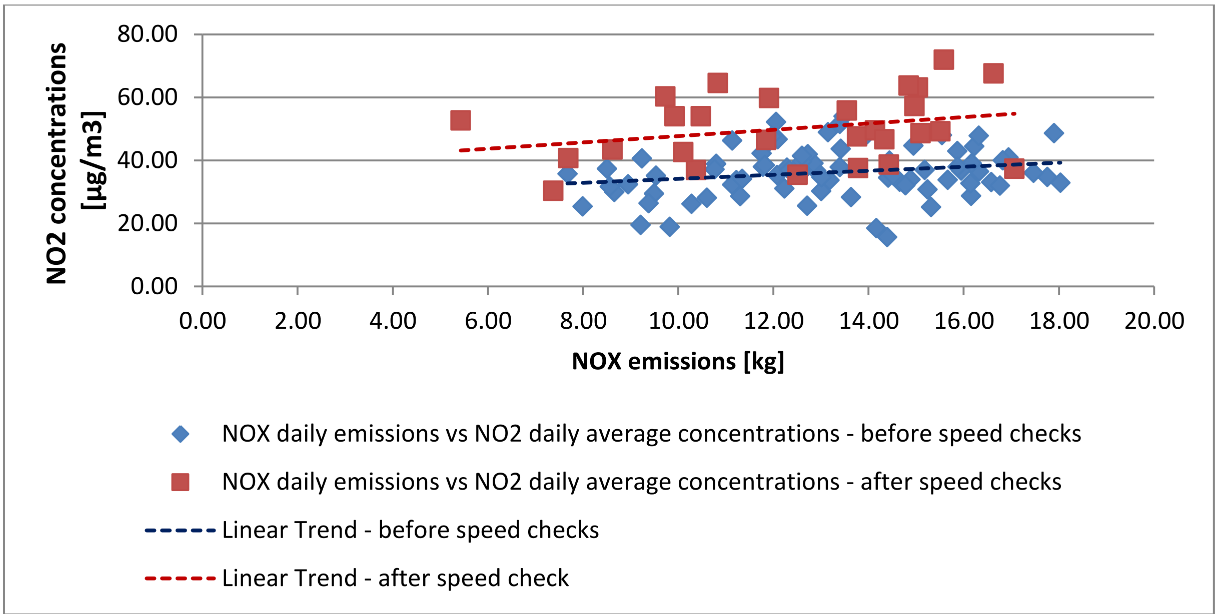

Figure 48: The correlation between emissions estimated on Galilei Street and air pollution concentrations measured by the station BZ4 (Claudia Augusta Street).

3.2 Eco-policy 3: traffic lights cycles changes

In January 2015, the Municipality of Bolzano has started to deploy an advanced software for the automatic management of the cycles of traffic lights. The main improvement will be the possibility for each traffic light to adapt the timing of the red / green phases on a real-time basis according to the traffic detections taken in correspondence of the controlled intersection. As indicated at the state-of-art [3], this optimization with respect a situation in which cycles are not dynamically adjusted is in the condition to determine the highest environmental improvements.

First tests with this new system have been organized in correspondence of the traffic lights that regulate access traffic in direction city centre through Druso Street, with the purpose to understand how to improve the transit of public transportation vehicles on the new dedicated bus lanes (Figure 49).

Figure 49: The road stretch in direction Druso Street where the eco-friendly traffic policy EP_2 has been experimented.

Key Performance Indicators	Druso Street (direction city centre)	During bad weather days only
Average speed	+ 3 %	+ 5 %
Nr. of vehicular detections	- 17 %	- 15 %
Nr. of congestion records	- 0.4 %	- 1.7 %
Nr. of speeding records	- 1.2 %	- 2.2 %
PM_{10} emissions	- 13 %	- 13 %

NO_X emissions	- 13 %	- 13 %
CO_2 emissions	- 14 %	- 14 %

Table 21: Summary of the combined impact associated to the eco-friendly policies EP_1-EP_2.

As summarized in Table 21, the introduction of this measure has further contributed to amplify the benefits obtained through the eco-friendly policy EP_1. No significant improvements have been associated yet to this policy (**improvements are in the order of -1 / -2% emissions**) since the test has covered only one traffic light with small impact on the traffic on Druso Street, but the expectation based on these preliminary results is that a 5-10% improvement can be further obtained when these policy will be applied to the traffic lights of Druso Street as well. It is important to underline how the highest improvements, as expected, have been observed during bad weather conditions, as a demonstration that the new policies have their highest effect when the traffic load is high.

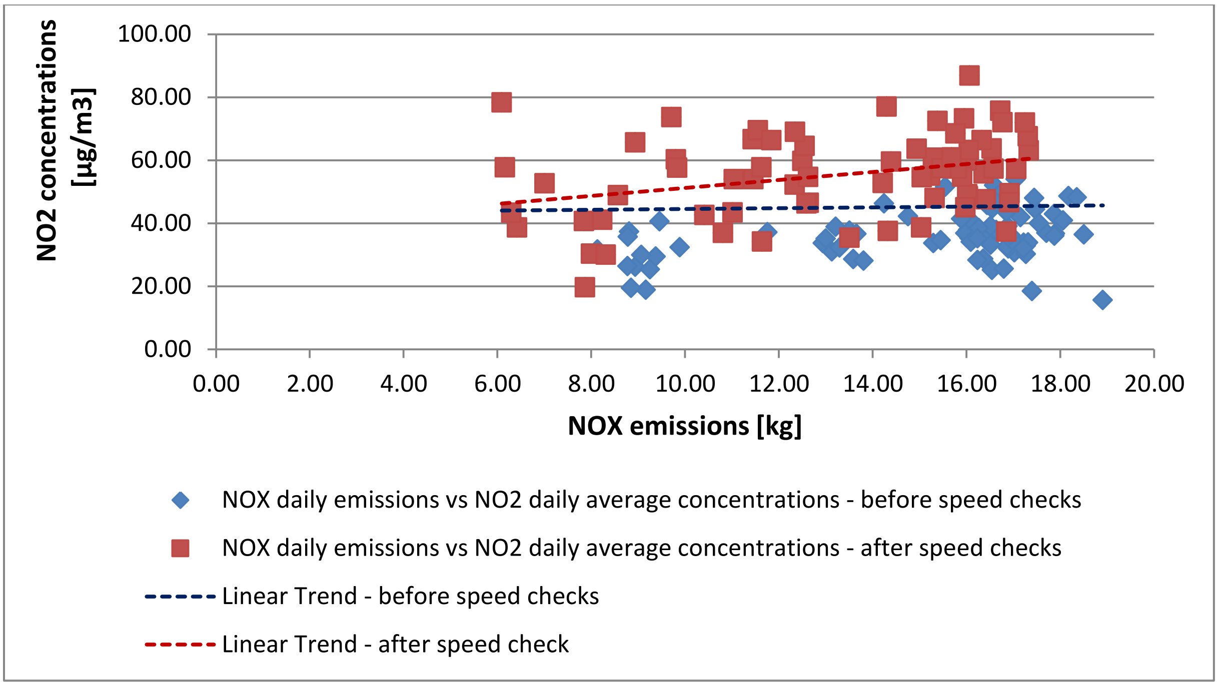

Figure 50: Eco-friendly policies 1 and 2: correlation between emissions estimated on Druso Street and air pollution concentrations measured by the station BZ5 (Adriano Square).

As far as the impact on air pollution concentration is concerned, the plot suggest that the environmental impact of traffic is significantly lowering, but without any clear effects on air pollution concentrations yet. For better comparisons, data related to the same periods of the year should be taken in consideration. Such more precise analysis will be possible from 2015 on.

The eco-friendly traffic policies EP_1 (speed enforcement detectors) combined with EP_2 (traffic lights cycles) have produced in the short term period the following impacts: (i) reduction of vehicular travel times of up to 5%; and (ii) reduction of emissions in the order of 10-12%. No immediate effects on the concentration levels of air pollution have been observed, as stated in the conclusions for EP_1 applied singularly.

3.3 Eco-policy 2: advanced end-users applications

In February 2015, the Municipality of Bolzano officially launched the end-users applications (BZTraffic, BZBus together with BZParking), presented in P.4.1.5 [7].

The launch was organized through a press conference in the City Council at the presence of the Mobility Assessor and other institutional and political authorities. The press conference took place on February 13th 2015, and the new availability of these advanced services has been widely promoted by the local media actors. For more information about this public launch, please refer to the Dissemination Final Report [8].

Figure 51: The press conference with the public launch of the end-users applications.

As summarized in Table 22, the introduction of this additional policy has not produced any additional benefit. The reduction of the environmental gain observed through policies EP_1 and EP_2 has been reduced of about the half. This is however likely to be related to the fact that the effect of speed detectors is not as strong as in the first months after their introduction. Local drivers do not feel any more (or at least not in the same way) the situation of being continuously controlled on these routes, and are starting to have the driving behaviour as before the introduction of this policy. On the other side, the end-users applications are a completely new instrument for local travellers, which will take some time to give evidence of their effects. Moreover, the availability of these new services must be furthermore promoted to citizens and tourists through large-scale promotion activities, which are going to take place as indicated in the After-LIFE dissemination plan [9].

Key Performance Indicators	Druso Street (direction city centre)	During bad weather days only
Average speed	+ 3 %	+ 5 %
Nr. of vehicular detections	- 12 %	- 9 %
Nr. of congestion records	- 0.2 %	- 0.6 %
Nr. of speeding records	- 1.2 %	- 2.8 %
PM_{10} emissions	- 7 %	- 11 %
NO_X emissions	- 7 %	- 11 %
CO_2 emissions	- 8 %	- 13 %

Table 22: Summary of the combined impact associated to the eco-friendly policies EP_1-EP_2-EP_3.

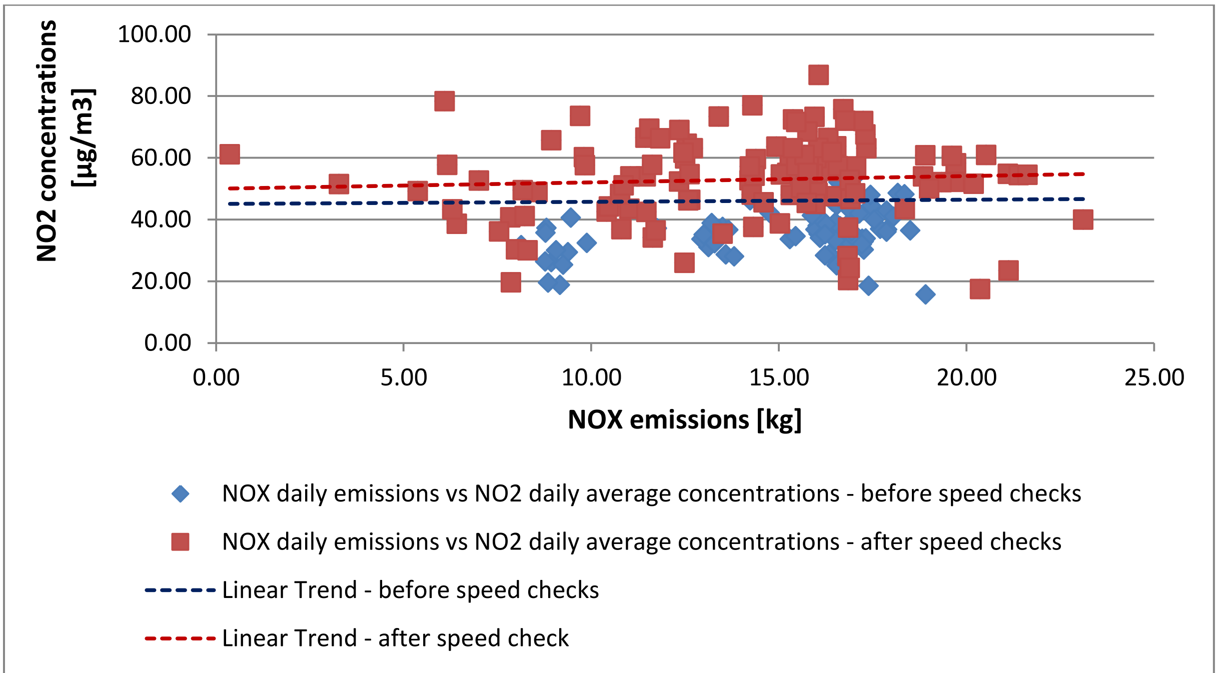

Figure 52: Eco-friendly policies 1 – 2 - 3: correlation between emissions estimated on Druso Street and air pollution concentrations measured by the station BZ5 (Adriano Square).

The eco-friendly traffic policies EP_1 (speed enforcement detectors) combined with EP_2 (traffic lights cycles) and EP_3 (end-users applications) have produced the following impacts: (i) reduction of vehicular travel times of up to 5%; and (ii) reduction of emissions in the order of 7-8%. No immediate effects on the concentration levels of air pollution have been observed, as stated in the conclusions for EP_1 applied singularly. It is important to underline that the contribution of EP_1 is significantly lowering after some months of the installation of the speed detectors, whereas the contribution of EP_2 and EP_3 is going to significantly increase once they will be fully deployed in the pilot area of the road network.

4 User needs validation assessment

In this final chapter, an evaluation of the results of the public questionnaire launched together with the end-users applications and an analysis of the level of fulfilment of the initial user needs is carried out.

4.1 Questionnaire results

In order to directly collect the feedback from the users concerning their impression in the usage and added value of the end-users applications, an online questionnaire was prepared and launched. The questionnaire, available both in Italian and German language, is accessible from the main pages of all end-users applications as well as from the home page of the project website (Figure 53). The full list of questions included in the questionnaire is presented in Annex 1 of this deliverable.

Figure 53: The link to the public questionnaire on the home page of the website.

In the following months after the launch, **84 questionnaires** were compiled (66 in Italian language and only 18 in German language). The details of the surveyed population is summarized in the following tables.

Most of the respondents live in Bolzano (65%) and are males (60%), but there is a significant share from the whole South Tyrolean region (the majority of the people who answered in German language). The age of the people is mainly 21 – 60 years (more than 80%). More than 70% of users have revealed to own a car.

Users' profile information	Indicator	TOTAL (nr.)	TOTAL (%)	Italian (nr.)	Italian (%)	German (nr.)	German (%)
Provenience	City of Bolzano	55	65,5%	49	58,3%	6	7,1%
	Province of Bolzano	26	31,0%	15	17,9%	11	13,1%
	Outside Trentino Alto Adige	2	3,6%	2	2,4%	1	1,2%

Table 23: Local travelers questionnaire – provenience of surveyed population.

Users' profile information	Indicator	TOT AL (nr.)	TOTAL (%)	Italian (nr.)	Italian (%)	German (nr.)	German (%)
Gender	Males	51	60,7%	38	45,2%	13	15,5%
	Females	33	39,3%	28	33,3%	5	6,0%
Age	< 20 [years]	3	3,6%	2	2,4%	1	1,2%
	[21-40] [years]	32	38,1%	20	23,8%	12	14,3%
	[41-60] [years]	37	44,0%	32	38,1%	5	6,0%
	> 60 [years]	12	14,3%	12	14.3%	0	0,0%

Table 24: Local travelers questionnaire - gender and age of surveyed population.

Users' profile information	Indicator	TOTAL (nr.)	TOTAL (%)	Italian (nr.)	Italian (%)	German (nr.)	German (%)
Car Ownership	Car owned	61	72,6%	46	54,8%	15	17,9%
	Car not owned	23	27,4%	20	23,8%	3	3,6%

Table 25: Local travelers questionnaire – detail about car ownership.

The first question is related to the **usefulness of real-time information**. Results can be summarized as follows, with more details reported in the following plots.

- **real-time parking information**: considered "much" or "very much" useful by 45% of respondents;
- **real-time public transport information:** considered "much" or "very much" useful by more than 80% of respondents;
- **real-time traffic information**: considered "much" or "very much" useful by about 60% of respondents.

As expected the majority of the preferences has been taken by the app BZBus, since most of the respondents are local citizens used to move in a sustainable way in the city.

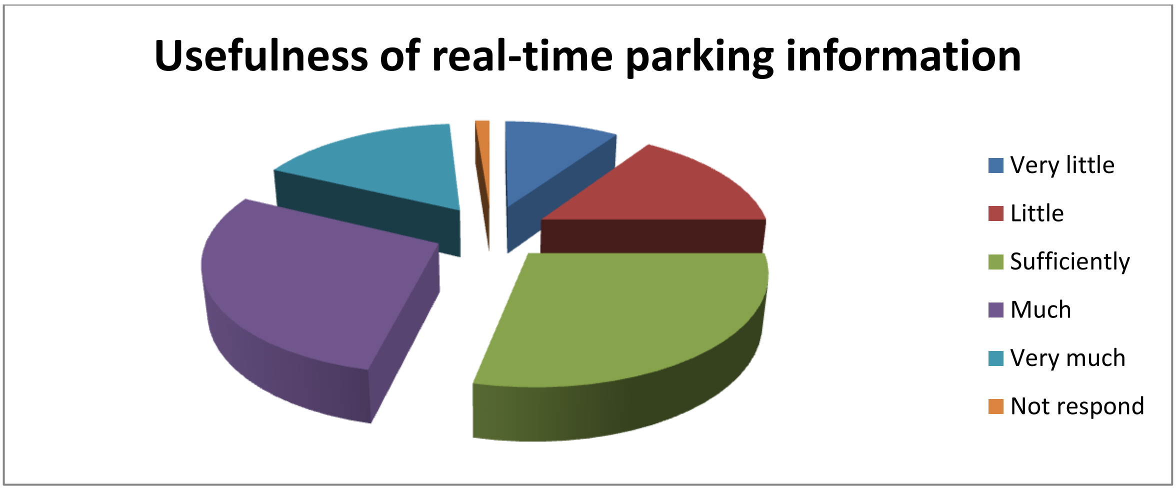

Figure 54: The perceived usefulness of real-time parking information.

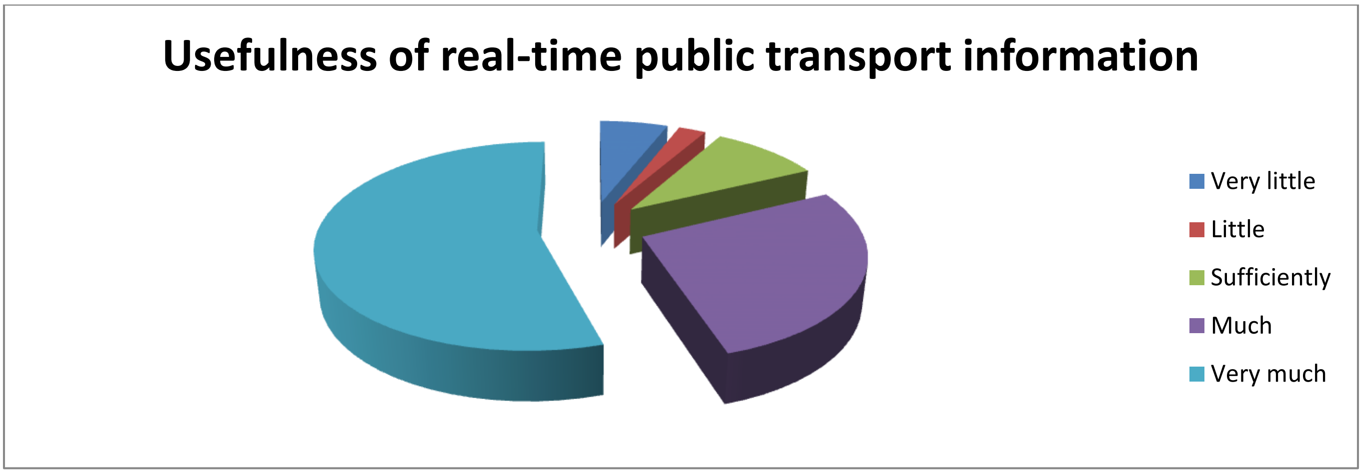

Figure 55: The perceived usefulness of real-time public transport information.

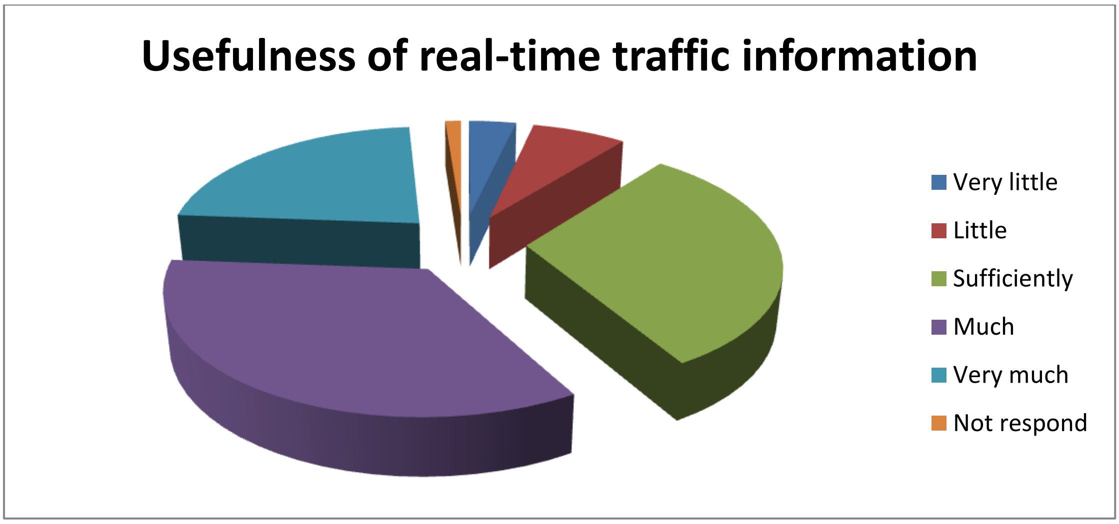

Figure 56: The perceived usefulness of real-time traffic information.

Similar feedbacks have been obtained as far the perceived usefulness of the three apps is concerned.

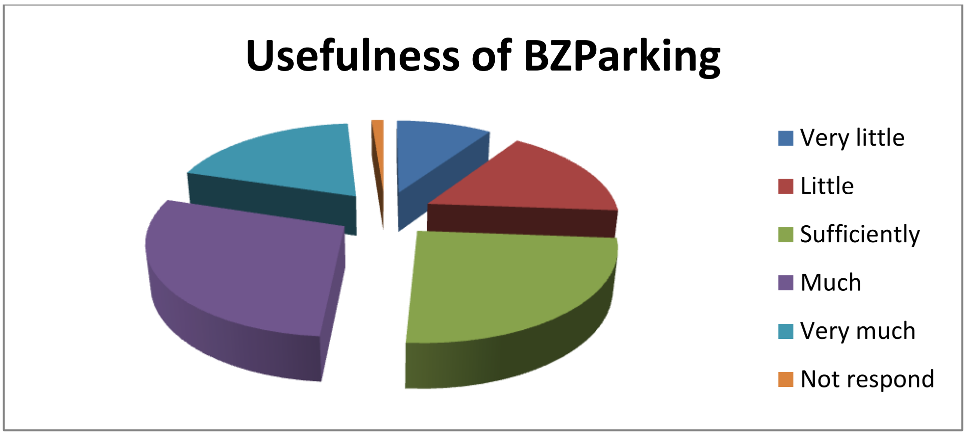

Figure 57: The perceived usefulness of application "BZParking".

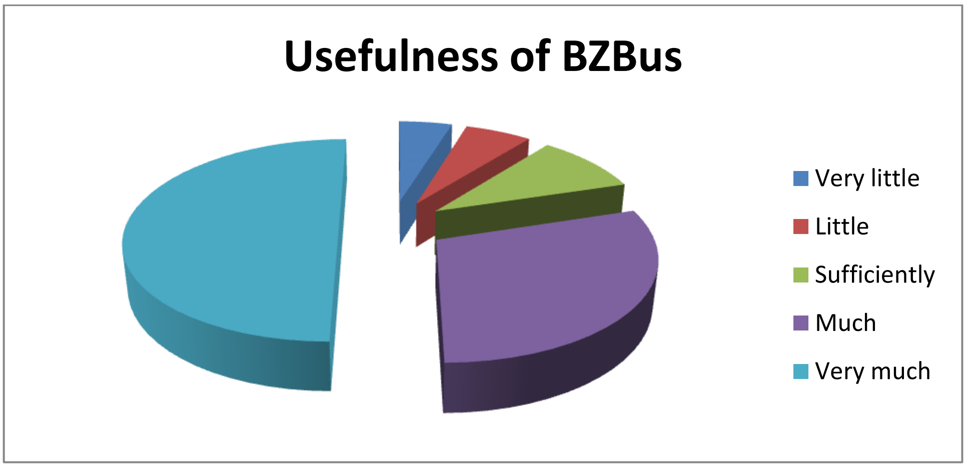

Figure 58: The perceived usefulness of application "BZBus".

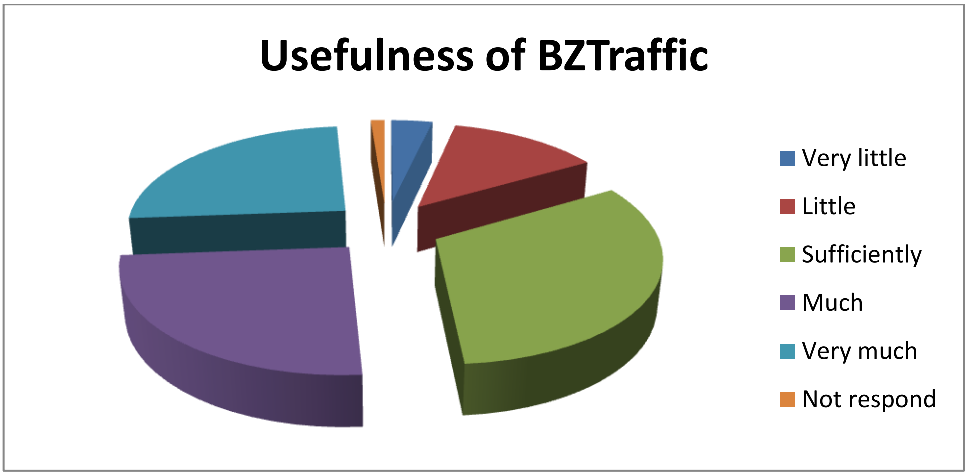

Figure 59: The perceived usefulness of application "BZTraffic".

The second question is related to the **perceived impacts** that the end-users applications will have **on the improvement of the mobility system** of the urban area of Bolzano. Results can be summarized as follows, with more details reported in the following plots.

- **improvement of travel comfort**: about 70% consider likely or very likely this impact;
- **reduction of air pollution levels**: respondents are not fully convinced that this policy will have a certain impact on the improvement of the environmental situation in Bolzano;
- **better management of parking areas and increase of modal share of public transportation and bicycles**: about 60% consider likely or very likely this impact;
- **reduction of traffic levels and congestions**: only 30% of respondents are convinced that the applications will improve the traffic conditions in the city;
- **reduction of road accidents**: respondents are very little convinced that this policy will produce road safety improvements.

These feedbacks reveal the necessity / opportunity to share more and more the impacts generated by the policies that will be introduced on top of the INTEGREEN system, even from an environmental point of view. This is important in order to create better informed travelers, changing preconceptions which are not fully correct.

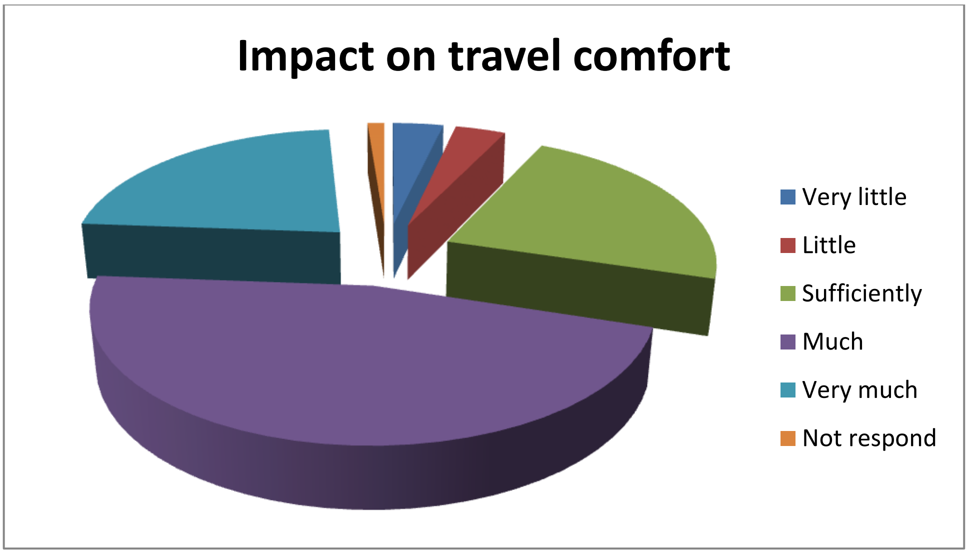

Figure 60: The expected impact of advanced mobility services in terms of travel comfort increase.

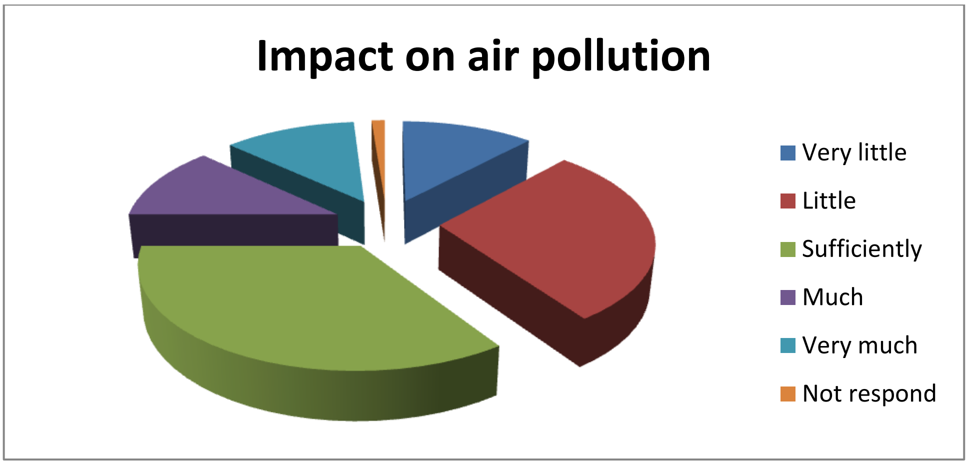

Figure 61: The expected impact of advanced mobility services in terms of air pollution situation improvement.

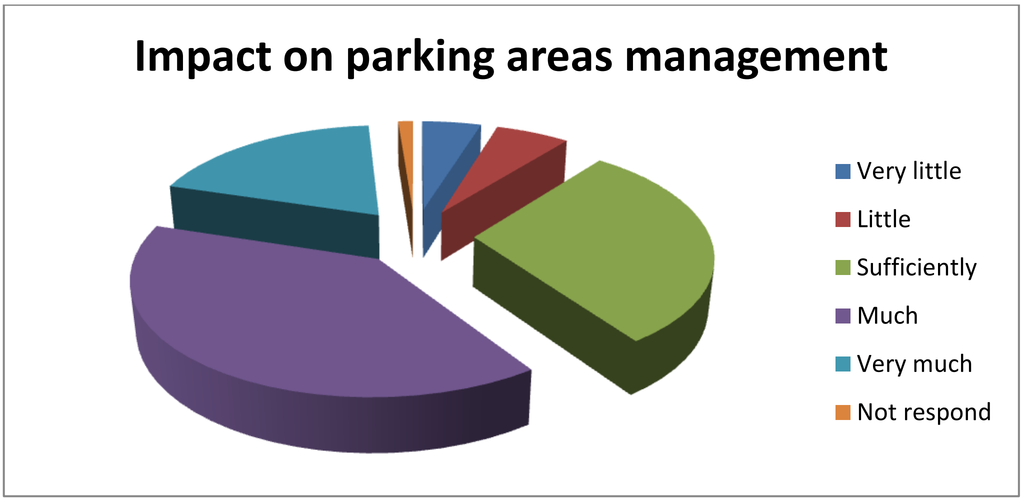

Figure 62: The expected impact of advanced mobility services in terms of parking areas management.

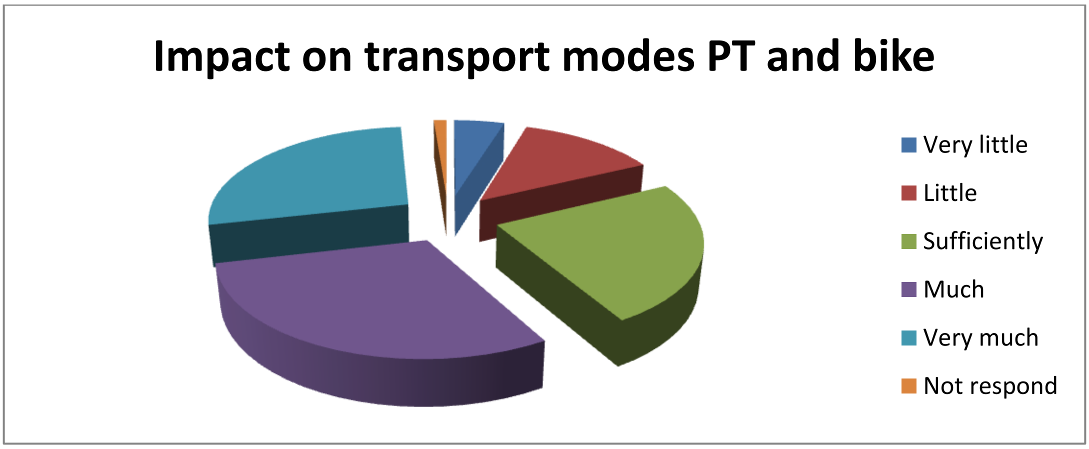

Figure 63: The expected impact of advanced mobility services in terms of improvement of the modal share of public transportation and bike.

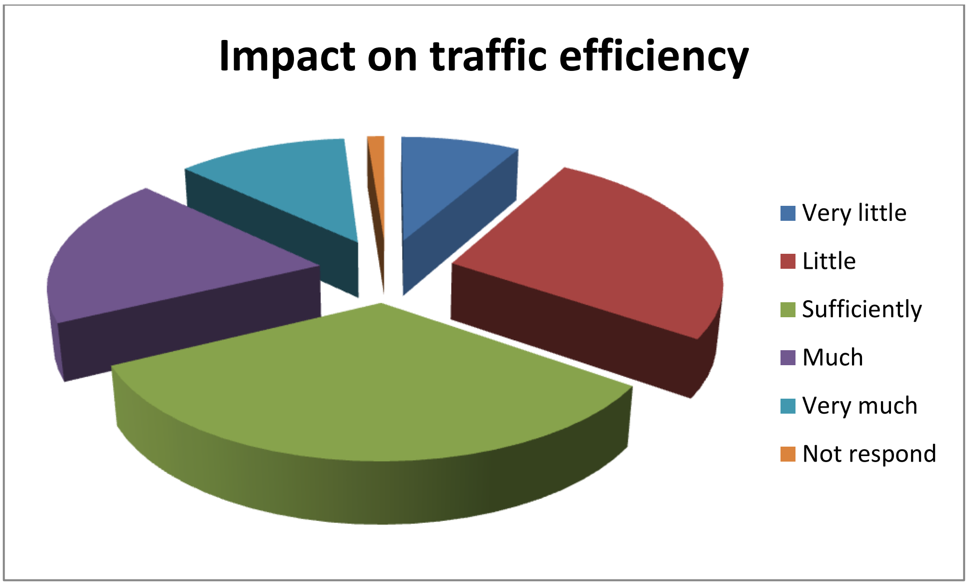

Figure 64: The expected impact of advanced mobility services in terms of reduction of traffic levels and congestions.

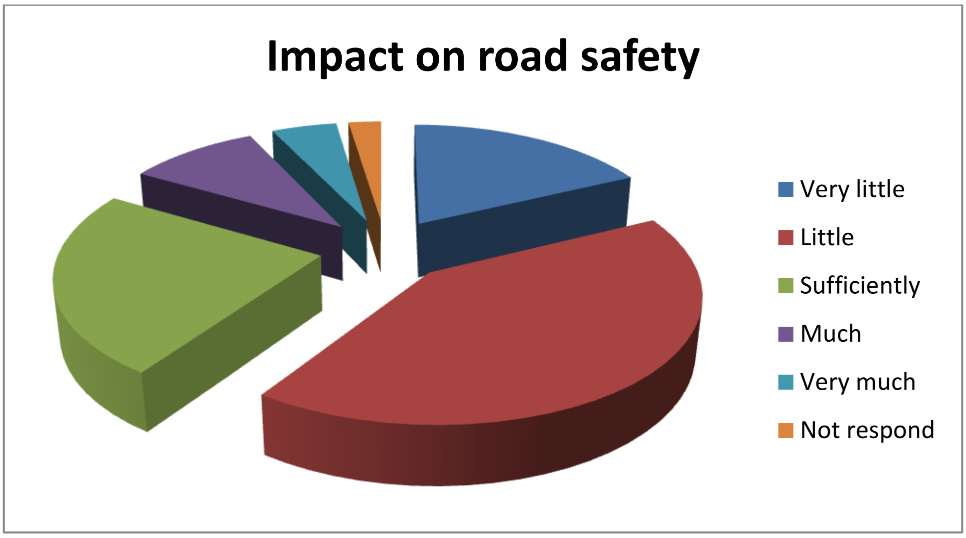

Figure 65: The expected impact of advanced mobility services in terms of reduction of accidents.

The third question is related to the **evaluation on how each respondent will the new mobility services**. Results are quite interesting, since they reveal that **most of the users will evaluate the applications only "when they need it"**, e.g. when traffic levels are higher because of bad weather. An increased usage is expected for **BZBus**, since it can give an added value to travelers every time they take a bus. This is indirectly a confirmation that the perceived quality of traffic conditions in the city is on average very good, since one can efficiently move by car through the city mainly on top of the perceived utility that each user develops every day in the road of the city.

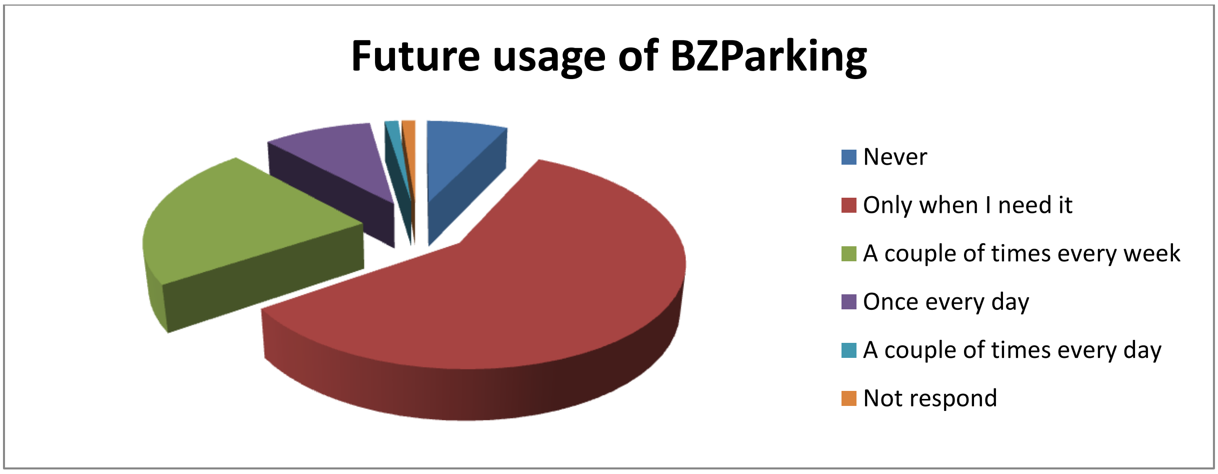

Figure 66: The expected usage of BZParking application.

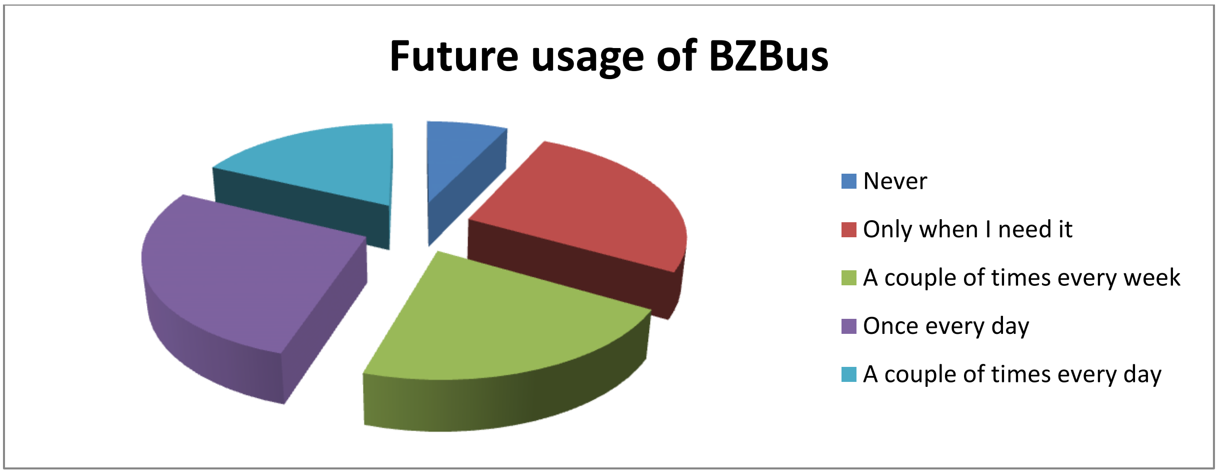

Figure 67: The expected usage of BZBus application.

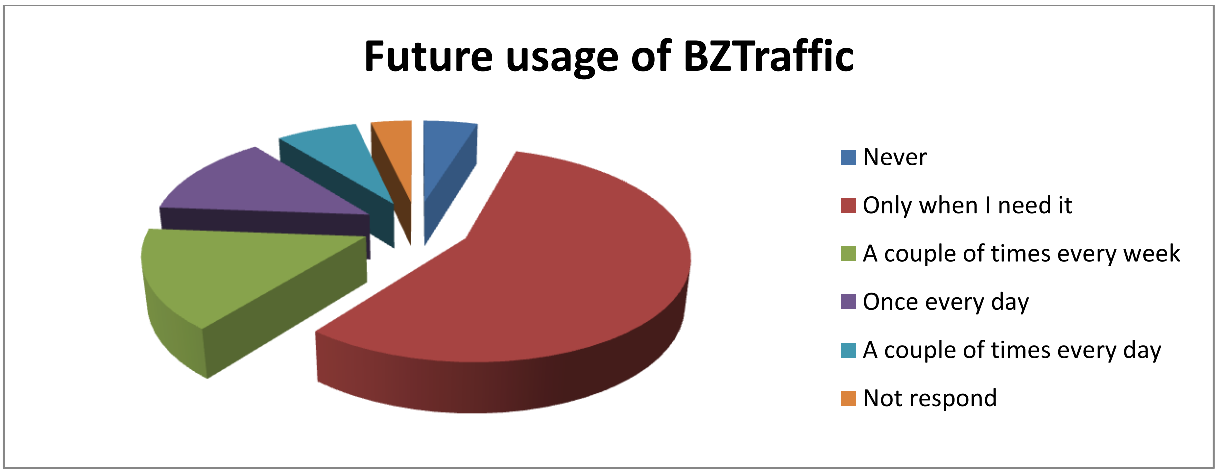

Figure 68: The expected usage of BZTraffic application.

The fourth and last question is related to the **evaluation of the usability of the new mobility services**. Users have revealed that the usability of the services is already good, but with further potential improvement, in particular as far as the BZTraffic application is concerned.

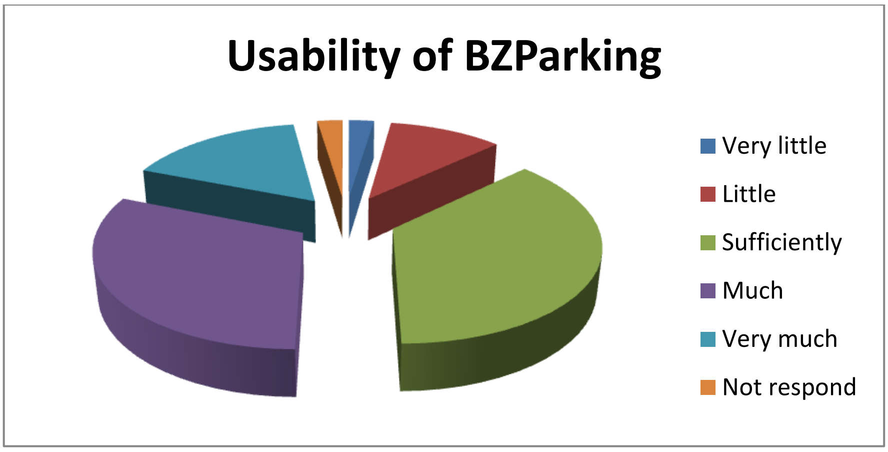

Figure 69: The perceived usability of BZParking.

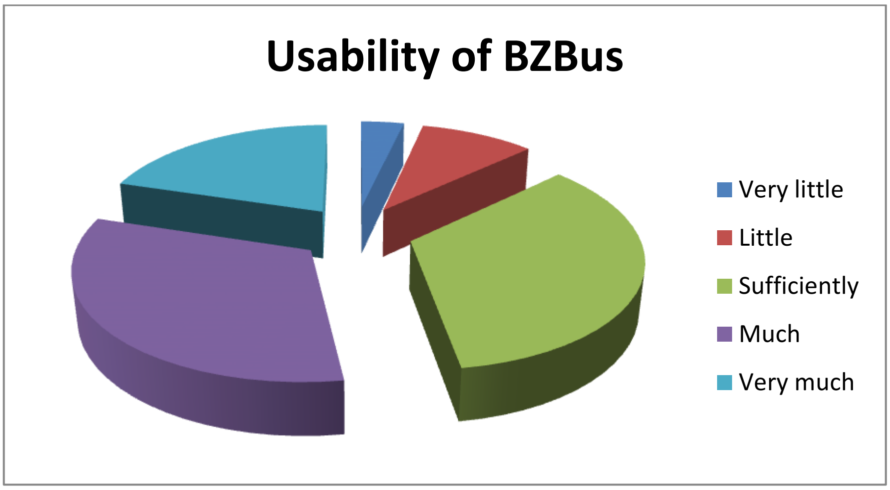

Figure 70: The perceived usability of BZBus.

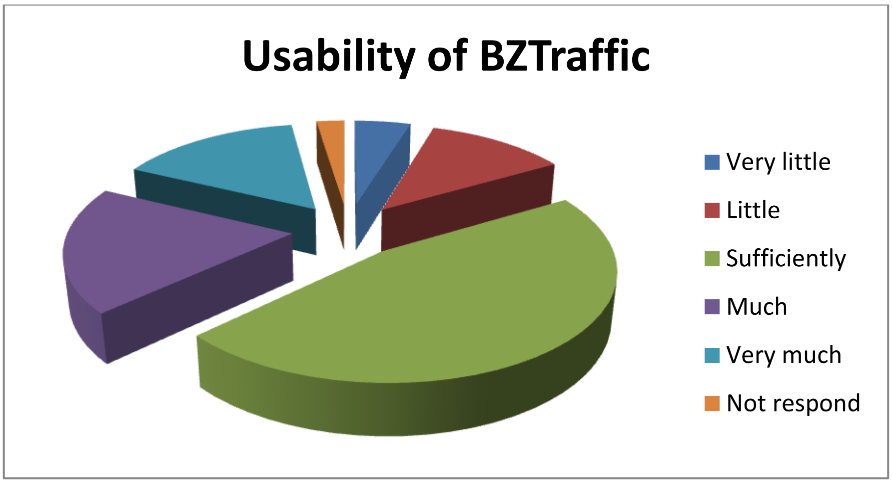

Figure 71: The perceived usability of BZTraffic.

The results of the comments and feedback received by the users after a first period of usage of the end-users applications can be summarized as follows:

Users have positively commented the launch of the end-users applications, despite they have reached a low penetration within the local traveling population (every week the number of accesses to the applications is in the order of 300-500 units). The best comments are related to the application BZBus, which will further promote the use of public transportation mode in the city. Detailed data on the modal split are not available, but qualitative indications provided by the urban public transport operator confirm an increasing trend in the usage of their buses. The usefulness of the applications is in general perceived as high, in particular for BZBus (80%) and BZTraffic (60%), while BZParking as expected is of less utility for local citizens, but could have much usefulness is used by occasional travellers such as tourists. Comments received on the expected ways of usage of the applications reveal that citizens will consider this real-time information mostly when they need it, i.e. when there is a certain disruption with respect the normal traffic and mobility conditions. This reveals that probably end-users (in particular, local citizens) may not want to pay for such information, and that applications could be provide an increased added value if they could automatically notify them only the appearance of certain troubling conditions.

4.2 User needs satisfaction level analysis

As a final step of this analysis of the results of the testing and validation activities, a comparison between initial user needs, as indicated in the deliverable D.2.1.1 [4], and their actual level of fulfillment is carried out. The results of this final assessment is presented in Table 26.

Users/stakeholder and level of fulfillment	Initial Needs	
Local travelers (LT). The end-users applications have improved the travel decision-making process. The level of acceptance of new policies is in general high, expect for the speed detectors, for which the reaction has been negative.	LT_1	The traveler shall be in the condition, depending on his/her particular mobility requirements, to choose the best urban travel option in both space and time dimension which optimizes the compromise between travel time and cost depending on real-time conditions.
	LT_2	The traveler should not be forced or limited in the travel decisions, but only have the minimum set of information that can efficiently support this decision-making process.
	LT_3	The INTEGREEN system should provide relevant recommendation according to the individual needs, both in the pre-trip and in the en-route phases, allowing dynamic modifications of the travel plan.
	LT_4	The system has to include additional information as well; for example, parking availability information can be a crucial information for deciding to take a car in the city. Air pollution levels can significantly influence trip decisions, in particular pollution hotspots can convince travelers to avoid travel choices which include these polluted areas.
	LT_5	Information received should be reliable and timely up-to-date, in order to maximize the efficiency of the travel decisions and thus the travelers' satisfaction.
	LT_6	The traveler desires that the air quality levels in the city are good, without any possible risk on his/her health.
	LT_7	The level of satisfaction of travelers is in general higher if the local public administration adopts proper soft and preventive traffic-related measures than hard and retroactive limitations for reducing the impact

		of traffic on the air quality. In this perspective, the city authorities should adopt policies based on incentives and benefits for intelligent and aware travelers, and penalize those who do not take care the system recommendations. In this way, it could be possible to foster a positive change in the travelling habits of the latter users.
	LT_8	The travelers accepts novel monitoring system which however demonstrate to guarantee their right to privacy.
Motorized vehicle drivers. The expectation of motorized vehicle drivers are fulfilled. The quality of the new services must be improved.	MVD_1	The motorized vehicle drivers desires to avoid congestions or in general most crowded urban roads, in order to minimize the time of their travels.
	MVD_2	The INTEGREEN system should provide relevant recommendation for intelligent routing and for determining the best time of the day in which a trip should be made.
	MVD_3	The chosen route is selected on the base of different parameters: traffic level, travel time, route comfort level, air pollution level, safety.
	MVD_4	En-route information like timers at traffic lights could be beneficial for crossing relevant urban intersections in an efficient way.
	MVD_5	When a relevant traffic event appears (e.g. accident at a crucial intersection), the driver should be aware of it in a very short time.
Passenger car and light truck drivers. The information of heavy vehicles has not been included yet, but will considered to improve the actual services. The management of high pollutant vehicles will be a primary objective of future project initiatives.	PC&LTD_1	Other relevant information that can significantly influence the choice of an urban trip is the amount of heavy vehicles (for example buses) present in a certain road section. Because of the limited road infrastructure, this has a significant impact not only on travel times (e.g.

		it is difficult to overtake a bus) but also on safety.
Passenger collective means and heavy trucks drivers. The information about traffic conditions in the industrial area gives an added value for these drivers.	PCM&HTD_1	Every delay in the passengers or goods transport service has an operational cost in terms of fuel, salary, maintenance, and has an impact on clients' satisfaction. Transport service efficiency should thus be maximized en-route through proper and timely-relevant urban travel recommendations, but without adding workload and causing distraction.
Local transport planners. A new awareness and willing to start new eco-driving initiatives has been created.	LTP_1	LT_3 need is particular crucial for local transport planner, since a bad pre-trip decision can have significant negative consequences in terms of quality of service.
	LTP_2	Minimization of environmental footprint is becoming more and more a parameter of choice for the customer: for this reason, it is important to have means to demonstrate that the offered service is likely to minimize air pollutant emissions.
	LTP_3	In this sense, a key aspect which should be taken more and more in consideration is the optimization of drivers' style, which can have significant impacts on whole fuel consumption and thus on fuel costs and air pollutant emissions.
Road operators. The fulfillment of initial needs has not been completed yet, since now these users are in the condition to start introduce the indicated eco-friendly traffic policies.	RO_1	Urban traffic shall be managed in a way that the compromise between traffic throughput, quality of life and safety (in particular of vulnerable road users) is maximized over all road network. Limited road capacity has to be maximized in time and space, and road users should have a high quality travel service in the city.
	RO_2	The traffic management system should be able to adapt traffic

		strategies easily and dynamically.
	RO_3	Sensitive areas (for example residential districts) should be managed properly, in order to minimize the effect of traffic on the quality of life. In this perspective, air pollution levels are an important parameter to take under control.
	RO_4	The same categories of travelers should have in general the same treatment and levels of service; however, various policies should be applied depending on the type of vehicle and travel choices.
	RO_5	Connection with the city access gates is particularly important for a city like Bolzano; for this reason, it is fundamental to establish a strict cooperation between all local road operators.
	RO_6	Prevent traffic events is much more effective than reacting to them; for this reason, systems which can support preventing strategies are desirable.
Traffic officers. These needs have been fulfilled. The challenge is now how to make best use of data available (in particular, related to historical use cases) in order to adapt dynamically the traffic management strategies.	TO_1	It is fundamental to have a clear and exhaustive up-to-date overview of traffic situation in the city.
	TO_2	The INTEGREEN system should allow to reduce the time which is needed to react to a traffic/environmental event, and possibly to enhance the ability to prevent such critical situations.
	TO_3	It should be possible to have instruments for timely recommending road users about best travel options and informing about traffic events. Ancillary information such as parking availability and air pollution hotspots should be provided to the travelers in a user-friendly way.

	TO_4	The INTEGREEN system should not increase the complexity and the amount of time which is necessary for the daily traffic management operations. The overall cost/benefit should be clear.
Traffic engineers. These needs have been fulfilled. See comments for traffic officers above.	TE_1	Monitoring systems should collect data than can be used for ex-post evaluations.
	TE_2	Novel traffic control solutions should be found in order to increase the capacity of existing bottlenecks in the urban road infrastructure, or at least to minimize the impact of a traffic event appearing in correspondence to these points.
	TE_3	Intelligent strategies have to be considered in order to reduce the transit of people and goods within the residential districts of the city; in particular, proper countermeasures targeting heavy goods vehicles have to be addressed in order to increase safety and comfort in these areas, reduce pollutant emissions and thus increase the overall quality of life.
	TE_4	It is fundamental to prioritize sustainable mobility in the city, in particular bicycles, public transport and pedestrians, for example through dedicated lanes. Safety issues have to be properly taken into account during the design process of an urban intervention on the road.
Mobile probes drivers. User needs completely fulfilled.	MPD_1	The collection of mobile data from the traffic management centre should be as transparent as possible, and not further complicate the driving operations, neither contribute to increase driver's distraction.
	MPD_2	The en-route information received by the traffic management centre should be reliable, consistent and significantly impacting the original

		trip choice (if applies, e.g. car sharing) or the normal level service (e.g. public transport).
City Council of Bolzano. The ability for measuring the environmental impact of traffic strategies is now available. In order to properly fulfill all these requirements, ambitious eco-friendly policies must be introduced on larger scale and properly calibrated as a function of the measured impacts.	CCB_1	Urban road traffic management should be able to minimize the number of accidents.
	CCB_2	Urban road traffic management should be able to minimize the overall fuel consumption and emissions.
	CCB_3	The right to mobility has to be guaranteed to every category of local travelers, with particular attention to those with reduced mobility ability (e.g. elderly people, people with motor impairments, etc.).
	CCB_4	The quality and safety of citizens' life takes precedence in the residential areas over traffic flows efficiency; traffic management policies have to consider this factor in the definition of access rules for different type of vehicles. The general objective is to maximize satisfaction among local citizens about traffic conditions in the city.
	CCB_5	Sustainable and efficient transport means, alternative to individual car, have to be favored for short trips within the city. Avoidable and parasitic car travels (for example, looking for an empty parking slot) should be minimized as possible.
	CCB_6	Accessibility to the city should be guaranteed independently from users' demand and weather conditions; however, critical events should be prevented as much as possible, and arrivals/departures should be organized wisely, in order to maximize the positive image of the city and the economical return produced by tourism.
	CCB_7	The maximum compromise between efficiency in traffic management

		operations and related costs should be obtained; a clear cost/benefit assessment produced in particular by INTEGREEN system should be demonstrated.
Autonomous Province of Bolzano. The cooperation with the regional operator can now start, in order to expand the impact of the INTEGREEN system not only in the urban area of Bolzano.	APB_1	It is necessary a strict and continuous cooperation between municipal and regional traffic management centres, in order to optimize and maximize the available monitoring capabilities and the integration of traffic regulations and countermeasures.
	APB_2	Multi-modal approaches based on integrated public transport services should be stimulated as much as possible through proper incentives as well as reliable and up-to-date information that allow users to efficiently organize their local travels.
Service and technology providers. User needs completely fulfilled.	S&TP_1	Traffic and mobility-related information collected by the traffic management centre should be reliable and timely-relevant. This information shall be usable by third parties in order to offer new telematic services and applications for the local travelers.
Environment protection organizations. The effort towards more eco-friendly approaches is recognized, but new initiatives must now be promoted in order to take up the relevant results of this project initiative.	EPO_1	Environment protection, in particular in terms of air quality, has to be more and more a must in the area of interest of the project for local policy makers. Emissions caused by traffic should be reduced as much as possible through targeted and integrated sustainable traffic and mobility management strategies. Modal split towards sustainable transport means and intelligent approaches for a more efficient use of existing urban road infrastructure should be introduced.
	EPO_2	Drivers themselves can have a significant role in the overall emissions caused by traffic: an increased awareness and responsibility assignment of their carbon footprint is therefore necessary, For creating a similar environment, is however recommended to introduce

		an incentive system aiming at rewarding travelers who decide to adopt sustainable travel options.
Consumers' associations. These needs have been fulfilled.	CA_1	The right of mobility shall not be in any case limited or denied.
	CA_2	It is important to educate people, and to provide them the right information and instruments to plan urban trips in an aware way. The diffusion of false convictions and thus of bad and inefficient behaviors shall be avoided as much as possible. People have to be able to find reliable information sources (e.g. on the web) with practical and few tips for eco-travelling and driving.
Driving schools/trainers. These needs have been fulfilled.	DS_1	Eco-driving recommendations shall be introduced more and more in the driving education courses programs, but without significantly impacting other important aspects of road safety education. Theoretical lessons as well as practical eco-driving guides should be considered. Eco-driving should become one of the main pillars of driving education.
Passenger fleet owners. These needs have been fulfilled. Specific cost/ benefit analysis have not carried out yet, but the expected added values have been confirmed.	PFO_1	The INTEGREEN mobile system should be of easy integration in the fleet monitoring system and not put into question the performance of the existing Automatic Vehicle Monitoring (AVM) applications.
	PFO_2	The data collection functionalities as well as the novel info-mobility services should be as transparent as possible, and not increase the activities of the drivers neither negatively impact their distraction.
	PFO_3	The overall cost/benefit of the system should be evidenced.

Table 26: Qualitative evaluation of the initial user needs.

Conclusions

This report has presented the most relevant results obtained within the Test Bed phase of the INTEGREEN project, according to the planning and the indications give in the plan presented in D.5.2.1.

The first part of the analysis has covered the 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;
- **pilot use case 4**: traffic operators evaluating real-time information.

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 analyzing 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 27.

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 27: Pilot use cases analysis results' summary.

The second part of the analysis has evaluation of the impacts associated to different eco-friendly traffic policies which have been initially deployed on certain test areas of the city. Results can be summarized as follows:

- **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, 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%**. 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.

- **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. Together with the speed enforcement system, this policy has demonstrated to **improve vehicular travel times of 5% and emissions in the order of 10-12%**.

- **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.

The third and last part of the analysis has been completed by an assessment of the level of fulfilment of the user needs identified at the project start, which has been carried by directly evaluating the feedback received by the traffic operators and through a user questionnaire. This survey has been launched together with the end-users application services and compiled by about 100 people. The initial level of acceptance to the new services is certainly good, with the best comments received for the application BZBus. Travelers 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.

Bibliography

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

[2] INTEGREEN consortium, "D.5.1.1: On-board modules and Supervisor Centre test results," 2015.

[3] INTEGREEN consortium, "D.5.3.1: Quantitative impact of eco-friendly traffic policies," 2015.

[4] INTEGREEN consortium, "D.2.1.1 "Supervisor Centre components requirements"," 2012.

[5] INTEGREEN consortium, "P.4.1.1 "Data management unit prototype"," 2014.

[6] INTEGREEN consortium, "P.4.3.1 "INTEGREEN system demonstrator"," 2015.

[7] INTEGREEN consortium, "P.4.1.5 "Public web interface prototype"," 2014.

[8] INTEGREEN consortium, "Dissemination Final Report," 2015.

[9] INTEGREEN consortium, "D.10.1 After-LIFE communication plan," 2015.

Annex 1: User questionnaire

Nell'ambito del progetto INTEGREEN, il Comune di Bolzano, in collaborazione con il TIS innovation park e l'Austrian Institute of Technology, hanno lanciato alcuni applicativi sperimentali per migliorare l'efficienza degli spostamenti all'interno della città di Bolzano. In particolare, l'applicazione BZParking (http://parking.bz.it) fornisce informazioni sullo stato di occupazione dei parcheggi, l'applicazione BZBus (http://bus.bz.it) permette di conoscere lo stato corrente del servizio di trasporto pubblico locale offerto dalla SASA e l'applicazione BZTraffic (http://traffic.bz.it) indica quali sono le condizioni di traffico in città.

Per continuare a migliorare questi primi applicativi e renderli via via sempre più funzionali rispetto alle esigenze concrete di spostamento degli utenti, vi chiediamo di rispondere a questo brevissimo questionario, che si compila in meno di due minuti.

Grazie per il vostro prezioso contributo, le vostre esperienze ed opinioni sono molto importanti per noi!

Il progetto INTEGREEN

Approfondire la conoscenza dei fenomeni di traffico e delle situazioni di inquinamento ad essi correlati: questo l'obiettivo del progetto INTEGREEN, che mira a creare i presupposti per l'introduzione e la sperimentazione di politiche di gestione del traffico e della mobilità in grado di tutelare maggiormente l'ambiente cittadino.

Non solo i decisori locali hanno un ruolo importante in questo scenario: i viaggiatori locali, grazie alle loro scelte di spostamento, possono fornire un contributo decisivo per il raggiungimento di questo target. In quest'ottica, però è fondamentale mettere a loro disposizione una serie di strumenti informativi che li possa permettere di decidere, in un certo istante, qual è la soluzione migliore per muoversi in città.

Per maggiori approfondimenti in merito alle iniziative promosse dal progetto INTEGREEN, visitate il sito http://www.integreen-life.bz.it

Il progetto INTEGREEN è un progetto LIFE+ coordinato dal Comune di Bolzano, in collaborazione con il TIS innovation park e l'Austrian Institute of Technology (AIT).

Profilo

Sesso

□ Uomo

□ Donna

Età

□ < 20 anni □ 21-40 anni □ 41-60 anni □ > 60 anni

Tipologia di utente

Lei risiede:

□ a Bolzano

□ In Provincia di Bolzano

□ Fuori dal Trentino Alto Adige

Uso di mezzi privati propri

Guida abitualmente un mezzo motorizzato di Sua proprietà?:

□ Sì

□ No

Applicazioni sperimentali

1. **Utilità delle informazioni in tempo reale**
   In generale, quanto può essere utile per Lei conoscere in tempo reale:

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
la posizione dei posti di parcheggio liberi					

il tempo esatto di arrivo degli autobus alle fermate					
le condizioni di traffico sulle vie principali della città					

2. **Utilità delle applicazioni sperimentali**
   Dopo aver cominciato ad usare le applicazioni sperimentali, quanto ritiene che possano essere utili per migliorare l'organizzazione dei Suoi spostamenti in città?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
BZParking					
BZBus					
BZTraffic					

3. **Ripercussioni sulla mobilità a Bolzano**
   Quali conseguenze potrà avere secondo Lei la diffusione delle applicazioni?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
Maggiore comfort per gli spostamenti delle persone					

Riduzione dell'inquinamento					
Migliore gestione dei parcheggi					
Maggiore utilizzo dei mezzi pubblici e delle bici					
Riduzione dei livelli di traffico e delle code					
Riduzione degli incidenti stradali					

4. Utilizzo previsto delle applicazioni sperimentali

In che misura ritiene che userà le applicazioni sperimentali?

	Mai, non ne vedo la necessità	**Di rado, solo quando ne avrò veramente bisogno**	**Ogni tanto, circa un paio di volte alla settimana**	**Spesso, circa una volta al giorno**	**Sempre, più di una volta al giorno**
BZParking					
BZBus					
BZTraffic					

5. **Utilizzo dell'applicazione BZParking**
Secondo Lei quanto verrà usata quest'applicazione da queste tipologie di utente?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
Turisti					
Studenti					
Pendolari					
Anziani					
Commercianti					

6. **Utilizzo dell'applicazione BZBus**
Secondo Lei quanto verrà usata quest'applicazione da queste tipologie di utente?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
Turisti					
Studenti					
Pendolari					

Anziani					
Commercianti					

7. **Utilizzo dell'applicazione BZTraffic**
   Secondo Lei quanto verrà usata quest'applicazione da queste tipologie di utente?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
Turisti					
Studenti					
Pendolari					
Anziani					
Commercianti					

8. Usabilità delle applicazioni sperimentali

Quanto sono usabili secondo Lei le applicazioni sperimentali?

	Pochissimo	Poco	Abbastanza	Molto	Moltissimo
BZParking					
BZBus					
BZTraffic					

Commenti e suggerimenti vari:

____
____
____
____

Il progetto INTEGREEN è un progetto LIFE+ coordinato dal Comune di Bolzano, in collaborazione con il TIS innovation park e l'Austrian Institute of Technology (AIT).