SMARTSANTANDER

SMARTSANTANDER PROJECT

# INFSO-ICT-257992 SmartSantander

# D4.3

# Evaluation Report on Potentials of IoT for Enhancing City Services

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**Abstract:** Relying on the work carried out in T4.1 and T4.2, this document summarizes the perception of some city services which have adopted IoT technology. This perception is collected according to KPIs which have been used as a basis for making an ulterior analysis about the management, use and sustainability of the described services.

**Keyword list:** IoT, management, KPI, services, evaluation

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## Acronyms and Abbreviations

| | |
|---|---|
| CO | Carbon monoxide |
| CO2 | Carbon dioxide |
| FP7 | Seventh Framework Programme |
| GPS | Global Positioning System |
| iOS | iPhone Operating System |
| IoT | Internet of Things |
| IR | Internal Report |
| KPI | Key Performance Indicator |
| MEF | MyEcoFootprint |
| NFC | Near Field Communication |
| NO2 | Nitrogen dioxide |
| POI | Point Of Interest |
| RD | Real Decreto (Royal Decree) |
| QR | Quick Response Code |
| SMS | Short Message Service |
| WP | Work Package |
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# EXECUTIVE SUMMARY

The SmartSantander FP7 project aims at the deployment of a unique facility composed of Internet of Things (IoT) nodes in the city of Santander as well as in Belgrade, Guildford and Lübeck. The main objective of the project is the creation of an infrastructure, which allows experimentation on top of it whilst concurrently supporting service provision related to the different operational domains of the city.

The smart city paradigm covers many disciplines from both technological and societal perspectives, where citizens play a major role as the final recipients of the services supported by the associated infrastructure.

In *[WP4]* we assess the service umbrella of the SmartSantander initiative, where over the duration of 20 months (month 8 to 28) of the project, we have analysed, designed and deployed several use cases. They were selected and prioritised in consultation with the local authorities, regional government and according to user/citizen preferences. Such use cases were based not only in the Santander deployment but also the Belgrade and Guilford testbed facilities. The covered use cases were parking control, environmental monitoring, participatory sensing, augmented reality, irrigation, public transportation and smart metering, amongst others. In some of the use cases, we have developed prototype applications/services whilst complete services and applications have been produced for a number of use cases. These have been made available for download and use by the citizens.

Moreover, in task 4.3 *[T4.3]* we provide an evaluation of the developed services according to the citizens' perspective. Different methodologies like questionnaires, qualitative interviews, workshops and real life testing are used to evaluate the work carried out in [WP4] (introduced [*IR4.2*]*)*. In particular, this deliverable [*D4.3]* includes a report on potentials of IoT for enhancing city services where the final conclusions and results are going to be presented. This report summarizes the outcome of the pilot test and includes evaluation of the selected smart city service and its comparison with the baseline in *[D4.1],* from the citizen's perspective. Its goal is an assessment, evaluation and comparison of services using/not using IoT .

The basis for the approach was the following:

- KPIs defined in the task 4.1 [*T4.1*] and KPIs defined for new scenarios that were developed after task 4.1 [*T4.1*], that will be calculated during the evaluation process
- The different methodologies defined in [*IR4.2*]
- The evaluation plan defined in [*IR4.3*]

# 1. INTRODUCTION

The smart city paradigm embraces many subjects both technological and sociological. Citizens play a major role in this paradigm as the end recipients of the services supported by the associated infrastructure. Furthermore, in order to meet tangible requirements it is important to involve them in the evaluation of such services. This can be achieved by observing them making use of such services, as well as considering their personal opinion about them.

In this framework, *[WP4]* provides the service umbrella to the SmartSantander initiative by analyzing, designing and developing the services that are interpreted as a priority by the local authorities, regional government and users.

In particular, this deliverable addresses the existing services in the Santander landscape prior to the introduction of the IoT technology and how these services eventually have been improved by the deployment of the appropriate technology. In order to make an assessment, a set of key performance indicators have been identified taking into consideration the work carried out in *[D4.1]* as well as the recommendations of the reviewers. The aim is to rely on objective qualitative and quantitative parameters that allow us to explicitly determine, for example, how the time to find a parking place has been reduced, or how much water for irrigation in parks and gardens has been saved, or how municipality services response time has been decreased thanks to participatory sensing.

It is always a difficult decision to carry out the selection of the use cases and KPIs to evaluate the improvement of using IoT, particularly when the expectations of the citizens are higher than the technology's possibilities. Furthermore, it is not easy at all to conciliate the ways in which services are traditionally exploited with the introduction of a new technology. The companies exploiting such services perceive that they lose part of the service control whilst the local authorities gain knowledge on its performance.

In this framework, it is the objective of this deliverable to show the advantages of using IoT for some services deployed in the framework of a medium size city. The main KPIs linked to those use cases are identified, as well as the improvements that IoT technology might bring to such use cases.

The goal of this task is to act as an external research partner willing to evaluate a smart city service on SmartSantander experimental research facility from the citizen's viewpoint. During the deployment and throughout the evaluation of services in *[T4.3],* information about the correctness, effectiveness and performance of the provided tools and procedures shall be captured and compiled in an internal report [*IR4.2]* that will be fed back to relevant work packages. The outcome of the field trials is assessed critically, evaluated and compared with the baseline produced in ***[***T4.1***].*** This result is summarized in this deliverable report [*D4.3*]. This document reports on services developed and deployed in WP4 for the period from M8 to M28 in Task 4.2 [*T4.2*].

This report is structured as follows:

- Section 2 enumerates the scenarios and services selected as a base for the assessment.

- Section 3 describes the conclusions of the analysis and comparison of services before and after using IoT.
- Section 4 includes the references.
- Next, Section 5 shows the appendix.

# 2. SELECTED SCENARIOS AND SERVICES

## 2.1. Traffic Scenario

Taking into account the traffic KPIs described in *D4.1 – Baseline Report with KPIs of Selected City Services [D4.1]*, we have selected some of the most appropriate among them in order to verify the improvement of the quality of service. In the case of Traffic Scenario one use case has been selected: Limited Parking Management.

In the following subsections there are the KPIs selected to verify the proper functioning of the services, using IoT technologies in comparison to the same service using traditional methods. Alongside the KPIs there are suitable tools or techniques that could be used to collect the data for their assessment. Those tools and techniques are described in the *IR 4.2 – Initial Usability Experience [IR4.2]*.

### 2.1.1. Limited Parking Management

As was described in [*D4.1*] some of the expected improvements in this scenario consist in:

- Making it easier for the driver to find free places in outdoor parking areas by informing her/him where and how many are available in a specific area and how to reach them (maximizing or minimizing some metrics).
- Easing the use of the parking service by allowing the extraction of occupancy models useful for further studies in terms of traffic prediction.

In order to improve the two items listed in the previous paragraph, SmartSantander project has deployed numerous sensors indicating the parking lots that were available or occupied in downtown Santander. Along with these sensors, 10 panels have also been deployed which inform drivers about the available places depending on which route they choose. In *Figure 1,* the location where sensors and panels (numbered squares) have been deployed is shown.


*Figure 1: Santander city parking areas*

Taking into account the aforementioned aspects, the selected Key Performance Indicators are the following:

| | |
|---|---|
| **KPI Name** | Efficiency of the use of parking spaces |
| **Description** (What?) | This KPI measures the usage percentage of parking spaces, in order to evaluate which parking areas are more in demand by citizens and also the rotation at those sites. This measurement can help to balance the number of available parking sites within a certain parking area. |
| **Relevance** (Why?) | One of the main goals of the limited parking management is to achieve a high turnover of the available places. The increase of efficiency is a clear indicator that this goal has been achieved. |
| **Methodology** (How?) | From the information provided by the system, regarding to the amount of and exact time a site is occupied, it will be possible to estimate the efficiency of the use of parking spaces. The value highly depends on the day and the hour (rush hour, weekend,…), in which the measurements are carried out. |

| | |
|---|---|
| **KPI Name** | Service Management Satisfaction |
| **Description** (What?) | This indicator aims to assess the degree of satisfaction by the technical staff in charge of the management of the limited parking area. |
| **Relevance** (Why?) | Such assessment has been selected as the managers rely on the information provided by the sensors deployed. Hence they are not biased by subjective opinions or uncontrolled variables as could be the case when interviewing citizens. |
| **Methodology** (How?) | The methodology relied on personal interviews with the technicians in charge of the management and surveillance of parking areas who have remarked on the degree of improvement achieved by using these technologies proposed in relation to the methods that they are currently using to perform similar tasks. |

In order to evaluate the limited parking scenario from the perspective of the previous indicators, we required statistical data from the company hired by the city of Santander for its management. Various meetings were held with them to allow us to be able to understand their opinions and experiences.

As an example, the traditional data collection methodology has been included in the *Appendix A*. A glance of this data along with the interview of the service responsible, made it clear that the data collection methodology could be greatly improved by using the automated process (IoT devices) provided by SmartSantander. The data included from the report was collected manually, once every fifteen days, by the guards who supervise each area in the city. The method basically consists of counting the places in a specific area and subtracts the result from the available places in that zone. Based on the obtained result the occupancy averaged is calculated.

By contrast the information collected by sensors deployed in SmartSantander allows us to make a detailed study of each of the parking places either alone or taking sets of streets, areas or various other approaches. Data collection can be equally bounded temporarily at different levels of granularity, i.e. from a concrete day to weekly, monthly or yearly periods. The performing of a minimum study using data mining techniques would offer lots of useful information about the degree of occupation of the area under study as well as potential problems of congestion at different times or dates. This is something that the manager of the concessionaire company recognized and showed a great interest in the adoption of these methodologies.

*Table 1* compares both approaches in terms of some specific parameters:

| Parameter | Traditional parking space management | IoT improved management |
|---|---|---|
| Number of parking spaces available in real time | Not possible. | Managers and citizens are able to access the information that the system provides in real time. |
| Facility map | Not available. | The parking spaces status is shown in real time. The information is shown in a map. |
| Informative panels | Not available. | The information about available parking spaces is shown in a panel so drivers are guided to available ones. |
| Daily control management | The person responsible has to carry this out manually. | By adding the information, a report is always available in real time just by clicking a button |
| Average occupation | No accurate control is possible. | By adding the information, a report is always available in real time just by clicking a button |

***Table 1: IoT based parking lot management compared to the traditional approach.***

In short, the IoT deployment clearly brings a plethora of possibilities to facilitate and optimize parking space service management. As an illustrative example, *Figure 2* shows the kind of analysis that can be carried out for any *IoTized* parking space in the city. In this particular case node 119 next to the Cathedral area has been selected and can be observed in *Figure 3* (daily and weekly reports) and *Figure 4* (monthly report):


*Figure 2: Santander city parking lot management by IoT implementation*


***Figure 3: Example of daily and weekly city parking lot management reports after IoT implementation***

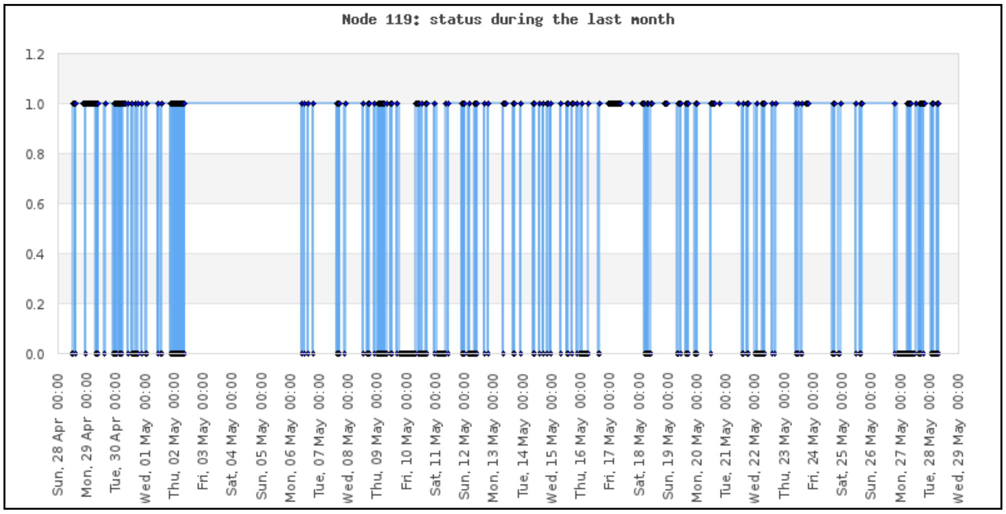


***Figure 4: Example of monthly city parking lot management report upon IoTizing the service***

## 2.2. Environment Scenario

In this section we have selected KPIs from [*D4.1*] which shows some of the most significant improvements achieved using IoT services implemented for use in the environment monitoring domain.

### 2.2.1. Monitoring of Pollutants (CO-$NO_2$)

Traditional pollution monitoring systems are built around a small number of a very accurate sensor stations. In Santander, two sensor stations monitor air quality. These measurements are used to verify that the air quality is of the acceptable level according to the national regulation. This approach provides a low spatial resolution. As described in [*D4.1*], by introducing IoT technologies it is possible to deploy a large number of low cost sensors covering a larger area for a fraction of the cost of highly accurate measurement stations. Some sensors have also been installed in buses which allowing the monitoring coverage area to be increased.

A very similar environment monitoring platform is deployed in the city of Pančevo. One official measurement station is installed in an area close to the city centre. The associated IoT service for pollution monitoring there is also deployed on public transport buses. This IoT service for monitoring of pollutants deployed in the city of Pančevo is described more in detailed hereafter.

In order to compare the scenario with and without IoT services, two KPI are selected and evaluated based on the data obtained in the IoT service for monitoring of pollutants in the city of Pančevo. The first KPI is “Coverage area” and the second is “Measurement accuracy”.

| **KPI Name** | Coverage area |
|---|---|
| **Description** (What?) | Wide sensor data distribution availability around different city areas. Data coming from fixed and mobile stations. This KPI should be derived for each type of sensor and city area. |
| **Relevance** (Why?) | This KPI indicates the degree of sensor coverage in the city. |
| **Methodology** (How?) | City areas have to be identified. Data collected as well as location and time interval have to be stored. |

Several areas were defined as the main parts of the city such as the centre, bus station, etc., as well as nearby industry like Azotara, Petrohemija, etc. Pančevo is well known as an area with relatively high air pollution. Predefined areas are shown to the public through the web application ‘**http://www.bustracker.rs’** and can be accessed in real time. A screenshot of the application is shown in *Figure 5*.

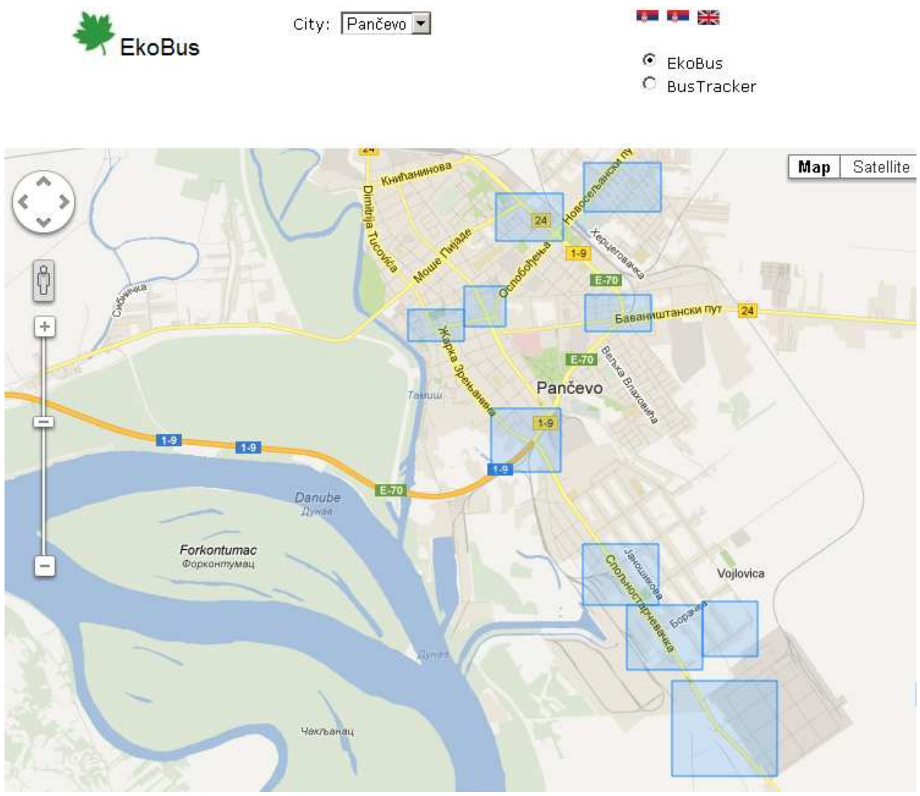


***Figure 5: Pancevo city pollutant sensor areas.***

If a specific area in *Figure 5* is selected, a new window is displayed showing the average values of $CO_2$, NO and $NO_2$ measured during the last hour and the last 24 h. The number of samples and limit of values are also shown as can be seen in *Figure 6*: Historical values for 1/24h are available on a separate page with measurement values, graphs and locations on maps:

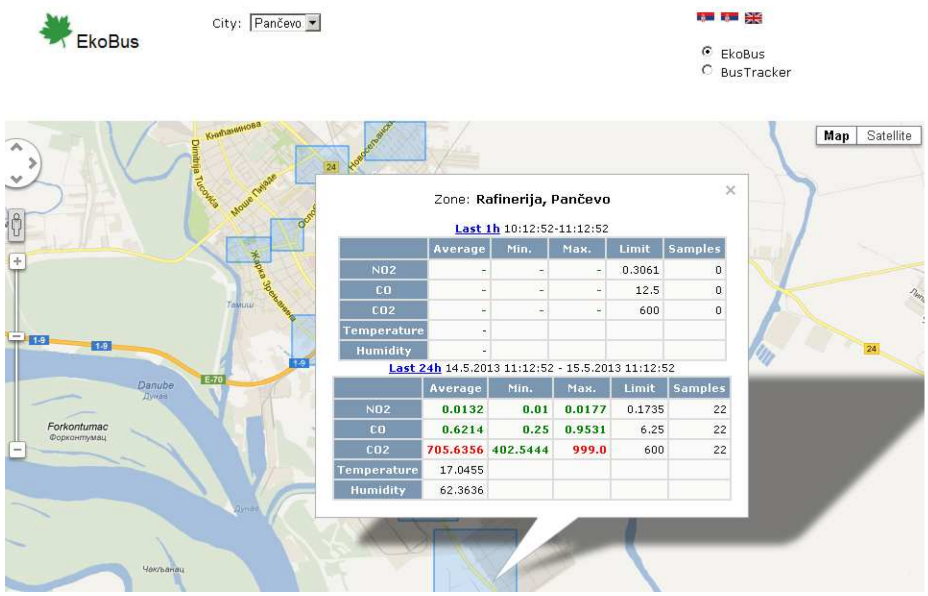


***Figure 6: Detail of pollutant measurements for a concrete area.***

Global results for Pančevo are shown both in *Table 2* and *Figure 7*:

| Duration | Centar | Autobuska stanica | Kotež | Misa | Tesla | Staklara | Azotara | Petrohemija | Vojlovica | Rafinerija | Starčevo |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24h | **56** | **136** | **24** | **33** | **19** | **16** | **14** | **27** | **1** | **22** | **12** |
| 36h | **77** | **217** | **29** | **51** | **26** | **21** | **15** | **35** | **2** | **27** | **18** |

***Table 2: number of pollutant measurements by area.***

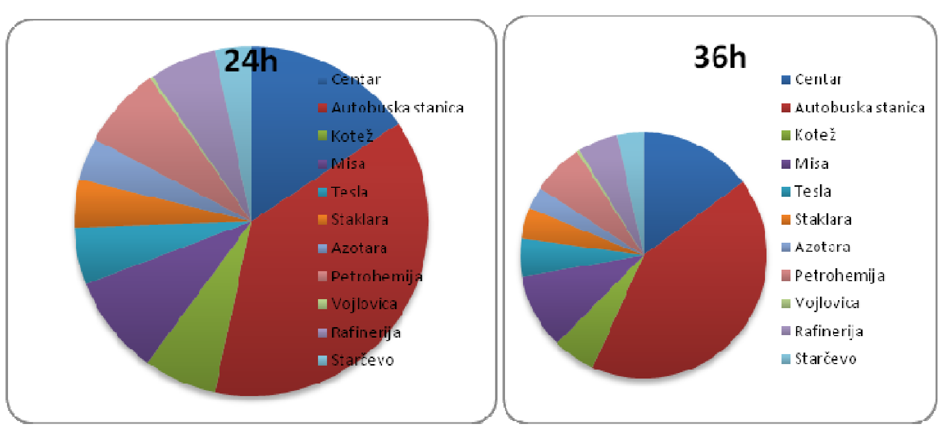


***Figure 7: number of pollutant measurements by area.***

From the results it is shown that measurements are not uniformly distributed across Pančevo. The city centre and the main bus station areas contain around 50% of all measurements taken. A more uniform distribution may be achieved by introducing additional fixed and mobile sensing devices.

| | |
|---|---|
| **KPI Name** | Measurement accuracy, in terms of both relative error and standard deviation |
| **Description** (What?) | Analyze measurement error in terms of the relative error and standard deviation for IoT deployed devices. |
| **Relevance** (Why?) | This KPI indicate measurement accuracy of the IoT deployment. |
| **Methodology** (How?) | Compare measurements from mobile sensors with appropriate monitoring station. Sensor readings, measurement location and measurement time period should be stored in the database. |

As has been highlighted previously, the ecoBus system deployed in Pančevo provides several enviromental measurements. CO and $NO_2$ concetration level measurements are compared with the official measurements and these are shown in both *Figure 8* and *Figure 9*.

Official measurements are taken from the Ministry of Energy, development and environmental protection of Republic Serbia (sepa.gov.rs). An official measurement station is placed in the area near the Pancevo city centre. The EcoBus system collects measurements across the whole city area. Measurements comparison for CO and NO2 are shown on *Figure 8* and *Figure 9*. A comparison on the data is performed for three days. Graphical results show the difference in values observed using the EcoBus system in comparison to the official measurements. One of reasons for such differences is due to the sensors quality difference. Another reason may be due to the different measurement locations. The EcoBus measurements are collected across the whole city area.

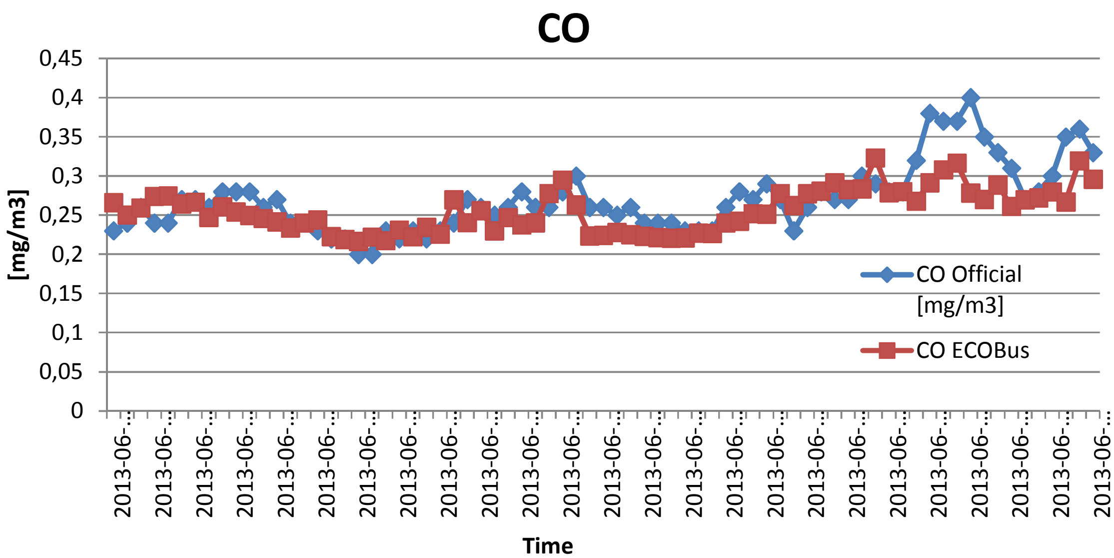


*Figure 8: Comparison of official and EcoBus CO measuments*

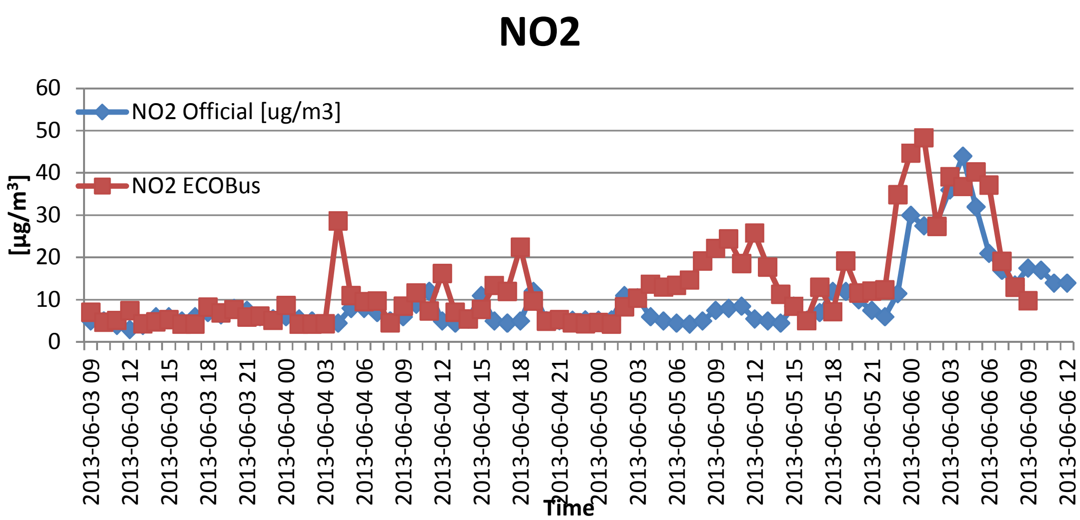


*Figure 9: comparison of official and EcoBus $NO_2$ measuments*

Workshops were held to understand the end user perception and viewpoint about this IoT service. Several workshops were held during February/March 2013 at the following locations:

- Center for the Promotion of Science, Belgrade, 27.2.2013.
- DunavNet, SME for Mobile and IT development, Novi Sad, 6.3.2013.
- Faculty of Transport and Traffic Engineering, University of Belgrade, Belgrade, 12.3.2013.
- Directorate for Digital Agenda - Ministry of Foreign and Internal Trade and Telecommunications, Belgrade, 15.3.2013.

The workshops took approximately 1.5 to 2 hours. The service was presented to the end users and their feedback was collected through a variety of surveys. The details related to all the questions as well as numbers of users interviewed, etc. can be referenced in *Appendix B*. Workshop attendees were selected from appropriate institution employers as well as invited guests.

As a result of the users' feedback the following aspects can be highlighted:

- 59 % of the end users think that the application is useful in daily life.
- 74 % of the end users provided a feedback:
    - It's good that everyone can be involved in monitoring the pollution in the city.
    - It can raise awareness about pollution and the quality of environment in the area.
    - It's easy to use and a lot of real-time information is provided in one place.
    - It provides accurate measurements that citizens are interested in.
    - Gathered data is available over internet or mobile application.
- 36 % of the end users provided a feedback about improvements that can be introduced in the application/service:
    - System could be enhanced with additional sensors and improved data analysis, comparisons with other cities in the region and even other cities in the world.
    - Presentation of monthly/yearly historical data
- From an economic perspective, 42 % of end users agree that this is an interesting application for the city
- From an environmental perspective, 62 % of end users agree that this is an interesting application for the city
- From a societal perspective, 72 % of end users agree that this is an interesting application for the city

### 2.2.2. Noise Measurement

Currently typical noise level estimation is based on measurements carried out by a small number of fixed sensors combined with mathematical models adjusted according to some temporal and spatial parameters (hour, city geometry…). However, thanks to IoT we can build the noise map of a city, something that could not have been done before in such a straight forward way. A noise level map across the city can be generated upon observations collected using deployed sensors. Noise level estimation based on the measurements from a wide set of sensors distributed across a city may provide a more detailed and accurate view of the real time noise distribution in the city.

| KPI Name | Availability of a city noise map |
|---|---|
| **Description** (What?) | Upon this KPI, a noise map of the city can be built indicating how a city is "equipped" in terms of noise sensors and which areas are affected more/less by noise |
| **Relevance** (Why?) | Currently such accurate noise maps do not exist and can be very interesting and useful for the local authorities and population (European directive). |
| **Methodology** (How?) | Appropriate city areas have to be defined. Data as well as location and time intervals have to be stored. |

The continuous increase of IoT deployments offers the possibility of elaborating such real time noise maps covering several city areas and making measurements much more accurate and ubiquitous. Two different acoustic maps have to be obtained according to the law. Their construction is regulated by Directive 2002/49/EC [*Ref1*], of 25 June, on the assessment and management of environmental noise, Law 37/2003 (Ley 37/2003) [*Ref2*] 17 November, on Noise, and Royal Decree 1513/2005 (Real Decreto 1513/2005) [*Ref3*] 16 December, implementing Law 37/2003 (Ley 37/2003), in reference to the assessment and management of environmental noise. Both maps share similar requirements, but address different objectives. The strategic map presents an average measurement per year, whilst the real time map shows the real time urban acoustic behavior. The acoustic map reports noise level according to an acoustic indicator, (for instance, equivalent noise levels every fifteen minutes expressed in dBA) compared with the maximum level accepted considering both, the area under consideration as well as the number of citizens and buildings which are exposed to it.

The strategic acoustic map is created upon averaging noise level values in order to evaluate the general situation along a specific period of time (usually one year), allowing for the determination of noise sources and to achieve global urban prediction and corrections.

According to Spanish law *Ley37/2003*, which transposes the European directive *2002/49/CE*, a strategic acoustic map must be obtained per each urban area, representing this map the acoustic quality degree that citizens perceive during that period. In order to obtain this, measurement must be taken at specific points over a one year period, using a specific sound level meter according to the previous directives and laws. That is, a certified type 1 (or type 2 before November 2014) that complies with *IEC 61672* Class 1 (or class 2).

Currently, in order to derive Santander's strategic map, measurements from different source categories (both certified and not certified sound level meters) are being considered. Although some of these devices might not be directly used to elaborate the strategic map, they will act as a guide to the authorities in taking decisions about the location of additional type 1 or 2 sound level meters, as well as to initially identify those areas with more acoustic problems.

Just as an example, the real time acoustic map would allow the service manager to route vehicle traffic in an efficient way, taking into consideration real time noise measurements. The consolidation of such a map, without the need to invoke a simulation package can be achieved currently relying on the values provided by the IoT devices deployed in SmartSantander. Furthermore, the availability of certified equipment, allows the calibration and improvement of the measurements provided by low cost equipment. As an example, *Figure 10* shows how certified and non certified equipment complement each other in an urban area by increasing the coverage. A higher number of devices increase the granularity of the mesh, thus allowing and achieving an acoustic map without any calculated or estimated values. Low cost devices do not offer the same accuracy as the certified ones, but they can be used as estimated values.

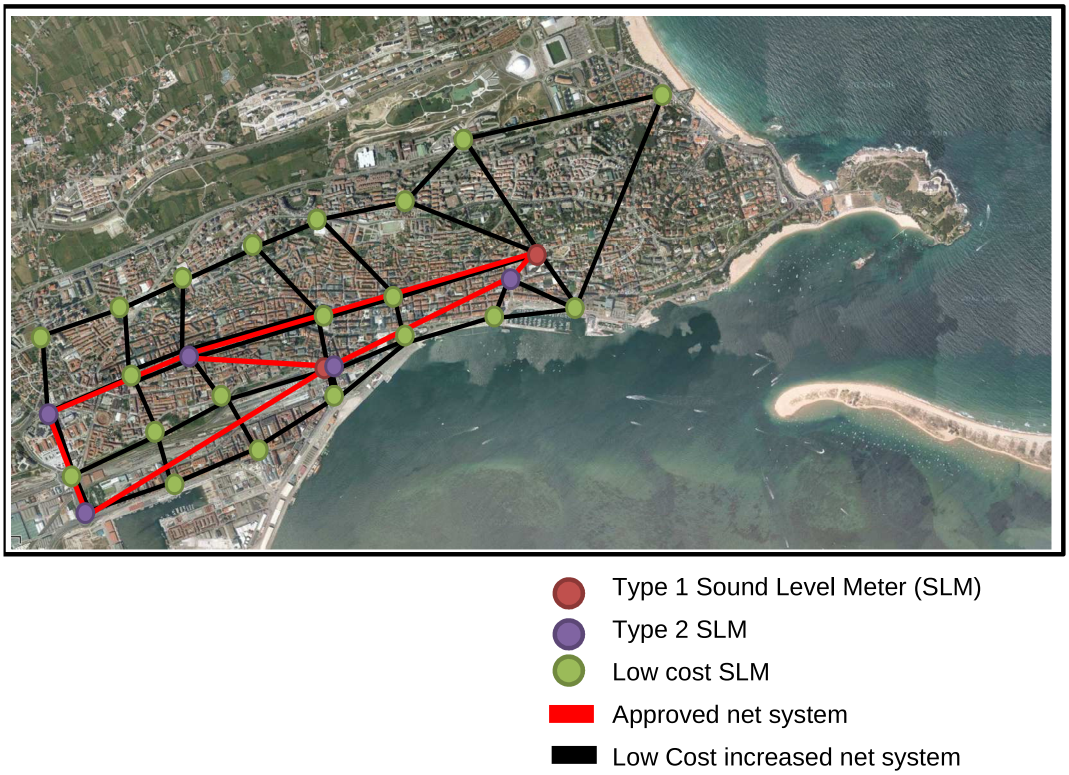


***Figure 10: Network of acoustic devices.***

As clearly shown in the figure above, the coexistence of both certified and low cost devices allows for an increase in the coverage area in a much more efficient way. Besides defining the location of the worst acoustic scenarios, it is also relevant to determine their fulfillment degree according to legal maximum noise levels. Following European directives, the Spanish law and cities acoustic ordinance, depending on the type of area (residential, commercial, industrial, etc.) as well as the period of time (day, evening or night) different maximum values can be tolerated. The ability of IoT devices to take measurements in a continuous way, allows the sharing of the collected values with the ones defined in the aforementioned regulations.

| | |
|---|---|
| **KPI Name** | Measurement quality ratio |
| **Description** (What?) | Number of settings where sound level meters (SLM) are placed. Two different types of SLMs will be available. Those which are certified (classes 1 or 2) and those which are not (low cost devices). In this regard, the percentage of each type (related to the overall number of SLMs considered) will be an indicator in terms of the quality of the map. |
| **Relevance** (Why?) | Useful to assess the quality of the measurement, determining if it fulfills the European legislation. |
| **Methodology** (How?) | Percentage of low cost equipment compared with total number of devices.<br><br>Percentage of approved SLM compared to the total of devices.<br><br>The increase of one or both of these is associated with an improvement of city noise monitoring. |

Currently there is no certified acoustic device yet deployed in Santander. Although a few of them are being deployed and calibrated in the framework of additional projects, *Table 3* shows the metrics just relying on the SmartSantander infrastructure.

| KPI name: Measurement quality ratio | Before SmartSantander | After SmartSantander | Future proposal /expectation |
|---|---|---|---|
| Number of low cost equipment | 0 | 52 | Increase |
| Number of approved sound level meter | 0 | 0 | Step by step increasing till the moment when strategic map control points are fulfilled |
| Total devices | 0 | 52 | Increase |
| Percentage of low cost equipment compared with total devices | - | 100% | Decrease |
| Percentage of approved sound level meter compared with total devices | - | 0% | Step by step increasing till the moment when strategic map control points are fulfilled |

***Table 3: KPI Measurement quality ratio***

| | |
|---|---|
| **KPI Name** | Ratio between real measurement points and estimated ones. |

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|---|---|
| **Description** (What?) | Noise maps are currently estimated, which means that only a few measurement points are used to determine the global city noise map. With IoT technology it will be possible to have more real measurements and, progressively, the number of estimated ones should decrease. |
| **Relevance** (Why?) | Models to estimate urban noise need lots of parameters (meteorology, material building components, 3D urban modeling, etc.). However, as the number of sound level meters increase, no models will be needed, making it easier & simpler to produce a noise map. |
| **Methodology** (How?) | Percentage of real measurements per total map points (both estimated and real measurements). |

Currently the total number of real measurement points is 52, with all of them distributed in an area of about 176 Ha (1.76 $Km^2$). This means that 5%, of the 35 $Km^2$ corresponding to the whole municipality, are currently being monitored (see *Figure 11*). *Figure 12* shows more detail about the areas and the concrete sites where acoustic sensors have been deployed.

***Figure 11: Santander municipality area***

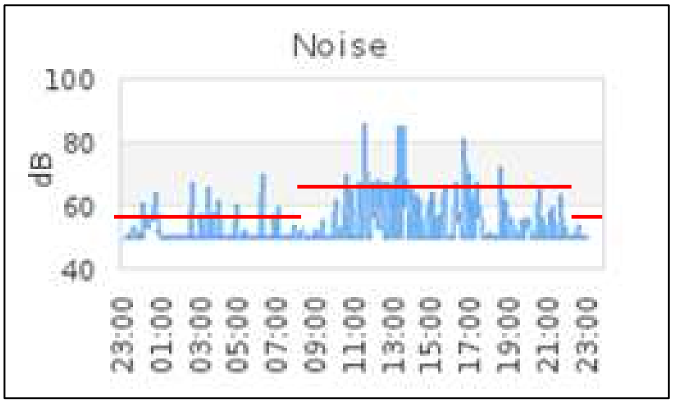
*Figure 12: Acoustic characterization coverage area in Santander*

*Figure 13* shows the real time map derived for some of the sensors deployed in the downtown area. Such information is very valuable in terms of decisions taken about traffic, urban services and many other aspects linked to the daily life of citizens.

*Figure 13: Santander acoustic measurement points. Information is shown as a HeatMap.*

| | |
|---|---|
| **KPI Name** | Legal acoustic control: Number of times that acoustic level is exceeded. |
| **Description** (What?) | All the measurements retrieved by the devices can be compared in real time to legal parameters. Hence, it is possible to define how many times the maximum value is exceeded. The gathered measurement has to be compared to the maximum level according to the law. This maximum depends on the type of urban area (residential, industrial, etc.) as well as on the period of time (day, evening, night). |
| **Relevance** (Why?) | Important to quantify acoustic situation in an urban scenario.<br><br>With all the collected values it is possible to determine whether a specific noise level is being exceeded. This information gives to the authorities an important tool to control noise levels, contributing to implement the corresponding policies. |
| **Methodology** (How?) | The frequency with which sound level measurements exceed maximum value per a defined period of time. |

A relevant feature to be further considered addresses data collection aiming at generating acoustic behavioral profiles characterizing different measurement sites. This allows a direct comparison with the limit values allowed by city regulations. As an example, *Figures 14*,15 and 16 show the time response of nodes ID-237, ID-380 and ID-486.




Limit values allowed by Santander regulations in a commercial area:

Tolerated value during the day: 65 dBA

Tolerated value during the night: 55 dBA

***Figure 14: Daily acoustic control for the node 237.***

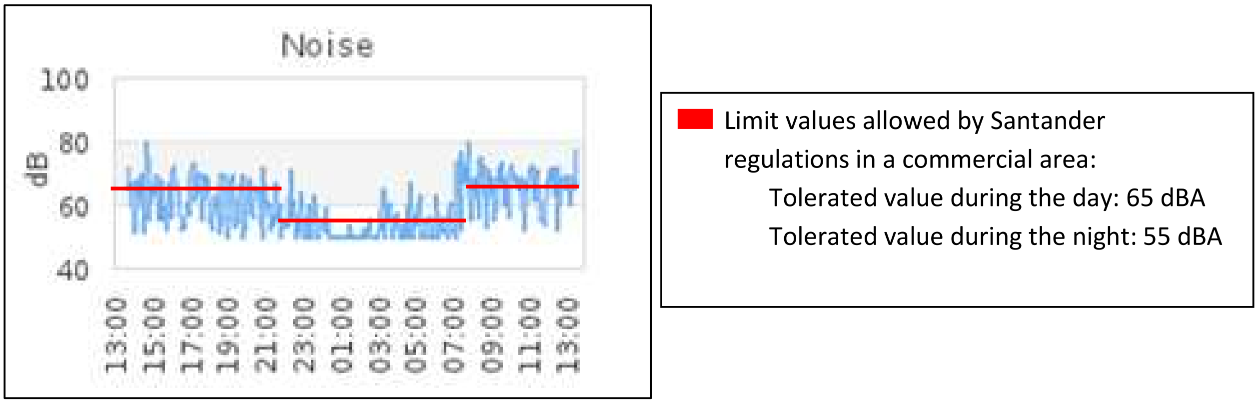



***Figure 15: Daily acoustic control for the node 380.***

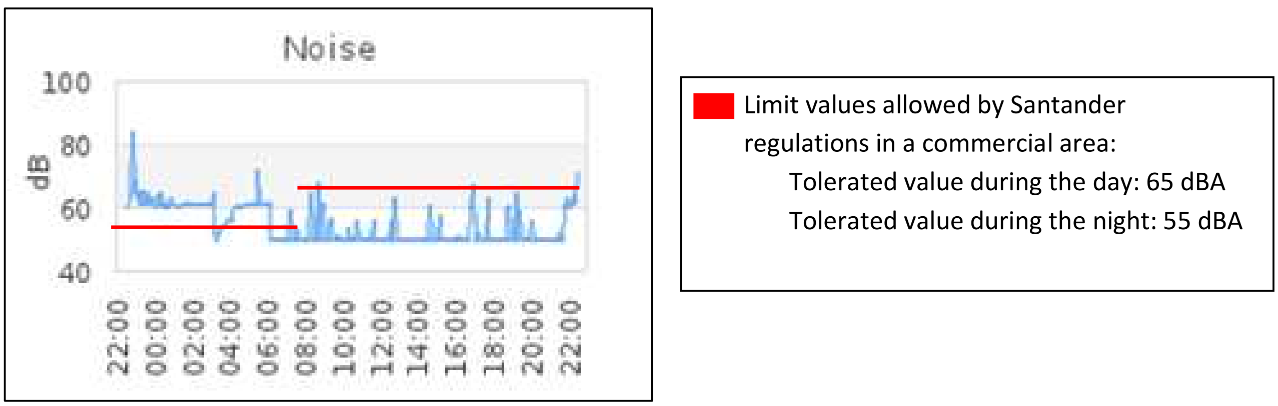



***Figure 16: Daily acoustic control for the node 486.***

More extensive analysis, in terms of the time framework, it can be carried out. Just as an example, the acoustic behavior over a period of 7 days is shown in the case of three nodes placed in different city environments.

The first node, ID237, is placed in a pedestrian area with relevant commercial activity. As it is more than evident, time periods with highest acoustic values correspond to commercial activity time period (see *Figure 17*):

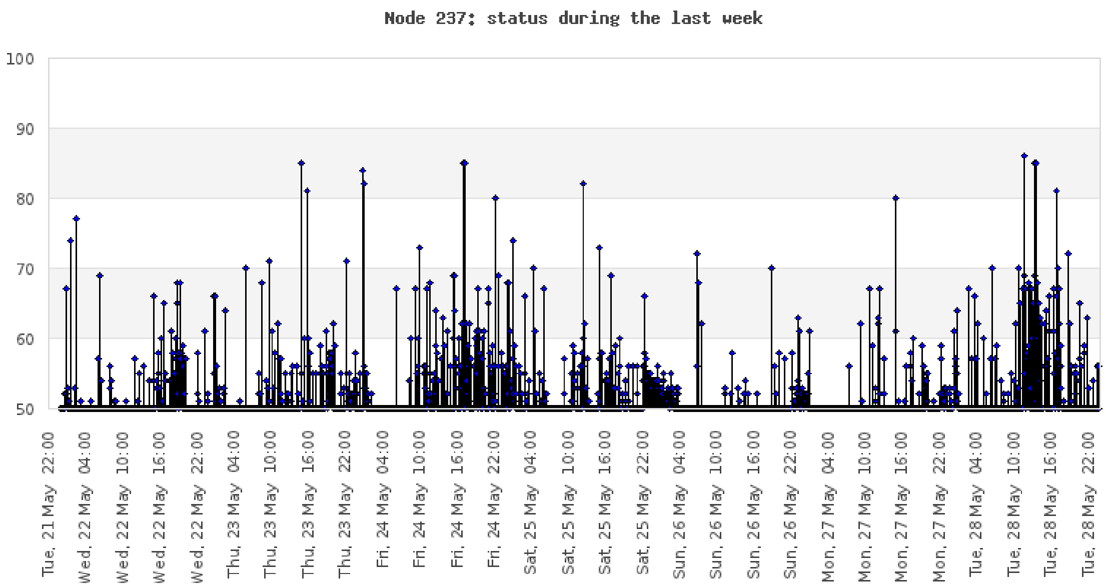



***Figure 17: Weekly acoustic control. Node 237***

The second one, node ID380, has been deployed in an area with an important presence of restaurants and leisure activity. Weekly and monthly plots show how during the weekend noise level values are higher than other days. This can be clearly observed in the *Figure 18*:

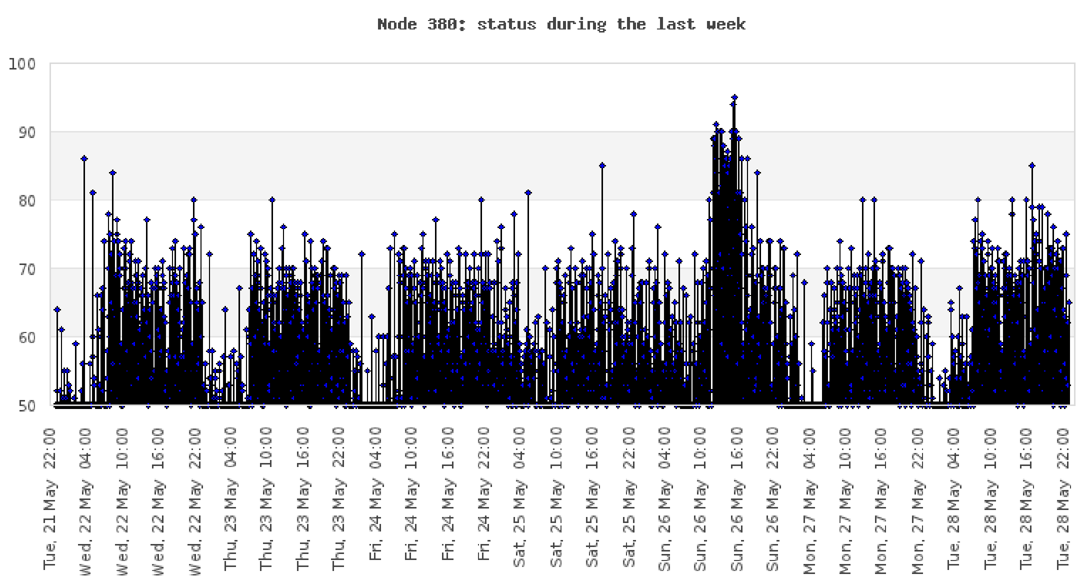



***Figure 18: Weekly acoustic control. Node 380***

The last node, ID486 is located close to a bar and a street which has intense activity during the evening throughout the whole week. (see *Figure 19*)

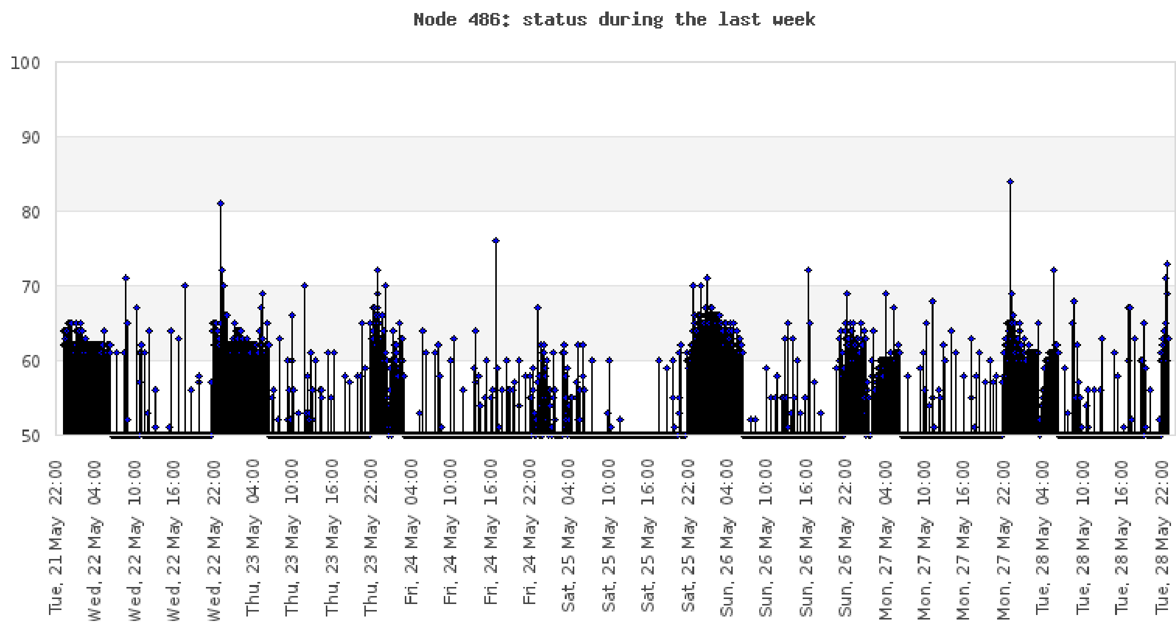



***Figure 19: Weekly acoustic control. Node 486***

## 2.3. Energy Measurement in Smart Building

Energy monitoring at employees' work desks is important in order to detect any situation of inefficiency due to employee negligence in managing the appliances at his work desk. Prior to the introduction of IoT technology, it was not possible to estimate the energy consumption of user owned appliances (i.e., laptop, desktop computer, LCD screen, battery charger, etc). Thanks to the introduction of such non-intrusive technologies it is now possible to estimate the energy consumption of these small appliances and understand their contribution toward the overall energy consumption of a building during a working day. The same technology also allows the detection of the presence of the user at his work desk and to detect certain situations of inefficiency, including measuring the energy wasted, i.e. energy used when user was not present at his work desk (i.e., LCD screen left on overnight).

By collecting all this information and by adequately providing it back to the user, the impact of such new IoT technology in changing user behavior, making it more energy conscious, can be then estimated and evaluated. Based on this, the measurements taken at the Centre for Communication Systems Research building, University of Surrey, consisted of two collection campaigns involving 150 desks:

- Passive observation of user appliances consumption through IoT technology. The collection phase lasted for 1 month baseline data acquisition (Phase 1);
- Active observation of user appliances consumption through IoT technology and provision of user passive feedback in the form of energy wasted (consumed when not present at his work

desk). This collection phase lasted for additional 5 months subsequent to the initial phase 1 (Phase 2).

All the details about the above described experiments campaign can be found in Internal Report 4.2 [*IR4.2*].
Based on this, the following KPI can be considered:

| **KPI Name** | Users energy consumption (Phase 1) |
|---|---|
| **Description** (What?) | This KPI measures the energy consumption by the appliances connected at a user work desk and its proportion with respect to the total building consumption |
| **Relevance** (Why?) | This KPI may provide an insight of the energy cost for providing employees with a desk space at their work place. |
| **Methodology** (How?) | All measurements are stored in a database, so the information that is necessary for calculating this KPI can be retrieved from there. The required information consists of the energy consumed by a user's work desk per day. Information about the total building is also available at building measurement level provided by Estate and Facility Management at University of Surrey. |

| **KPI Name** | User energy wasted (Phase 1) |
|---|---|
| **Description** (What?) | This KPI measures the energy wasted by the user, i.e., consumed when not present at his work desk, during Phase 1 observation. |
| **Relevance** (Why?) | This KPI may provide an insight on how conscious the user is about his energy consumption/wastage when no information about it has been provided to him. |
| **Methodology** (How?) | All measurements shall be stored in a database, so information that is necessary for calculating this KPI can be retrieved from there. Information requires energy consumed at user work desks and his energy presence per day. |

| **KPI Name** | User energy consumption after feedback platform introduction (Phase 2) |
|---|---|
| **Description** (What?) | This KPI measures the energy consumption by the appliances connected at user work desks after deploying and making available to the user a platform for him to be aware of his consumption and energy wasted. |
| **Relevance** (Why?) | This KPI may provide an insight to the effectiveness of the proposed technology (measuring and passive feedback) towards making the user more conscious about his energy consumption/wastage |

| | |
|---|---|
| **Methodology** (How?) | All measurements shall be stored in a database, so information that is necessary for calculating this KPI can be retrieved from there. Information requires energy consumed at user work desk and his energy presence per day. |

| | |
|---|---|
| **KPI Name** | User energy wasted (Phase 2) |
| **Description** (What?) | This KPI measures the energy wasted by the user, i.e., consumed when not present at his work desk, during Phase 2 observation and passive feedback provision. |
| **Relevance** (Why?) | This KPI may provide an insight on how conscious the user becomes about his energy consumption/wastage that information provided to back to him. |
| **Methodology** (How?) | All measurements shall be stored in a database, so information that is necessary for calculating this KPI can be retrieved from there. Information requires energy consumed at user work desk and his energy presence per day. |

| | |
|---|---|
| **KPI Name** | Technology engagement |
| **Description** (What?) | This KPI measures the time the user spends interacting with the provided technology (passive feedback platform) in order to gain an understanding of his current energy consumption. |
| **Relevance** (Why?) | This KPI may provide an insight on how well accepted and attracting the proposed technology results for the user. |
| **Methodology** (How?) | All measurements shall be stored in a database, so information that is necessary for calculating this KPI can be retrieved from there. Information involves the number of time and the duration of access to the platform per user and per day. |

In the following, the results of the above-described KPIs are presented and discussed. Among the 200 available nodes and the 100+ recruited participants in the experiment, in order to simplify the processing of the large collected dataset, the analysis has been focused on 20 nodes. The properties of which well cover a different and varied set of scenarios.

*Figure 20* shows the profiling for the same day of two contrasting user behaviors that have been obtained thanks to the deployed IoT technology and that otherwise would have been impossible in the case of energy consumption analysis performed only at building level. The red line shows the user energy consumption in (J), while the green one shows the presence of the user at his work desk. Node 13, on the left, shows the behavior of an energy-conscious user that generally only turns on the used devices during the working time and switches them to power-saving mode when not present at his desk. In contrast, Node 9, on the right, shows the behavior of a less energy-conscious user, that while turning on some of the devices when at work and during the time when he is present at his work desk, also generally leaves other appliances on when not present outside of the working day time, leaving them to consume/wasting a constant baseline quantity of energy. The two behaviors are representative of an average and worst case user behavior that can be observed among the monitored work desks.

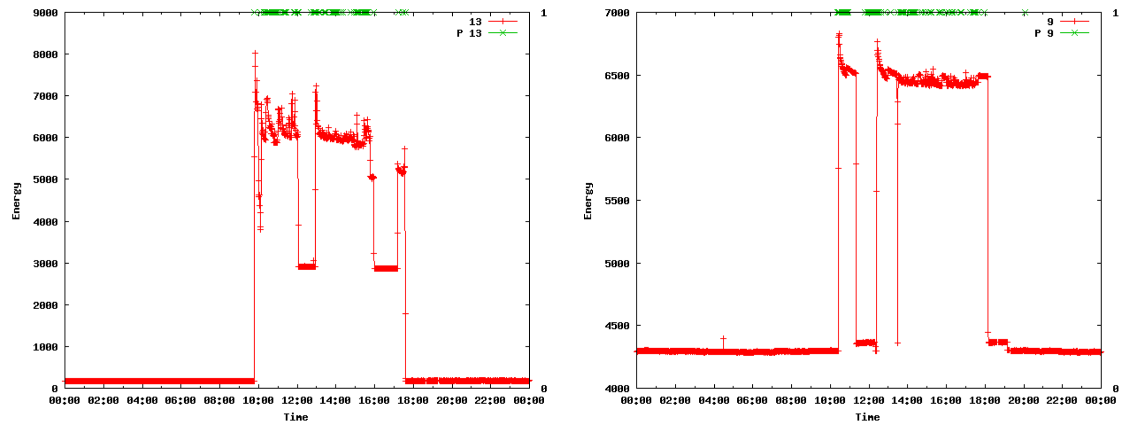



***Figure 20: Node 13, user energy-conscious behavior (left); Node 9, user energy-indifferent behavior (right).***

Starting from the above observation, two metrics have been defined:

- Energy used: is the energy used when the user is present at his desk, where presence has been defined as user present when a movement of the user is detected for at least 15 seconds every minute (with a passive infrared sensor with a sampling period of every 3 seconds). If two presences occur within the distance of two minutes, the user presence is inferred also for the intermediate period.
- Energy wasted: is the energy consumed when the user is not present at his work desk, either because he is outside of the office or of the building.

According to KPI1 and KPI2, Figure 21 shows the energy consumed for an energy-conscious user over a period of one week, with highlighted useful consumed energy (blue bars), when the user is present at his desk, and correspondingly wasted energy per day, consumed when the user is not present at his desk. As expected, an energy-conscious user that mainly uses power for his desktop computer machine and the connected screen for running everyday tasks  (such as Internet browser, email client, word processing, etc) does not consume too much energy when not present at his work desk, and especially during the week-end days (June 09/10). The overall consumed energy is expressed in energy consumed per day with an average daily consumption of 0,42KWh that corresponds to 42% of the maximum expected consumption per desk. A similar setting for a user that is supposed to work on his computer and screen at full time and speed (i.e., by running complex simulations) indeed exhibits a consumption of roughly 1KWh per day for the same observation period.

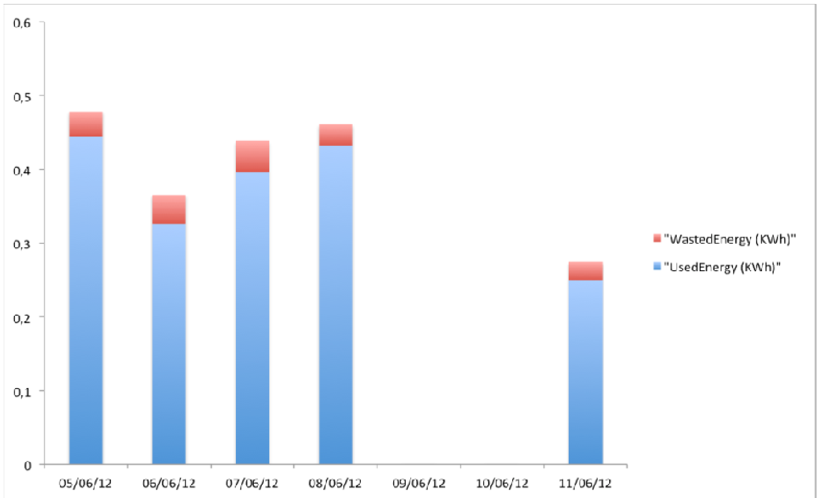



***Figure 21: User energy-conscious used and wasted energy (hourly consumption per day)***

*Figure 22* shows the ratio between the energy used in useful tasks and the energy wasted for the energy-conscious user over a period of one working week. As expected the energy wasted (red portion of the pie chart) represents only 8% of the total consumed energy, which shows the very effective behavior of the user. However, this ideal behavior is not always observed when looking on a larger scale in a normal office environment, as such the one observed by the SmartCCSR testbed site of the SmartSantander deployment.

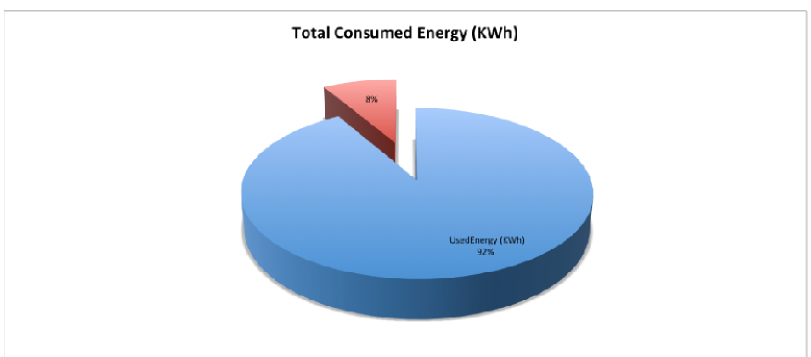



***Figure 22: User energy-conscious used and wasted energy ratio (weekly consumption)***

In order to characterize the impact on energy consumption in the work place due to the different user behaviors and evaluate the energy used and wasted by all the participants, the following analysis has been performed according to KPI1 to KPI4.

The data has been averaged among the different participants for the duration of a month. Only weekdays have been considered and a period five months have been observed. The month of May represents “phase 1”, during which the baseline energy consumption for each user has been collected. The following four months (July, August, September and October) represent “phase 2”, months where while collecting the data, the user can also review their energy consumption through the deployed desktop gadget and the MEF web-based tools. The month of June has not been considered because the user involved is supposed to register accessing their energy data. This way the effects of late registration are avoided and not taken into consideration.

*Figure 23* shows the average energy consumed per hour by the participants over an entire day (red area), with wasted energy highlighted (green area), i.e, the energy consumed by a user work desk and the connected appliances when the user is not present. The blue area shows the maximum energy consumed by a desktop computer and an LCD screen when always on for the same time and with the computer working at full speed.

It can be observed that the average user consumption is much lower than the maximum expected one that an office building could be required to provide, however it is interesting to note the high percentage of energy wasted with respect to the energy used. This is clearer from *Figure 25* that shows the portion of energy wasted and used with respect to the total consumed energy in a day for the month of May, when the baseline consumption data have been collected. The energy wasted results are as high as 78% and although this derives from a simplistic model considered for defining energy wasted and used (i.e. when the user is not present), however it clearly shows that there is a lot of improvement that can be achieved if the users are properly conscious of their consumption and change their behavior with regards to it.

*Figure 23* shows that as expected the overall energy consumed per hour is reduced when the users are informed about their consumption after few months of observation in August. However the negative trend observed in the following month shows that the short-lasting impact of this experimented feedback mechanism clearly decreases over time as gets people become less involved. The almost constant gap between used and wasted energy, shows the small number of users affected by this change of behavior toward a more energy-conscious one.

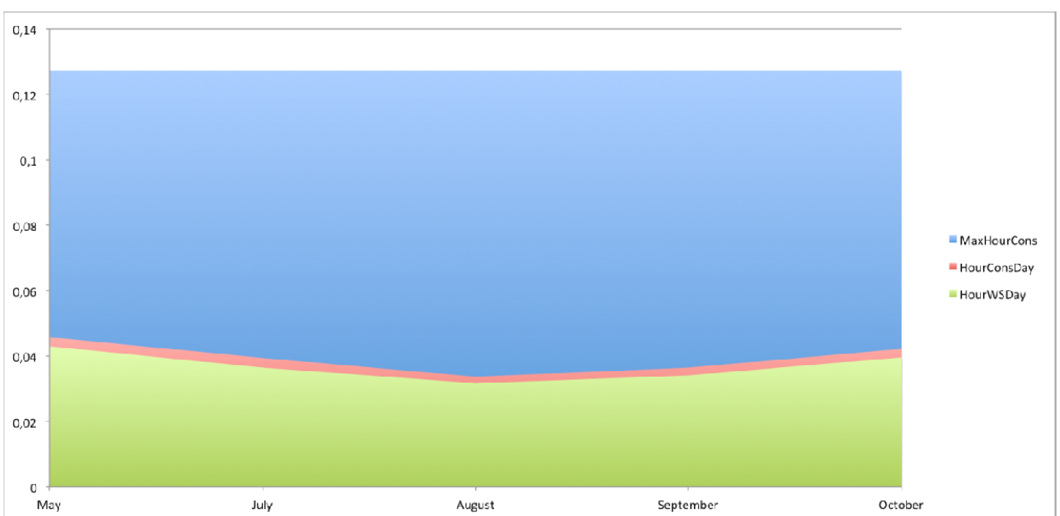



***Figure 23: Average hourly-consumed energy per day (KWh)***

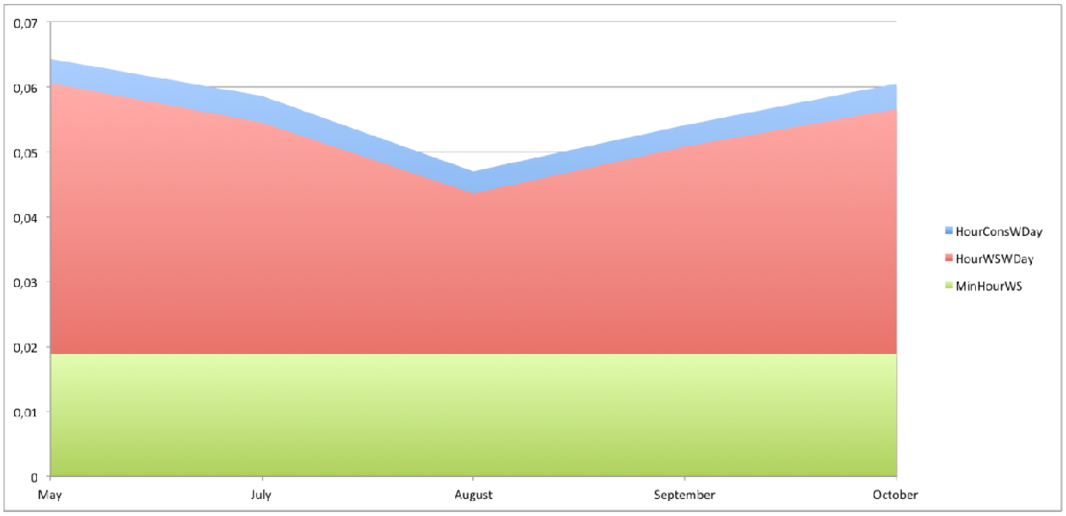



*Figure 24: Average hourly-consumed energy per working day (KWh)*

Similarly to *Figure 23, Figure 24* shows the same hourly energy consumed portion for an observation time corresponding to the working day (from 9am to 5:30pm). The trend is similar to the one shown in *Figure 23* and the comparison with the minimum energy consumed by a perfectly energy-conscious user (as discussed previously) clearly highlights the expected improvement that a proper feedback mechanism could achieve.

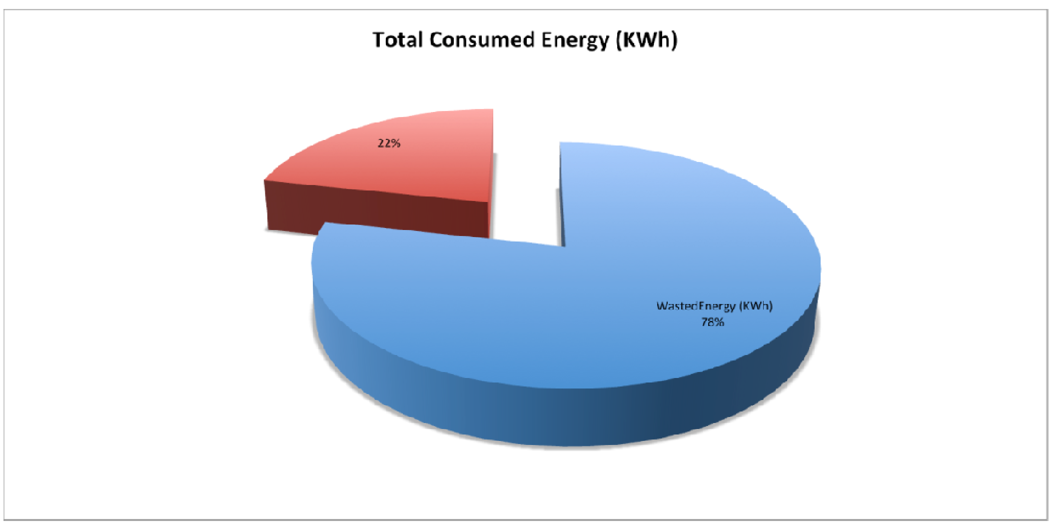



*Figure 25: Used and wasted energy ratio*

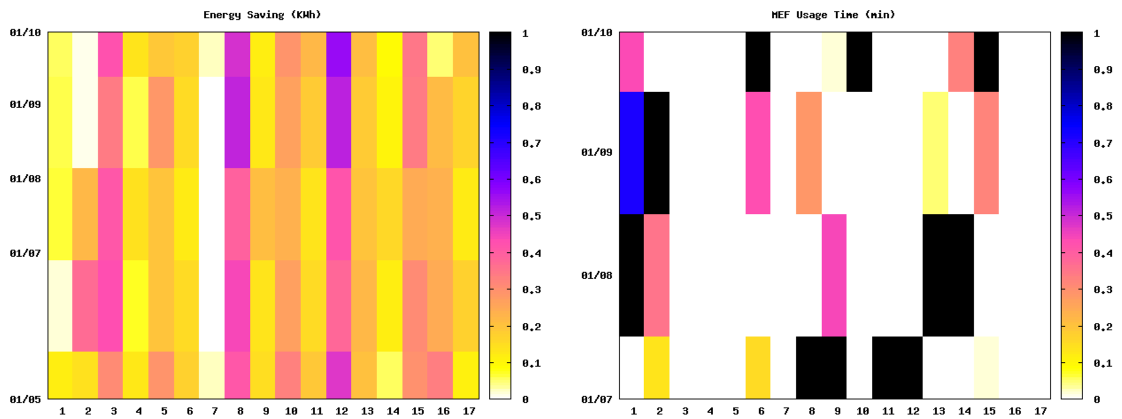



***Figure 26: Energy saving (left) and MEF access duration (right) for user***

*Figure 26* shows the energy saved by the each given user for every given month (i.e. the portion of energy that is used when the user is present with respect to the total consumed energy within the month) and the time the user spent on reviewing its energy consumption breakdown using the MEF web based GUI. A few main conclusions can be derived from this.

By looking at the same time slots and comparing the two heat-maps, a clear relation between user engagement with the feedback technology and its energy saving (highlighting a change in its behaviour towards a more conscious one) cannot be identified. A few users do show an improvement in their energy saving but there is not a clear increasing trend and the lack of evidence of the user spending time on the MEF interface shows that the observed saving is mainly due to indirect effects, such as the user consciousness of being monitored. Additionally, when observing the user engagement with the MEF (right heat-map) two major trends can be identified: the first relates to the user indifference to the provided technology as shown by the user that never accesses the platform; the second relates to user behaviour when engaging with a new technology, i.e. after an initial excitement (large amount of time spent on the platform in its early life) the engagement time quickly drops in the following month, clearly showing the lack of interest from the user for the provided technology together with the lack of ability of the technology to maintain this required high the interest. This can be related to the very passive nature of the designed feedback mechanism that relies mostly on active user engagement. Additionally only a few users show a growing interest towards the proposed technology, this most likely representing the users that form the trend observed in *Figure 23* and *Figure 24*. The small number of users exhibiting this behavior confirms the small reduction in the overall energy consumption observed.

To conclude, *Table 4* 4 shows the targets that IoT technology deployment allows to achieve.

| Target | Possible without IoT | Possible with IoT |
|---|---|---|
| Quantify average energy consumption of a user desk ? | **Not possible** | **Possible** |

| | | |
|---|---|---|
| Quantify average energy wasted by a user at his work desk? | **Not possible** | **Possible** |
| Understand user behavior at his work desk? | **Not possible** | **Possible** |
| Understand the impact of feedback mechanism to make user more energy conscious? | **Not possible** | **Possible** |

***Table 4 IoT impact***

## 2.4. Parks and Gardens Scenario

### 2.4.1. Precision Irrigation

Regarding the precision irrigation use case, SmartSantander has deployed agricultural IoT devices and weather stations in two major parks of Santander: the Las Llamas park and gardens around the Magdalena Palace area. A total number of 48 IoT sensor nodes, covering an area of 55000 $m^2$, are deployed at key positions inside these two areas, equipped with special agricultural sensors measuring parameters like: air temperature and humidity, soil temperature and moisture, atmospheric pressure, solar radiation, wind speed/direction, rainfall etc.

SmartSantander developed and integrated a precision irrigation service (consisting of IoT device deployment and end-user applications) that estimates plants' requirements in water in the different subareas of the deployment. This service focuses on individual plants or small areas within a park, rather than taking a 'whole-field' approach. Thus, a certain degree of flexibility is required in order for such an irrigation system to adapt to specific plant species and their growth while lessening the effort required by the park personnel.

Soil moisture sensors have been used in agricultural scenarios for many years, due to their low cost, accurate measurements and low maintenance needs. The data provided by these sensors enables the development of tools to interact with the smart irrigation control systems. Traditionally these systems are based on stand-alone controllers or devices that have an interface with time-based controllers. Soil moisture sensor data incorporated into these systems will allow service managers to activate irrigation when needed rather than on a predefined schedule.

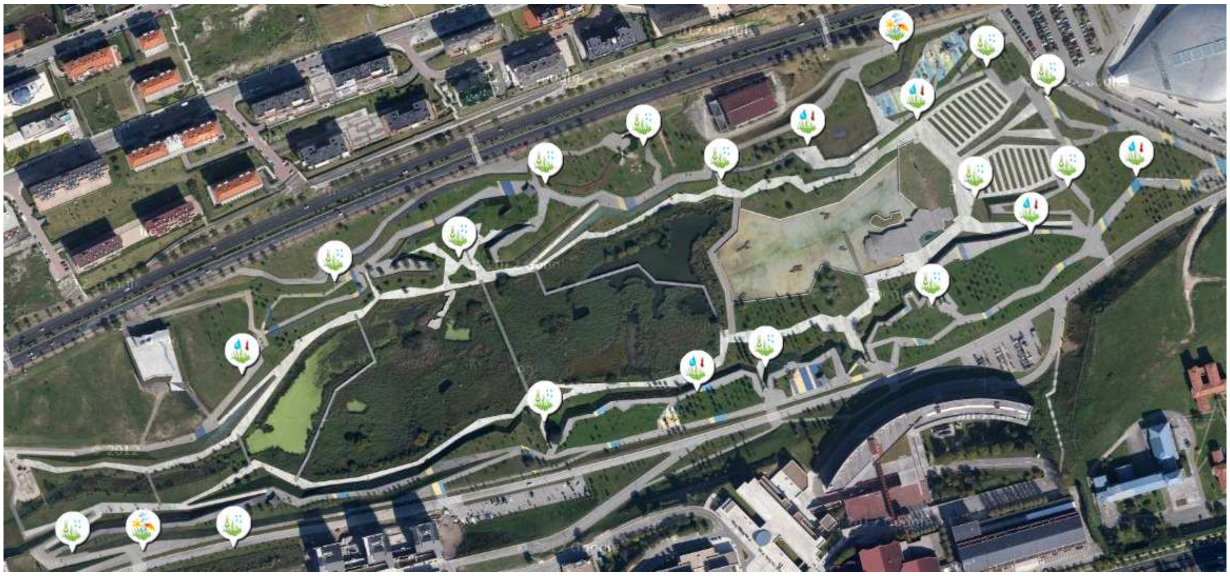


*Figure 27. Irrigation sensors deployed in Las Llamas Park*

The real-time information from the field enables park technicians to adjust irrigation strategies at any given time. Instead of taking decisions based on uncertain average conditions, which may not be even close to reality, or having to be constantly physically present on-site, a precision park irrigation approach recognizes differences and accordingly automates management actions. For this reason a smartphone application, developed for the Android platform, complements the main web application providing easy access to the measured parameters inside the park areas.

Taking into account the IoT-supported irrigation service KPIs described in D4.1 – Baseline Report [*D4.1*], we have concluded to carry out an evaluation of the most appropriate of them, in order to verify how IoT technology improves the quality of the current irrigation procedures. Very briefly, the goals of this evaluation are:

- The assessment of how realistic and accurate is the presentation of the park/garden's status by the IoT device deployment and the corresponding applications.
- The assessment of how much the use of the IoT-supported irrigation service facilitates savings in certain resources like water and labour.

**Overall Methodology for Evaluation:** For a limited period of time (2 weeks) park authorities will apply the irrigation procedure, first without using the IoT service (1 week) and then the rest of the time using the IoT-supported service. During both periods, apart from the proposed KPIs, they will also record/characterize the overall park status (i.e.,. dry/wet/normal, etc.) and comment on how well the IoT service depicts the status of the park (e.g. fine/med/coarse/…).

| **KPI Name** | Volume of actual used water |
|---|---|

| | |
|---|---|
| **Description** (What?) | In this KPI for a certain period of time, the actual utilized water for irrigation will be measured. |
| **Relevance** (Why?) | This KPI will facilitate the evaluation of the IoT irrigation service:<br>1. Assessment of how the IoT enabled irrigation service leads to more precise irrigation and thus to reduced water waste.<br>2. Assessment of how realistic and accurate is the presentation of the park/garden's status by the IoT device deployment and the corresponding applications to the gardeners, thus leading to better decisions being taken. |
| **Methodology** (How?) | This KPI can be calculated for one specific period and then can be compared with historical data from the Parks and Gardens maintenance service prior to IoTizing it. In the case in which there is not any historical data we can perform a small trial of 1+1 week as mentioned in the overall methodology of evaluation. |

Aqualia water utility service has three caudal meters installed in the Las Llamas Park of Santander. The following figure shows the water consumption during the last two years.

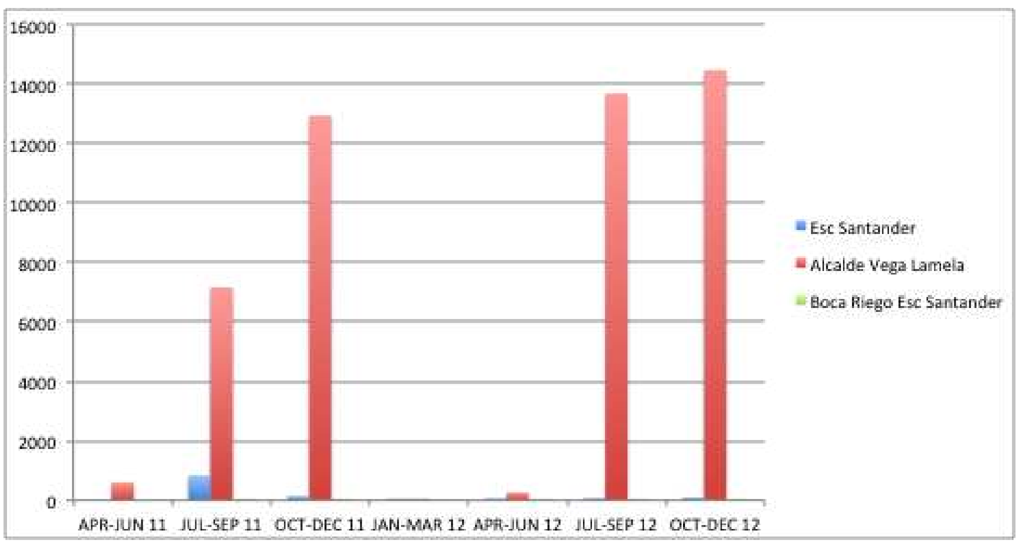



*Figure 28. Water consumption in the Las Llamas park provided by the caudal meters*

| | |
|---|---|
| **KPI Name** | Number of Visits on-site |
| **Description** (What?) | In this KPI for a certain period of time, the total number of on-site visits by a gardener for irrigation purposes will be recorded for a certain period of time. |

| | |
|---|---|
| **Relevance** (Why?) | This KPI will facilitate the evaluation of the IoT irrigation service in terms of:<br>1. Assessing how the IoT-enabled irrigation service enables more precise irrigation (in terms of less frequent on-site visits) and thus to reduced labour waste.<br>2. Assessing how realistic and accurate is the presentation of the park/garden's status by the IoT device deployment and the corresponding applications to the gardeners and thus leading to more informed solid decisions. |
| **Methodology** (How?) | This KPI can be calculated for a specific period and then can be compared with historical data from the Parks and Gardens maintenance service. In the case in which there is not any historical data available we can perform a small trial of 1+1 week as mentioned in the overall evaluation methodology. |

The following figures show the soil moisture measurements carried out by a sensor deployed in the Las Llamas Park as well as the rain precipitation in Santander during February 2013. During this period, it had been raining a lot, keeping the terrain saturated (no needs to irrigate). The low values collected by the soil moisture sensor confirm that. Once the rain stopped, there is one-week period, where this parameter increases up to 28 centibars, which is not considered enough to start the irrigation system in the park. Hence, during this month, the use of IoT technology allows parks and gardens managers to avoid visits to the park in order to inspect the different areas and take the decision whether to irrigate or not.

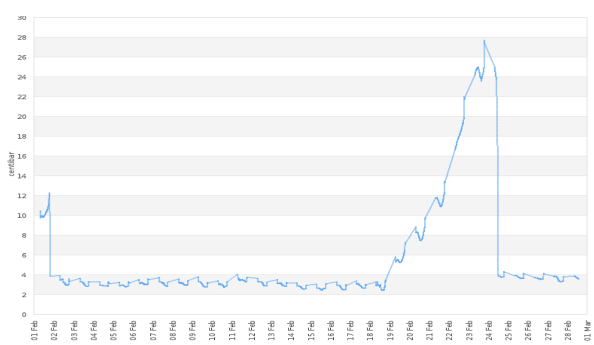


*Figure 29. Soil moisture tension during Feb 13*

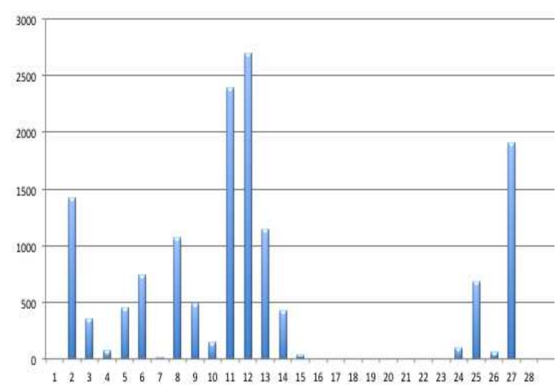



*Figure 30. Rain precipitation on Feb13*

*Figure 31* shows the real time heatmap derived of the measurements collected by sensors already deployed in Las Llamas Park. Maps like this one are really valuable for the park managers in order to take a decision on whether to irrigate or not the different zones of the park.

*Figure 31. Heatmap based on the SoilMoisture tension measurements carried out in Las Llamas park*

## 2.5. Tourist and Cultural Scenario

### 2.5.1. Information through Augmented Reality

In Santander, as in many other cities, there is a huge amount of information that may be of interest for tourists and citizens alike. This data is usually fragmented over different websites and therefore not of easily accessible. For this reason we have created this scenario, where we unify the access to all data sources and present them in a context-sensitive, location aware manner to the end users using augmented reality technology. The SmartSantanderRA application was developed for the Android and iOS platforms and published in the respective markets in August 2012. Since then 7314 downloads for the Android version and 6146 downloads for the iOS version have been recorded.

The Augmented Reality service includes information about around 2700 places in the city of Santander. This information includes: beaches, parks and gardens, monuments, buildings, tourism offices, shops, art galleries, libraries, bus stops, taxi stops, bike stations, parking lots, sports centres, etc. It also allows real time access to traffic and beach cameras, weather reports and forecast, public buses information and bike rental service. All this information creates a unique ecosystem that increases the experience and assists the tourist or citizen within the city.

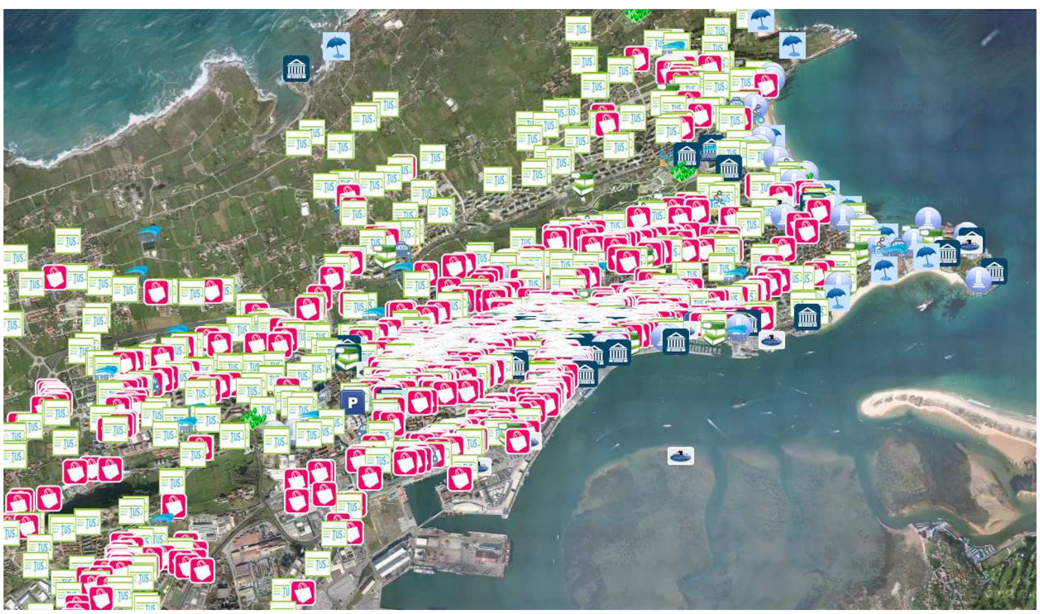


***Figure 32. Augmented Reality POIs map***

As an example, the service offers an interactive experience through a “stroll in the city” mode, where the visitors receive information about specific points of interest (POIs) taking into account their defined preferences (language, places to visit, etc) and have an interactive context-sensitive experience visiting the city rather than using the traditional standalone applications.

For this scenario we have also deployed stickers including QR codes and NFC tags in strategic places in the urban landscape that will provide location-sensitive information (transport service, the cultural agenda, shops, monuments, buildings). By reading these stickers the visitors and citizens will be redirected to the same information that is included in the Augmented Reality Service. Additionally, it complements the SmartSantanderRA app, providing precise information about specific POIs.

A final important functionality included in the augmented reality service allows us to monitor user behaviour. Valuable sensory information is sampled periodically and sent to our platform, this includes GPS location, acceleration, etc. The further analysis of this data will allow us to create new services and experiments within the smart city context.

| **KPI Name** | Overview of the distribution of number of visits to specific places in the city of Santander * |
|---|---|
| **Description** (What?) | This KPI measures the number of times a specific tag was read, or information about a specific place in Santander was requested. Information about the user's phone language can give an idea of the distribution between tourists and locals. |
| **Relevance** (Why?) | This KPI measures popularity of specific places in Santander, denoted by a RFID tag or a specific POI that gets hit using the augmented reality functionality of the SmartSantanderRA. This KPI is of relevant importance for the Santander City Council or tourism agencies/departments, allowing them to use this information for improvement of certain areas of the city, creation of new businesses, etc. |
| **Methodology** (How?) | This KPI is measured at server side (Augmented Reality Server), each time a tag is read a counter increments or each time a specific POI is requested. Information from the mobile phone like language is sent from the mobile phone to the server, allowing the creation of a distribution between locals or tourists. |

Taking into account that both SmartSantanderRA App and the tags provide the same information to the end users, the measurement of this KPI is carried out following two approaches: On the first one, it analyzes how end users access to the POIs information by using the SmartSantanderRA app. On the second one, the KPI is measured by counting the number of times that the different tags have been read.

*Figure 33* shows the evolution of number of requests sent by the users when utilizing the SmartSantanderRA App. During the last 10 months, more than 225.000 requests have been received. Note that requests for the cultural agenda information are not included in this count, as that information is provided by an external content provider.

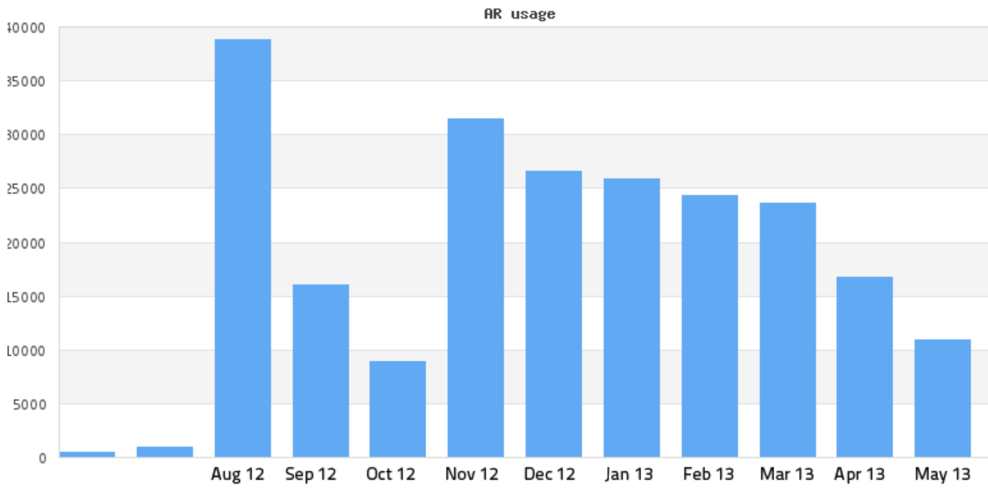



***Figure 33. AR requests evolution***

When using the AR view in SmartSantanderRA app, POIs are divided into five categories: tourism, shopping, cultural agenda, transport and Parks and gardens. Every time the AR Content server receives a new request sent by the end user smartphone, an observation is generated to the SmartSantander platform including context information. The collected information allows service developers to create tools for analyzing the end user behavior. For example, *Figure 34* shows the distribution of requested information, when accessing to the different augmented reality views: 55 % of the requests correspond to transport information, 21% to commerce and 20% to tourism information.

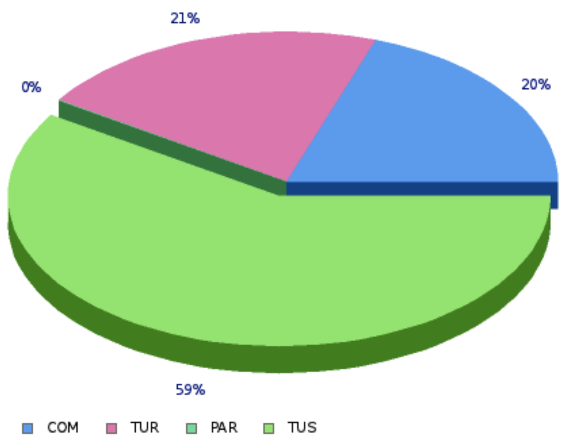



***Figure 34. AR usage by type of information requested***

As occurs with the SmartSantanderRA app, the analysis of number of tags read for each service shows that the most demanded information is that provided by the tags installed in the bus stops.

The next figure presents total number of read tags deployed in bus stops since the installation on March 13, detailing the distribution of NFC and QR code reads. As it can be seen, the increase of readings during this last two months is considerable, reaching almost 7000 reads in this last month.

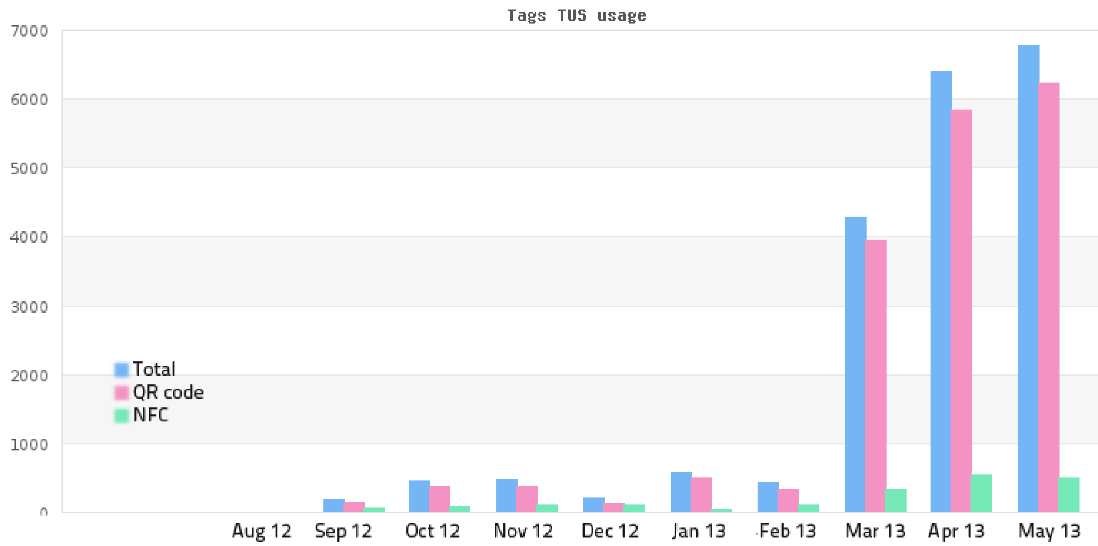



***Figure 35. Number of read tags in bus stops***

As the observations are generated at tag level, the information related to a specific tag can be analyzed in order to extract end user behavior for a particular POI. In this sense, *Figure 36* shows how visitors have read the tag installed in the Magdalena Palace. During the first 4 months. since its installation on Jan 13, most people have used a QR code reader. In May NFC reads have increased, exceeding QR code reads.

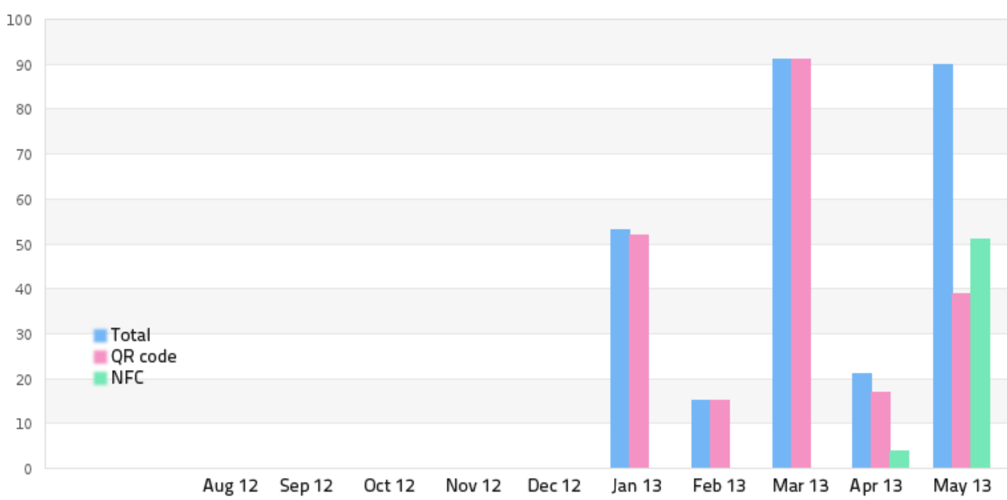



***Figure 36. Number of times that the tag intalled in the Magdalena Palace has been read***

| KPI Name | Number of downloads of the application and user feedback |
|---|---|
| **Description** (What?) | This KPI measures the number of downloads of the applications for both Android and iOS platforms. A temporary overview of downloads is also provided. User feedback (rating of the application), as well as written comments are provided. |
| **Relevance** (Why?) | This KPI is very important for all the consortium, it allows us to have feedback on the applications built, written comments from the users allows us to consider further developments or improvements to the current functionalities. The overview of downloads with temporary information can also be of great importance allowing to identify or map events happening in the city, or publicity of the application and its impact on the acceptance of the application. |
| **Methodology** (How?) | This information can be collected via App Store or Google Play. As developers and submitters of application into both markets we have information about the applications. |

Since its launch on 3rd August 2012, the AR service has reached more than 13500 downloads of the App. In the next pie graph, it is depicted the distribution of downloads by country: 95 % of downloads from Spain, followed by US with 1% and Italy with 0.45 %.

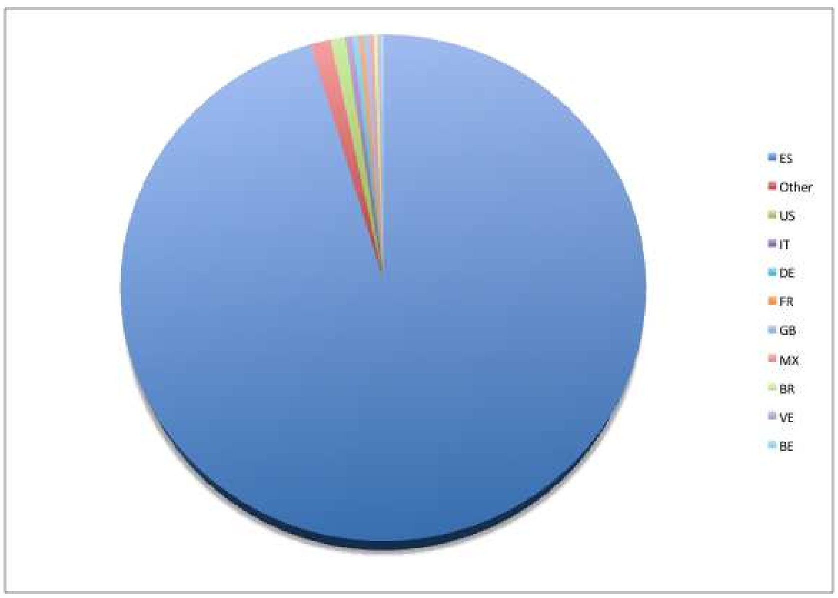



***Figure 37. SmartSantanderRA downloads by country***

## 2.6. Participatory sensing

Participatory Sensing service aims at exploiting the use of citizens' smartphones to make people to become active in contribution and generation data for the SmartSantander Platform.

Citizens, Santander City Council and the local newspaper “El Diario Montañes” are connected into a common platform where they can report, share and be notified of events happening in the city. Users also utilise their mobile phones to send physical sensing information, e.g. GPS coordinates, compass, environmental data such as noise, temperature, etc, feeding this information into the same platform.

The Pace of the City application is the tool provided to citizens in order to generate the Pace of the City. Available for both Android and iOS platforms since November 2012, it has reached more than 3500 downloads. The application provides two main functionalities to the end user. Firstly, the application samples and sends all the sensor measurements, based on the built-in smartphone sensors, periodically to the SmartSantander platform. Secondly the application allows the citizens to report the occurrence of events, which will subsequently be propagated to the SmartSantander platform and shared with the rest of the Pace of the City applications users. Furthermore, users with smart phones can receive the notifications on the occurred events via a smartphone application, by subscribing to the Pace of the City service. The users without a smart phone can subscribe to this service via the web interface of UAS, receiving notifications from the latter on the occurred events via SMS and/or e-mails. This allows both kinds of users to receive alerts for specific types of events currently occurring in the city.

Apart from the Pace of the City application, a web interface has been created both for Santander City Council and Local newspaper El Diario Montañes in order to allow them to report their own geo-positioned events.

Pace of the City Service is linked to their Citizens’ Inbox service at Santander City Council, reporting those events that need to be solved by the municipality. Once they receive an event, they analyse and assign it to the corresponding team. In some cases, depending on the event type, some of them are automatically assigned (the most common ones).

As an example, a user is walking in the city centre and finds a hole in the pavement; he can take a picture, write a text and finally share this incidence with the other users of the application. The Santander City Council will therefore be notified of the occurrence of the event and proceed accordingly by sending an employee to the location in order to fix this problem. Another example can be that a user reports on a road accident, all the other users (drivers) that are subscribed to this type of event will get notified and try to avoid this area. By being also connected to the Participatory Sensing service, the local newspaper “El Diario Montañes” also enriches this body of knowledge by sharing the daily news information with all the other users of the service, The newspaper has created an online information channel called “ElPulsodelaCiudad”, which provides an interface to the citizens to access the Participatory Sensing events as well as public transport information, cultural agenda and sensors values retrieved from the SmartSantander IoT infrastructure from the same website.

As the end recipients of the Pace of the City service, citizens play a very important role in the measurements of the KPIs.

| | |
|---|---|
| **KPI Name** | Number of application downloads |

| | |
|---|---|
| **Description** (What?) | Applications downloaded since it was launched on November 20th 2012 |
| **Relevance** (Why?) | Application is developed for both Android and IOS platforms. This KPI reflects how many citizens have the application and are allowed to send events to the Pace of the City Service |
| **Methodology** (How?) | Sum of downloads provided by Google Play and App Store through Google Play developer console and Itunes connect services, respectively. |
| **Measurement** | More than 5000 people downloaded the application since its launch. |

| | |
|---|---|
| **KPI Name** | Incidents reported to the municipality services |
| **Description** (What?) | How many incidents have been reported since its creation |
| **Relevance** (Why?) | Incidents reported provids a valuable indicator to understand how the citizens have used this service. It is important to note that not all the Pace of the City Events generate an incident to the municipality services |
| **Methodology** (How?) | This KPI is obtained accessing to the Pace of the City service and checking how many incidents have been notified to the municipality services. |
| **KPI value** | Before launching the Pace of the City service, 122 incidents were reported to the municipality services through the citizens' inbox during a 10 month period in 2012. Since November 11th 2012 to the end of the year, 251 incidents were received by the municipality services. During the 2013, 449 incidents have been notified using the Pace of the city application whereas the traditional citizens' inbox has been used 116 to report incidents. |

| | |
|---|---|
| **KPI Name** | Municipality service response time |
| **Description** (What?) | Response time from when an incident has been registered, |
| **Relevance** (Why?) | This KPI provides a good idea of the commitment within the City Council to resolve the problems reported by the citizens. If it is compared with the past, it clearly indicates that the citizens' inbox service has been improved thanks to the Pace of the City Service |
| **Methodology** (How?) * | Citizens' inbox database stores time intervals for all the actuations executed during the incidents resolution process. |

| | |
|---|---|
| **KPI Measurement** | The response time to assign the reported incidents to the relevant service dealing with their resolution is 1.31 days.<br><br>Note that to calculate this KPI, incidents that are assigned directly to the corresponding team are not considered. |

| | |
|---|---|
| **KPI Name** | Time to solve incidents |
| **Description** (What?) | How much time has passed since an incident was created through to its resolution |
| **Relevance** (Why?) | The use of IOT technology has changed the way in which the City Council solves the incidents registered by the citizens, driving a complete reorganization in the municipality services. This KPI allows us to determine how the City Council has improved the response to the citizens. If this indicator is analysed sorting the KPI by municipality service, we can conclude that incidents related to "Public streets" and Police that make this KPI have increased, but, in general, the response is much better since the Pace of the City service was created. |
| **Methodology** (How?) | Citizens' inbox database stores time intervals for all the actions executed during the incidents resolution process. |
| **KPI Measurement** | Before the Pace Of the City service existed, the time to resolution of incidents was 38.5 days. Once the Pace of the City was launched, in the last two months of 2012, this time was reduced to 14.6 days. This KPI has improved even more in 2013, taking 9.43 days on average to solve an incident. |

The following table summarizes the number of incidents reported by citizens to the corresponding municipality service using the Pace of the City application and the media time to resolve them by each service. As can be seen, there are several services, like that of architecture, that notably increase the value of this KPI.

| Service | Number of incidences | Resolution time |
|---|---|---|
| **Water** | 17 | 21 |
| **Architecture** | 7 | 46 |

| | | |
|---|---|---|
| **Police** | 155 | 7 |
| **Culture** | 4 | 7 |
| **Sports** | 5 | 4 |
| **Streets** | 120 | 11 |
| **Public Constructions** | 7 | 17 |
| **Citizen participation** | 14 | 4 |
| **Parks and gardens** | 46 | 8 |
| **Health** | 7 | 5 |
| **Maintenance** | 5 | 9 |
| **Transport** | 21 | 4 |
| **Tourism** | 4 | 12 |
| **Roads management** | 37 | 10 |

| | |
|---|---|
| **KPI Name** | Satisfaction level once the incidence is solved** |
| **Description** (What?) | Citizens opinion about the service and the level of satisfaction once an incidence is closed |
| **Relevance** (Why?) | In order to evaluate the service provided by the municipality, citizens' opinion plays an important role because it is important to know the quality of service the perceived by the user |
| **Methodology** (How?) | This KPI could be obtained creating a form within the Pace of the City application, where the citizens can report their level of satisfaction once the incidence is solved by the corresponding municipality service. |

| | |
|---|---|
| **KPI Name** | User perception of application and service concepts |
| **Description** (What?) | This KPI measures the user's perception of the use case scenario on a conceptual level. |
| **Relevance** (Why?) | This KPI measures the user's perception of the quality and relevance of the service and application, This includes what is good/bad about the concept. |

| | |
|---|---|
| **Methodology** (How?) | This KPI will be measured through interviews and workshops with potential end users. |

| | |
|---|---|
| **KPI Name** | User perception of the design and features of the developed application |
| **Description** (What?) | This KPI measures the user's perception of the design and existing features of the application. It is possible to evaluate/validate the application design by getting the user's feedback on the use of the application and its features. |
| **Relevance** (Why?) | This KPI helps to validate the design and usefulness of the application by getting the feedback from the users and also provide design input for further development of the application |
| **Methodology** (How?) | This KPI will be measured through interviews and workshops with potential end users. |

For the evaluation of the Participatory Sensing scenario end-users were engaged through the use of workshops and qualitative interviews to gain deeper insights into their perception of the participatory sensing application "PulsoDeLaCiudad" in relation to the concept, the design and the functionalities and to get their input to potential areas of development for the application.

As this is a qualitative evaluation the results will not be presented as percentages in graphs. Instead we provide a written summary of insights on how and why people perceive the application and service in a certain way. We explore the user perception of the application and jointly generate ideas for potential future improvements. This kind of knowledge is valuable not only to measure the current perceived quality or effect of the developed application, but also contributes with new insights and inspiration, thereby acting as a guideline for further developments.

A full description of the methods applied and the users engaged can be found in *appendix C*

All respondents engaged during the five qualitative evaluation sessions were generally positive towards the concept of the "PulsoDeLaCiudad" application and related services. Especially the ability to contact the municipality directly via the application is viewed as a valuable service, while the "news service" is viewed as a matter of secondary importance.

People are willing to share their measurements, but do not want to see these measurements shown in the application. Many respondents feel that too much is shown in the user interface which makes the design confusing and cluttered. They would like to be able to limit the amount of information shown. There is a strong request for advanced search functions and more qualified filtering. Finally people stress the importance of validating the information displayed. People will only use the application if they feel the data is correct and can be trusted.

A more detailed description of the main findings and a list of the design inputs generated during the sessions can be found in *appendix D*.

# 3. CONCLUSIONS

The goal of this document was initially to collect the results of the field trials' assessments defined in Task 4.1 [*T4.1*], together with the recommendations for use of IoT for enhancing and improving city services in European cities.

We believe that aim has been reached. Hence, we have analyzed not just the scenarios generated in the baseline of *[D4.1]* but also extended to other scenarios originally not addressed such as participatory sensing, environmental scenario- noise measurement and energy measurement in smart buildings.

After an analysis of KPI values collected we observe that thanks to IoT technology all services assessed have been improved either from a citizen point of view or from authorities/service managers' point of view or even from both. Quantitative and qualitative perspectives also demonstrate the benefits of IoT technology introduction and usage. As examples of such evidence, in the following section we detail the scenarios evaluated in this document:

- Traffic scenario: From the results obtained it is evident that IoT deployment clearly brings a plethora of possibilities to facilitate and optimize parking lot service management.
- Environment scenario – Monitoring of pollutants: Regarding the performed workshops we obtained figures which show the interest and benefits to citizen and authorities from an environmental, economic and societal perspective. As much as 72% of end users find it useful in their daily life. Even more, thanks to IoT sensor deployment, a pollutant map is publicly available and area coverage has been extended. From the workshop results it is evident that end users would like to use results obtained by IoT and suggest service implementation for further data analysis.
- Environment scenario – Noise measurement: thanks to IoT a noise map of the city can be built in a straight forward way, something that could not have been done before. Noise level estimation based on the measurements from a wide set of sensors distributed across a city may provide a more detailed and accurate view of the real time noise distribution in the city. Moreover, as collected values are taken in an automatic mode in real time, it is possible to focus data analysis from specific zones of the city and during specific time windows.
- Energy measurement in smart buildings: prior to the introduction of IoT technology, it was not possible to estimate the energy consumption of user owned appliances (i.e., laptop, desktop computer, LCD screen, battery charger, etc). Thanks to the introduction of such non-intrusive technologies it is now possible to estimate the energy consumption of these small appliances and understand their contribution toward the overall energy consumption of a building during the working day. The evaluation of an initial metric for classifying the consumed energy, into used and wasted, and relying on the definition of energy wasted as energy spent when the user is not present at his work station, allowed us to derive other interesting conclusions otherwise impossible without the introduction of the proposed IoT technology. While the evaluation of the considered metric showed that most of the energy consumed by a user work station can be classified as wasted, thus requiring a more detailed analysis of the used and spent energy and the application of more precise definition and methodology, the initial results show that there is a big margin for improvement and for the experimentation with technology aiming at making the user aware of his energy consumption and waste in order to reduce it. As an initial step towards this, by collecting all this information and by adequately providing it to the user, the impact of such new IoT technology in challenging user

behavior, making it more energy conscious, has been then estimated and evaluated. While a clear and persistent pattern about energy used/wasted was not found after the introduction of the IoT platform, some users showed the correct understanding of the provided technology thus demonstrating the usefulness of the sensors deployment. By studying and analyzing the social interaction of the users with the provided technology it has been possible to identify the relatively small chance technology has in influencing end user habits in technologies such as the one proposed. This wouldn't have been otherwise possible without the establishment of the SmartCCSR deployment and the study performed will be useful to provide adequate guidelines for design and consequently evaluate new and more effectively persuading technology based on IoT.

- Parks and gardens scenario: with the aid of data provided by soil moisture sensors and the development of tools to interact with the smart irrigation control systems, service managers are allowed now to activate irrigation when needed rather than on a predefined schedule. Also the real-time information from the field enables park technicians to adjust irrigation strategies at any time. Instead of taking decisions based on some uncertain average conditions, which may not be even close to reality, or having to be a constant physical presence on-site, a precision park irrigation approach recognizes differences and automates management actions accordingly. For this reason a smartphone application, developed for the Android platform, complements the main web application providing easy access to the measured parameters inside the park areas. The use of IoT technology allows parks and gardens managers to avoid visits to the park in order to inspect the different areas and take the decision whether to irrigate or not. Real time heatmaps derived from the measurements collected by sensors already deployed in Las Llamas Park of Santander City are really valuable for the park managers in order to take the decision on whether to irrigate or not the different zones of the park.
- Tourist and Cultural scenario – SmartSantanderRA is a free Augmented Reality technology app that has been downloaded massively by more than 13500 people in less than one year, providing an interactive experience for both citizens and visitors when walking along the city. It provides a unified access to all city data sources, presents them in a context-sensitive and location aware manner to the end users using augmented reality technology. Additionally, the information implicitly generated by the user when using the application is processed by the system with the aim of acquiring knowledge about citizen preferences, mobility patterns and other statistics. The further analysis of this data will allow the creation of new services and experiments within the smart city context.
- Participatory sensing. Thanks to the"Pace of the city" App developed, quantitative KPIs collected show evidence of improvements gained after the introduction of IoT, Specific examples we have are "City council time to resolve incidents" has decreased from 38 days (before IoT) to 5.71 (after), "Incidents reported to the municipality services", Before launching the Pace of the City service, 122 incidents were reported to the municipality services through the citizens' inbox during 10 months period in 2012 year. Since November 11th 2012 to the end of the year, 251 incidents were received by the municipality services. During the 2013 season, in a six months period, 449 incidences have been reported. From a qualitative point of view it is important to highlight the interest from the population with more than 5000 people downloaded the application in 8 months.

In terms of areas for improvement with IoT in the short term future, we propose the following:

- To increase the number of pollutant nodes in order to extend coverage area .
- Similarly to increase the number of noise sensors to extend coverage area.
- To make available, as a public information (Web Portal Application) to citizens, the noise map

- To extend parking sensors to try to cover all car parking areas of the city.
- Similarly to extend soil moisture sensors to all parks in the city.
- To investigate further how people's habits can be altered to become more energy conscious, relating to energy use within smart buildings.

# 4. REFERENCES



| | |
|---|---|
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| [IR 4.3] | Internal Report 4.3, “Evaluation plan” |
| [D4.1] | Deliverable 4.1, “Baseline report with key performance indicators of selected city services”. |
| [D4.3] | Deliverable 4.3, “Evaluation report on potentials of IoT for enhancing city services”. |
| [T4.1] | Task 4.1, “Assessment of selected scenarios and services”. |
| [T4.2] | Task 4.2, “Development of selected services”. |
| [T4.3] | Task 4.3, “Evaluation of SmartSantander experimental research facility”. |
| [WP4] | Work Package 4, “Development, evaluation and impact of use cases for research community and end-users”. |
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| [Ref2] | LEY 37/2003, de 17 de noviembre, del Ruido.http://www.boe.es/boe/dias/2003/11/18/pdfs/A40494-40505.pdf |
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# 5. APPENDICES

## 5.1. Appendix A: Parking management statistics from Santander City (Year 2011)

| | | | ZONA 2 | | | | | | | | | 2011 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STREET | LINE | BATTERY | LIMITED | LOAD/UNLOAD AREAS 2H | L/U AREAS 4H | DISABLED | TAXIS | MOTOCYCLE | OTHER | BINS | BUS STOPS | WORKS | WORKS U/L 2H | WORKS U/L 4H | TOTAL WORKS | TOTAL PLACES | TOTAL PLACES WITH PAYMENT |
| D. Y VELARDE | 33 | | 33 | | 5 | 1 | | | | 15 | | | | | | 35,5 | 35,5 |
| E.BENOT | 7 | | 7 | | | | | | | | | 3 | | | 3 | 7 | 4 |
| GENERAL MOLA | 21 | | 21 | | | | | | | 8 | | | | | | 21 | 21 |
| GOMEZ OREÑA | 8 | | 8 | | 5 | | | 10 | | 2 | | | | | | 10,5 | 10,5 |
| HERNAN CORTES | 14 | | 14 | | | | | | | 2 | | | | | | 14 | 14 |
| INFANTAS | | | | | | | | | | | | | | | | | |
| LOPE DE VEGA | 44 | | 44 | | | | | | | 7 | | | | | | 44 | 44 |
| LOPEZ DORIGA | | | | | | 4 | | | | | | | | | | | |
| MOCTEZUMA | 6 | | 6 | | | | | | | | | | | | | 6 | 6 |
| PANCHO COSSIO | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P. PEREDA PORTALES | 11 | 11 | | | 5 | | | 2 | | | 11 | 11 |
| PEDRUECA | 6 | 6 | 5 | | | | 1 | | | | 8,5 | 8,5 |
| PIZARRO | | | | | | | | | | | | |
| SANTA LUCIA | 6 | 6 | 7 | | | 4 | 6 | 1 | | | 9,5 | 9,5 |
| P. PEREDA MARGEN SUR | 33 | 33 | | | | | | | | | 33 | 33 |
| P. PEREDA ZONA MARITIMA | 32 | 32 | | 1 | | 11 | | | | | 32 | 32 |
| TOTAL | 221 | 221 | 22 | 6 | 5 | 25 | 41 | 3 | 3 | 3 | 232 | 229 |

| | ZONA 10 | | | | | | | | | | | 2011 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STREET | LINE | BATTERY | LIMITED | LOAD/UNLOAD AREAS 2H | LOAD/UNLOAD AREAS 4H | DISABLED | TAXIS | MOTOCYCLE | OTHER | BINS | BUS STOPS | WORKS | WORKS U/L 2H | WORKS U/L 4H | TOTAL WORKS | TOTAL PLACES | TOTAL PLACES WITH PAYMENT |
| PASEO PEREDA PORTALES | 12 | | 12 | | | | | | 1 | | 1 | | | | | 12 | 12 |
| GENERAL MOLA | 11 | | 11 | | 2 | | 6 | | 2 | 11 | | | | | | 12 | 12 |
| HERNAN CORTES | 9 | | 9 | | 13 | | | 26 | 1 | 9 | | 1 | | | 1 | 15,5 | 14,5 |
| PEÑA HERBOSA | 24 | | 24 | | 3 | 1 | | 7 | 1 | 11 | | | | | | 25,5 | 25,5 |
| BONIFAZ | 25 | | 25 | | 3 | | | | 4 | 8 | | | | | | 26,5 | 26,5 |
| GANDARA | 42 | | 42 | | | 1 | | 17 | 3 | | | | | | | 42 | 42 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SANTA LUCIA | 36 | 36 | 6 | | | | 3 | 15 | | | | 39 | 39 |
| PASADIZO ZORRILLA | 7 | 7 | | | | | | | | | | 7 | 7 |
| JUAN DE LA COSA | 91 | 91 | 7 | | | 3 | 9 | 13 | | 5 | 5 | 94,5 | 89,5 |
| REINA VICTORIA | 52 | 52 | 2 | 2 | | | 6 | 8 | | | | 53 | 53 |
| SAN MARTIN | 30 | 30 | | | | | | 5 | | | | 30 | 30 |
| ANTONIO DEL PUERTO | 8 | 8 | | | | | | | | | | 8 | 8 |
| SAN VICENTE | | | 2 | | | | | | | | | 1 | 1 |
| BARCELONA | 6 | 6 | | | | | | | | | | 6 | 6 |
| ANDRES DEL RIO | 15 | 15 | 3 | | | | 1 | | | | | 16,5 | 16,5 |
| PASEO PEREDA MARGEN SUR | 25 | 25 | | | | | | | | | | 25 | 25 |
| PASEO PEREDA ZONA MARITIMA | 20 | 20 | | 1 | | | | | | | | 20 | 20 |
| TOTAL | 413 | 413 | 41 | 5 | 6 | 53 | 31 | 80 | 1 | 6 | 6 | 433,5 | 427,5 |

SUMMARY OF REGULATED PLACES 2011

| **ZONE** | LINE | BATTERY | LIMITED | LOAD/UNLOAD AREAS 2H | LOAD/UNLOAD AREAS 4H | DISABLED | TAXIS | MOTOCICLES | OTHERS | BINS | BUS STOPS | WORKS | WORKS U/L 2H | WORKS U/L 4H | TOTAL WORKS | TOTAL PLACES | TOTAL PLACES WITH PAYMENT | RESIDENT CARDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZONA2 | 221 | | 221 | | 22 | 6 | 5 | 25 | | 41 | 3 | 3 | | | 3 | 232,0 | 229,0 | 211 |
| ZONA10 | 413 | | 413 | | 41 | 5 | 6 | 53 | 31 | 80 | 1 | 6 | | | 6 | 433,5 | 427,5 | 573 |
| TOTALES | 634 | | 634 | | 63 | 11 | 11 | 78 | 31 | 121 | 4 | 9 | | | 9 | 665,5 | 656,5 | 784 |

RESIDENTS 2011

| ZONE 10 | | | | | ZONE 0 | RESIDENT CARDS + ZONE 0 | TOTAL RESIDENTS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLACES | 10H | 12H | 17H | # CARDS | #CARD | TOTAL | # PLACES | 10H | 12H | 17H | # CARDS |
| 427,5 | 409 | 399 | 228 | 573 | 220 | 1004 | 656,5 | 548 | 533 | 301 | 784 |

**SMARTSANTANDER PROJECT**

| | 14/01/2011 | 31/01/2011 | 15/02/2011 | 28/02/2011 | 15/03/2011 | 30/03/2011 | 14/04/2011 | 29/04/2011 | 13/05/2011 | 30/05/2011 | 15/06/2011 | 30/06/2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 26 | 11 | 7 | 13 | 14 | 21 | 51 | 15 | 21 | 27 | 11 |
| | 27 | 10 | 13 | 11 | 21 | 21 | 4 | 10 | 27 | 4 | 24 | 20 |
| | | | 26 | 10 | 2 | 5 | 9 | 9 | 15 | 19 | 11 | 8 |
| | 12 | 31 | 5 | 8 | 2 | 7 | 12 | | 9 | 12 | | 11 |
| TOTAL FREE PLACES | 57 | 67 | 55 | 36 | 38 | 47 | 46 | 70 | 66 | 56 | 62 | 50 |
| OCCUPIED PLACES (TICK + RESIDENTS) | 599,5 | 589,5 | 601,5 | 620,5 | 618,5 | 609,5 | 610,5 | 586,5 | 590,5 | 600,5 | 594,5 | 606,5 |
| OCCUPIED PLACES (ONLY TICKETS) | 138,8 | 128,8 | 140,8 | 159,8 | 157,8 | 148,8 | 149,8 | 125,8 | 129,8 | 139,8 | 133,8 | 145,8 |
| AVERAGE (TICKETS + RESIDENTS) | 594,50 | | 611,00 | | 614,00 | | 598,50 | | 595,50 | | 600,50 | |
| AVERAGE (ONLY TICKETS) | 133,83 | | 150,33 | | 153,33 | | 137,83 | | 134,83 | | 139,83 | |

SEVENTH FRAMEWORK PROGRAMME

**SMARTSANTANDER PROJECT**

| | 15/07/2011 | 29/07/2011 | 16/08/2011 | 31/08/2011 | 15/09/2011 | 30/09/2011 | 14/10/2011 | 31/10/2011 | 15/11/2011 | 01/12/2011 | 15/12/2011 | 30/12/2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 55 | 25 | 3 | 36 | 17 | 19 | 17 | 34 | 20 | 13 | 11 | 61 |
| | 22 | 3 | | 9 | 6 | 19 | 10 | 4 | 12 | 3 | 17 | 9 |
| | 32 | 11 | 9 | 3 | 22 | 7 | 30 | 29 | 17 | 9 | 6 | 13 |
| | 6 | 7 | 3 | 3 | 5 | | 7 | 19 | 10 | 27 | 6 | 14 |
| TOTAL FREE PLACES | 115 | 46 | 15 | 51 | 50 | 45 | 64 | 86 | 59 | 52 | 40 | 97 |
| OCCUPIED PLACES (TICK + RESIDENTS) | 541,5 | 610,5 | 641,5 | 605,5 | 606,5 | 611,5 | 592,5 | 570,5 | 597,5 | 604,5 | 616,5 | 559,5 |
| OCCUPIED PLACES (ONLY TICKETS) | 80,8 | 149,8 | 180,8 | 144,8 | 145,8 | 150,8 | 131,8 | 109,8 | 136,8 | 143,8 | 155,8 | 98,8 |
| AVERAGE (TICKETS + RESIDENTS) | 576,00 | | 623,50 | | 609 | | 581,5 | | 601 | | 588 | |
| AVERAGE (ONLY TICKETS) | 115,33 | | 162,83 | | 148,3 | | 120,8 | | 140.3 | | 127.3 | |

## 5.2. Appendix B: End user evaluation of the Environment Scenario Monitoring Pollutants

In this section more details about organized workshops are presented. Workshop attendees did not have previous knowledge of the SmartSantander project. The objective of the workshop was orientated towards the IoT service for pollution monitoring deployed in the city of Pančevo, as well as a SmartSantander concept. The data has been collected during workshops where the service is presented to the end users and their feedback is collected.

The survey is composed of the following questions in order to collect some useful information on improvements of the presented service as well as end users satisfaction with the current implementation. A total of 50 end users attended the workshops providing their feedback on the developed technology.

The questionnaire undertaken by the participants contained the following questions:

1. Do you think the application is useful in your daily life? Why?
2. What is good about the concept of this application/service?
3. What is bad about the concept of this application/service?
4. Do you think this is an interesting application for the city?
    a. From an economic perspective, e.g. saves costs?
       (no opinion/strongly disagree/disagree/neutral/agree/strongly agree)
    b. From an environmental perspective, e.g. reduces pollution?
       (no opinion/strongly disagree/disagree/neutral/agree/strongly agree)
    c. From a societal perspective, e.g. helps people?
       (no opinion/strongly disagree/disagree/neutral/agree/strongly agree)

The following results were gathered from this questionnaire:

1. Usefulness of the application in the daily life (see *Figure 38*)
    - 59 % of the end users think that the application is useful in the daily life
    - 18 % of the end users think that the application is not useful in the daily life
    - 23 % of the end users have no opinion on this subject

   Based on the answers provided from this question, the majority of the end users interested in this application are highlighting the importance of the specific area measurement. The area of interest can be the area where people spend most of the time, like public places, parks, or places where pollution is higher like industrial areas or places with heavy traffic. Also, accuracy of the measurements is of great importance for the end users.

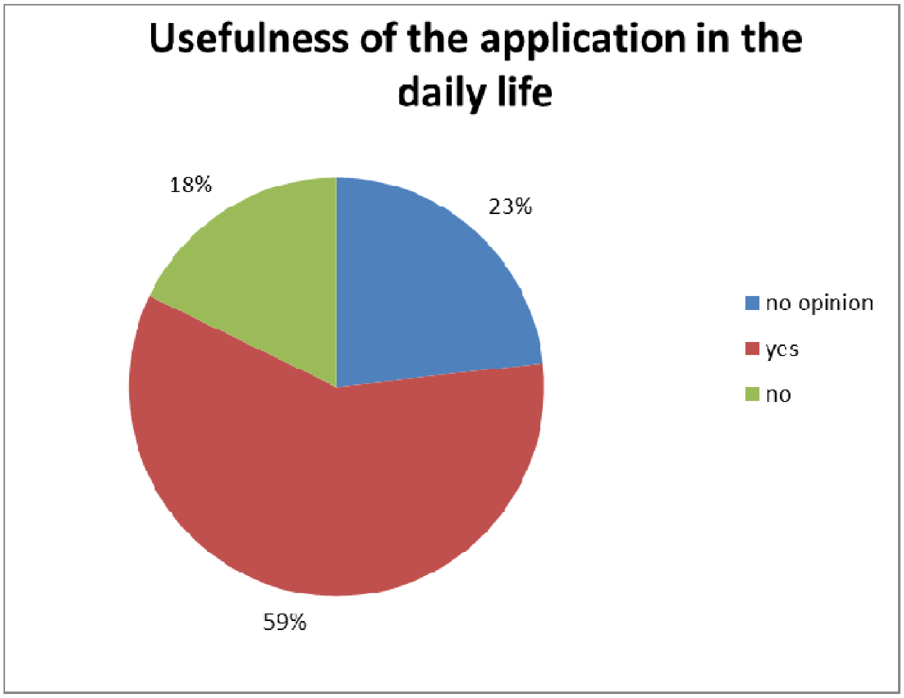


***Figure 38: Feedback about usefulness pollutant App in the daily life.***

2. Benefits of the application/service (what is good about the concept of this application/service? see *Figure 39*)

- 74 % of the end users provided a feedback
- 26 % of the end users have no opinion on this subject

The main points raised are: it's good that everyone can be involved in monitoring the pollution in the city; it can raise awareness about pollution and the quality of environment in the area; it's easy to use and a lot of information is provided in one place in real-time; it provides accurate measurements that citizens are interested in; gathered data is available over internet or mobile application.

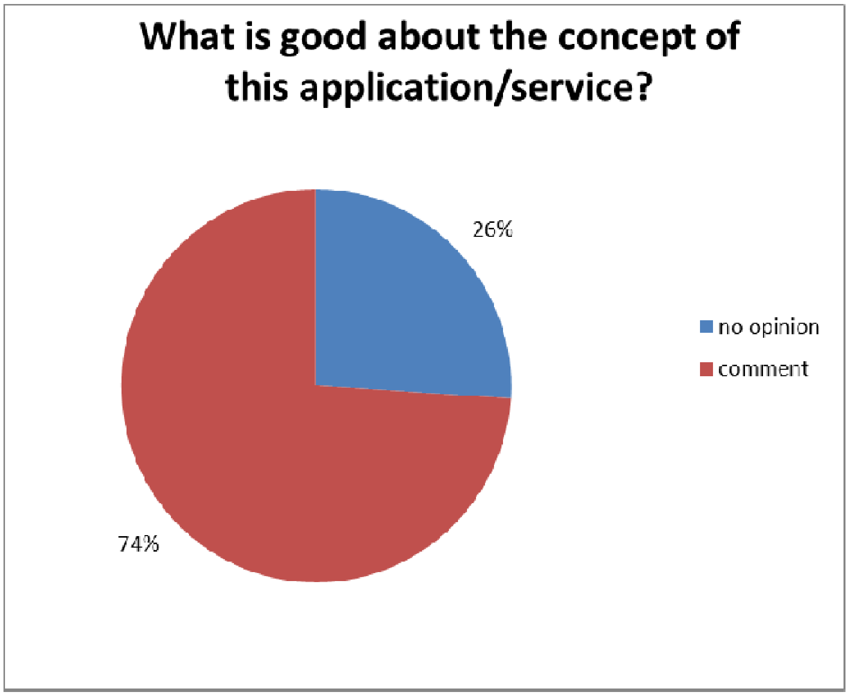


*Figure 39: Feedback about benefits of pollutant App.*

3. Improvements that can be introduced in the application/service (what is bad about the concept of this application/service?)

 - 36 % of the end users provided a feedback
 - 64 % of the end users have no opinion on this subject

 The main points raised are: It could be enhanced with additional sensors and some analysis of the measurements in regard to the allowed ranges and comparisons with other cities in the region and the world; presentation of monthly/yearly historical data; accreditation of the collected measurements. See results in *Figure 40*

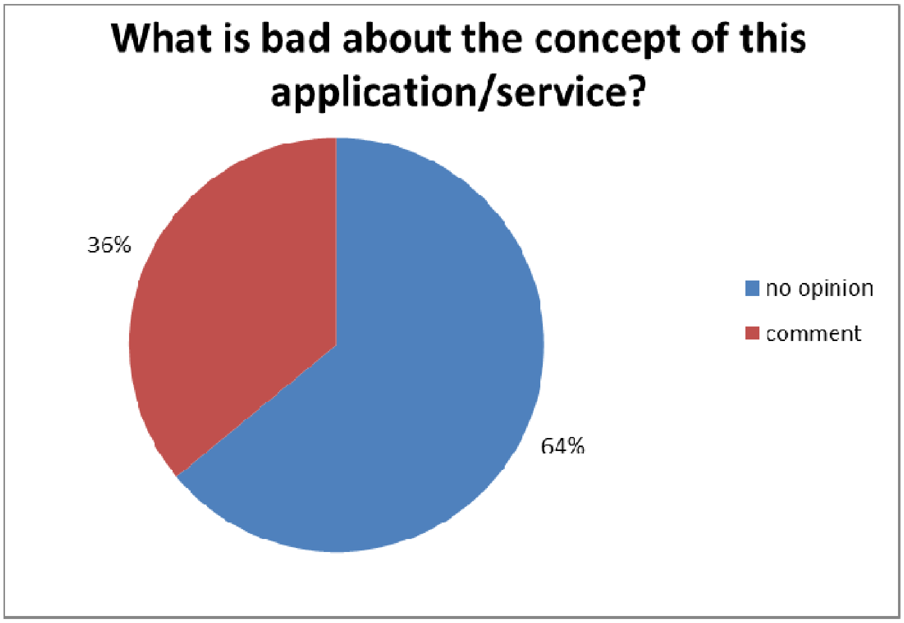


*Figure 40: Feedback about pollutant App improvements.*

4. The value of the application for the city from different perspectives (see *Figure 41*)

   From economic perspective, 42 % of end users agree that this is an interesting application for the city. The following results were gathered:

   - 30 % of the end users have no opinion on this subject
   - 2 % of the end users strongly disagree and 6 % disagree that the application brings any value for the city from economic perspective
   - 20 % of the end users are neutral on this subject
   - 26 % of the end users agree and 16 % strongly agree that the application brings a value for the city from economic perspective

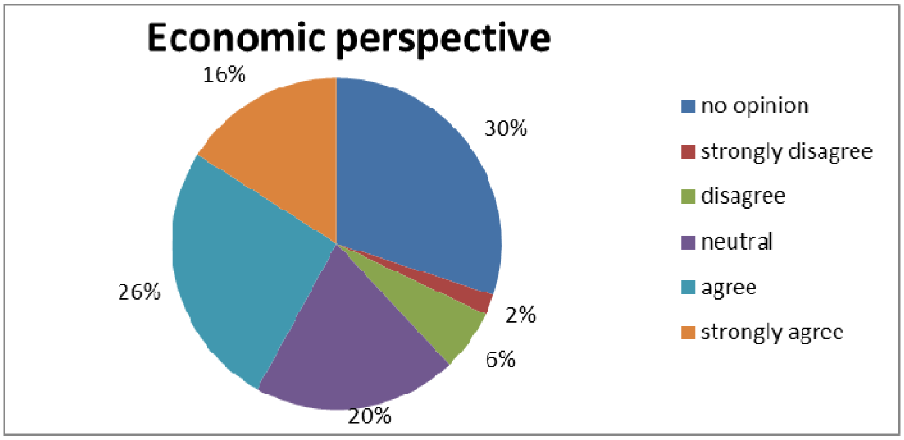


*Figure 41: Value of pollutant App from economic perspective.*

From environmental perspective (see *Figure 42*), 62 % of end users agree that this is an interesting application for the city. The following results are gathered:

- 24 % of the end users have no opinion on this subject
- 6 % of the end users strongly disagree and 4 % disagree that the application brings any value for the city from environmental perspective
- 4 % of the end users are neutral on this subject
- 30 % of the end users agree and 32 % strongly agree that the application brings a value for the city from environmental perspective

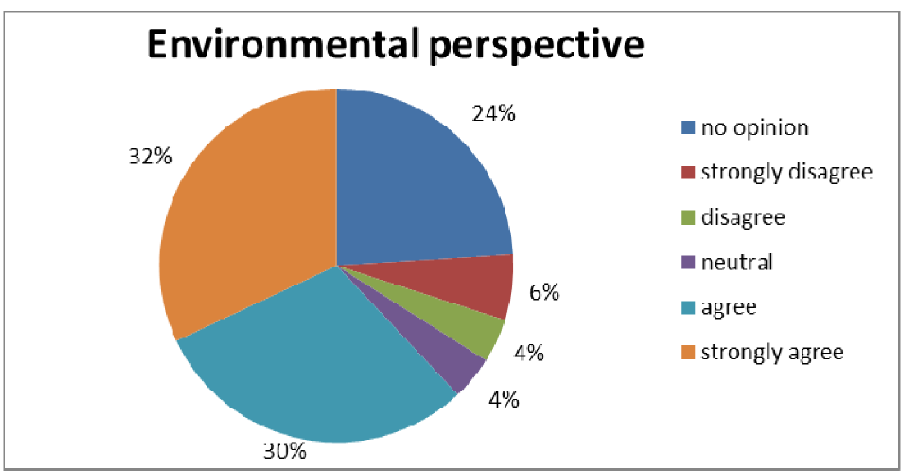


*Figure 42: Value of pollutant App from environment perspective.*

From societal perspective (see *Figure 43*), 72 % of end users agree that this is an interesting application for the city. The following results are gathered:

- 18 % of the end users have no opinion on this subject
- 2 % of the end users strongly disagree and 4 % disagree that the application brings any value for the city from societal perspective
- 4 % of the end users are neutral on this subject
- 46 % of the end users agree and 26 % strongly agree that the application brings a value for the city from societal perspective

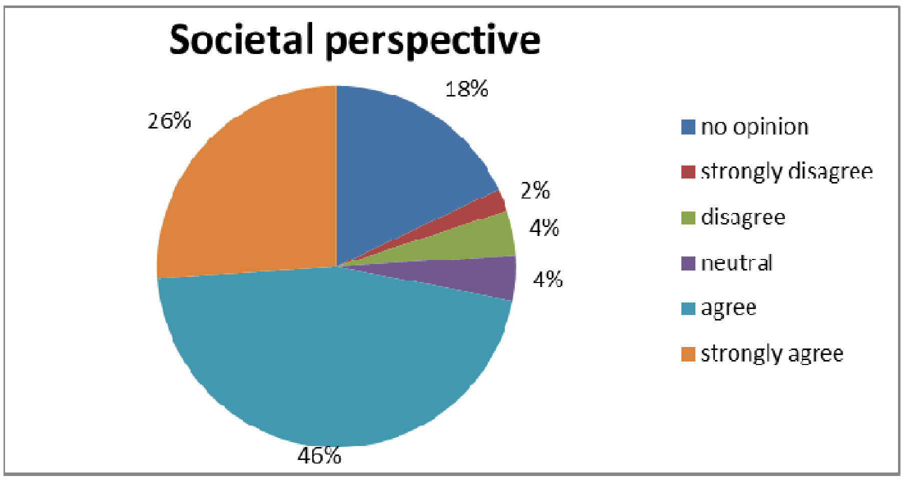


***Figure 43: Value of  pollutant App from social perspective.***

## 5.3. Appendix C: End User Evaluation of the Participatory Sensing Scenario: Method, Users and Preconditions.

Three workshops and two in depth qualitative interviews were carried out over a period of two weeks.

The users had no prior knowledge of the SmartSantander project. They were asked to download the app before the sessions, but were not expected to use it actively. In addition there was a language barrier in the fact that none of the participants spoke Spanish. These preconditions can all potentially complicate the evaluation process, but this does not mean that a meaningful evaluation could not be accomplished. We started with a thorough introduction to the project and the application and its concept, to make sure the users understood the project set up, as well as the context of the application. All sessions therefore began with a 20 min overall introduction to the application and the project.

The following sessions took their point of departure in an open-ended interview guide. The overall themes covered were:

What do you think about the concept?

- Direct and easy contact to the municipality
- Local news

What do you think of the design/functionalities?

- How does it look
- Are you able to do the things you want to
- How is it to navigate
- What other features would you like the app to provide

Even though some of the above are formulated as questions they are merely regarded as guidelines, ensuring that all the themes were covered. The specific sessions took very different directions depending on the interests and ideas of the participants and this was allowed and supported by the facilitator to get as much information as possible from the participants.

People with a more technical background, who were also very experienced app users, were able to give more detailed feed back in relation to the design and functionalities while the less experienced app users tended to keep their focus on the conceptual issues.

After discussing the central themes outlined above participants were asked to brainstorm ideas for potential improvements of the application or service. Subsequently they were asked to choose the two they found most important, useful or interesting and we then spent time jointly elaborating further on those. In the interviews one idea was chosen ("if you should give one recommendation for something that you want to be able to do with the application – What would it be?") and discussed in depth.

## Overview of Sessions and Participants

Interview 1

Private home 21st of May

Participant: Morten

Workshop 1

Private home wed 22nd of May

Participants: Anne, Kasper, Maibritt, Mie

Workshop 2

Alexandra Institute on the 24th of May

Participants: Mads, Laura

Interview 2

Private home 26th of May

Participants: Kristina

Workshop 3

Statsbiblioteket 28th

Participants: Julie, Jonas, Maria, Thomas

More details are shown in *Table 5*.

| Name | Session | Age | Profession | OS used |
|---|---|---|---|---|
| Anne | WS1 | 28 | Architect | Android |
| Kasper | WS1 | 27 | Economist | Android |
| Thomas | WS3 | 35 | Teacher | iOS |
| Maria | WS3 | 31 | Designer | iOS |
| Julie | WS3 | 30 | Journalist | iOS |
| Laura | WS2 | 27 | Anthropologist | Android |
| Mads | WS2 | 32 | Computer scientist | Andriod |
| Maibritt | WS1 | 31 | Anthropologist | Android |
| Kristina | I2 | 35 | Dentist | iOS |
| Morten | I1 | 37 | Building engineer | iOS |
| Mie | WS1 | 32 | Nurse | iOS |
| Jonas | WS3 | 32 | PhD - Information and Media Studies | iOS |

***Table 5, Sessions and participants in Qualitative Psens Workshops***

## 5.4. Appendix D: End User Evaluation of the Participatory Sensing Scenario: Main Findings and Design Inputs.

## Main findings

Although the workshops took quite different directions the following write up presents the findings from all five sessions as a collected entity to increase readability, outlining central themes across the sessions.

## Concept

### Posting Reports// Contact to the Municipality

When it comes to contact to the municipality, people are generally very positive towards this idea. They like the opportunity to get in touch with the municipality in an easy way. On the other hand some are also worried, that it might lead to an abundance of complaints that will require a lot or resources for the municipality to manage

### Local news

In relation to the news people are mostly interested in local events: information on what is going on, when and where. A new restaurant opening or a cool event within their areas of interest. “Regular” news they would rather get elsewhere and most are not really that interested in geotagging of this type of news.

They see the point from the newspaper’s perspective in getting access to the data provided via the application in order to locate potential stories and provide more relevant news.

People generally seem to be most positive towards the idea of enabling contact to the municipality and show no great interest in getting the news via the application. It is difficult to say how much the language barrier influences this finding. None of the participants speak Spanish, so the news presented in the app makes no sense to them. Some say that the “news feature” could be interesting in relation to special events in the city – like the Aarhus festival, where it would be relevant to know what is going on different places in the city. But in their normal everyday life they would rather just visit the newspaper website to get their daily news input.

## Design//Functionalities

### Measurements

All participants answered that they would be willing to share sensor data. They all see the point in providing the information to the platform to enable new services. On the other hand they have no interest in seeing all the measurements in the application. That should be something separate most of them feel.

*I have no interest in seeing other people's measurements. I don't event really know what the different numbers mean or how to read them in a meaningful way. So as default they should not be visible*

### Categories and Icons

Respondents like the fact that events are categorized enabling them to filter out information not relevant to them and only get information within their areas of interest.

*"I like the fact that I can choose the subjects I am interested in and focus on those"*

The icons are also viewed as a positive feature. Along with the categories they make it easier to get a quick overview of the different events, but not all of them make sense to the end users

*"What is the culture icon? To me it looks like the colosseum. I don't get that. It does not really make sense…?"*

Though users agree that the intentions of these individual features are good, they still also feel that they are not being used to their full in the application. Many initially say that the interface appears chaotic, despite the effort to develop different layers of information and enabling people to filter out post they find irrelevant.

"tror der skal arbejdes lidt mere med det – det er som om, det virker lidt ufærdigt"

### Filters and Search Functions

Many users say that too much is shown on the screen at the same time, which makes the design somewhat confusing, creating an information overload and making the interface appear cluttered.

As a user you can clean it up by choosing to view a specific category, but most users would rather have it the other way around. They would rather see as little as possible to begin with and then add on layers of information corresponding to their needs and interests.

Another very important requirement that all users agree on is the request for more advanced search functions.

*"When so much information is contained in one application it makes high quality search functions very important. Otherwise it is just impossible to navigate!!"*

People find it very frustrating that you are not able to set multiple search parameters simultaneously. It makes it harder to find, what you are looking for. A few people also point to the fact that they find it annoying when they are directed to a "search page" and argue that it would be more convenient if you could stay on the same screen instead of being redirected. But the main issue without a doubt is the need for more advanced search functions.

### Events/Report?

There are several differences in configuration between Android and iOS. It is not a big problem, if you just have your own version, but when you compare across the two (as we did in the workshops) some differences leap out immediately. In the sessions we spent a lot of time discussing the difference between "Events" and "Reports". Users perceive "events" as something that happens in the future – like a concert next Saturday. Whereas "report" on the other hand is seen as something that has happened, that you want to tell somebody about. So to them it would make the most sense, if messages sent to the municipality were called "reports". Alternatively "posts" is suggested as a neutral term (ws3).

### Validation of Information

It is very important to all the respondents that the information provided can be trusted, otherwise the app will have no value to them. If the data turns out not to be valid, people will stop using the application. If the information is doubtful, and you feel you have to check other sources as well, it is inconvenient and users might as well find the information elsewhere where they trust the information and the sender.

Some say that they consider the events/reports posted by the newspaper more credible than the rest of the posts (that are anonymous). People know that the newspaper would probably not print something unless they checked it first – but all the other posts do not have a clear sender, which by default makes them less trustworthy.

All users are positive towards the fact that you can follow the status of the events/reports posted. They consider this a sort of validation. If the municipality take the incident seriously and work to correct it the information must be valid. Also it gives an insight into the work in the municipality that might otherwise be obscure to the general public. Now it becomes very visible and easier for people to follow, creating increased openness.

## Design input

A lot of interesting inputs were generated during the five sessions. The ideas very much centered around validation of data, personalization of settings and advanced search options, picking up on the central themes of the evaluation.

In the following lines the eight design concepts developed are presented in outline. Further information on the diff concepts can be found in the appendix.

**#1: Calendar View** (ws 1)

The system provides a calendar view as well as a geotagging of news and events.

**#2: Mood Tagging of Events/Reports** (Interview 2)

Posts are labeled (pos/neg – maybe using smiley) so you can filter out negative comments, if you wish to do so.

**#3: User Validation of Events** (ws1)

Letting other people know what you think about events (like/dislike) to help each other rate or validate posts

**#4: Personal Settings** (Interview 1)

You can "build" your own interface according to your specific interests, and the system remembers and saves these preferences.

**#5: Advanced Search Options** (WS2)

The system enables advanced search options – like for instance using several search parameters simultaneously.

**#6: System validation of data** (WS2)

The system provides automatic validation of data, possibly drawing on other relevant (open) data sources.

**#7: Less is more** (WS3)

As default less information is shown. This would make it easier to get a quick overview

**#8: Multiple Search Parameters** (WS3)

The system enabels multiple search parameters so you can search for instance category, time and location at the same time.