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		EU FP7- ENV-2012 Collaborative project

Deliverable D 6.4

Final report on methodology

Work Package 6

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0.4	17.05.2016	Content Perception questionnaire	A. Tamilin
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Peer review summary

Internal review 1			
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Internal review 2			
Reviewer	Johanna Robinson (JSI)		
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Executive Summary

This document is a technical description of the CITI-SENSE main products described in the CITI-SENSE portfolio of products (Annex D). The status is related to the date of completion of this document (June 30 2016). These products were developed, extended or adjusted in this project to fulfil and maintain the overall chain "sensors-platform-products-users" with primary focus on the interface and link between the products and the end users.

The products are described from a developer's view with description of architecture, code structures and database and storage platforms used. This differs from the D6.2 "Interim report on the methodology to link elements" which was an initial description of possible solutions based on requirements found in collaboration with CITI-SENSE's three Empowerment Initiatives i) Urban Quality, ii) Public Spaces, and iii) School Indoor Quality. One product, SENSE-IT-NOW, part of the Environmental Empowerment toolkit in public places, was developed during the project and is based on the interim report's suggestion of a smartphone application to support the Empowerment Initiatives (EIs).

Some of our products are 3rd party properties and belong to SMEs and partners within this project. These products have been extended or updated based on our internal and external tests, or further developed according to new requirements to align with the aim of this project and to help the EIs to do successful engagement activities with the users. In some of these cases the development code is not open for the public. This can be complete code of smartphone applications like the ExpoApp, CivicFlow, or parts of algorithms and procedures developed. But we also have open source codes and products:

- Data visualization web page and widgets code
  - Widgets code: http://citisense.u-hopper.com/
  - Web page: http://srv.dunavnet.eu/new/citisense/OutdoorDataPortal/

- SENSE-IT-NOW – Cross platform smartphone application for environmental monitoring toolkit for public places
  - Code: https://git.nilu.no/citi-sense/sense-it-now

- CityAir Cross platform smartphone application for collecting citizens air quality perceptions
  - Code: https://git.nilu.no/citi-sense/cityair

This document consist of one chapter for each product according to the Annex D. Each chapter follows almost the same structure of sections:
- Case studies, what requirements where given and from who and what it solves
- Technical description, architecture, code structure and data storage
- Suggested improvements and lessons learned
- Current status of the product

Table of contents

1 Context of this deliverable

This document is related to other deliverables and documents developed in the CITI-SENSE project. This additional information should be considered to get the full overview of the products and services in the project. This table lists the most related documentations:

Table 1-1 Links between this deliverable and other existing and planned deliverables

Requirements for products and services and information about planned case studies for different locations	**D2.1 Pilot Case Study Protocol (RE[1])** **D3.1 Pilot Case Study Protocol (RE)**
Refinement of requirements after evaluating the pilot study	**D2.2 Pilot study evaluation and main study protocol: from phase 1 to phase 2 of the CITI-SENSE urban air Empowerment Initiative (RE)** **D3.2 Pilot study evaluation and protocol for phase 2 (RE)**
Description of CITI-SENSE architecture and platform, specifications and operations	**Current document D7.5 CITI-SENSE Platform and architecture (PU[2]), updated version will be available in September 2016, D7.6 (PU)**
Information about the Citizens' Observatories Toolbox (COT) with software, hardware, services, resources, guidance and procedures	**http://co.citi-sense.eu/CitizensObservatoriesToolbox.aspx**
Testing and evaluation of products	**D6.5 Report on implementation and demonstration (PU, September 2016)**
Description of other products, services and sensors providers (those not part of Annex D)	**D7.5 CITI-SENSE Platform and architecture (PU), updated version Sept.2016, D7.6 (PU)**
Definition of sensor platforms, results of validations tests in laboratory and field campaigns	**D8.2 Pilot Studies Platform (RE)**

[1] RE – Dissemination level: Restricted to a group specified by the consortium
[2] PU – Dissemination level: Public

2 Personal Air Monitoring Toolkit

The toolkit includes the mobile sensor unit LEO (Little Environmental Observatory) and the ExpoApp application for mobile devices.

2.1 Little Environmental Observatory (LEO)

The LEO (**Error! Reference source not found.**-1) is a portable sensor pack. It measures NO, NO_2 and O_3 using electrochemical sensors. It also measures the current temperature and relative humidity.

Figure 2-1 Little Environmental Observatory

The sensor unit requires a connection to an Android smartphone with Bluetooth connectivity in order to collect data.

2.2 ExpoApp

ExpoApp is an application for Android devices that communicates with the LEO. It reads and uploads the observations from the LEO and it also reads and uploads information from the user's smartphone about location and physical activity recorded by the so called accelerometer that is already built-in in each smartphone. The ExpoApp allows the user to establish the connection between the LEO device and the smartphone via Bluetooth. It also provides a quick access to information about the status of the communication between the smartphone and the sensor and between the sensor and the server. The results are displayed as an APIN – Air Pollution Indicator Value. This indicator is related to a Common Air Quality Index CAQI, but cannot directly be compared as the air quality monitoring methods underlying the measurements differ.

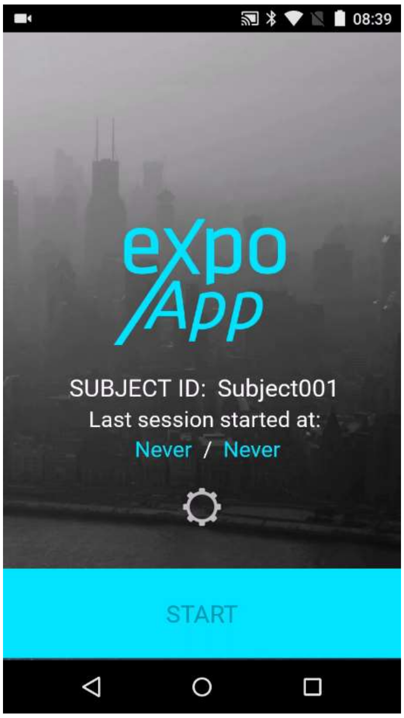


Figure 2-2. ExpoApp Initial Screen

2.3 Installation Requirements:

The hardware requirements for installation are:

- Android Smartphone with Bluetooth 2.0, GPS and accelerometer
- Android 2.3.3 (GINGERBREAD_MR1) or later
- Dual core CPU smartphone[3].

2.3.1 Battery life

While the battery life of the smartphone is dependent upon how intensely the user interacts with the phone, ExpoApp has been designed so that it minimizes battery use, in order to be able to log data for up to a 16-hour period (approximately the duration of waking hours). However, the real battery life is highly dependent on the location of the user and the amount of signal, as well as the physical activity, and I practice much shorter times have been recorded.

2.4 Technical description

ExpoApp uses the smart phone's built in GPS receiver and accelerometer to track the user's physical activity and the location of the participant. The ExpoApp allows the user to establish the connection between the LEO device and the smartphone via Bluetooth.

2.4.1 Development Environment

Since the use of the LEO sensors is limited to Android devices, ExpoApp was developed as a native app. There are a number of advantages to writing apps in this way: they offer the fastest, most reliable and

[3] Due to the high volume of data and hardware interruption when polling the smartphone sensors when the app is running, it is recommended for the app to be used in dual core smartphones.

most responsive experience to users and can tap into the wider functionality of the device, including accelerometer, location and notifications.

The development environment used to develop the app was Android studio which is the official integrated development environment (IDE) for Android platform development.

The app also has a visualization part (Figure 2-3 and Figure 2-4). This part was developed using HTML5 instead of the native Java used for android devices, and is based on the several widgets developed in the project.

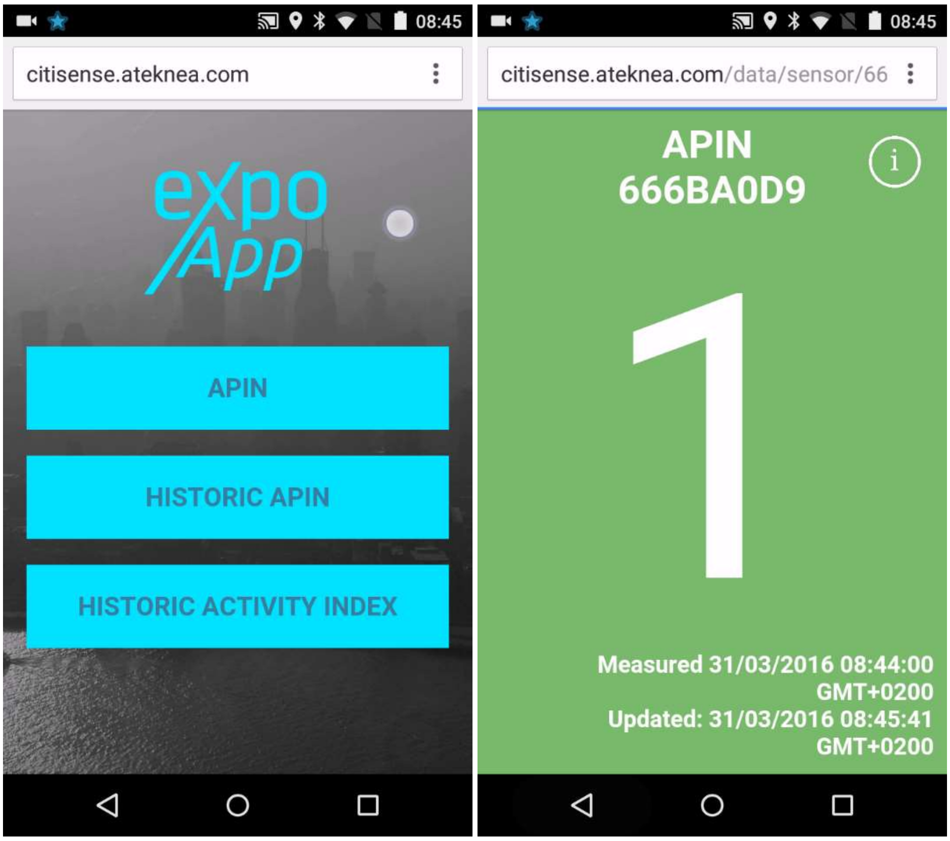


Figure 2-3. HTML5 Visualizations in ExpoApp

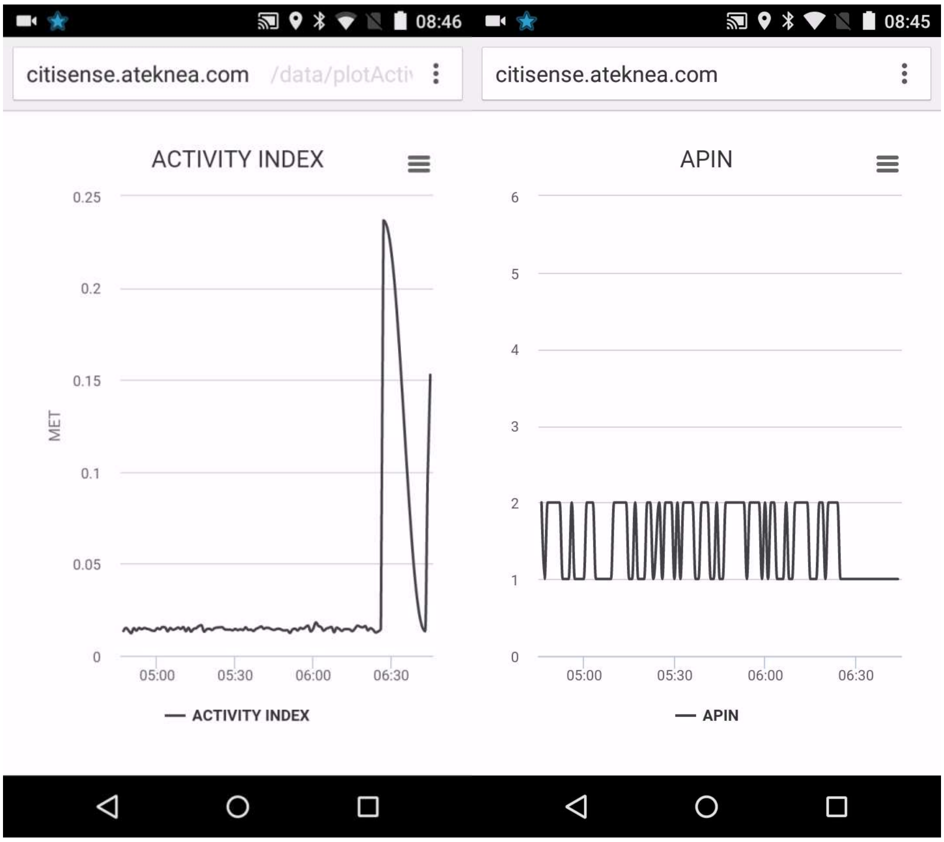


Figure 2-4. Visualizations in ExpoApp

2.4.2 Architecture

ExpoApp was designed to be a modular app. Several independent services are loaded in specific times in the background of the app that communicate internally by means broadcast messages. The main services are:

- Main service: In charge of the visualization of the app. All the information and graphical interface is handled by this service.
- Bluetooth service: In charge of handling the communication with the LEO sensors.
- Sensor polling service: This service is in charge of polling the available sensors in the smartphone. For the specific case of CITI-SENSE only the GPS and accelerometer sensors are used.
- Data upload service: In charge of uploading the files contain the session data generated by the sensors.

The figure 2-5 below shows the main components involved in running the Little Environmental Observatory.

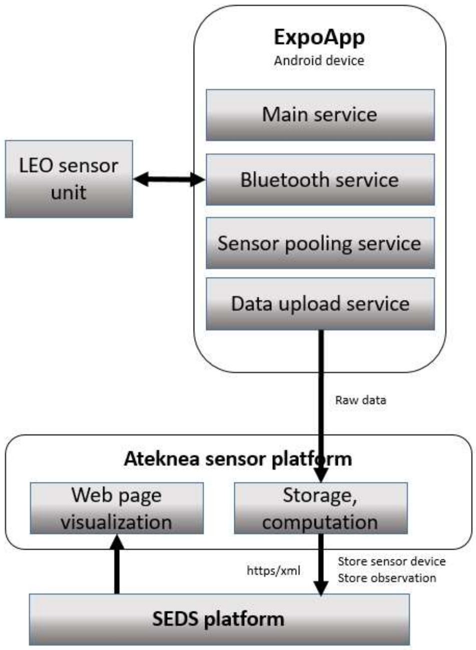


Figure 2-5 LEO system architecture

2.5 Planned further improvements, problems, weaknesses, lessons learned

2.5.1 Sensor Communication Reliability

Developing apps for Android devices is a difficult task due to the large pool of available hardware. This makes it particularly complicated when using the Bluetooth connectivity. The LEO sensor makes use of Bluetooth 2.0 to communicate with the smartphone.

The app has been tested in several android devices and unfortunately some fail to maintain a reliable connection. Several bugs related to this issue have been identified and fixed.
For the new version of the LEO sensor only Bluetooth ready smartphones will be used. Hence, this will guaranteed that the latest hardware of android devices is used with the sensor.

2.6 Current Status

The current version of ExpoApp is 0.8.5 (version on 15.06.2016). During the period of the project several bugs have been fixed with each release of the app.
The latest versions improves the performance and reliability of the communication of the LEO and smartphone as well as the upload service.

3 CityAir

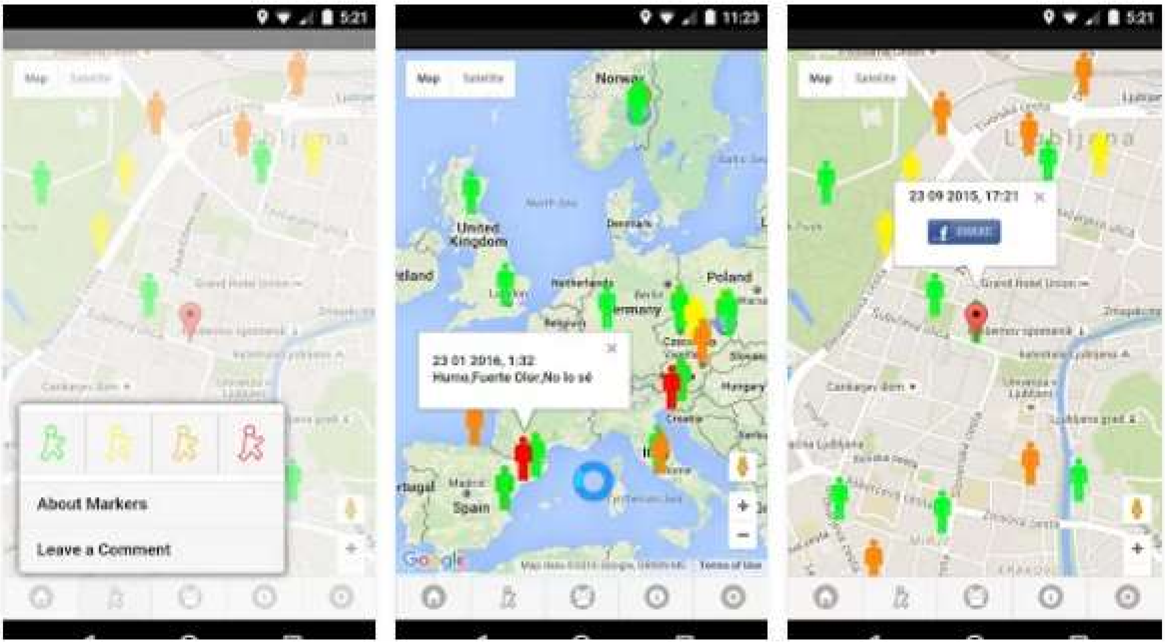


Figure 3-1 Screenshots of the CityAir app

CityAir is a smartphone application developed for the android and iOS platform to collect users' perception of the current air quality at a specific geographical position.

3.1 Case studies

The requirement for a tool for collecting citizens' perceptions about air quality using smartphones, was raised by Work Package 2 Urban Quality (WP2). A development for an Oslo specific app for displaying air quality measurements from sensor devices and collect user opinions about the current air quality was ongoing at the time in the collaboration with EMMIIA project Citi-Sense-MOB[4].

Development for a generic perception smartphone application was therefore based on this ongoing work.

3.1.1 Requirements

The following requirements were addressed:

[4] http://cwi.unik.no/wiki/CSM:Home

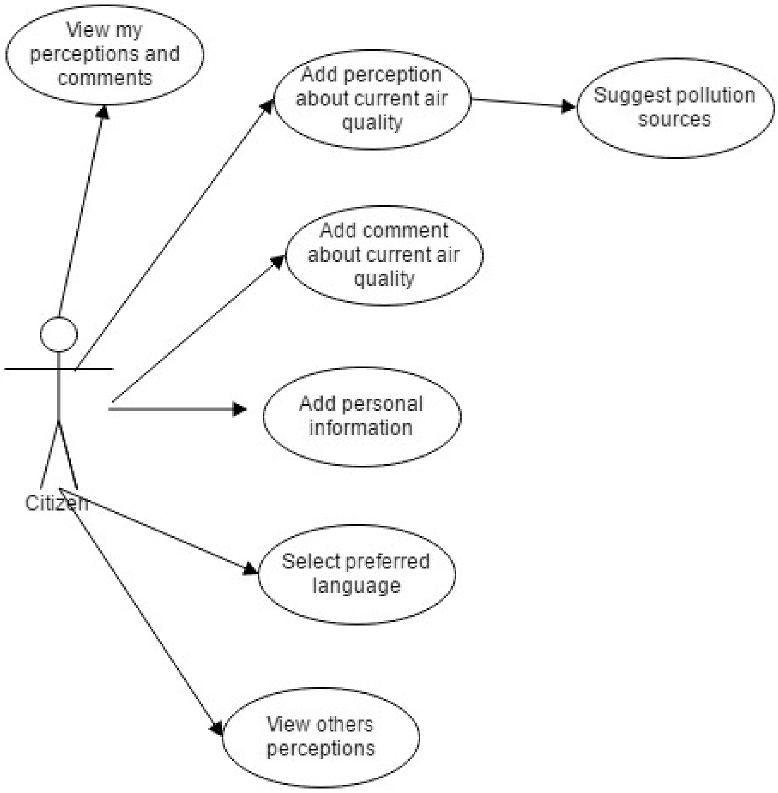


Figure 3-2 Use Case diagrams for requirements

View my perceptions and comments
The user can view his/hers perceptions and comments marked on a map.

Add perception about current air quality
The user will click a marker and select between green, yellow, orange and red to indicate his/hers perception about the air quality where the user is at the current moment.

If the user indicates other that green, the user will be presented with a list of possible pollution sources and asked to suggest what causes the pollution.

Add comment about current air quality
The user can open a text field and write a comment. This will be stored on the current GPS position detected by the phone and marked on the map.

Add personal information
The user chooses to add personal information about gender, year born and education level. This is not mandatory and the information will be prefilled with some default data.

Select preferred language
The user can choose a language from a list and app will change the text accordingly. Currently English, Norwegian, Spanish, Catalan, Serbian, Czech and Slovene are available.

View others' perceptions
The user can view perceptions and markers added by others.

3.2 Technical description

3.2.1 Development environment

This application has been developed using Microsoft Visual Studio 2015 with the VS Tool for Apache Cordova. It was a consortium agreement to go for a HTML5 based smart phone application, based on the requirements from the Air Quality App Working group within WP2 and the platform architecture developed within this project.

The requirements from the Air Quality App Working group highlighted a need to support both iOS and Android platforms, but did not describe extensive use of the phones' hardware and not much interaction with the end user. The requirements and mock-ups can be found in ANNEX A and ANNEX B. In this context developing a cross platform application seemed to be cost effective due to one code base for all platforms and would fit within the requirements.

Choosing Cordova as a platform for developing the CityAir is also aligned with the CITI-SENSE platform architecture and made it possible for easy reuse of the widgets developed in JavaScript. Widgets are small pieces of code or application with limited functionality. In the CITI-SENSE projects we developed widgets for creating common visualizing of the collected data, using jQuery; a cross-platform JavaScript library. The CITI-SENSE platform is described in detail in D7.4 CITI-SENSE Platform and Architecture Version 2.0.

CityAir uses the jQuery Mobile framework (https://jquerymobile.com/), a HTML5 based JavaScript library, for graphical user interfaces. This framework is compatible with a large variety of smartphones, tablets and desktops. In addition CityAir use the jQuery Mobile Icon Pack for creating buttons and icons.

3.2.2 Architecture

Context diagram

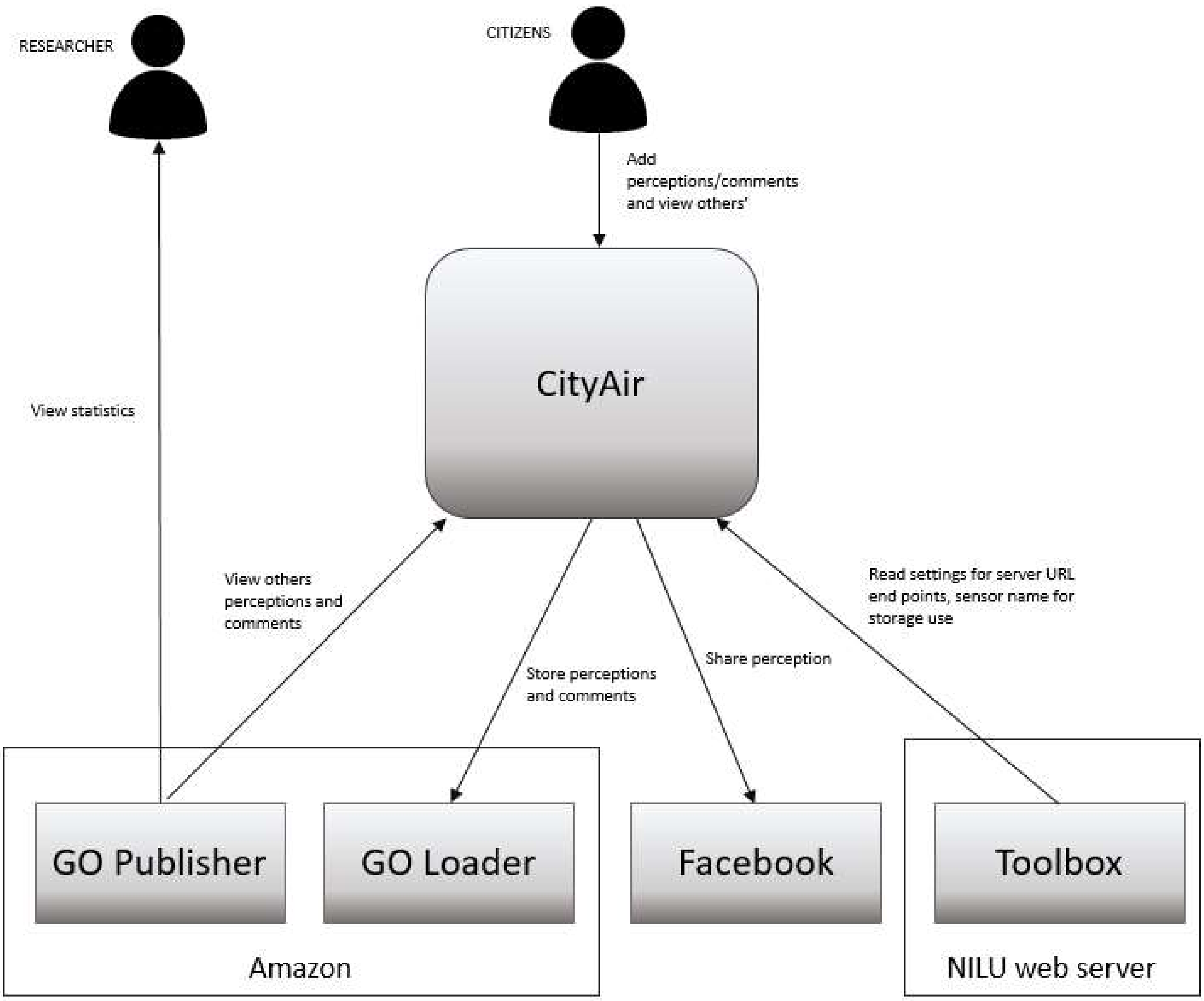


Figure 3-3 CityAir Context Diagram

The CityAir application works in a wider context and communicates with different services across the Internet. It stores the registered perceptions on the CITI-SENSE platform using a product called GO Loader. And can also download perceptions reported by other CityAir users using the GO Publisher. This is also an endpoint that researcher can download the collected perceptions with the personal information.
The user can also choose to share a perception on his/hers personal Facebook wall as a link to a page that displays the reported perception.

Containers diagram

On the unit, CityAir app uses the built in HTML Rendering engine run the application. The next figure 3-4 shows the common architecture for a Cordova based application on Android or iOS platforms.

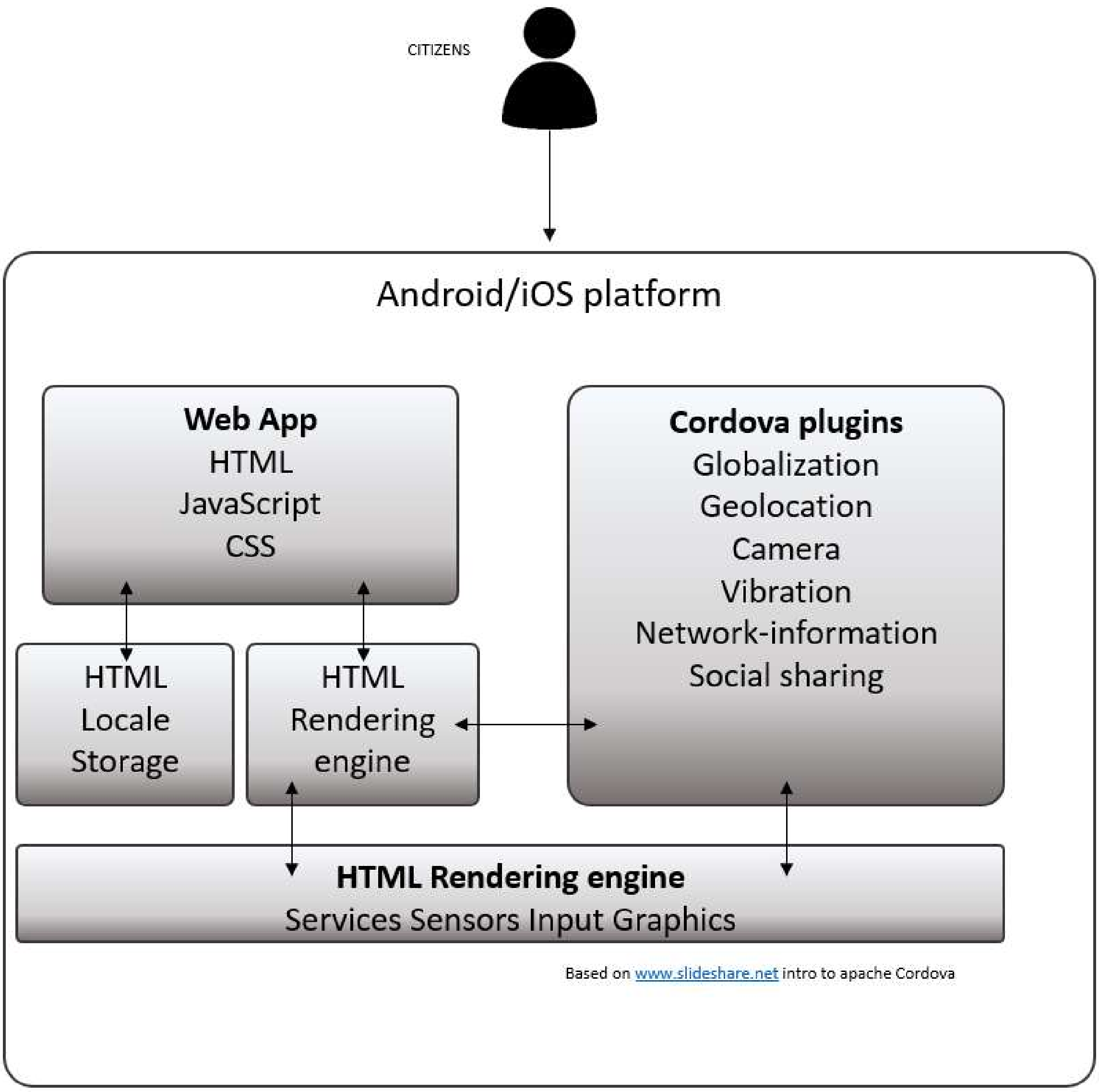


Figure 3-4 CityAir Containers diagram

The Cordova community offers a wide range of native plugins to add functionality to communicate with the native layer of the device and make use of the device's camera, built in applications like Facebook app, GPS sensors and file systems.

Components diagram

The figure 3-5 shows one of the major components of the CityAir app and their interactions, the process of uploading the local stored perceptions and comments to the cloud server.

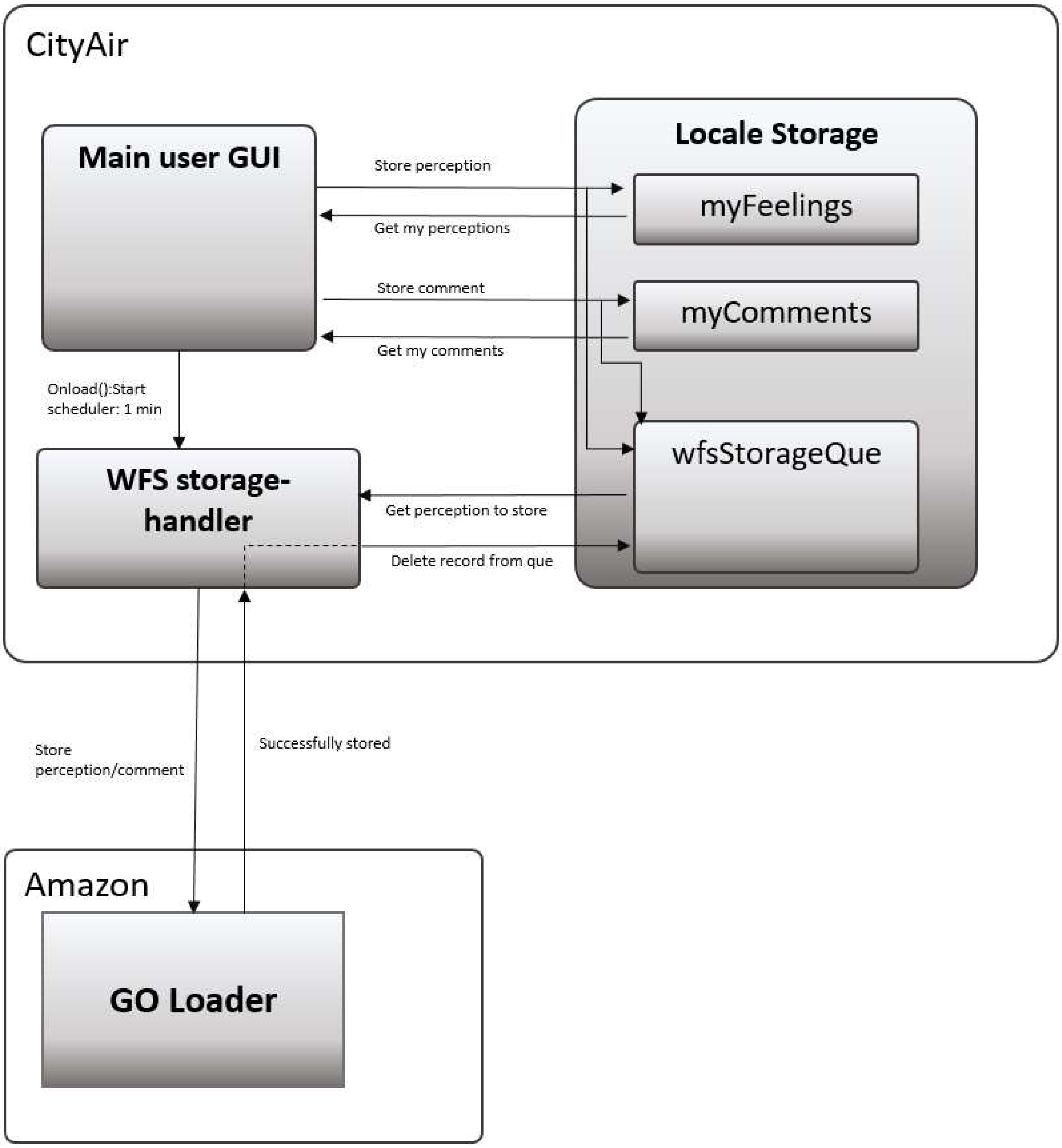


Figure 3-5 Main components diagram

CityAir uses the local storage to store the perceptions made by the user. Since the user can choose to only upload data on WI-FI connection, a handler is created when the application starts and is scheduled every minute to check if correct network connection is available, upload the perceptions and remove them from the que of perceptions to store on the server.

The diagram below describes the exact logic of the functionality.

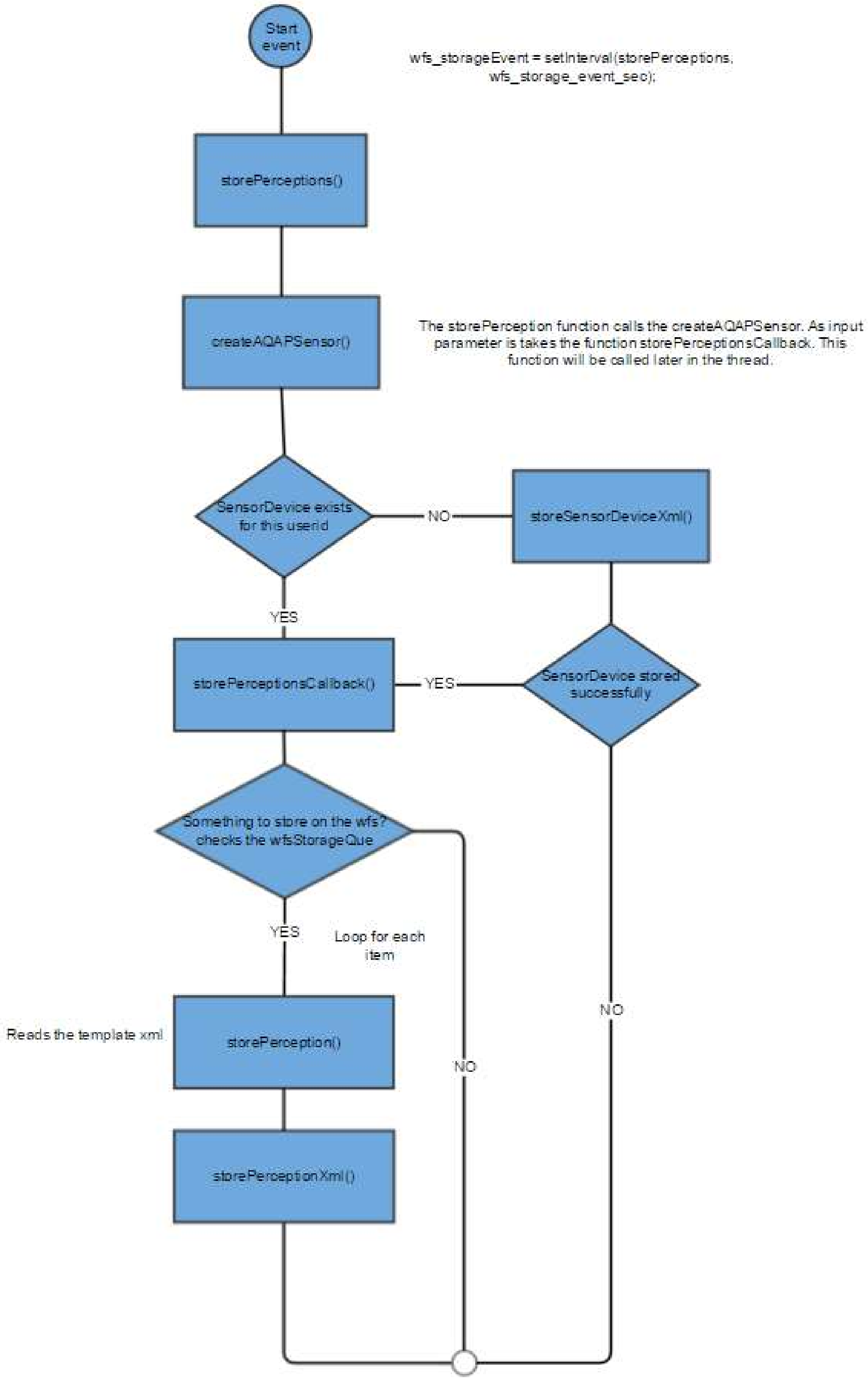


Figure 3-6 Process of storing data on the CITI-SENSE platform

3.2.3 Data Storage

Local storage
CityAir uses the HTML Local Storage. This is a web application software and protocols used for storing data in a web browser. It is being standardizes by World Wide Web Consortium (WC3) and is supported by a wide range of browsers like Internet Explorer, Mozilla, Safari, Chrome and Opera.
The data stored have no expiration date and will not be deleted when the browser closes.

In CityAir, all personal information and different user settings are stored in the local storage in addition to the perceptions and comments made.

Cloud server storage
All perceptions and comments registered by the user are uploaded to CITI-SENSE's cloud storage on Amazon. The database is a PostgreSQL server, an open source relational database. The data is sent with https (secure ftp with user name/password) to the server as an XML structure. This process is described in D7.4.

3.3 Dependencies

The CityAir app can run independently, but the perceptions and comments made by the user will only be storage locally on the device. All script sources like moment.js, jquery.mobile-1.4.5.min.js, jquery-1.11.1.min.js are included in the installation package.

The CityAir app depends on the following:

1. NILU web server for reading settings
   When the CityAir app starts, it reads a settings file on the NILU server. This file contains information about the URLs to different resources like storage and data access endpoints and prefix name for registering the app as a sensor device on the cloud storage platform. These settings have default values stored on the app's local storage if there is no network connection at the time.
2. Google Maps
   When the app starts, the user is presented with a map of her/his current area. If the network connections is too slow to download the app, the user is presented with an alternative screen.
3. Snowflakes products GO Publisher and GO Loader for displaying other CityAir users' perceptions and for storing the user's perceptions made on the CITI-SENSE platform.

3.4 Additional resources

Several web pages have been set up to support the use of the CityAir smartphone application. Each city can download and view the collected perceptions in addition to compare each location, using a simple web page CityAir statistics (Figure 3-7).
The app has been promoted several times in presentations at different conferences or in campaigns run by the case study cities. A campaign page template has therefor been developed to show an overview of the use of the CityAir app within a time period and specific location (Figure 3-8).

All web pages are simple HTML5 pages using the jquery library and highcharts JavaScript library for creating graphs (http://www.highcharts.com/)

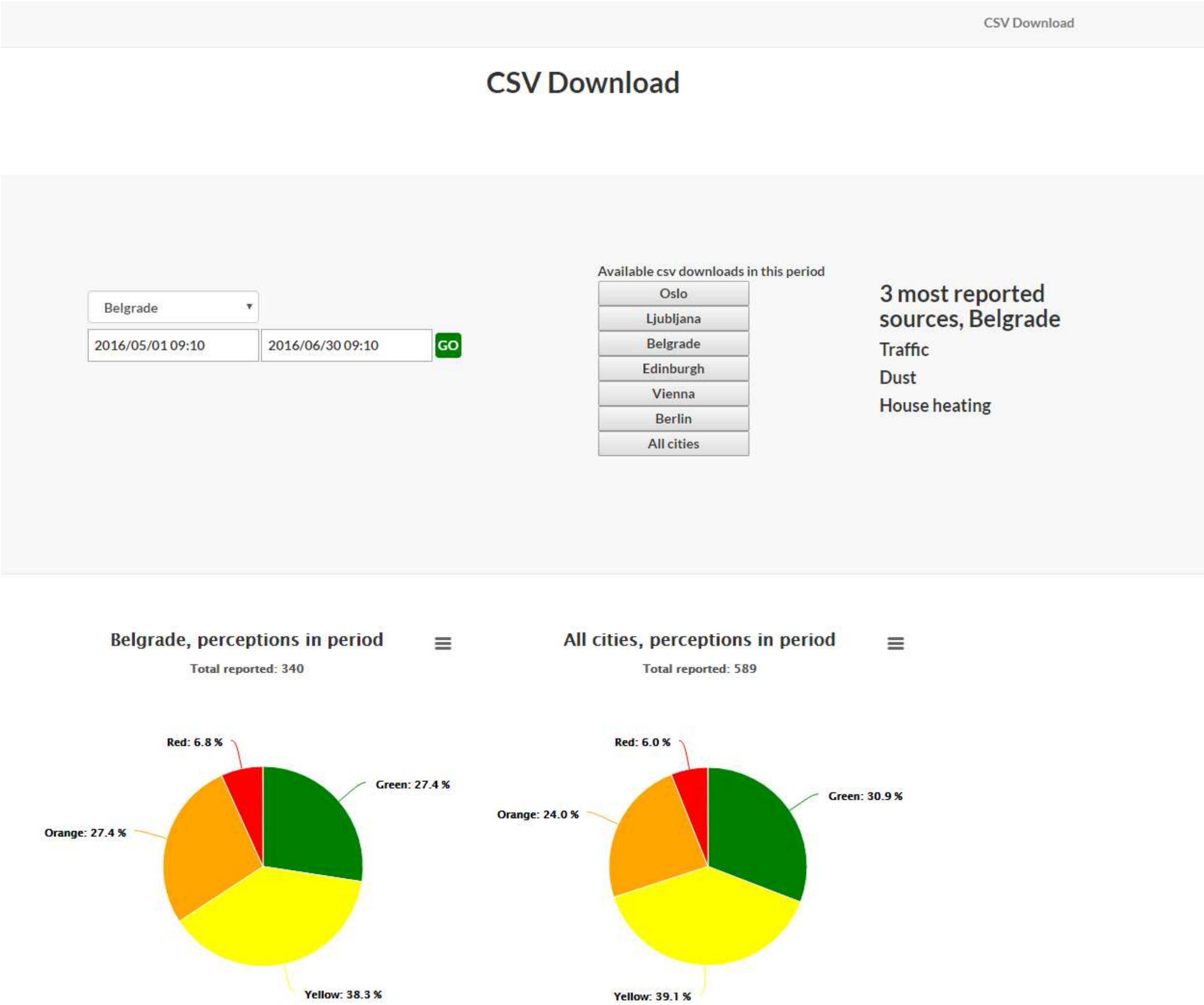


Figure 3-7 Web page for CityAir Statistics

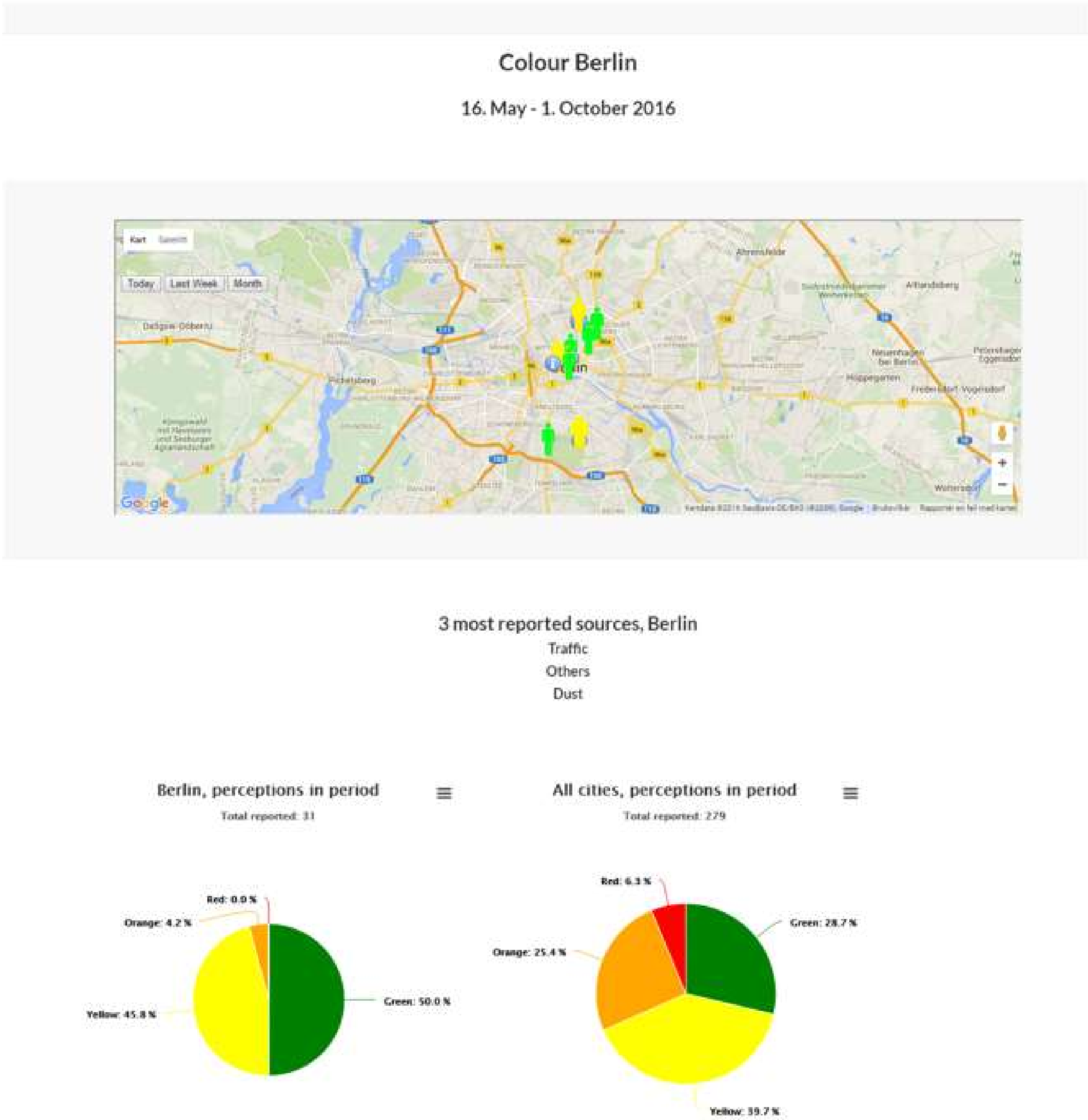


Figure 3-8 CityAir template web page for running campaigns

3.5 Suggested further improvements/problems/weaknesses and lessons learned

3.5.1 Usability

How to keep users interested in using the app

After testing with different user groups, both with people inside and outside of the project, we see a user pattern where the end user reports perceptions the first days after download but then the report frequency goes down. A possible way to keep up the users' interest would be to include some mechanisms for alerting the user to remember to add perceptions or add functionality, and use of gamification techniques into the app that give the user a reason for opening the CityAir app regularly.

Google maps

The experience with the Google APIv3 is that it needs a good internet connection to download the map and displays it on the smart phones.

We do not use native plugins v2. We looked into changing to this one, but found out that it effected the mark-up and a lot of work was needed for refactoring the code.

We implemented therefore a different first screen if no or slow internet connection and if GPS was found or not (Figure 3-9).

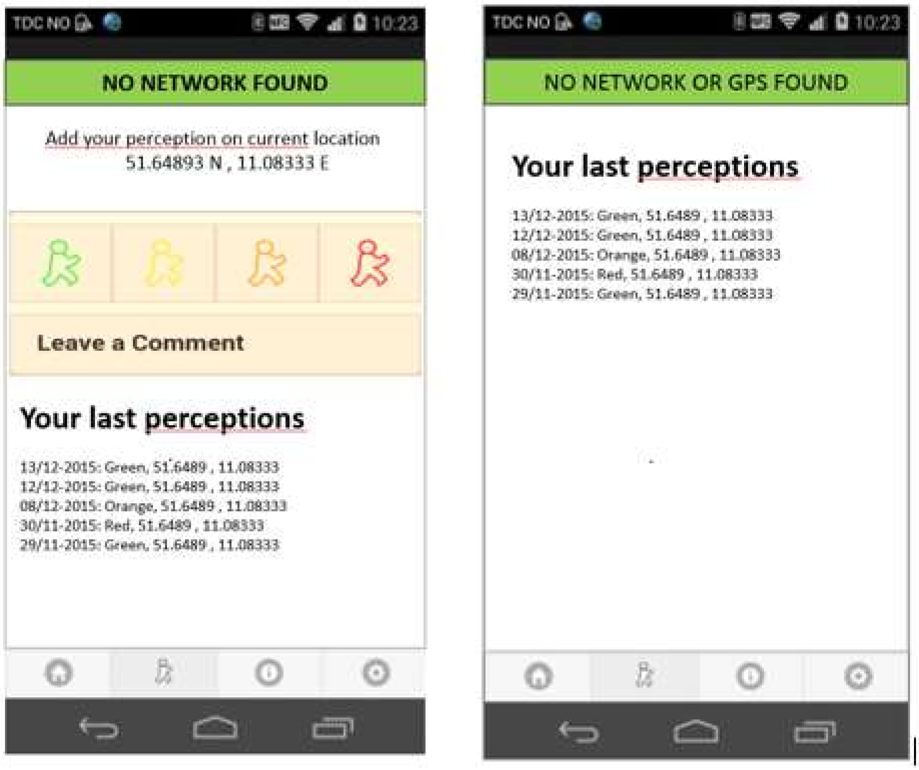


Figure 3-9 CityAir Alternative start up screen

The lessons learned indicate that we should have developed a simpler first page for the user and not display a map. The map could have been moved to menu button. This would have given the user a better experience of the CityAir app as the user will have no failures opening the application.

3.5.2 Code structure

Since the development of this application was made based on previous work, the idea was to build on the same code on both projects. The original name conventions and code structuring in the projects were therefore kept. The requirements between the two projects Citi-Sense-MOB and CITI-SENSE did however change, so the code was structured in two different branches.

The original code did not separate excessively into code layers and some effort was made to structure the code. The application should have made use of libraries for the Model-View-View-Model (MVVM) pattern like knowckout.js or Angular.js for better readability and maintenance of the code. MVVM is a software architectural pattern developed by Microsoft based on Martin Fowler's Presentation Model design pattern.

3.6 Current Status

The CityAir app is being used by all Empowerment Initiatives in WP2 and beyond.
As of per 30th of April 2016, there are currently 620 units running the CityAir app across the world.

Figure 3-10 Google Play and iTunes current Installs

Since the CityAir app currently relies on the CITI-SENSE platform for collecting perceptions from all CityAir users, the app will be closed when the project ends if no further development is made to support and use other platforms or the CITI-SENSE platform is not kept running after project end.

The complete code for the app is open source and available on [https://git.nilu.no/citi-sense/cityair.](https://git.nilu.no/citi-sense/cityair)

4 Online Air Quality Perception Questionnaire

Online Air Quality Perception Questionnaires are implemented with the use of CivicFlow web application provided by the CITI-SENSE partner U-Hopper (http://www.civicflow.com). CivicFlow is a web portal allowing authenticated Location Officers (LOs) to create in a visual way, perception acquisition questionnaires, monitor in real-time citizens' participation to the questionnaires, access visual analytics related to the user participation, and also export results in Comma-Separated-Values (CSV) format for rich analysis of acquired data in other third party applications (e.g., Excel, or programmatic analysis in R). In order to facilitate citizens' participation to the developed perception questionnaires, CivicFlow provides widgets for easy embedding of perception questionnaires in CITI-SENSE pilot portals and other third-party web portals, as well as incorporate questionnaires in mobile applications. Utilization of modern HTML5 technologies allows responsive visualization of perception questionnaires given as such appropriate visualization to citizens' accessing the questionnaire both from desktop computers and their smartphones.

4.1 Case studies

The requirement for a tool for acquiring subjective perceptions of citizens' was raised by Work Packages 2 and 3. LOs of CITI-SENSE pilots expressed the need for an instrument allowing to template a common perception questionnaire agreed between cities, have easy way to instantiate the template into a dedicated questionnaire for a given city, be able to translate the questionnaire into various pilot city languages, and also to have later on the possibility to compare acquired perception data across cities. In order to facilitate the participation, LOs requested the possibility to easily embed participation questionnaires in CITI-SENSE pilot portals and mobile applications, have the possibility to acquire a respondent geographical position, as well as have the possibility to generate QR codes to trigger the participation with smartphones via QR code scanning.

In the following we discuss in more details those requirements and corresponding decisions implemented in the system in order to accommodate those requirements.

4.1.1 Requirements

The following requirements were addressed:

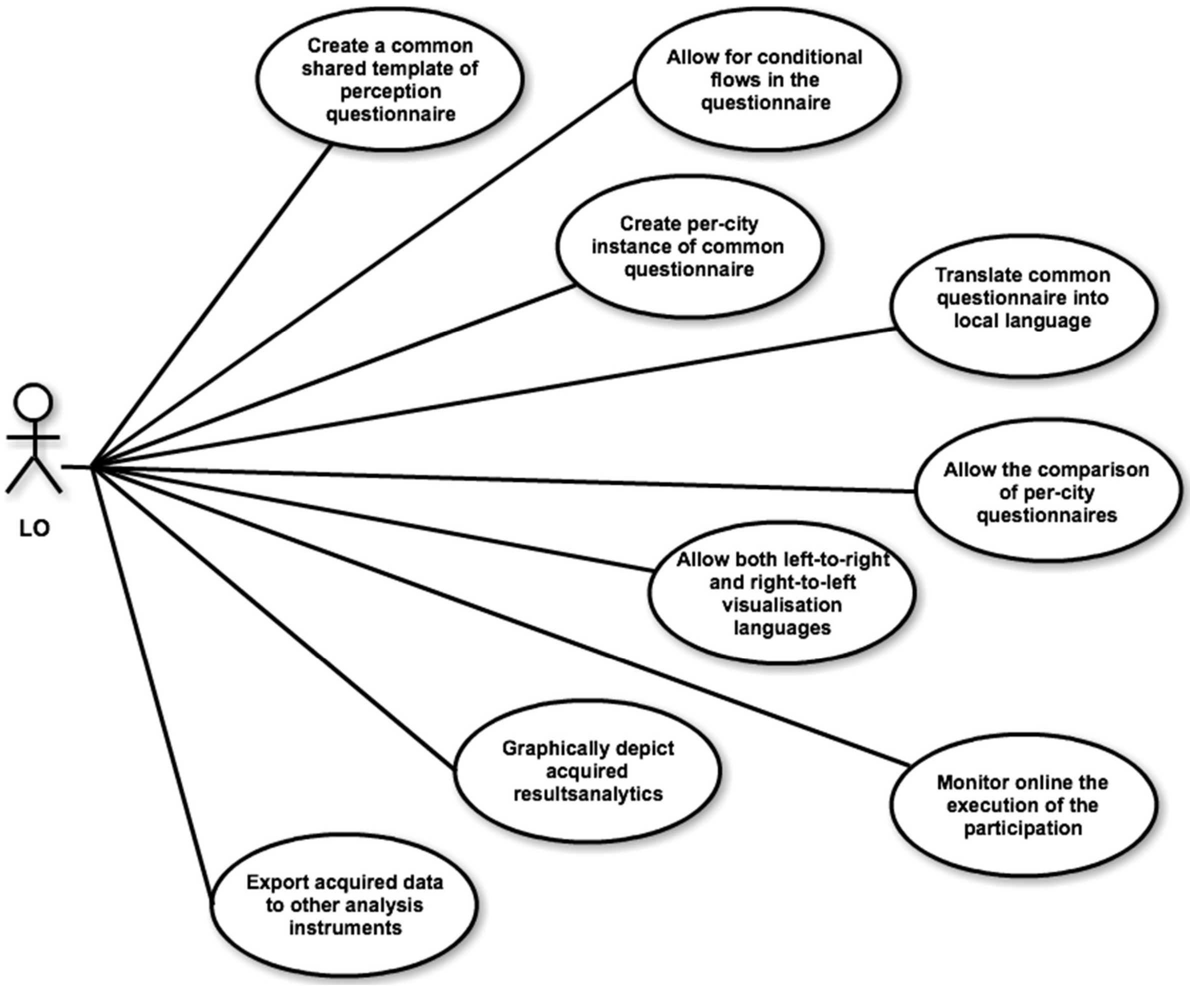


Figure 4-1 Use Case diagrams for perception questionnaires life-cycle

Create a common shared template of perception questionnaire

Location Officers should be able to create in CivicFlow a shared, agreed template for a common perception questionnaire. Such a template is created in English with a later possibility to be adopted into the local language used in the CITI-SENSE pilot cities.

Allow for conditional flows in the questionnaire

A perception questionnaire should accommodate the possibility to define the conditions allowing user-friendly participation. Specifically, the following conditions have been requested:

- If a question Qx is answered with an option Oi then enable (show) questions Qy…Qz
- If a question Qx is answered with an option Oi then disable (hide) questions Qy…Qz
- If a question Qx is answered with an option Oi then go immediately to the end of the questionnaire (submit results)

Create per-city instance of common questionnaire

Once the common template is created agreed among LOs, each LO should be able to instantiate (clone) the template into a per-city questionnaire.

Translate common questionnaire into the local language
Since CITI-SENSE piloting activities are executed in various cities, LOs should be able to translate per-city instance of the common perception questionnaire into local language, so that citizens have "low-barrier" for participating in data acquisition.

Allow the comparison of per-city questionnaires
Provide the possibility to compare the results acquired with per-city questionnaires. Specifically, provide a possibility to assign a "code" to question responses, so that despite the local translation the questionnaire and answer can be clearly identified with the comparable code.

Allow both left-to-right and right-to-left visualization languages
Since there are partners among the CITI-SENSE pilot cities using the standard in Europe left-to-right writing that are using right-to-left languages (such as for example Haifa, where Hebrew is used), besides the possibility to provide the translation, the system should allow appropriate alignment of the user interface and buttons.

Monitor online the execution of the participation
LOs should have a possibility to check online the execution of perception acquisition campaign. Specifically, being able to check how many respondents participated recently in answering.

Graphically depict acquired results
The system should be able to provide visual analytics, graphically depicting acquired data. Specifically, appropriate chart should provide per-question the possibility to see the distribution of answers provided by participants.

Export collected data to other analysis instruments
The system should be able to provide questionnaire data export functionality to CSV format, so that it can be easily used in other analysis instruments (such as Excel, or R programs).

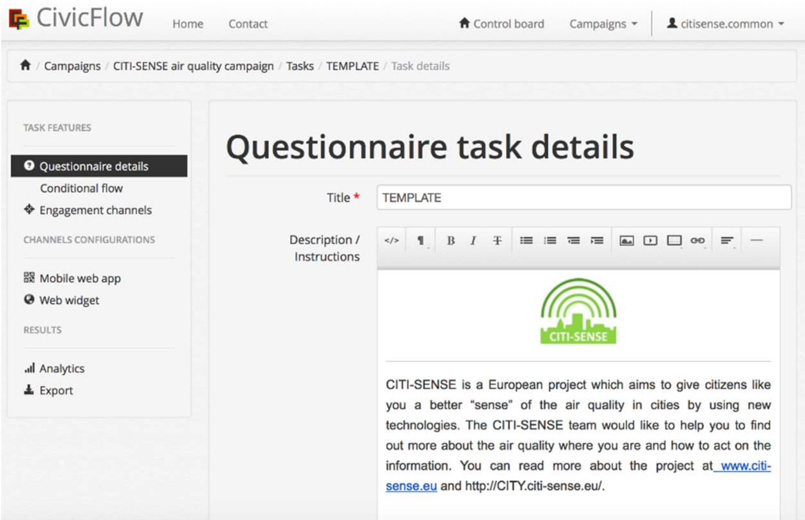
4.2 Technical description

4.2.1 Development environment

The CivicFlow system is an online portal accessible via web at http://www.civicflow.com. The portal allows the users to: register, create perception campaigns in forms of questionnaires, execute data collection, analyse and export the collected results. The platform is implemented using modern HTML5 technologies, allowing as such to use the user interface and graphically consume the collected data both from web browsers of desktop computers and smartphones. The CivicFlow provides additional functionality for members of CITI-SENSE, allowing to propagate collected data to CITI-SENSE platform.

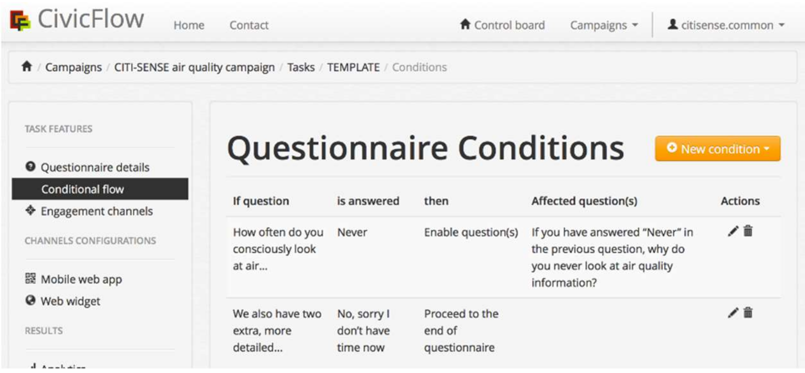
In order to address the requirements specified by CITI-SENSE Location Officers (LOs) the portal provides the following functionalities:

- **Create a common shared template of perception questionnaire**



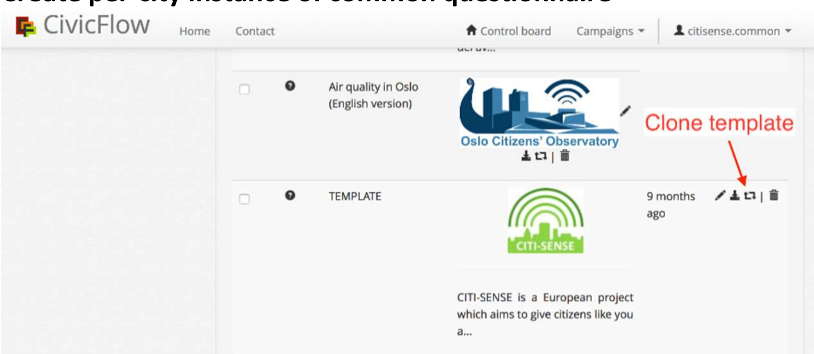
By means of the CivicFlow platform, LOs have created together the common template for acquisition of air quality information.

- **Allow for conditional flows in the questionnaire**



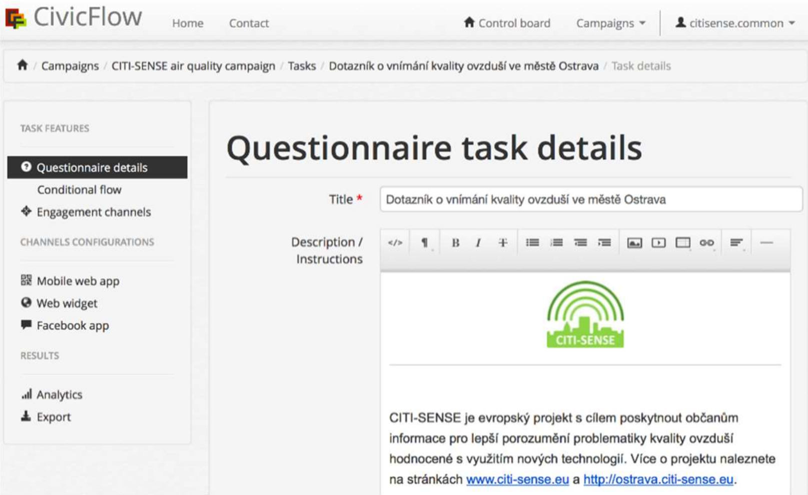
Conditional flows allowed to accommodate the user-friendly way of questionnaires: showing parts of the questionnaire only if citizens' answered certain options. Having at hand the way to define conditional workflows also allowed LOs to split the questionnaire in two parts: short and long, and inquire citizens' to participate to a longer version only if they are willing to.

- **Create per-city instance of common questionnaire**



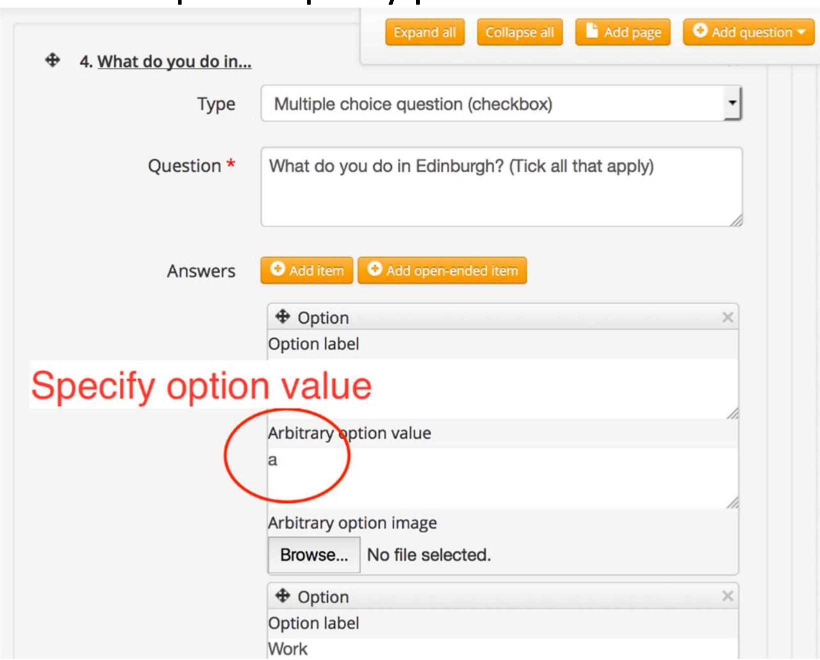
Implemented cloning functionality allowed LOs to easily clone the template into questionnaires dedicated per different cities, with further possibility to translate it to local language.

- **Translate common questionnaire into the local language**



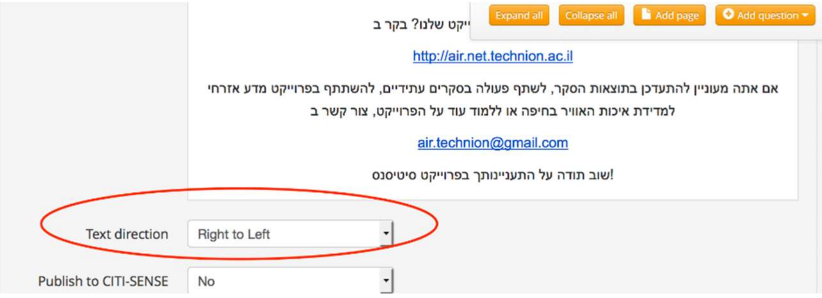
Questionnaires created by each city have been translated by LOs into local languages to lower the participation barrier. The system has demonstrated to work well not only with Latin based languages, but also with Hebrew language.

- **Allow the comparison of per-city questionnaires**



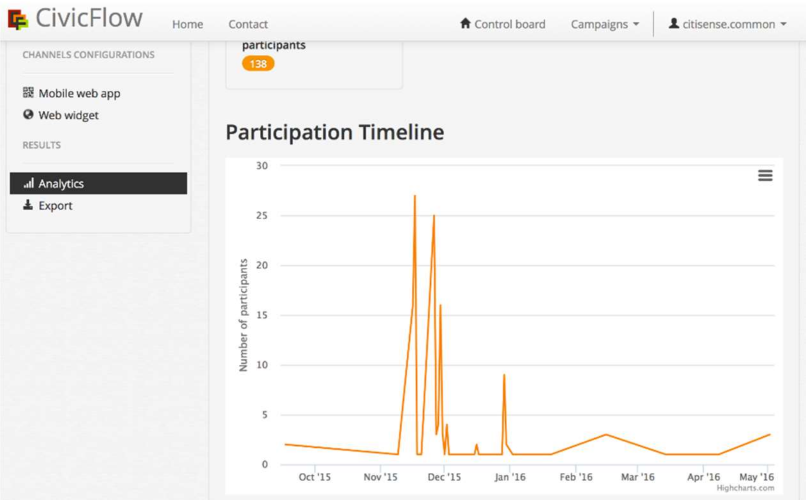
In order to perform cross-city comparison of the collected data, LOs could set up specific option code corresponding to answer options, in a way that no matter in which language a question was asked, the answers were collected with the defined option codes. This allowed for systematically compare results from different cities.

- **Allow both left-to-right and right-to-left visualization languages**



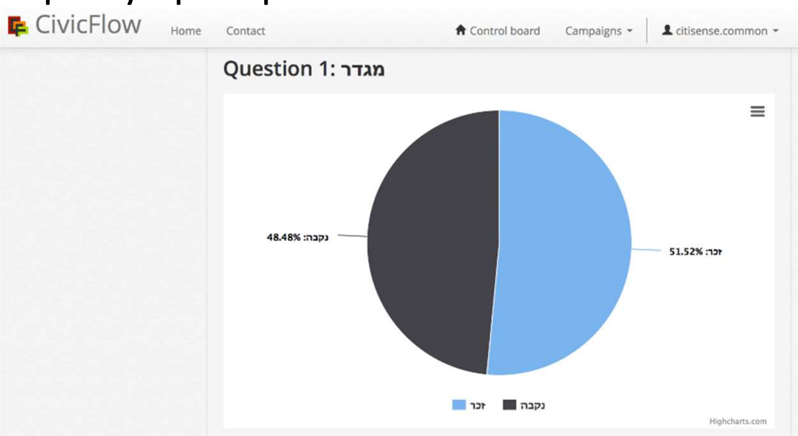
Since among piloting cities the CivicFlow-based air quality perception questionnaire was also executed in Haifa, the platform was enriched in order to accommodate right to left Hebrew language.

- **Monitor online the execution of the participation**



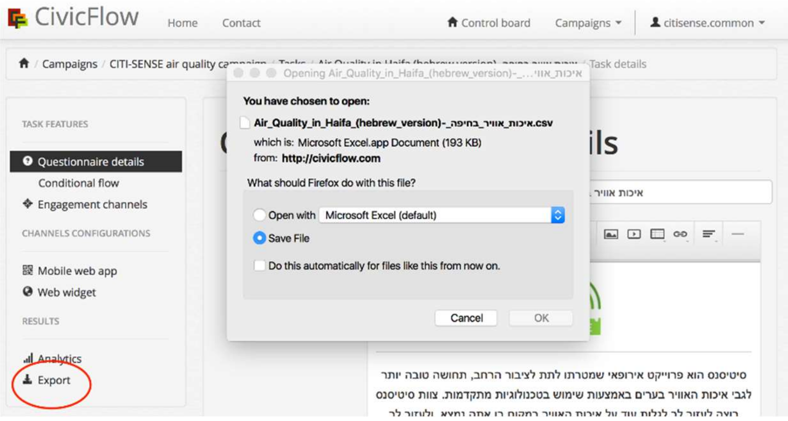
Demonstration of participation timeline to LOs allowed them to monitor the execution of data acquisition and see in real-time the amount of participants on a timeline.

- **Graphically depict acquired results**



Acquired results, in a question-per-question basis are graphically depicted, allowing to see the distribution of answers.

- **Export collected data to other analysis instruments**



In order to perform even richer analysis of collected results, the CivicFlow provided the exported possibility, allowing to see export results in a Comma-Separated-Values (CSV) format, that can be easily imported in various third party tools (such as Excel, R) or programmatically analysed.

4.2.2 Architecture

Architecture diagram

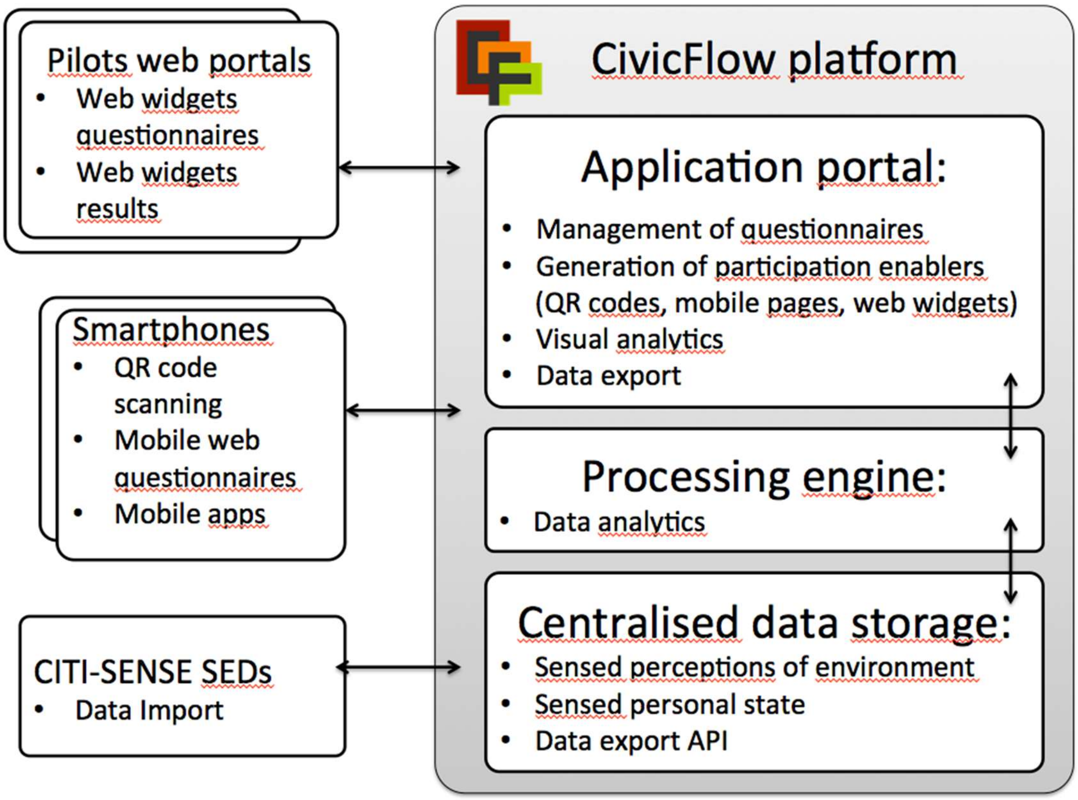


Figure 4-2 Perception Acquisition with CivicFlow Context Diagram

The acquisition of air quality in CITI-SENSE pilots has been implemented leveraging CivicFlow application. Through the application portal Location Officers (LOs) are able to create air-quality perception questions, generate participation enablers, monitor the execution of collection campaign and access the visual analytics and raw collected data. The following enablers are experimented during the execution of pilots:

- The use of web widgets embedded in pilot web portals;
- The use of mobile web questionnaires triggered by scanning of QR codes (or typing the url);
- The use of web widgets directly embedded in PhoneGap based CITI-SENSE applications.

Participation widgets submit the data to the CivicFlow where those data are stored for processing and visual analysis. Besides that the data are also forwarded to CITI-SENSE SEDs in order to be used by other visualization widgets for showing participatory data.

4.3 Suggested further improvements/problems/weaknesses and lessons learned

4.3.1 Usability

Preparation of air quality information acquisition campaigns in various pilot cities allowed to validate the usability and ease of use of the platform for preparing the data collection campaigns by non-technical people. The part of management questionnaires was well-perceived by LOs and with a minimal training allowed them to work autonomously in setting up the questionnaires.

In a similar way, the use of mobile web apps triggered by QR code scanning was well perceived and easy to be used.

The part of embedding the questionnaires in the piloting portals created a major source of difficulty, since it is requiring basic web-programming skills. In order to perform the embedding, hence, the intervention of technical support from consortium members was required in order to setup the embedding of questionnaires.

4.4 Current Status

The CivicFlow web application was launched at the very beginning of the project. It significantly evolved considering the requests from EI participants in order to accommodate the requirements. Common air quality perception questionnaires have been launched in 8 pilot cities, namely Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava and Vienna. In some cities the questionnaires were launched only in local language, in other in both English and local language. For the results on collected data we refer the reader to the dedicated reports of WP2.

5 Environmental Monitoring Toolkit in Public Places

The aim of the toolkit is to integrate technological solutions to engage citizens into the observation of public places and the assessment of its quality. The solution collects information from the participants and provides them with adequate information (synthesis and summarized data) of the measurements they have carried out.
The case study was carried out at the city of Vitoria-Gasteiz (Spain), where more than 50 people were engaged for observing and assessing four different urban areas (e.g. urban square, parks). 10 kits of sensors-smartphone were available to be given to the selected participants.

The environmental monitoring toolkit is a collection of different tools:

- a mobile weather tracker sensor
- android smartphone applications for reading the sensor's Bluetooth stream and upload the data to a server over the http protocol
- platforms for storage of sensor and user data
- web services and APIs for calculation of results
- Android smartphone service for detecting sound.

Figure 5-1 gives an overview of the different modules involved and their relationship.

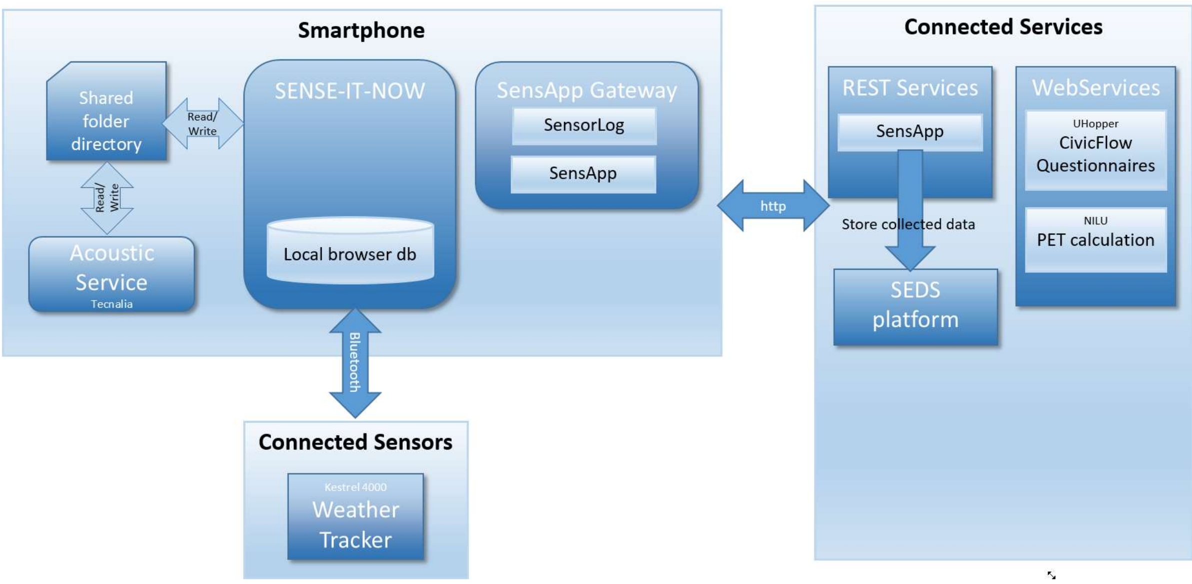


Figure 5-1 Updated model from D7.4 Toolkit in Public Places

The following chapters will first look at the overall toolkit and then have specific chapters for the SENSE-IT-NOW smartphone application (5.4) and the data visualization web portal for the public spaces empowerment initiative (5.5).

5.1 Toolkit requirements

The objective of the toolkit was to allow citizens collecting objective and subjective data at urban places, as a way of empowering them towards the management of urban places. This should be reached by engaging people in the evaluation of acoustic parameters: what does this mean in terms of tools, how to build an attractive design, constructing a user friendly solution, and giving feedback to the citizens in diverse ways, for example, quick and simple on-site feedback, while they are making their observations of the places, as well as more in-depth feedback, although not in real time.

Sensors units selected for this EI concerned the following aspects:

- Acoustic Comfort: a microphone is required to obtain sound level data. This information is combined with the user's perception to obtain an acoustic comfort assessment.
- Thermal Comfort: a device to measure temperature, humidity and wind speed is required. This information is combined with the user's perception to obtain a thermal comfort assessment.
- Landscape perception: providing information regarding the user's perception about landscape requires a camera to link his/her opinions with the aspects which motivate them.
- Personal perception: Involving other subjective aspects and variables that may alter the general perception of the urban areas, like cleanness or personal state of mood.

In order to collect data, several sensors were added to mobile devices and some questionnaires were created and divided into six different parts in order to ask participants about the following subjective aspects:

- Thermal comfort perception
- Acoustic comfort perception
- Urban landscape perception
- General satisfaction
- Other variables (safety, cleanliness)
- Health and emotions

In order to collect objective data to correlate with these subjective perceptions, mobile sensors carried by the participants (citizens) provide information that is centralized in a smartphone.

Collection and analysis of acoustic data includes the measurement of sound levels in terms of LAeq acoustic parameter (equivalent energetic level), with a 1 sec. sample, and the app also identifies sound events applying a dynamic threshold. Additionally, the participant is asked to report the type of noise source that caused the event and how he/she perceived it. Information of acoustic values and events detected are used to calculate an overall **acoustic comfort** index. The calculated values are sent to the CITI-SENSE platform.

In the case of the evaluation of **thermal comfort**, information on different climatic variables (mean radiant temperature (T_{mrt}), wind speed, air temperature and relative humidity) are required. Due to the complexity of the measurement, T_{mrt} is previously modelled as a function of cloudiness and solar radiation exposure and uploaded to an accessible database during the measurement campaigns. Temperature, relative humidity and wind speed are transmitted each second from the sensor to the Smartphone. During the measurement period mean values are calculated and visualized, and finally stored in CITI-SENSE platform by an app. Finally, the physiological environmental temperature (PET) is calculated, stored and shown at the smartphone.

In the case of **urban landscape perception**, information on specific sites/areas inside the public space is required. Finally, participants are asked to use the camera of the smartphone to take pictures and evaluate them. These photographs are stored on the SensApp platform as a Byte64 string, and serve as an objective token of the reality that causes the pleasant or unpleasant reaction of the urban landscape.

Thus, the smartphone receives data from mobile sensors, it supports an interface to collect comfort perception (i.e., questionnaires), and its camera is also used to allow evaluating urban landscape perception. Questionnaires play a vital role on the data collecting process, as they act as unique interaction module between the participants/citizens and the capture, processing and storage of data processes. Thus, the questionnaire content has to be displayed in the smartphone in subsequent friendly screens. Special care is given to the content, design and time effectiveness of the questionnaire.

All the information registered in the questionnaire (both mobile measurements and the opinion of the citizens/participants about the general perception of the specific public spaces) is collected during the process and sent to the CITI-SENSE platform.

5.2 Suggested further improvements/problems/weaknesses and lessons learned

After the Full Implementation was deployed and the data collected had been analysed, the interdisciplinary team working on it shared some thoughts about the problems or weakness found in the process. This reflection was made among experts from three partners in the consortium: NILU, TECNALIA and SINTEF. There were two items analysed: Difficulties in the access to the data in the SensApp and communication problems during the observations between the SensApp and the smartphone. Both issues are explained, their consequences described and improvements needed were identified. Annex C gives more detail on this.

1. Difficulties in the access to the data in the SensApp.

- *Description of the problem:*
  The preliminary version of the SensApp was using the sensors as the elements to access the data. In the case of Vitoria, these sensors were: Thermal, Acoustic and Composite.

  This structure to present the data did not fit well with the needs of the EI. In the case of the EI Public Spaces, the information must be organized allowing the definition of sets of data distinguishing user and observation (user ID, area and site, and date).

  The idea of the data structure created in SensApp was to facilitate to query and make statistics programmatically directly from SensApp. The structure then differed a lot from a relational database view. This might have led to difficulties when trying to convert the data.

- *Consequences of this limitation on accessing the data?*
  - A big effort is needed on analyzing the data to create the sets of data, not being completely sure about the consistency of the information.
  - The duplication of the database implies that the analysis is done only after all the observations are finalized or a process to manage the different versions of the database is needed.
  - Will it be possible to repeat the process of accessing the data and copying it once that all EIs have uploaded their data?

- *Which would be the best solution to improve the access to data?*
  The database schema used in SensApp implements the SenML standard. It seems that an option could be to create for each observation a SenML composite sensor (and the respective sensors) with attached as metadata the location (e.g., name of location, GPS

data). CivicFlow Questionnaires should also be taken into account during the composite sensor conception process. The date of creation of this composite sensor would then be the starting date of the observation. The name of the composite should contain the UserId and maybe also the observationId. This could be a better way to have multiple observations per Users.

2. Difficulties during the observation in communication between the SensApp and the Smartphone

- *Description of the problem 1:*
  One of the aspects that conditioned the development of the observation was the organization of the SensApp by timestamps. This required that each observation must start exactly at the same time. This requirement was integrated in the instructions of the observation.

- *What are the consequences of this limitation?*
  It was not possible allowing the citizens doing the observation on their own; that is, being free to go to each area and site in the time of the day/week that they prefer. Since previously it was decided to help citizens on doing the observations due to the instabilities found in the services, during the Full Implementation this limitation was not critical but it will be a clear limitation on further applications, besides an necessary increase in the resources for the implementation, being more costly.

- *Which would be the best solution to improve it?*
  Creating a composite sensor for each observation could also solve this issue, since it would help to reunite individual data stored within SensApp. As pointed before, maybe an extra effort would help to unify also the CivicFlow data. If this is not possible, a triple check (User-Location-Time) would allow the integration.

- *Description of the problem 2:*
  On the other hand, during the Full Implementation phase in April/May 2015, some problems of the communication between the SensApp and the smartphone occurred.

- *What are the consequences of this problem?*
  Some data of observations were lost. Only 22% of the total number of observations was completely correct. 4 participants could not upload any data and there were 41 observation completely lost.
  There were different types of errors, but the most frequent error was related to the thermal index. To calculate this index, not only data measured by the sensor, but also a value pre-calculated and stored previously in SensApp were required. However, in these cases data of the thermal variables measured by the sensors were also missing.
  There was a risk of losing confidence on the technology used and even on the results of the project. This risk was well managed on the communication with participants.

- *Which are the reasons for each of the types of errors?*
  In general, every single data available in the SensApp database seems to derive from an independent communication process, thus, it is common to find incomplete datasets.
  Furthermore, this process greatly increases the communication needs, also increasing the chances of defect communications and, thus, incomplete datasets.
  Where missing only the Thermal Index, this could be a communication error where the T_{mrt} values could not be retrieved and, thus, it was impossible to calculate the thermal index value.

However, in most of the cases not only the Thermal Index, but all the Thermal values measured were missing.
Other reasons could be: that the user did not push a button for calculation their indexes, the app did not create them and store them; or that the user wrote a wrong email address and then the app could not get the questionnaire with the needed information to calculate the indexes.
The results of the Thermal values would be stored when the result of the thermal was calculated. If that was not possible then the Thermal values would not be stored. That means that if there was no index (result) then no information about the temperature, wind speed and humidity was stored on the result composite sensor, but were only on the specific sensor.

- *Which is the best solution to avoid this problem in future implementations?*
  Two different protocols were suggested to improve the current infrastructure and obtain better datasets:
  - Create a complete user-point (area & site) dataset, prior to send the information to the dataset. This implies to perform the data linking process on the mobile device and send the complete data to the server, where it can be retrieved on future queries.
  - Verify that the data sent by the mobile device correctly arrived on the server using a feedback signal. Until such signal is received on the device, the mobile device should be able to store the unsent/not-received data locally and try to resend if GRPS signal is available. This approach must consider that, nowadays, the timestamp is the key element to link every data and so, data creation time must also be stored and sent (as the creation/sending/receiving timestamps may diverge).

  This approach would allow the following: validating the data on the smartphone (all data is there, communication between smartphone and sensors is working), push the data only when maximal connectivity of the smartphone to the network is ensured, keep the data on the smartphone until it has been successfully stored (SensApp use REST and already provide a ACK, if the current ACK is not enough it can be improved) into SensApp. If the timestamps are properly aligned during the linking process on the smartphone, it is already possible to define a specific timestamp when pushing the data into SensApp

In general, one lesson learned is to think smaller when it comes to what a smart phone app developed using HTML5/JavaScript actually should do and do more of the work on the server side. A smart phone app works better and gives better user experience with smaller tasks and less complexity.

5.3 Current Status

The Environmental Monitoring Toolkit in Public Places was used by the Empowerment Initiative in WP3a in the city of Vitoria-Gasteiz linked to a dedicated campaign of observation in spring 2015.
As other products do, it works on the CITI-SENSE platform. Tecnalia is considering developing a new product from the technical lessons learned during the project and answering to the feedbacks received by stakeholders in the empowerment evaluation.

There has been interest for developing a version of this toolkit that is more generic and can be used across locations. There has been internal discussions within the project on how this can be solved and technically there is not too much work to create another version of the toolkit. This will be taken into consideration together with the time and resources left in the project.

5.4 SENSE-IT-NOW

SENSE-IT-NOW is a cross platform smartphone application developed in HTML5 and Cordova (https://cordova.apache.org/) to link the different applications and services to give the end user one tool to make observations and add perceptions regarding their public environments. The need for this tool was raised by the Empowerment Initiative Outdoor Public Places in WP3a.

5.4.1 Requirements

The requirements were collected during D6.2 **Interim report on the methodology to link elements** and WP3a Vitoria pilot case protocol in D3.1 **Pilot study protocol**.

The following use case diagram captures the main requirements and the use case description contains detailed description about the main procedures.

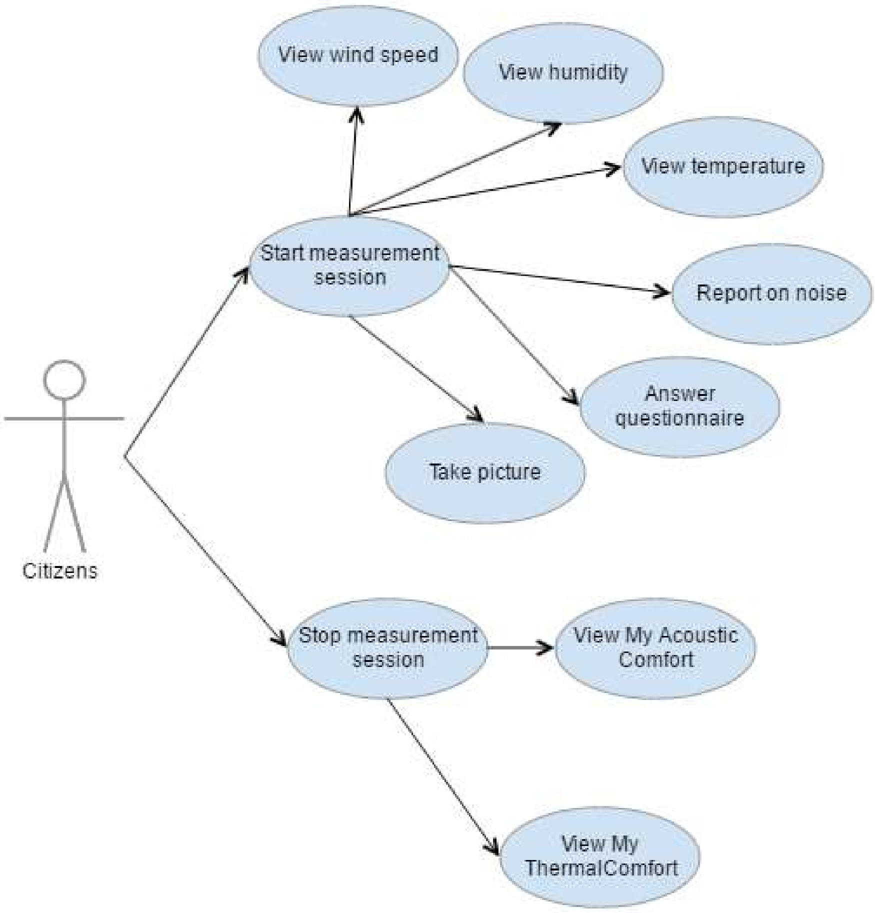


Figure 5-2 Use Case Diagram SENSE-IT-NOW

Start measurement session

- The user inserts the Kestrel Sensor Id
- The user inserts an email address
- The user hits the Start session button
- Time the button was hit and email address are stored on the app
- The user can see the last measured values of temperature, humidity and wind speed (updated every 10s)
- The user can push a button to see the evolution of the measured values
- This screen shows 3 graphs: temperature, wind and humidity
- (Query based on start time, kestrel sensor id and type)
- The user hits the end session button
- End time is stored on app and email is sent to the provided email address and to the email address of the contact person in WP3a with url containing Kestrel sensor id, start time and end time.

Taking a picture

- The user hits the Take photo button
- The user takes a photo with the smart phone camera
- The user chooses pleasant or unpleasant value
- The user hits the Upload button
- The photo is then stored in SensApp Web application with photo, gps position, app id and perception value (pleasant/unpleasant)

Stop measurement session

- The user can see the calculated Thermal and Acoustic index for the session

5.4.2 Technical description

Development environment

SENSE-IT-NOW has been developed using Visual Studio 2013 as IDE (integrated development environment) provided by Microsoft and with Visual Studio Tools for Apache Cordova CTP3.2.

Architecture

The SENSE-IT-NOW application was built with PhoneGap/Cordova. This is an open source framework that uses standardized web APIs (JavaScript, HTML5, CSS3) to develop applications for different mobile platforms (Figure 5-3).

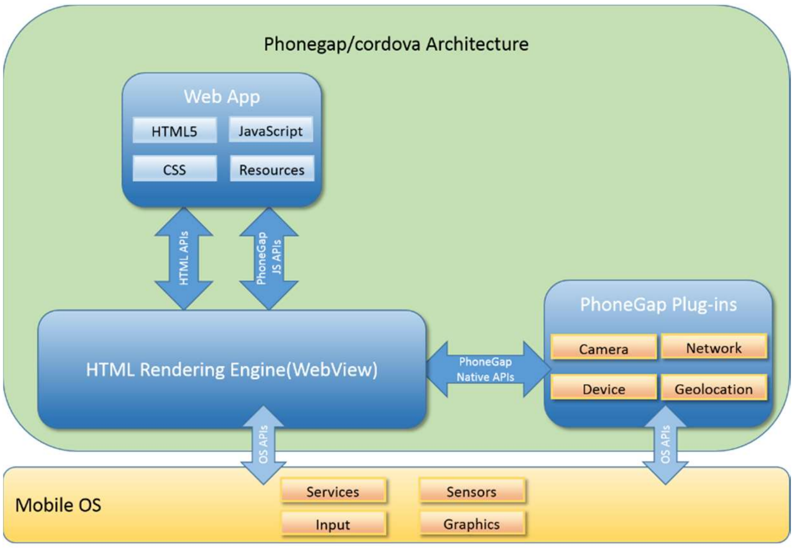


Figure 5-3 SENSE-IT-NOW Cordova Architecture (from D7.4)

SENSE-IT-NOW has the following plugins available to access sensors on the device:

- Camera, Use of the phones camera
- Network, Access Wi-Fi and cellular network
- Device, Access information about the device`s hardware and software
- Geolocation, Access location data based on GPS or network signals

Data Storage
SENSE-IT-NOW stores pictures in SensApp provided by SINTEF for easy storage and retrieval of simple sensor data (part of the CITI-SENSE platform). They are scaled down to 800x800 pixels before uploading the picture using http.

5.4.3 Dependencies

SENSE-IT-NOW is a complex application due to its dependencies to different servers and applications both for visualization of real time measurements collected by the Kestrel sensor, detecting sound alerts from the acoustic service and for the calculation of end results and indexes (Figure 5-4).

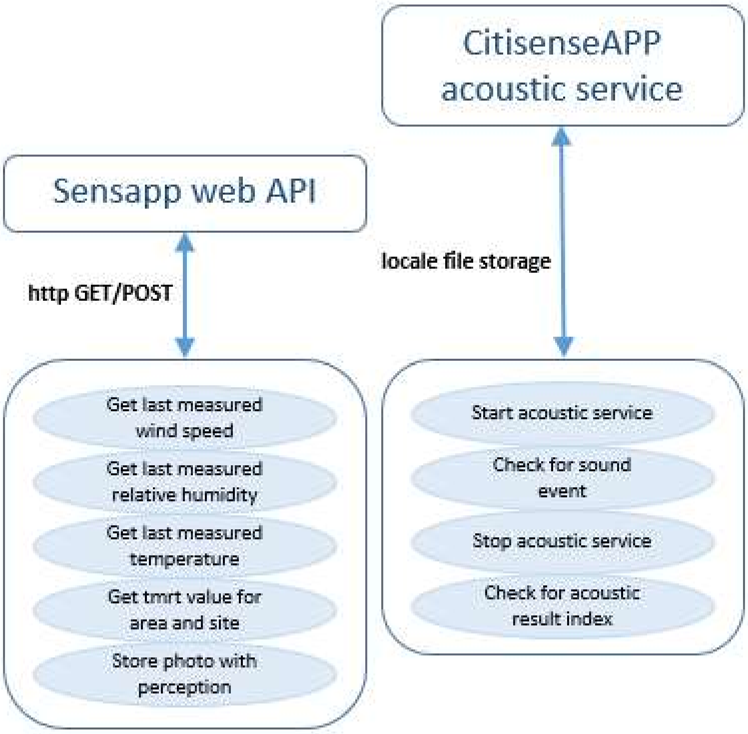


Figure 5-4 SENSE-IT-NOW Communication and dependencies

CityNoise APP is an android smartphone acoustic service that measures LAEQ and stores it on the SensApp server and creates a text based file in a dedicated folder on the phone when it detects a sound event. This file is then detected by the SENSE-IT-NOW app and the user is provided with a message box where the user can select the type of sound and the perception of the sound heard. SENSE-IT-NOW creates a file when the user hits the button for starting and stopping a measurement session, on the same local folder to alert CityNoise. After the session has ended CityNoise calculates a result index which SENSE-IT-NOW reads and creates the acoustic comfort graph.

CivicFlow – a questionnaire app developed in HTML5 by UHopper and included in SENSE-IT-NOW through an iframe tag. The users' answers are uploaded to UHopper's web server and stored and can be retrieved thru their API.

SensApp part of the CITI-SENSE platform: SensApp provides a web API for reading and storing simple data using SenML.

5.5 Data visualization web portal for public spaces EI

5.5.1 Case studies

A web portal was developed in the context of CITI-SENSE WP3a case study in Vitoria-Gasteiz (http://vitoria.citi-sense.eu/). The web portal should access data bases in the CITI-SENSE platform and provide users with the information required.

In collaboration with WP3a, a web site was developed explaining the project and providing access to the participants' data in the pilot studies of Vitoria-Gasteiz. The web page is multilingual, having a version in English, Spanish and Basque, in order to be understood widely. The web site is divided in different parts that respond to different objectives that has been previously explained in D3.2 (Robinson et al., 2015).

5.5.2 Requirements

The information to be presented to the participants, as part of the empowerment initiative, should be adjusted to the purpose in order to balance the quantity of data and to maximize the empowerment. In some cases providing too much data can be counterproductive to have an overall comprehension of the situation or evaluation.
The web portal should be simple and clear, and should aim to motivate stakeholders in the project

Different users of the web portal will have different data access permissions: 'Public/participant' access will be limited and 'Administrative' access will have full access to the information.

5.5.3 Technical description

In "Resultados" ("results"; http://citi-sense.tecnalia.com/resultados.jsp), the data of the results of the evaluation are displayed. These results were post-processed to facilitate obtaining conclusions of the evaluation as part of the empowerment initiative.
CITI-SENSE is a project that is based on the empowerment and active participation of the stakeholders and citizens. Therefore, in the Vitoria EI, we have organized a co-design workshop with a group of volunteers during the recruitment period. This workshop was focused on the co-design of the visualization of the results for the Vitoria EI on the webpage. The aim was to tailor the visualization of the results with the views and preferences from the citizens. Based on the outcomes, Tecnalia developed a new url with a different architecture from the main project web pages (www.citi-sense.eu) to display different options of representations.

5.5.4 Data Management

As detailed in the requirements, the web portal should provide both generic and user-specific information regarding the different components of the project. However, different modules store data in different servers and thus, making it difficult to access the information on real time in case of network failures. In order to cope with these situations and enable a user-friendly data visualization experience, we decided to create a specific database with involving every available data linked by user and observation place. In this way, all the necessary information is available with a single database query, avoiding unnecessary delays and time lags.
First, we retrieved the data stored in both SensApp and CivicFlow servers. By doing so, we realized that linking the sensor data with the corresponding questionnaire responses was not a trivial issue. The whole system was organized to link data on time basics, but two different problems arose when trying to do so. The first one being the different means to represent the measured time, with SensApp using

Linux Timestamp value as reference (number of milliseconds since January 1st 1970), and CivicFlow uses a Date value. The second problem derives from the fact that both servers were located in different countries, and so, different time zones and summer/winter times were involved.
After solving these issues, we discovered that some data was lost in the linking process, due to the network connectivity issues that took place during some of the workshops in Vitoria. In order to cope with the data lost issue and the impossibility to use time as the main parameter to connect the different datasets, several other approaches where undertaken based on both the user and the area/site along with the time marks of the available data. After such a process, and once an acceptable amount of data finally linked, a unique SQL Database was consolidated in order to feed the web visualization. This database stores in a unique table the complete data of all the dataset that we were able to link, and by this enables an easy data retrieval based on user and location parameters.

The following figure summarizes the final data status for each user-area combination:

			AREA/SITE								
Kit	Clave	Email	CONS-1	CONS-2	SALI-1	SALI-2	OLA-1	OLA-2	HERR-1	HERR-2	HERR-3
1	88133359	citisenseobservador01@citisense.eu	x						x	x	x
2	89635172	citisenseobservador02@citisense.eu	x						x	x	x
3	97963331	citisenseobservador03@citisense.eu	x						x	x	x
4	64297397	citisenseobservador04@citisense.eu	x						x	x	x
5	43673736	citisenseobservador05@citisense.eu	x						x	x	x
6	36651676	citisenseobservador6@citisense.eu	x						x	x	x
7	77914671	citisenseobservador07@citisense.eu	x						x	x	x
8	38568637	citisenseobservador08@citisense.eu	x						x	x	x
9	32433875	citisenseobservador09@citisense.eu	x						x	x	x
10	43181435	citisenseobservador10@citisense.eu	x	x	x	x	x	x	x	x	x
1	68611632	citisenseobservador11@citisense.eu	x	x	x	x	x	x	x	x	x
2	29367491	citisenseobservador12@citisense.eu	x	x	x	x	x	x	x	x	x
3	13596113	citisenseobservador13@citisense.eu			x	x	x	x			
4	66229369	citisenseobservador14@citisense.eu			x	x	x	x			
5	46459595	citisenseobservador15@citisense.eu			x	x	x	x			
6	61755767	citisenseobservador16@citisense.eu			x	x	x	x			
7	77339615	citisenseobservador17@citisense.eu			x	x	x	x			
8	51762128	citisenseobservador18@citisense.eu			x	x	x	x			
9	35955461	citisenseobservador19@citisense.eu			x	x	x	x			
3	59211928	citisenseobservador20@citisense.eu	x	x					x	x	x
5	76991392	citisenseobservador21@citisense.eu	x	x					x	x	x
4	79865439	citisenseobservador22@citisense.eu	x	x					x	x	x
6	25169858	citisenseobservador23@citisense.eu	x	x					x	x	x
7	67825392	citisenseobservador24@citisense.eu	x	x					x	x	x
8	99252423	citisenseobservador25@citisense.eu	x	x					x	x	x
9	82344388	citisenseobservador26@citisense.eu	x	x					x	x	x
2	61615791	citisenseobservador27@citisense.eu	x	x	x	x	x	x	x	x	x
8	19261373	citisenseobservador28@citisense.eu			x	x	x	x	x	x	x
9	18316897	citisenseobservador29@citisense.eu	x	x					x	x	x
2	85698221	citisenseobservador30@citisense.eu			x	x			x	x	x
1	89317474	citisenseobservador31@citisense.eu	x	x			x	x	x	x	x
1	15566433	citisenseobservador32@citisense.eu	x	x	x	x			x		
3	49987966	citisenseobservador33@citisense.eu	x	x		x	x	x	x	x	x
3	22434395	citisenseobservador34@citisense.eu	x	x							
	25327928	citisenseobservador35@citisense.eu			x	x	x	x			
4	37321753	citisenseobservador36@citisense.eu	x	x	x	x					
10	75115969	citisenseobservador40@citisense.eu					x	x			
9	29483656	citisenseobservador41@citisense.eu	x	x			x	x			
5	74479116	citisenseobservador42@citisense.eu			x	x	x	x			
8	62247112	citisenseobservador43@citisense.eu			x	x	x	x			
5	42871512	citisenseobservador44@citisense.eu			x	x	x	x			
1	63889216	citisenseobservador45@citisense.eu	x	x							
4	63322661	citisenseobservador46@citisense.eu	x	x							
6	49673782	citisenseobservador47@citisense.eu	x	x			x	x			
7	55439711	citisenseobservador48@citisense.eu					x	x			
6	43962874	citisenseobservador49@citisense.eu					x	x			
1	15399291	citisenseobservador60@citisense.eu	x	x	x	x	x	x	x	x	x
4	83679477	citisenseobservador61@citisense.eu	x	x	x	x	x	x	x	x	x
4	97529113	citisenseobservador62@citisense.eu			x	x					
1	91944151	citisenseobservador63@citisense.eu				x					
9	56865431	citisenseobservador64@citisense.eu			x	x					
1	11474661	citisenseobservador65@citisense.eu			x	x					
9	83688714	citisenseobservador66@citisense.eu			x	x					
9	71199613	citisenseobservador67@citisense.eu					x	x			
1	28147572	citisenseobservador68@citisense.eu			x	x					
		TOTAL	32	23	26	28	26	26	26	25	25

- All information is provided correctly
- No information of Thermal index
- No informationof Thermal and Acoustic index
- All the information of the observation is lost
- Other incidences

Observator 9 in HERR-3 all data is available except Acoustic index
Observator 10 in CEA-2 all data are missing except Acoustic Index
Observator 33 in CONS-1 all data are missing except Acoustic Index
Observator 47: acoustic and thermal indexes are shown but graphs regarding landscape and confort are not displayed (civivflow information)

Figure 5-5 Final data status for user-area

5.5.5 Data Visualization

In order to create the necessary widgets for data visualization, we explored several graphical libraries that would allow us to perform the necessary charts. After some research, we decided to use Highcharts libraries.
Highcharts is a charting library written in pure JavaScript, which offers an easy way of adding interactive charts to on a web site or application. It is solely based on native browser technologies and does not require client side plugins like Flash or Java, and do not require any installation on the server side, either.
On the visualization side, it supports several charts like: line, spline, area, column, bar, pie, scatter, and many more. Besides, on hovering the chart, it is possible to display a tooltip text with information on each point and series. Furthermore, users can export the chart directly to PNG, JPG, PDF or SVG formats. These two features were considered as high value, as they encourage visitors to interact with the graph.

In the following figures, the information displayed for one monitoring site of one area is presented as an example of the data that is available for every area.

Figure 5-6 Visualization of global landscape perception

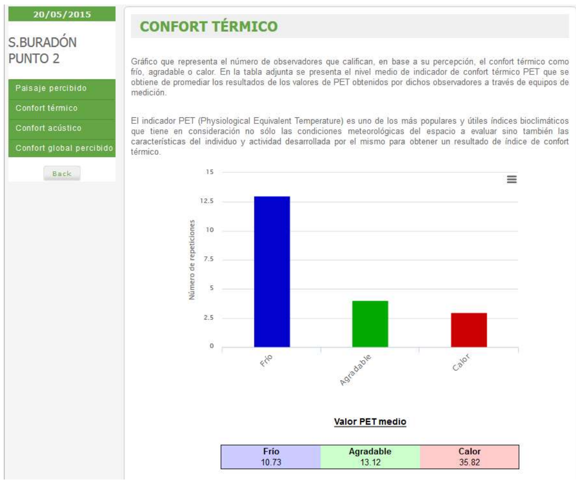


Figure 5-7 Visualization of global thermal comfort

The thermal and acoustic comfort indexes are presented by combining objective and subjective data. The bars with different colors in the figure refer to the number of users that have perceived the area as cold (frio), pleasant (agradable), and hot (calor). The data displayed in the row below the graph shows the PET (thermal comfort index) average of the users that have perceived within each particular thermal condition.

Information in private access (for participants only)

In order to access the private area of the Result part, the ID (e-mail specifically created for the project) and password (specifically created for the project) must be entered.

The information displayed in the private area presents the landscape perception and perception of the global comfort overlaid together with the individual perception of the user (Figure 5-8 and 5-9).

Figure 5-8 Visualization of the individual landscape perception.

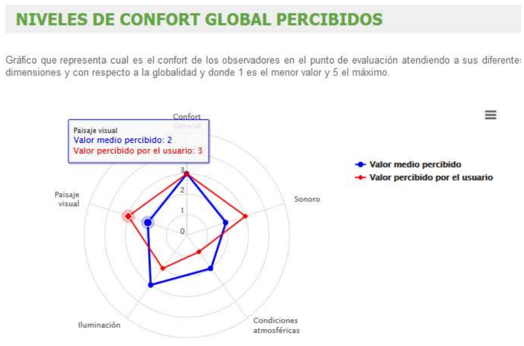


Figure 5-9 Visualization of the individual global comfort.

We considered these types of visualizations the best, since they show the most relevant information regarding the comfort in the area. It will help to empower citizens having more information to make decisions and being able to evaluate the plans developed by city planners and stakeholders.

Participants have access to the private area of the web portal to see their personal results by using the e-mail and personal password that has been provided to them before making their observations.

5.5.6 Suggested further improvements/problems/weaknesses/lessons learned

As mentioned in the technical description section, several issues arose during the implementation of the data visualization module. However, these issues were not directly derived neither from visualization requirements nor from the selected technical approach to deal with them, but from the data architecture employed along the project and the data loss caused by the network issues during the data acquisition process.

5.5.7 Current Status

The web site is up and running, and can be accessed on the following address: http://citi-sense.tecnalia.com/resultados.jsp

6 Data Visualization Web Portal

The Data Visualization Web Portal provides information about collected sensor data on the CITI-SENSE platform. Results are displayed on the map with various options for enabling and showing different types of data, statistical analysis and data filtering.

6.1 Case studies

6.1.1 Requirements

The following requirements were addressed:

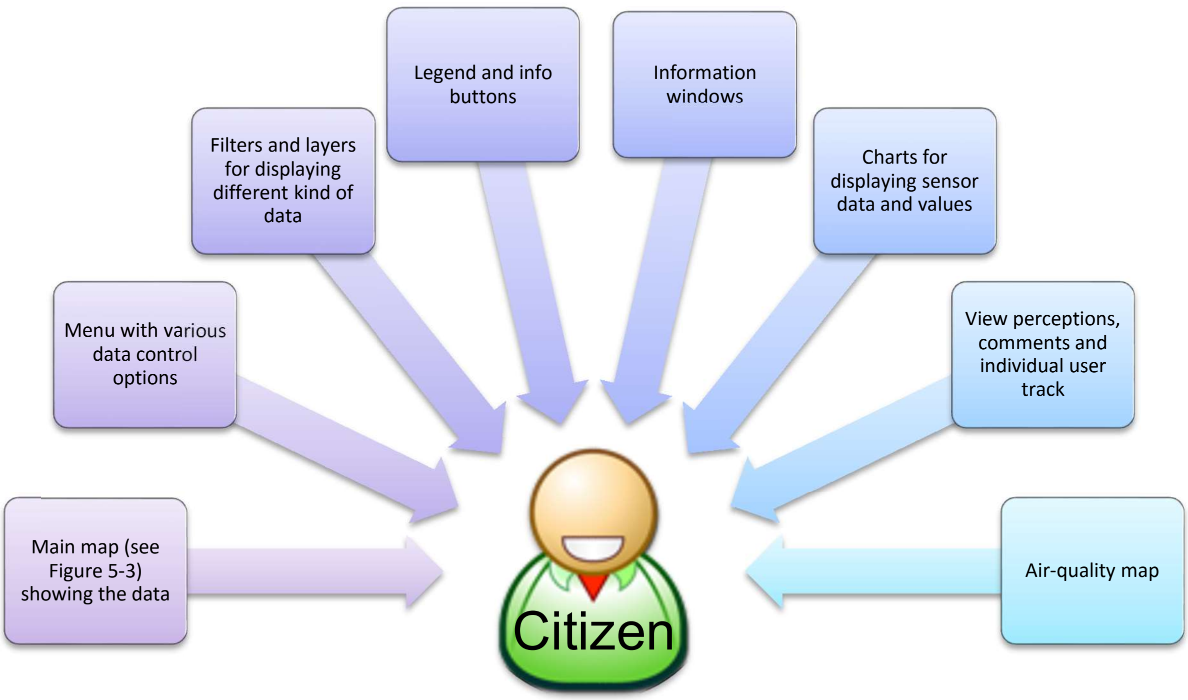


Figure 6-1 Data visualization web portal requirements

6.2 Current status

The User can select a city and then see the sensor data with various mobile and static sensors, user perceptions and user comments on a map (Figure 6-2).

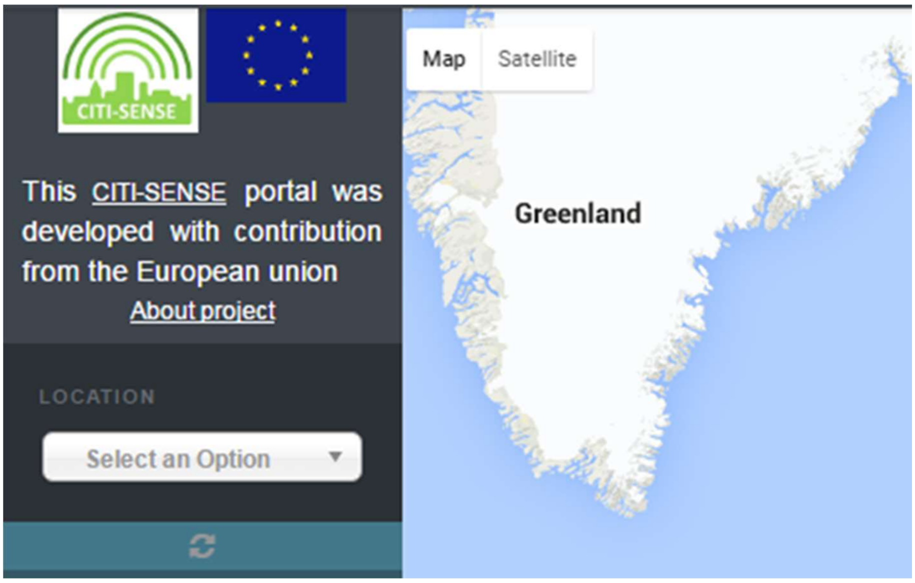


Figure 6-2 Location drop-down menu

Menu with various data control options

From the menu the user can choose various options, such as different layers, filtering data, and control data displayed on the map.

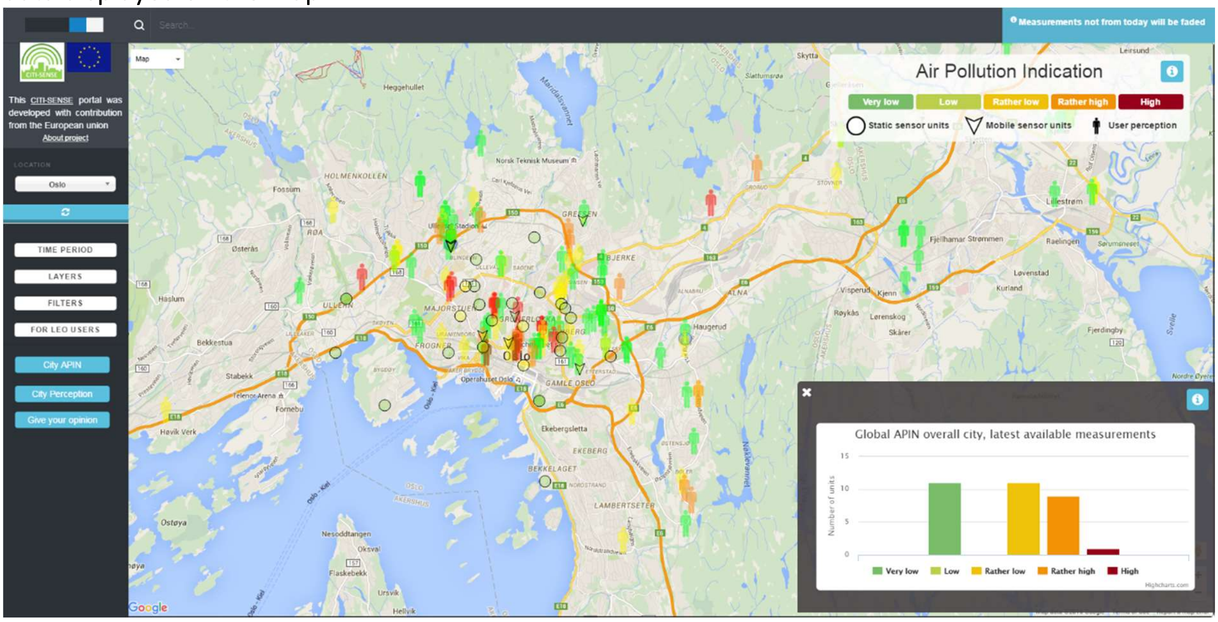


Figure 6-3 Main map

Filters and layers for displaying different kind of data

Data can also be filtered applying the FILTERS option where different pollution data can be enabled and disabled (Figure 6-4).

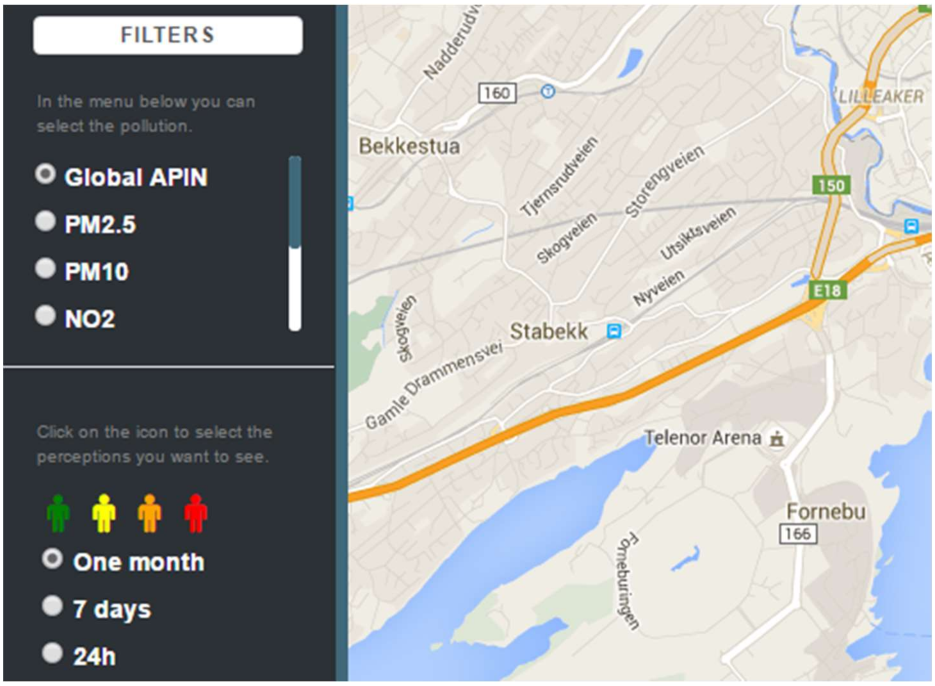


Figure 6-4 Layers and filters

The portal uploads last measured values for several types of sensors: Mobile, Static, User Perceptions, User Comments (Figure 6-5).

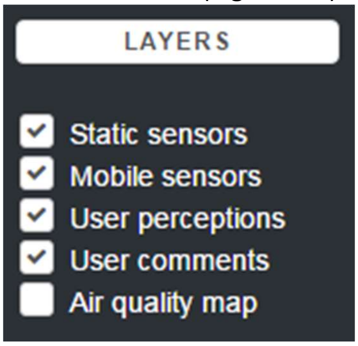


Figure 6-5 Layer types

These various types of sensors are shown as different LAYERS on a map which can be enabled and disabled using the appropriate check box option in the main menu.

Legend and info buttons

The legend and info buttons are used for more information about APIN[5], information windows providing more information about sensors, charts for displaying sensor data and values.

Information windows

Information windows provide more information about sensors such as the type of sensor, last measured date and time, latitude and longitude, etc.

[5] APIN is the abbreviation used for Air Pollution INdicator. Our measurement results are displayed as APIN who is related to a Common Air Quality Index /CAQI), but cannot directly be compared as the air quality monitoring methods underlying the measurements differ.

Charts for displaying sensor data and values

The charts are used for summing and displaying sensor values for a short time period so that continuity can be seen over time.

Viewing perceptions, comments and individual user track

One can see user comments and perceptions created with the CityAir app on a map. Also, for mobile sensors the user can fill in their user ID from the ExpoApp to see a track of their measurements (Figure 6-6).

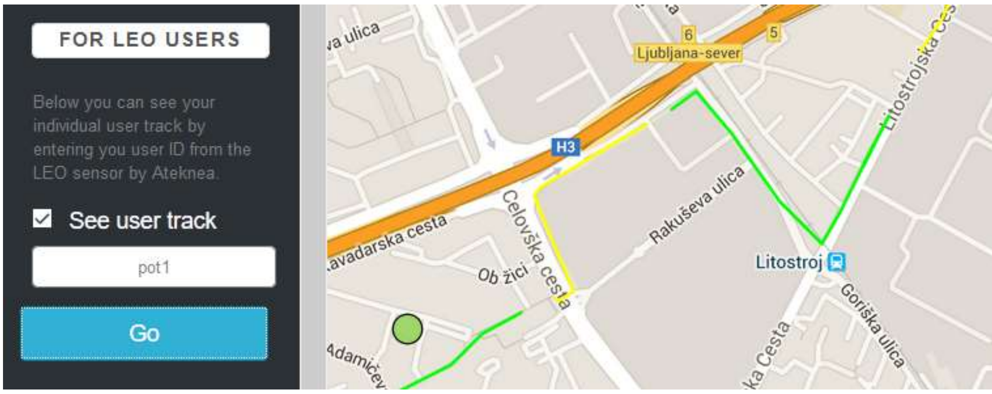


Figure 6-6 Mobile sensor data viewing

Air-quality map

By choosing Air-quality map from the LAYERS section, the user can see the air quality in a larger area, but only for cities that have an air-quality map. This layer can be combined with other layers (Figure 6-7).

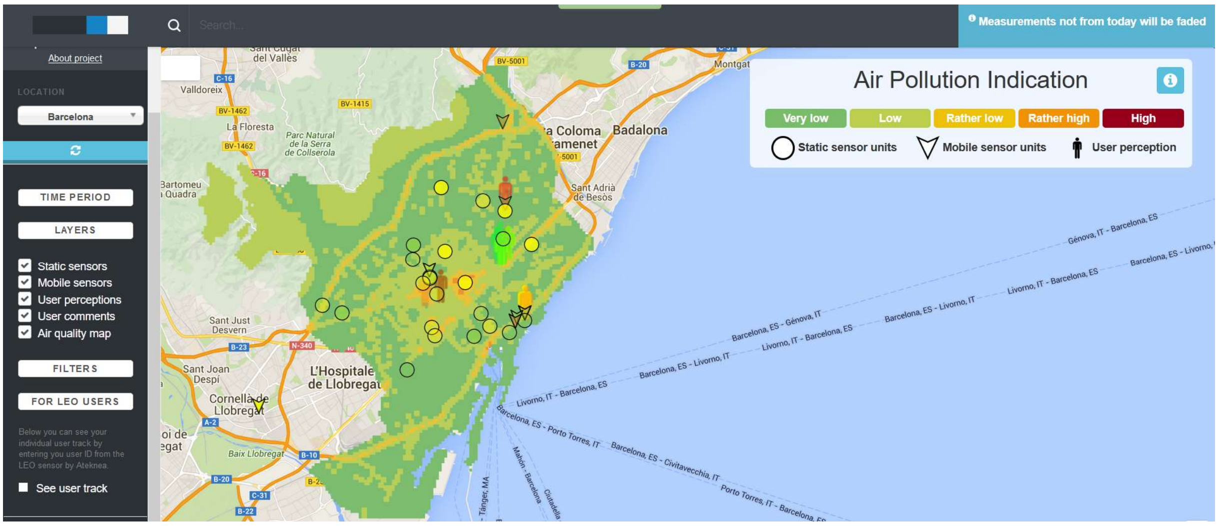


Figure 6-7 Example of air-quality map for Barcelona

6.3 Technical description

6.3.1 Development environment

This portal is developed in Notepad++ work environment. For implementation and integration of all components, Java Script and jQuery have been used as for getting and displaying data on a map widget. For portal appearance, HTML and CSS are used and for mobile compatibility Bootstrap framework. For info buttons and other icons, Font awesome library is used.
Data visualization web portal consists of following components:

1. U-Hopper visualisation widgets, for displaying data, and different data types.
2. Highcharts widgets with data collected and downloaded from Snowflake web service.
3. Filters and layers combined with U-Hopper widget in order to control data visualisation
4. JSON and XML data structure from Snowflake web service.
5. Google maps which are implemented in U-Hopper visualisation widgets

6.3.2 Architecture

The portal communicates with several different services. It obtains data and widgets from the U-Hopper platform which again uses Google Maps and Snowflake web service. Part of the data is displayed indirectly from Snowflake, trough U-Hopper widgets (mobile, and static sensors, individual user track measurements), and another directly through Ajax request (perception data, comments, Highcharts data).

6.3.3 Database

Most of the data is placed and collected from the Snowflake web-service. Data for Air quality maps is gathered through NILU service.

6.4 Suggested further improvements/problems/weaknesses and lessons learned

6.4.1 Improvements and weaknesses

The portal is user friendly because of its visual approach. Info buttons are crucial for understanding air pollution system mechanism. Page speed is sometime a problem because of the large amount of data that has been gathered and showed, but the main slowness part is resolved.

7 Data download web page

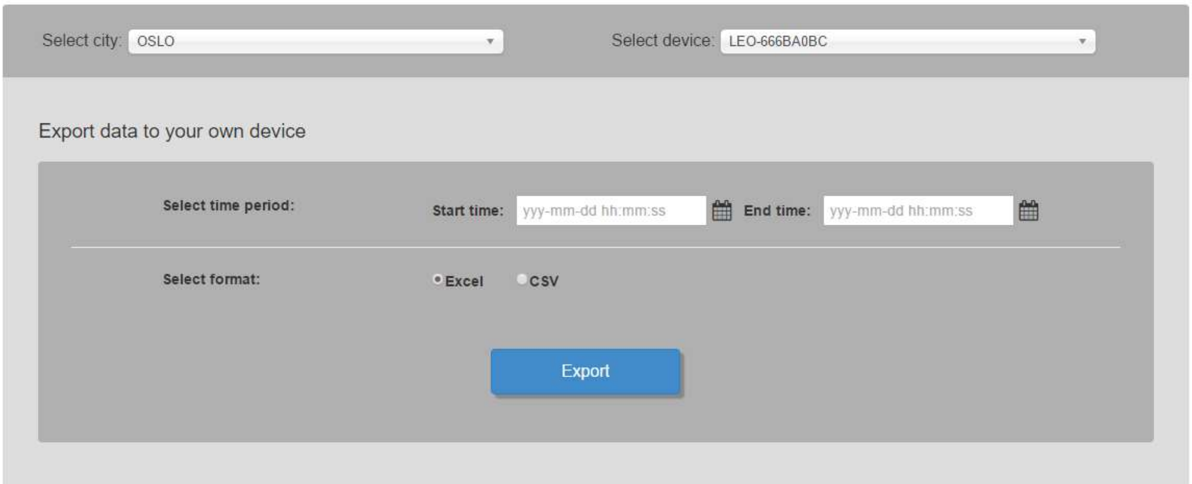


Figure 7-1 Screenshot Data download web page

The Data download web page is a simple web page designed for automatically downloading of a file with measurements from a specific sensor unit within a time period. The format of the file can be either an Excel or a csv file.

The application creates an https call to the CITI-SENSE platform to retrieve the selected data and then creates a table. The table is then parsed into a Workbook object by using an xlsx.core.min.js (https://github.com/SheetJS/js-xlsx/blob/master/README.md) library. This is a java script library for parsing and writing various spreadsheet formats and supports xslx, csv and json.

8 Citizens' Observatories Web Portal

The main CITI-SENESE platform for all activities, products and services, is the Citizens' Observatories (CO). The citizens' observatory evolved as a concept in the 90s. It defines a combination of participatory monitoring, technology and governance structures that are required to observe, monitor and manage an environmental issue (Lanfranchi et al., 2014; Liu et al., 2014).

In the case of CITI-SENSE, this was a variety of issues, which were all supported through the development of a CO model. This model was created by Work Package 4, in collaboration with the other work packages and project participants.

The basis for the COs in the participating cities, schools, etc., was a web based portal for dissemination, and a combination of tools, such as web apps, questionnaires, etc.

The various COs Web Portals are all linked by a Meta portal – Citizens' Observatories Web Portal (COWP; http://co.citi-sense.eu/). It encompasses all aspects of the project, and contains, or provides access to, large amounts of content, services, applications and tools.

COWP is hosted on an advanced, virtual server and has a 100% up-time due to the redundancies built into the server architecture.

Other COs are also hosted on the same system. These COs are the products of the various use cases performed in the project, and can be found in the Table 8-1.

Table 8-1 CITI-SENSE location-based citizens' observatories web portals.

Location-based Citizens' Observatories No.	Empowerment Initiative	Portal Domain Name
1	Outdoor air quality in Barcelona	barcelona.citi-sense.eu
2	Environmental quality in public space, Vitoria	vitoria.citi-sense.eu
3	Outdoor air quality in Belgrade	belgrade.citi-sense.eu
4		
5	Outdoor air quality in Ostrava	ostrava.citi-sense.eu
6	Outdoor air quality and indoor air quality in schools in Edinburgh	edinburgh.citi-sense.eu
7	Indoor air quality in Ghmskola, Belgrade	ghmskola.citi-sense.eu
8	Outdoor air quality in Haifa	http://air.net.technion.ac.il
9	Outdoor air quality in Ljubljana	LjubLjana.citi-sense.eu
10	Outdoor air quality in Oslo	oslo.citi-sense.eu
11	Indoor air quality in 12 Schools	schools.citi-sense.eu
12	Indoor air quality in Vič High School, Ljubljana	vic.citi-sense.eu
13	Outdoor air quality in Vienna	vienna.citi-sense.eu
14	Indoor air quality in Vigimnazija school, Belgrade	vigimnazija.citi-sense.eu
15	Indoor air quality in 20. OKTOBAR school, Belgrade	20.oktober.citi-sense.eu
16	Indoor air quality in VODMAT elementary school, Ljubljana	ves.citi-sense.eu

8.1 The COWP portal

The CITI-SENSE COWP and location-based COs portals were developed using a free, open source, content management server called DotNetNuke (DNN). DNN is an industry leading CMS due to its configurability, support and 3rd part development.

DNN comprises a base system, which provides a website 'out of the box' but can be extended with additional modules, according to need. It is developed using the Microsoft .NET platform. Originally, it was written in VB.NET, though the development has shifted to C# since version 6.0.

The CITI-SENSE COWP uses version 07.04.02 (Build 216). It runs on MS SQL.

The COWP has been configured to provide dynamic content to the user, including text and images, video content, links to social media, as well as access to the GEOSS Portal (Figure 8-1).

Figure 8-1 Screenshot of the COWP front page.

The COWP has three layers - the CO central web portal, thematic areas, and individual web portals of participating cities. The thematic areas are Air Pollution Perception, Outdoor Air Quality in Cities, Indoor Air Quality in Schools and Environmental Quality in Public Spaces (Figure 8-2). The home page describes also the CITI-SENSE relationship to the Global Earth Observations (GEO) and gives a link to the GEO System of Systems (GEOSS[6]). More information is accessible using the embedded videos, hosted on YouTube. Social media platforms are presented with links as well.

[6] http://www.earthobservations.org/index.php

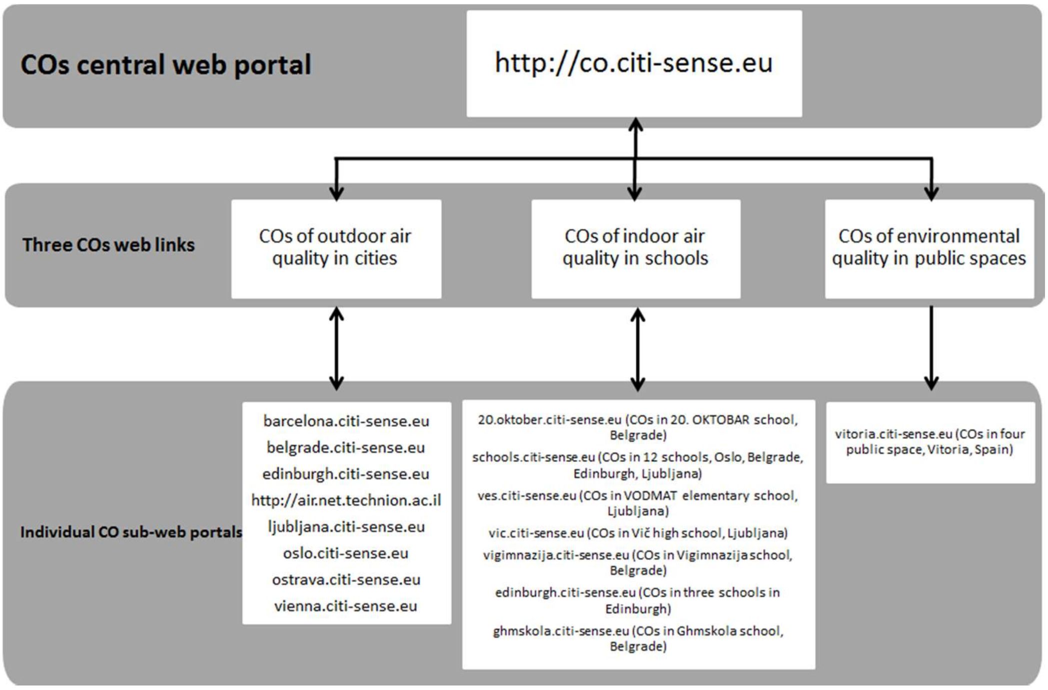


Figure 8-2 Triple-layers of web portals.

In addition, the Portal contains the COT, or Citizen's Observatory Toolbox. The COT is a collection of services, applications, sensors and widgets that comprise the heart of the project. A main focus of the Portal is to provide access to these. In addition, the Portal contains information about how to acquire, install and use our tools. For the technically minded, you can get specifications about the sensing devices, and detailed information about how to use our data for your own applications. And of course you can learn more about the CITI-SENSE project that brought this to you, and the various Citizens' Observatories that have been implemented within CITI-SENSE, i.e., Citizens' Observatories on outdoor air quality in eight cities, on indoor air quality in 12 schools, and on environmental quality in four public spaces. Additional features are links to various Citizens' Observatories social media platforms as well as the synergy and integration with GEOSS.

No 3rd part commercial modules were used in the project, however, user requirements demanded certain functionality that was not available. Consequently, Work Package 6 developed modules for the displaying of real-time data relayed from sensors, as well as data from the main project data repository.

Figure 8-3 demonstrates the model developed to support the CO needs of the project: There are three types of COs across nine cities (left side), there are four core components along the information chain as "citizens – sensors and sensors platform – data server platform – services and products" (right), and one single access to CITI-SENSE COs (middle).

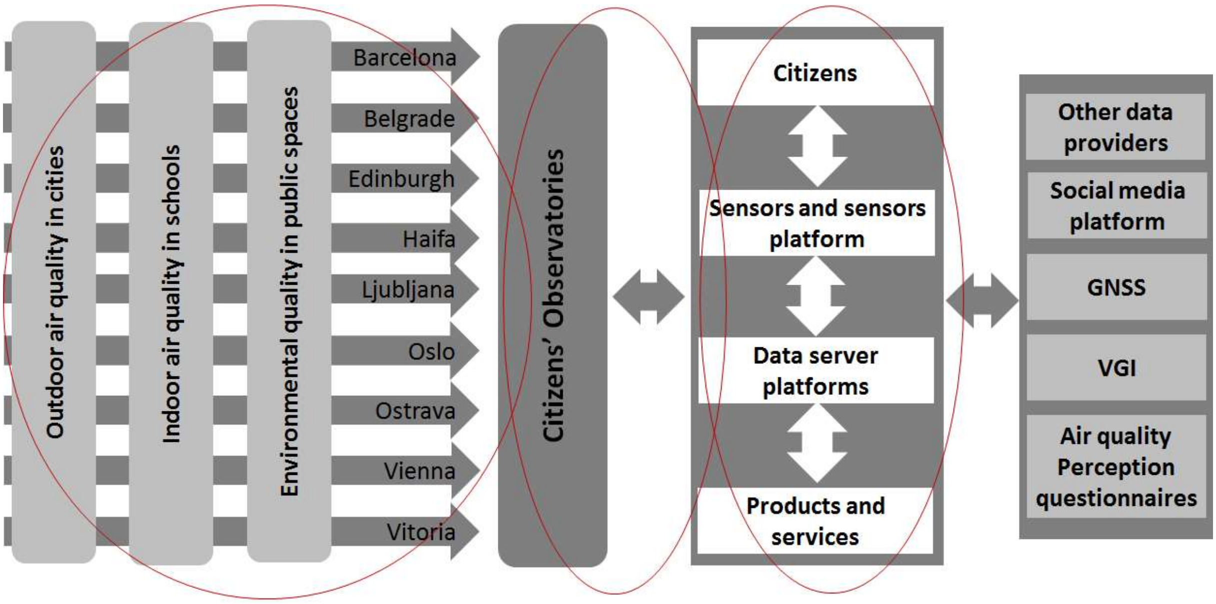


Figure 8-3 Support for CO needs in CITI-SENSE

8.2 DNN Architecture

The DNN architecture is designed to be flexible, scalable and secure. It can utilize the latest storage systems, including cloud storage, as well as traditional storage solutions.

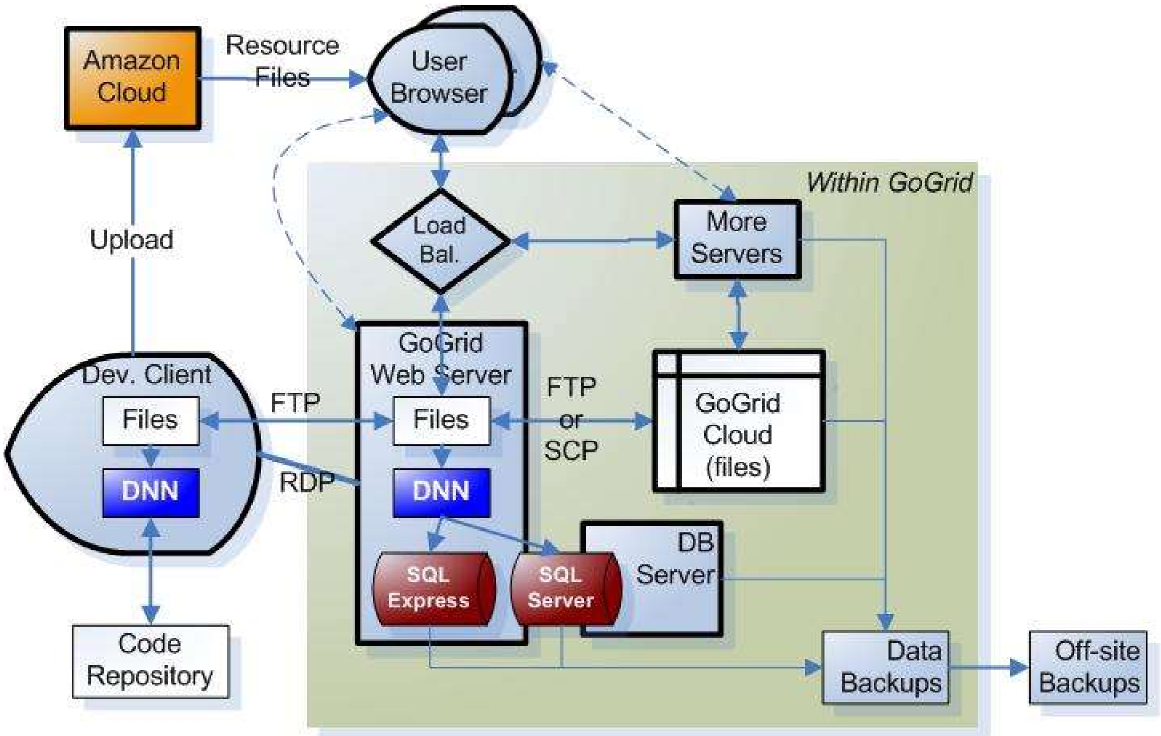


Figure 8-4 DNN architecture (from http://www.wilsonmar.com/dot_net_nuke.htm)

8.3 Current status and further improvement

Currently, the COWP is in the final phase to be completed. It is operating now. Based upon the consortium and the external users feedback, WP4 are improving the portal, checking all the typing errors, hyperlinks and other functionalities, restructuring and organizing the content better, working on the synergy with GEOSS. For more detail descripiton about COWP and its usebility assessment, please see D4.5, D4.4 and D6.5.

9 Data fusion maps

9.1 Introduction

The low-cost microsensors deployed within the CITI-SENSE project have significant potential for improving high-resolution mapping of air quality in the urban environment. However, one major shortcoming of the data obtained by such sensors is that there are significant data gaps in both space and time. To overcome this issue, we present a data fusion method based on geostatistics that allows for merging crowdsourced observations of air quality with the information from an urban-scale air quality model. The performance of the methodology is evaluated using a simulated dataset of NO_2 over the city of Oslo, Norway. First results indicate that the method is capable of producing a concentration field that replicates the spatial patterns of a simulated true concentration field. Cross-validation of the fused concentration field carried out against a second set of simulated observations shows that the technique provides a robust way of bias-correcting the model information and that the prediction errors are on the order of the same magnitude as the perturbation applied to the simulated values. The achievable accuracy of the data fusion method is highly dependent on the number of observations and their spatial distribution.
The methodology for creating the data fusion maps is described in detail in CITI-SENSE deliverable D6.3, so only a brief overview will be given here. For more comprehensive information please see D6.3 and D6.5.

9.2 Methodology

The data fusion methodology applied here is based on geostatistical principles (Isaaks and Srivastava 1989; Cressie 1993; Goovaerts 1997; Kitanidis 1997; Wackernagel 2003; Webster and Oliver 2007; Sarma 2009; Chilès and Delfiner 2012). It uses universal kriging to combine observations with model data by predicting the concentrations at unknown location by simultaneously interpolating the observations and using the model data to provide information about the spatial patterns.

In contrast to ordinary kriging, universal kriging allows for the overall mean to be non-constant throughout the domain and to be a function of one or more explanatory variables. Universal kriging is similar to kriging with external drift and mathematically equivalent to regression kriging (Hengl, Heuvelink, and Rossiter 2007) or residual kriging (Denby et al. 2010; Horálek et al. 2013) but can perform the linear regression against auxiliary variables and the spatial interpolation of the corresponding residuals in a single step. Universal kriging assumes a non-stationary mean and in addition the presence of local spatial variation. As such the parameter in question is modelled by a deterministic regression component that provides the large-scale spatial variation and provides spatial patterns in areas where no observations are available, and a kriging component that provides the small-scale random variation.

In general, the estimated concentration $\hat{Y}(s_0)$ at point s_0 is computed as

$$\hat{Y}(s_0) = c + a_1 \cdot x_1(s_0) + a_2 \cdot x_2(s_0) + \cdots + a_p \cdot x_p(s_0) + \varepsilon(s_0)$$

where c is a constant, a_1, a_2, etc are regression coefficients, X_1, X_2, …, X_p are the values of the p predictor variables of the regression component, and ε is a stationary random process with a given semivariogram.

In practice, the spatial trend or drift ε of the mean is estimated here using a single predictor variable, which is the annual average concentration map provided by the EPISODE chemical dispersion model

(Slørdal et al., 2003). The observations are provided by the air quality sensors deployed throughout the environment. As such, the system takes the overall spatial patterns of the concentration field from the annual average map, which acts as a *climatology* (essentially a long-term mean), and adjusts this field based on the observations.

Before the actual data fusion takes place, both the modelled and observed concentrations are first transformed into log-space using the natural logarithm. This approach follows previous work such as that carried out by Denby et al. (2008), De Smet et al. (2010), and Horálek et al. (2014) and is done because the frequency distribution of observed and modelled concentrations most often resembles the lognormal distribution. A log-transformation therefore is able to convert these distributions into an approximately Gaussian distribution, which is what is assumed for universal kriging. Taking the lognormal distribution of the concentrations into account has further been shown to provide superior mapping accuracy (Denby et al. 2008; Horálek et al. 2013).

The theoretical semivariogram required for calculating the covariances in the kriging process was fitted automatically to the empirical semivariogram for each new set of observations (generally at hourly intervals). The variogram model types were kept the same as those derived for the model-derived basemaps, while the respective range of the models was allowed to vary by up to 30% around the values derived for the basemaps. The nugget and sill parameters were allowed to vary freely.

After universal kriging is carried out in log-space, the resulting concentration field and the corresponding mapping uncertainty have to be back-transformed from log-space. Denby et al. (2008) showed that the theoretical back-transformed expectation value of a concentration C is given as

$$E[C] = \exp\left(\mu + \frac{\sigma^2}{2}\right)$$

where μ and σ represent the mean and standard deviation of the log-normal-transformed data, respectively. In practice the concentration values resulting from the data fusion process are thus back-transformed by exponentiation with the kriging error as

$$\hat{Z}(s_0) = \exp\left[\hat{Y}(s_0) + \frac{\sigma^2(s_0)}{2}\right]$$

where $\hat{Z}(s_0)$ is the estimated back-transformed concentration value at point s_0, $\hat{Y}(s_0)$ is the concentration at point s_0 resulting from the data fusion process, and $\sigma(s_0)$ is the kriging standard deviation at point s_0 (De Smet et al. 2010).

The theoretical back-transformed variance of the log-normal distribution is computed as

$$\mathrm{var}[C] = [\exp(\sigma^2) - 1] \cdot \exp[2\mu + \sigma^2]$$

where μ and σ represent the mean and standard deviation of the log-normal-transformed data, respectively (Denby et al. 2008). Thus the back-transformed standard deviation (uncertainty) $\delta(s_0)$ at point s_0 of the fused map can be calculated in practice as

$$\delta(s_0) = \sqrt{\exp[\sigma^2(s_0) - 1] \cdot \exp\left[2 \cdot \hat{Y}(s_0) + \sigma^2(s_0)\right]}$$

where $\sigma(s_0)$ is the kriging standard deviation at point s_0, and $\hat{Y}(s_0)$ represents the concentration at point s_0 resulting from the data fusion process (Denby et al. 2008; De Smet et al. 2010).

9.3 Results

Figure 9-1 shows an example of applying the data fusion methodology to a simulated example for the city of Oslo, Norway. The top left panel shows a "true" concentration field which is supposed to be recreated using incomplete data. The truth field here represents the modelled concentration of NO_2in the Oslo area at 08:00 CEST on 8 January 2013. The top center panel shows the two datasets that are available for the data fusion. This includes in the background the model proxy dataset, in this case the 2014 annual average concentration field of NO_2while the points represent observations of NO_2which were simulated from the "truth" field using a random perturbation of 10 µg m^{-3}. The locations of the simulated observations are the same as used in a real-world deployment of static sensor nodes in the CITI-SENSE project (www.citi-sense.eu). Note that the color scale used is the same for both datasets, so the observations indicate significantly higher concentrations than the model-based proxy dataset would predict.

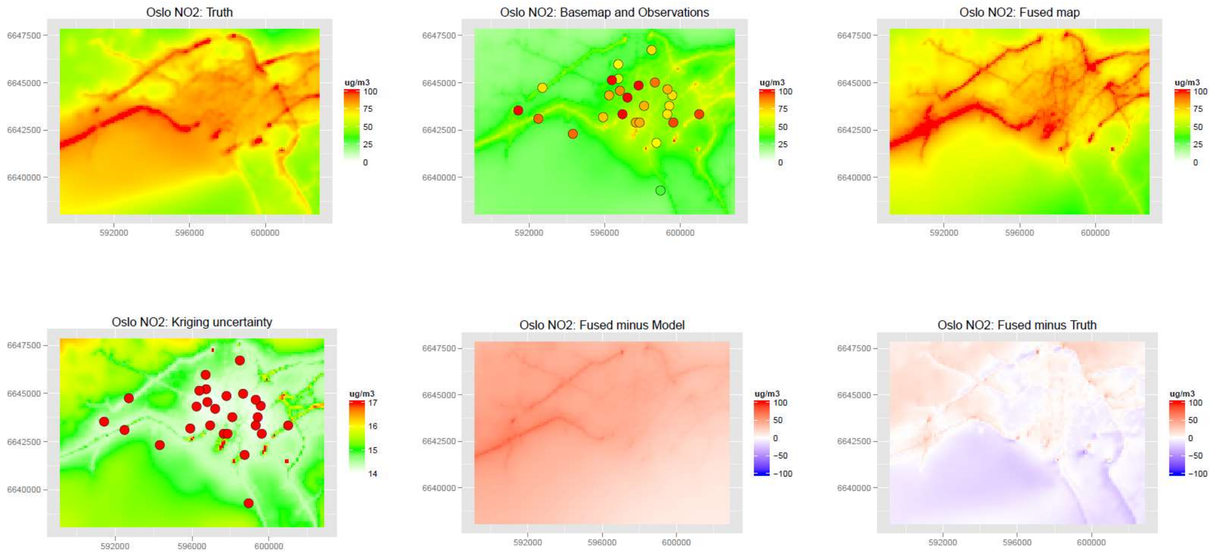


Figure 9-1 Example of data fusion with simulated observations. Top left panel: "true" NO_2 field (in practice, unknown). Center top panel: model-derived annual average basemap of NO_2 and observations simulated from truth field using a random error. Top right panel: map from data fusion algorithm applied to basemap/observations. Bottom left panel: uncertainty associated with data fusion process. Bottom center/right panels: difference between fused map and model and "truth", respectively.

The top right panel of Figure 9-1**Error! Reference source not found.** shows the result of a fusion of the two datasets shown in the top center panel, following the methodology described above. It can be observed that the spatial patterns in general are quite well replicated. Even more importantly, the overall levels appear quite similar to those in the truth field. One area that is not picked up well by the data fusion process is the relatively high concentrations in the southwestern corner of the truth field. This is because there were no observations available in this area.

The bottom left panel of Figure 9-1 shows the uncertainty associated with the universal kriging process and the locations of the simulated observations (as points). It can be seen that the interpolation error is quite low in areas where many observations are available. However the uncertainty increases towards the southwest and northwest where no observations are available. The uncertainty map shown here includes both the uncertainty related to the regression component of universal kriging as well as the uncertainty resulting from the spatial interpolation process. However, it should be noted that this uncertainty does not give an indication of the overall true uncertainty since the measurement error in the observations is not considered at this point.

In order to see how the modelled concentration field has been modified during the data fusion process based on the observations, it is helpful to calculate a difference image between the original modelled long-term mean and the fused map (see bottom center panel of Figure 9-1). In this example, the difference map indicates that the concentration field has been increased throughout most of the domain, while in the southeastern corner the concentration values have been mostly left as they were predicted by the model. It can also be observed that the concentrations along some of the larger roads, particularly in the western half of the mapping domain, have been increased more than the surroundings.

For evaluating the success of the data fusion algorithm it can further be helpful to compute a difference image between the truth field and the fused result. Such a map is shown in the bottom right panel of Figure 9-1. It can be seen that the differences are quite close to zero in those areas where the majority of the simulated observations were located. In areas outside of the center of the mapping domain the error increases. In the southern half of the mapping domain the differences are primarily negative (indicating that the concentration field had higher values in these areas than the fused map was able to recover), whereas towards the north of the mapping domain, the differences tend to be mostly positive (indicating that the fused map overestimated the true concentration field in this regions).

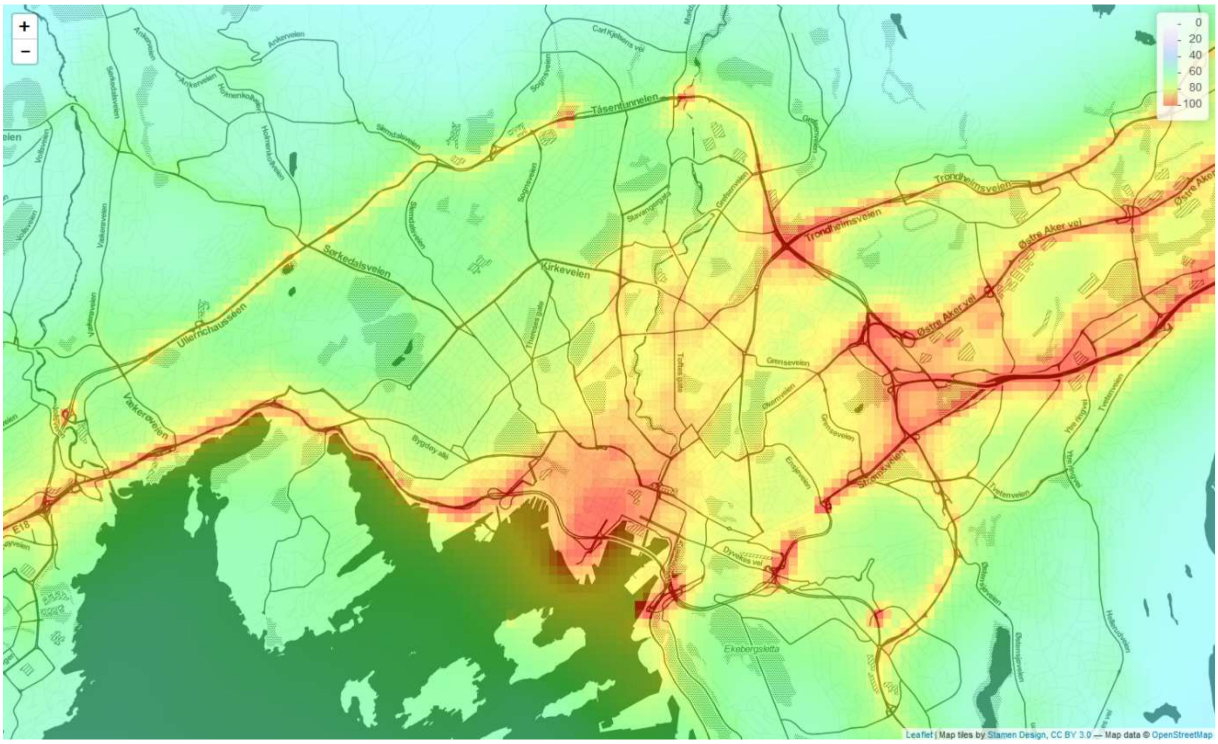


Figure 9-2 Example of a data fusion-based surface concentration field of NO_2 for Oslo, Norway, at 100 m spatial resolution

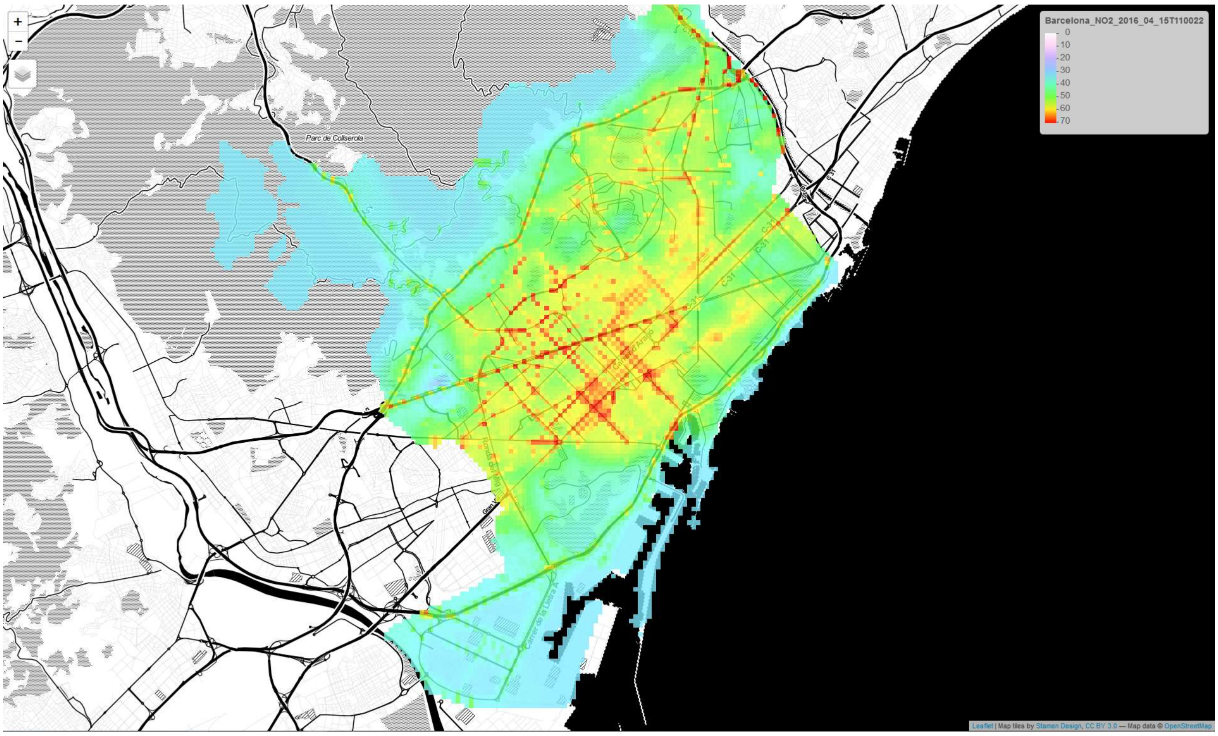


Figure 9-3 Example of a data fusion-based surface concentration field of NO_2 for Barcelona, Spain, at 100 m spatial resolution

Figure 9-2 and Figure 9-3 show examples of concentration fields as produced by the data fusion process. These examples show the typical NO_2 concentration fields for Oslo and Barcelona at selected hours in January and April 2016.

In practice, the concentration fields coming out of the data fusion technique are converted to an air quality index before being communicated to the users. This is done for easier communication of the results to the users and to some extent also to mask some of the pixel-level uncertainty. Figure 9-4 shows an example of a concentration field converted to the Common Air Quality Index (CAQI). Due to the coarse nature of the classes the spatial gradients have now disappeared, however the general spatial patterns of the concentration field can still be observed.

Figure 9-4 Example of a concentration field coming out of the data fusion process after conversion to the Common Air Quality Index. This index is used as the basis for the Air Pollution Indicator (APIN) which is used for the CITI-SENSE web portal

9.4 Technical description

9.4.1 Development environment

The core data fusion code has been developed in the R programming language version 3.2.4 in the RStudio IDE version 0.99.893.

9.4.2 Architecture

The core data fusion algorithm has been developed in the R programming language. Around this code a wrapper has been written in the Python language in order to simplify the operationalization of the code. In addition, Python code was developed to retrieve the latest observations from the Snowflake platform.

Each hour, the Python code is called in a cronjob for six of the CITI-SENSE locations (Oslo, Barcelona, Haifa, Ljubljana, Belgrade, and Ostrava). The code then retrieves the latest AQMesh observations for each location from the Snowflake platform and launches the core data fusion code separately for each site. The core data fusion code then performs the processing and creates a map of the current best-guess field of the concentrations for each pollutant at the given location.

9.4.3 Code structure

Two R packages have been developed in the R programming language:

The *datafusion* package contains code for fusing the observations from the AQMesh sensors with the corresponding model-derived basemap for each CITI-SENSE location.

The *caqic* package performs the conversion of the fused concentration fields to the Air Pollution Indicator (APIN), which is based on the Common Air Quality Index (CAQI)

In addition, a Python package called *snowflakepy* was developed. It performs the data acquisition from the Snowflake server, calls the underlying data fusion code developed in R, and performs some housekeeping of the various files generated in the process.

9.4.4 Data storage

The output of the data fusion code is stored locally on a NILU server as various files. The fused maps are stored as GeoTIFF files, which offer the advantage of being standardized and easy to import in most software packages, yet are georeferenced, i.e. they include all the required spatial georeference information required in order to display the data in a Geographical Information System (GIS), or make use of the information in other spatially aware software solutions.

In addition to the GeoTIFF files, various statistics for quality monitoring are output as a text in JSON format.

9.4.5 Data publish

For display of the APIN maps on the Dunavnet website, the concentration maps coming out of the data fusion methodology are converted to APIN maps and are subsequently saved as KML files on a web server hosted by NILU, which are then directly retrieved and displayed by Dunavnet.

9.5 Dependencies

The R code developed within the framework of the data fusion work is dependent on the following main libraries/packages:

Package	Package Description
sp	Implements spatial foundation classes for R and many underlying tools and functionality
gstat	Provides tools for geostatistical analysis in R
automap	Provides automated modelling of the semivariogram
raster	Provides foundation classes for spatial raster datasets and a large number of tools to process them
Hmisc	Various functions and tools

The mentioned packages are in turn dependent on a large number of R libraries, which are not listed in detail here, but such dependencies will generally be automatically loaded if the above mentioned packages are installed.

All packages mentioned here are freely available from CRAN.

9.6 Suggested improvements

While the data fusion core code provides overall reasonable results, the quality of the resulting maps sometimes suffers from unrealistic values coming from the AQMesh sensors. Unfortunately no comprehensive and centralized quality control of the sensor data has been implemented within CITI-SENSE. For this reason, quality control of the data had to be performed in an automated fashion before using the sensor data with the data fusion methodology. Due to time and budget constraints only rudimentary error checking and quality control measured could be implemented. For future work it is recommended to put more emphasis on the quality control of the data before the data is exploited for mapping and similar activities.

Further improvements should also revolve around better characterization of the representativity of each static sensor node. Future work should thus better restrict the spatial influence of a sensors node to the surroundings that it is representative for, i.e. a sensor node located very close to a road should be regarded as a “traffic” station and its influence should be better restricted to the road network than it is currently the case.

9.7 Conclusions

A methodology is presented to combine observations from a large number of crowdsourced air quality monitoring devices at static locations with information from a high-resolution urban-scale air quality model. The result of the data fusion process, which is based on geostatistical techniques, is a new value-added map representing the best-guess concentration field at the time at which the observations were made. This concentration field inherits properties from both input datasets.

For evaluation purposes, the methodology has been tested using simulated datasets for which a “true” concentration field was known. Point-based observations were then sampled from this “truth” field and a random error component was added. The outcome of the data fusion process has then been evaluated against the original “true” concentration field both for the entire mapping domain and at simulated validation stations. The results indicate that the concentration field provided by the data fusion technique is able to quite well replicate the original concentration field in terms of both spatial patterns and absolute values. While there is a strong dependence of the achievable mapping accuracy on the total number of available stations providing air quality observations, the mapping accuracy for, e.g. NO_2, was found to reach RMSE values of less than 5 µg m^{-3} when a total number of 50 or more simulated stations were used throughout the mapping domain.

We show that data assimilation and data fusion of crowdsourced air quality observations with model information offers a novel way of generating spatially detailed maps of air quality in the urban environment. Additional future work will focus on improving the characterization of the spatial representatively and the uncertainty of the crowdsourced observations.

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ANNEX A: Air quality App v4 – requirements

AIR QUALITY APP

Working Group: Mark (lead), Nuria, Miriam, Vlasta

Aim: to obtain information from citizens on the perception of air quality in cities at different time periods and locations

Narrative: The air quality app can be installed by any citizen in the city on their smartphones and citizens can rate the air quality at different times and different locations in their city. The citizen can report their air quality perception as many times as they want. The data will be mapped and show the perception of air quality in different parts of the city over time. The best time and geographical resolution to map the data will be determined.

The App:
System: Android (and IPhone?)
When installing the App for the first time, the user will be asked to give:

- Age
- Gender
- Higher educational levels (Primary school, secondary school/high school, University/college up to 4 years, University/college longer than 4 years)
- Or an option to do this later

After installing, the user can open the app and will be asked the following question:

How is the outdoor air quality where you are now:

(symbol) Very good
(symbol) Good
(symbol) Poor
(symbol) Very poor

A further hidden option is available to give the source (traffic, …) of the pollution if the citizen answer poor or very poor, and a possibility for taken a photo
Select the pollution sources (with possibility of selecting several):

1. Traffic
2. Industry
3. House heating
4. Port/Harbour
5. Pollen
6. Dust
7. Smoke
8. Strong oudor
9. Others

Dataflow:
The data from the App will be sent to a central server (WFS server, snowflake). The data will be processed and will be visualised on a map, individually and as a smoothed map (similar to the sensor data) without identifiable information attached to it and accessible by the general public.
The data sent to the server will need to have information on user/smartphone Id, age, gender, education, perceived air quality, time stamp, location stamp, whether the location comes from network or satellite. This data will be accessible by a limited group of the researchers involved in the CITI-SENSE project followed strict data protection protocols.

Languages:
English
Catalan
Castellano
Norwegian
Hebrew
Slovene
Serbian
Czech
German

Download site: It should be available in the CITI-SENSE web page, not sure how can it be available on the google store.

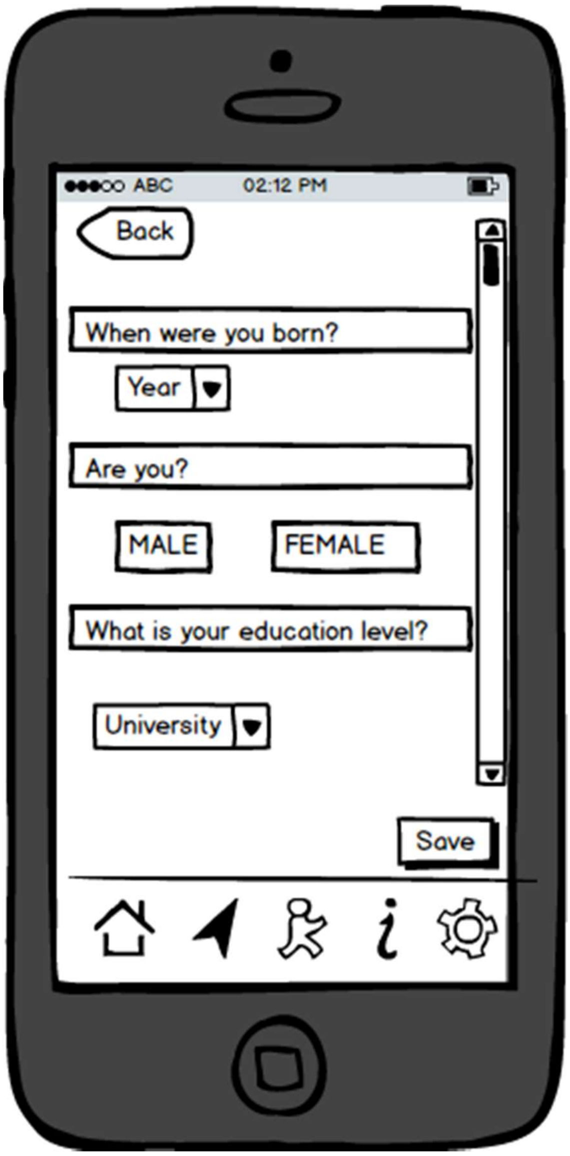
Target group: Any citizen living in the cities

Recruitment:

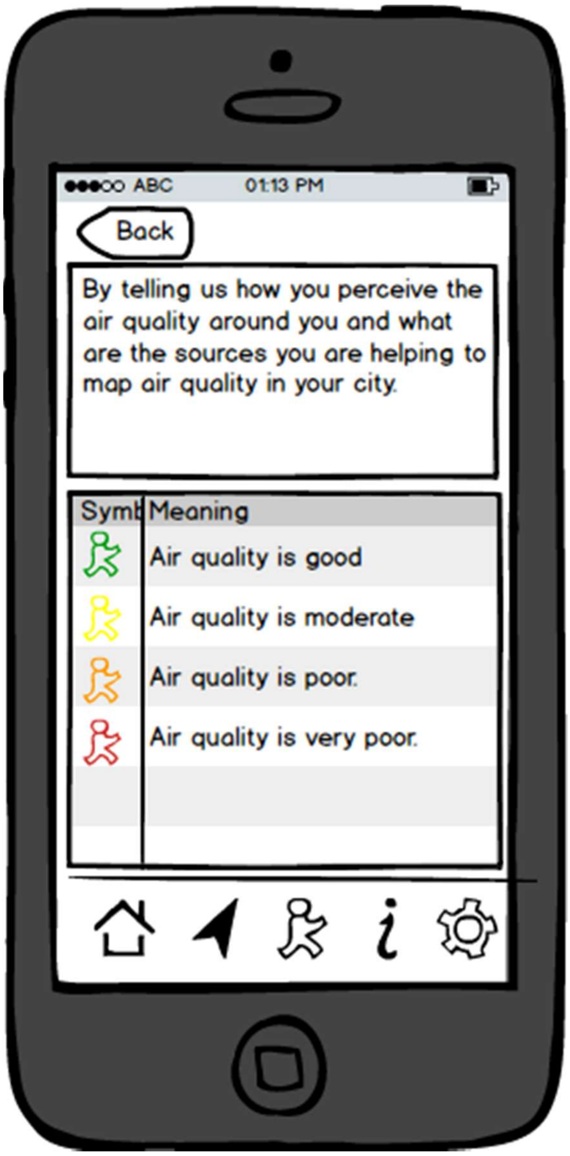
- Contact organization with an interest in environment and air quality and ask members to install app and send it around
- Put information on the our websites
- Send emails to existing mailing lists
- Put ads in news papers
- Write press releases and talk to journalists
- Attend local meetings with related topics and announce App
- Put on facebook, twitter, instagram
- Produce monthly news letter with results for local audiences

Timeline:
23 March 2015 finalizing protocol
13 April prototype available for Oslo and Barcelona
27 April translation in different languages
18 May App ready for download in different cities and testing by some volunteers
1 June Big launch of the App in different cities

ANNEX B: Air quality App – mock-up



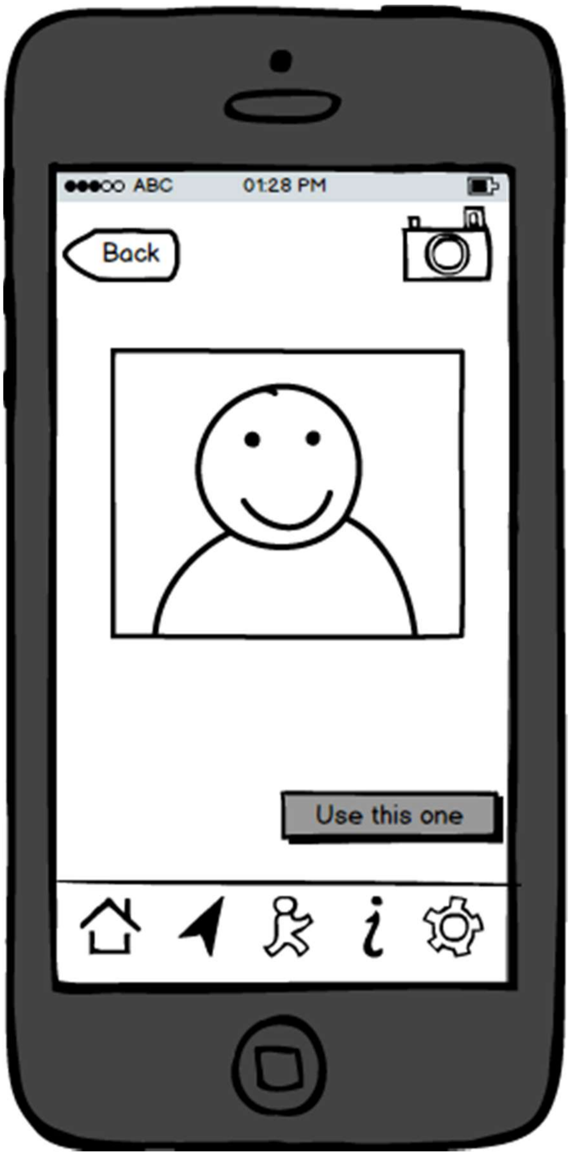
Input of user information data.



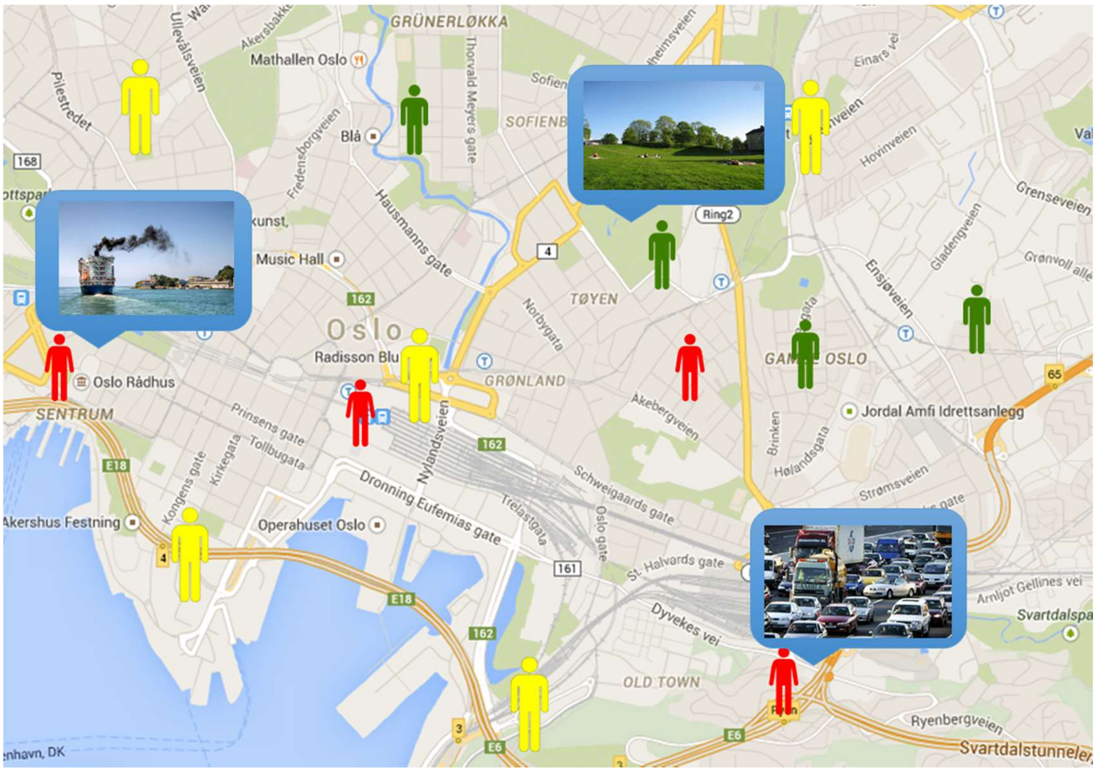
Under information (i) the user gets a description of how to use the air quality perception and the meaning of the colours.


ABC
01:13 PM
Little Grensen
Rosenkrantz' gate
Nedre Vollgate
Tollbugata
Comment and take a picture

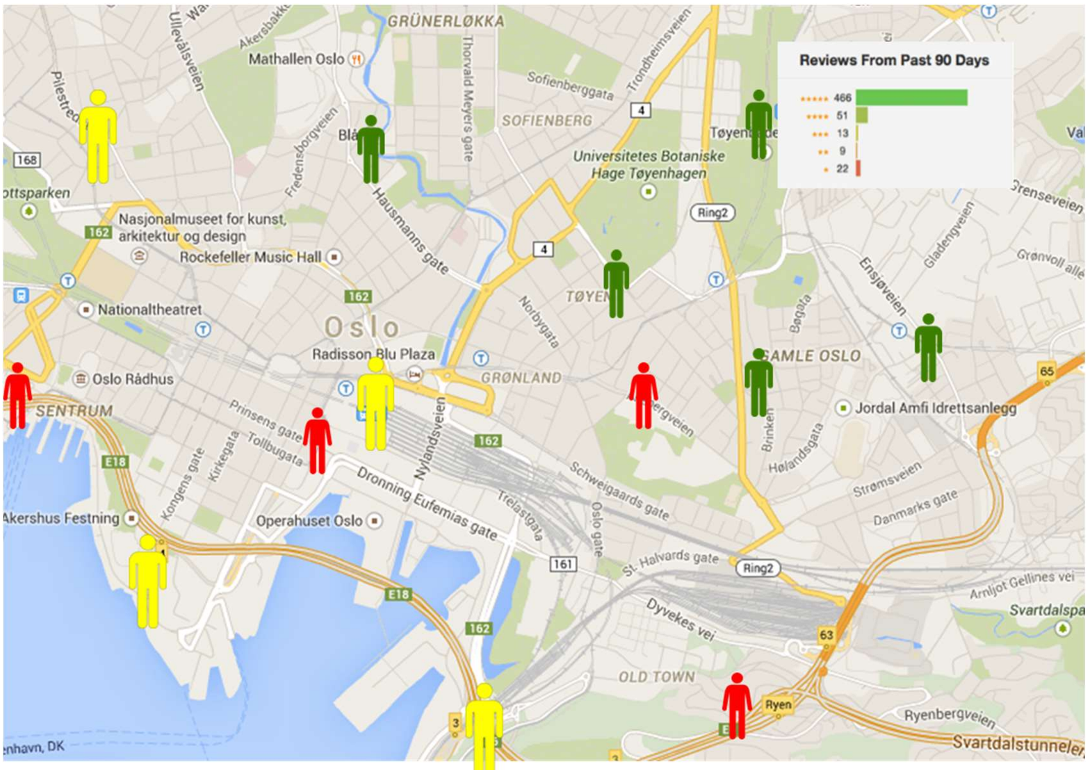

ABC
03:08 PM
Back
Select the pollution sources
Traffic
Industry
House heating
Port / Harbour
Pollen
Dust
Smoke
Strong oudor
Others
Save



When the user clicks on yellow, orange or red it goes to select the pollution sources. The user can also take a picture and leave a comment.



An example of what the user visualized on the mobile screen. When clicking on the men, it is possible to see the pictures from other users.



If participation is high we can rate the places, how many people has said the air quality in that place is good, or poor, etc.

ANNEX C: Difficulties and problems to use the SensApp in WP3 EI Public Places in Vitoria-Gasteiz

The aim of this brief document is to explain the most prominent difficulties identified during the full implementation of the EI in Vitoria-Gasteiz.

1. Difficulties in the access to the data in the SenseApp.

The preliminary version of the SensApp was organized using the sensors as the elements to access obtained data. In the case of EI Vitoria, these sensors were: Thermal, Acoustic and Composite.
This structure to present the data did not fit well with the needs of the EI. In the case of the EI Public Spaces, the information must be organized allowing the definition of sets of data distinguishing user and observation (user ID, area and site, and date).
The idea of the data structure created in SensApp for the results, was to make it easier to query and make statistics programmatically directly from SensApp. The structure then differed a lot from a relational database view. This might have led to difficulties when trying to convert the data.
To solve this situation, an intense job was developed by Tecnalia in collaboration with NILU who proposed the time stamp to identify linked data collected in each observation and to create sets of information. It was not the most desirable option but it provided to the EI a possibility to access understandable data.
Applying this approach, the Tecnalia`s website developers created a parallel database to the one in SensApp in order to organize the data as the EI required to analyse information organized by users, areas and sites. The aim is to obtain conclusions for empowerment: average information of thermal, acoustic and general comfort and also about landscape and other characteristics of the evaluated areas and sites.
The database created by Tecnalia is implemented using SQL language, so any software capable of reading this language will work fine for the process.
The main problem arose when trying to retrieve different parameters (user, site, area, PET, …) as it would have implied summoning different URL to access each of them and organize the data in order to visualize it on the website, which would have been too much time consuming for a website visitor. Organizing all the data into a more accessible database allows us to retrieve the “complete” information (except those with missing data) for each observation using a single SQL Query.

Finally to develop the “Results” part of the EI web site, a collaborative work between Tecnalia and NILU was carried on in order to present the data linked to each observation made by the users involved during the Full implementation phase.

What are the consequences of this limitation on accessing the data?

- Big effort is needed on analysing the data to create the sets of data, not being completely sure about the consistency of the information.
- The duplication of the database implies that the analysis is done only after all the observations are finalized or a process to manage the different versions of the database is needed.
- Will it be possible to repeat the process of accessing the data and copying it once that all EIs have uploaded their data?

Which would be the best solution to improve the access to data?

The database schema used in SensApp implements the SenML standard. It seems that an option could be to create for each observation a SenML composite sensor (and the respective sensors) with attached as metadata the location (e.g., name of location, GPS data). CivicFlow Questionnaires should also be taken into account during the composite sensor conception process. The date of creation of this composite sensor would then be the starting date of the observation. The name of the composite should contain the UserId and maybe also the observationId. This could be a better way to have multiple observations per Users.

This could have been avoided if the design of application and data structure would be based on what outputs were needed.

2. Difficulties during the observation in communication between the SensApp and the Smartphone

- One of the aspects that conditioned the development of the observation was the organization of the SensApp by timestamps. This required that each observation must start exactly at the same time. This requirement was integrated in the instructions of the observation.

  What are the consequences of this limitation?

  It was not possible allowing the citizens doing the observation on their own; that is, being free to go to each area and site in the time of the day/week that they prefer. Since previously it was decided to help citizens in doing the observations due to the instabilities found in the services, during the Full Implementation this limitation was not critical but it will suppose a clear limitation on further applications, besides an increase in the resources needed on the implementation, being more costly.

  Which would be the best solution to improve it?

  Creating a composite sensor for each observation could also solve this issue, since it would help to reunite individual data stored within SensApp. As pointed before, maybe an extra effort would help to unify also the CivicFlow data. If this is not possible, a triple check (User-Location-Time) would allow the integration.

- On the other hand, during the observations developed in April/May, some problems of communication between the SensApp and the smartphone occurred.

  What are the consequences of this problem?

  - As it can be seen in the table, some data of observations were lost. The total number of observations was 237 and only 53 were completely correct (just a 22%). 4 participants could not upload any data and there were 41 observation completely lost.
  - As it can be seen in the table, there are different types of errors, but the most frequent error was related to the thermal index. To calculate this index it was needed not only the data measured by the sensor, but also a value pre-calculated and stored previously in SensApp. However, in these cases data of the thermal variables measured by the sensors were also missing.
  - There is a risk of losing confidence on the technology used and even on the results of the project. This risk was well managed on the communication with participants and it should also be managed in the relation with the municipality and other stakeholders.

			AREA/SITE								
Kit	Clave	Email	CONS-1	CONS-2	SALI-1	SALI-2	OLA-1	OLA-2	HERR-1	HERR-2	HERR-3
1	88133359	citisenseobservador01@citisense.eu	x						x	x	x
2	89635172	citisenseobservador02@citisense.eu	x						x	x	x
3	97963331	citisenseobservador03@citisense.eu	x						x	x	x
4	64297397	citisenseobservador04@citisense.eu	x						x	x	x
5	43673736	citisenseobservador05@citisense.eu	x						x	x	x
6	36651676	citisenseobservador6@citisense.eu	x						x	x	x
7	77914671	citisenseobservador07@citisense.eu	x						x	x	x
8	38568637	citisenseobservador08@citisense.eu	x						x	x	x
9	32433875	citisenseobservador09@citisense.eu	x						x	x	x
10	43181435	citisenseobservador10@citisense.eu	x	x	x	x	x	x	x	x	x
1	68611632	citisenseobservador11@citisense.eu	x	x	x	x	x	x	x	x	x
2	29367491	citisenseobservador12@citisense.eu	x	x	x	x	x	x	x	x	x
3	13596113	citisenseobservador13@citisense.eu			x	x	x	x			
4	66229369	citisenseobservador14@citisense.eu			x	x	x	x			
5	46459595	citisenseobservador15@citisense.eu			x	x	x	x			
6	61755767	citisenseobservador16@citisense.eu			x	x	x	x			
7	77339615	citisenseobservador17@citisense.eu			x	x	x	x			
8	51762128	citisenseobservador18@citisense.eu			x	x	x	x			
9	35955461	citisenseobservador19@citisense.eu			x	x	x	x			
3	59211928	citisenseobservador20@citisense.eu	x	x					x	x	x
5	76991392	citisenseobservador21@citisense.eu	x	x					x	x	x
4	79865439	citisenseobservador22@citisense.eu	x	x					x	x	x
6	25169858	citisenseobservador23@citisense.eu	x	x					x	x	x
7	67825392	citisenseobservador24@citisense.eu	x	x					x	x	x
8	99252423	citisenseobservador25@citisense.eu	x	x					x	x	x
9	82344388	citisenseobservador26@citisense.eu	x	x					x	x	x
2	61615791	citisenseobservador27@citisense.eu	x	x	x	x	x	x	x	x	x
8	19261373	citisenseobservador28@citisense.eu			x	x	x	x	x	x	x
9	18316897	citisenseobservador29@citisense.eu	x	x					x	x	x
2	85698221	citisenseobservador30@citisense.eu			x	x			x	x	x
1	89317474	citisenseobservador31@citisense.eu	x	x			x	x	x	x	x
1	15566433	citisenseobservador32@citisense.eu	x	x	x	x			x		
3	49987966	citisenseobservador33@citisense.eu	x	x		x	x	x	x	x	x
3	22434395	citisenseobservador34@citisense.eu	x	x							
	25327928	citisenseobservador35@citisense.eu			x	x	x	x			
4	37321753	citisenseobservador36@citisense.eu	x	x	x	x					
10	75115969	citisenseobservador40@citisense.eu					x	x			
9	29483656	citisenseobservador41@citisense.eu	x	x			x	x			
5	74479116	citisenseobservador42@citisense.eu			x	x	x	x			
8	62247112	citisenseobservador43@citisense.eu			x	x	x	x			
5	42871512	citisenseobservador44@citisense.eu			x	x	x	x			
1	63889216	citisenseobservador45@citisense.eu	x	x							
4	63322661	citisenseobservador46@citisense.eu	x	x							
6	49673782	citisenseobservador47@citisense.eu	x	x			x	x			
7	55439711	citisenseobservador48@citisense.eu					x	x			
6	43962874	citisenseobservador49@citisense.eu					x	x			
1	15399291	citisenseobservador60@citisense.eu	x	x	x	x	x	x	x	x	x
4	83679477	citisenseobservador61@citisense.eu	x	x	x	x	x	x	x	x	x
4	97529113	citisenseobservador62@citisense.eu			x	x					
1	91944151	citisenseobservador63@citisense.eu				x					
9	56865431	citisenseobservador64@citisense.eu			x	x					
1	11474661	citisenseobservador65@citisense.eu			x	x					
9	83688714	citisenseobservador66@citisense.eu			x	x					
9	71199613	citisenseobservador67@citisense.eu					x	x			
1	28147572	citisenseobservador68@citisense.eu			x	x					
		TOTAL	32	23	26	28	26	26	26	25	25

- All information is provided correctly
- No information of Thermal index
- No informationof Thermal and Acoustic index
- All the information of the observation is lost
- Other incidences

Observator 9 in HERR-3 all data is available except Acoustic index

Observator 10 in CEA-2 all data are missing except Acoustic Index

Observator 33 in CONS-1 all data are missing except Acoustic Index

Observator 47: acoustic and thermal indexes are shown but graphs regarding landscape and confort are not displayed (civivflow information)

Which are the reasons for each of the types of errors?

In general, every single data available in the SensApp database seems to derive from and independent communication process, thus, it is really usual to find incomplete datasets.

Furthermore, this process greatly increments the communication needs, also incrementing the chances of defective communications and, thus, incomplete datasets.

In the cases of missing only the Thermal Index it could be a communication error where the tmrt values could not be retrieved and, thus, it was impossible to calculate the thermal index value. However, in most of the cases not only the Thermal Index, but all the Thermal values measured by sensors were missing.

Other reasons could be: that the user did not push a button for calculation their indexes, the app did not create them and store them; or that the user wrote a wrong email address and then the app could not get the questionnaire with the needed information to calculate the indexes.

The results of the Thermal values would be stored when the result of the thermal was calculated. If that was not possible then the Thermal values would not be stored. That means that if there was no index (result) then no information about the temperature, wind speed and humidity was stored on the result composite sensor, but were only on the specific sensor.

This could have been changed in that way that the app stores each value separately. But would lead to more data traffic.

Which is the best way to avoid this problem in future implementations?

The main challenge with this case was the integration of all the different parts from storage and platforms, integration of native 3rd part apps (acoustic sensor) with platform independent app (SENSE-IT-NOW), use of 3rd part web services (U-Hopper, CivicFlow), connections to sensor devices and dependences of other smart phone apps for data (SensorLog, SensApp) and to have one app depended on all of this to work without problems (SENSE-IT-NOW). There was also limited time for tests scheduled for such complex solutions.

Two different protocols were suggested to improve the current infrastructure and obtain better datasets:

- Create a complete user-point (area & site) dataset, prior to send the information to the dataset. This implies to perform the data linking process on the mobile device and send the complete data to the server, where it can be retrieved on future queries.
- Verify that the data sent by the mobile device correctly arrived to the server using a feedback signal. Until such signal is received on the device, the mobile device should be able to store the unsent/not-received data and try to resend if GRPS signal is available. This approach must consider that, nowadays, the timestamp is the key element to link every data and so, data creation time must also be stored and sent (as the creation/sending/receiving timestamps may diverge).

This approach would allow the following: validating the data on the smartphone (all data is there, communication between smartphone and sensors is working), push the data only when maximal connectivity of the smartphone to the network is ensured, keep the data on the smartphone until it has been successfully stored (SensApp use REST and already provide a ACK, if the current ACK is not enough it can be improved) into SensApp. If the timestamps are properly aligned during the linking process on the smartphone, it is already possible to define a specific timestamp when pushing the data into SensApp

In general one lesson learned is to think smaller when it comes to what a smart phone app developed using html5/javascript actually should do and do more of the work on the server side. A smart phone app works better and gives better user experience with smaller tasks and less complexity.

ANNEX D: CITI-SENSE selected products information

CITI-SENSE
CITIZENS' OBSERVATORIES AND WHAT THEY CAN DO FOR YOU

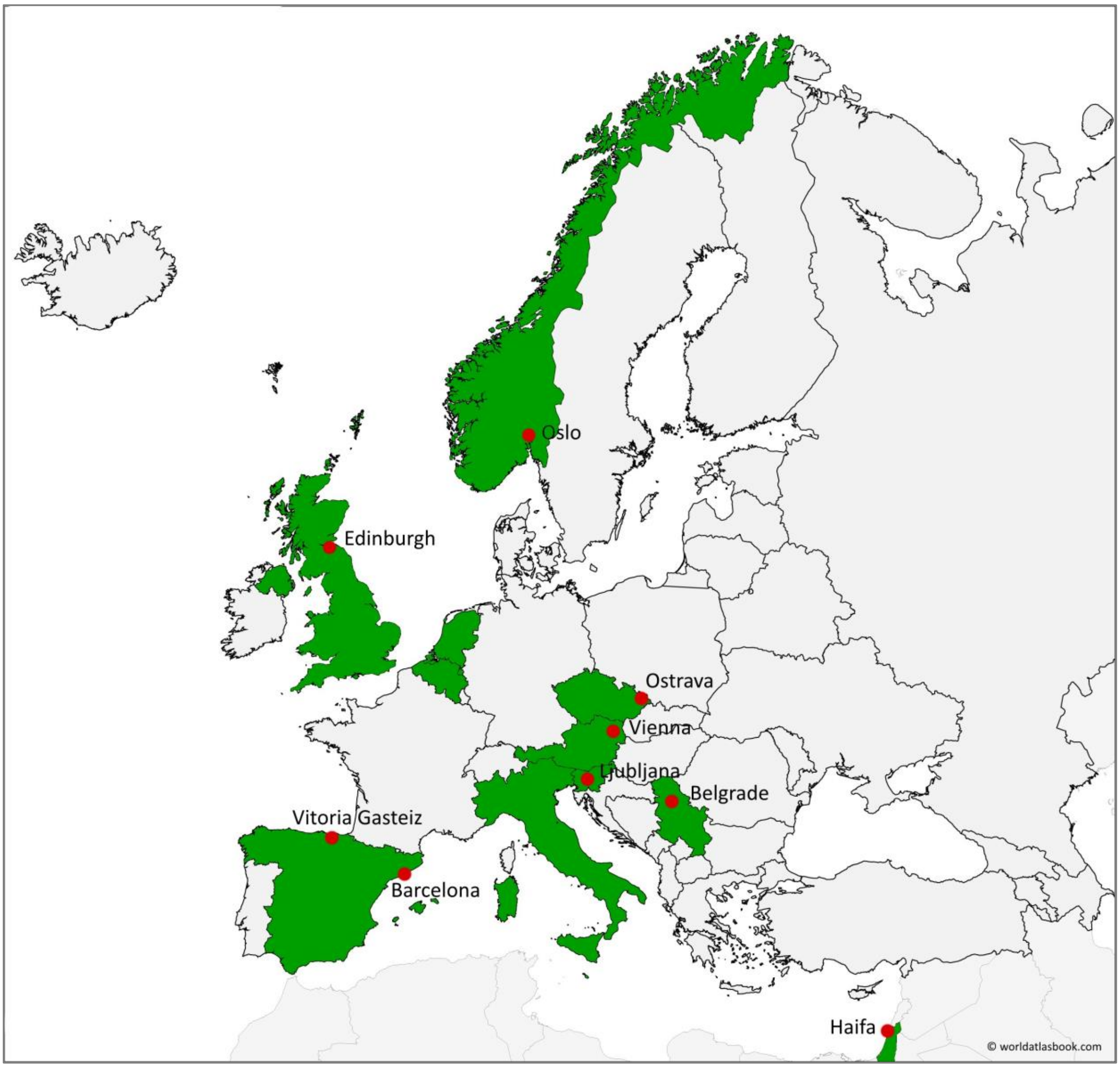


Table of Contents

CITI-SENSE Citizens' Observatories and what they can do for you

This brochure is an overview of the main tools developed in the CITI-SENSE project (2012-2016). The aim of these tools is to involve citizens in assessments of air and environmental quality to empower them to participate in environmental governance. In CITI-SENSE, we are targeting people connected to our nine participating cities - Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Ostrava, Oslo, Vienna and Vitoria, but most of the tools are available to everybody, everywhere, as long as the project infrastructure is in place.

If you are a public authority or a public interest organization and you would like to try these products in your city or area, do not hesitate to contact us (aba@nilu.no).

If you are a developer of apps, a web designer, or have monitoring devices that provide similar information that you will see on the following pages, we are pleased to make available to you the tools that will enable you to connect to our platform, so you can use the information there for any.

With this brochure, we invite all individuals, groups, organisations and businesses who would like to help make their cities better places to live in, to try our products. We are grateful for your inputs, feedback and suggestions!

Alena Bartonova and the CITI-SENSE team Oslo/Kjeller, March 2016
Contact: alena.bartonova@nilu.no

CITI-SENSE, www.citi-sense.eu, is a collaborative project co-funded by the European Union's Seventh Frame-work Programme for Research, Technological Development and Innovation, grant agreement no 308524.

OVERVIEW

CITI-SENSE has been working for and with people to share objective and subjective information about air quality, and acoustic and thermal comfort. Our tools are accessible through our web portal (http://co.citi-sense.eu). This brochure gives a first glance of our most widely used tools.

The **CITI-SENSE Citizens' Observatories Web Portal** (p. 6) provides an access point to all our apps, widgets, web pages and sensor based tools and questionnaires. You can get information about how to acquire, install and use them. You can also access the data already collected. For the technically minded, you can get information about the sensing devices, and about how to use our data for your own applications. And of course, you can also learn about the project that brought this to you, CITI-SENSE, and links to our social media platforms.

The **Personal Air Monitoring Toolkit** (p. 8) allows you to assess air quality in your immediate surroundings. It is based on a sensor device that monitors three gases (nitrogen dioxide, nitrogen monoxide and ozone).

The **City Air Smartphone App** (p. 13) allows you to share your perception of air quality, and the dominant pollution source, anytime, anywhere.

The **On-Line Air Quality Perception Questionnaire** (p. 15) can be used in campaigns to assess citizens' perception of air quality and get feedback.

The **Environmental Monitoring Toolkit for Public Places** (p. 17) can be used in campaigns to assess thermal comfort, soundscapes and visual qualities of outdoor places such as parks or public areas in need of rehabilitation.

The **Data Visualisation Web Page** (p. 21) provides an overview of all our sensor-based tools. If a measurement is taken using our tools, you should be able to find it there in some form or shape (sometimes, for privacy reasons, as part of an aggregated picture).

The **Data Download Web Page** (p. 23) provides access to sensor device data from the CITI-SENSE platform and enables their download in CSV format or directly into an Excel sheet.

Externally contribution: phone application to display air pollution in cities (p. 24) demonstrates that it is possible to use data collected within the CITI-SENSE framework to create your own services.

Information is also available through CITI-SENSE Twitter and Facebook, and on YouTube:

Twitter:
https://twitter.com/citizensobs
https://twitter.com/CitObsBCN

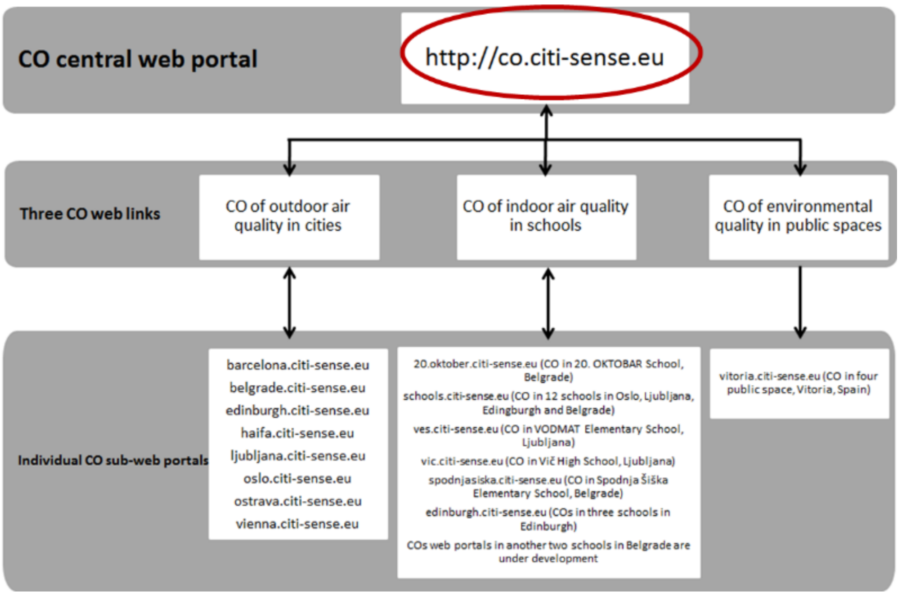
Facebook:
https://www.facebook.com/int.cit.obs/
https://www.facebook.com/oslocitizensobservatory/
https://www.facebook.com/CitiSenseLjubljana/
https://www.facebook.com/BarcelonaCitObs/
https://www.facebook.com/obcanskapozorovatelna/
https://www.facebook.com/Citi-Sense-Vitoria-Gasteiz-785414554863775/?fref=ts
https://www.facebook.com/CitiSenseGimVic/
https://www.facebook.com/cityairapp/

YouTube
https://www.youtube.com/channel/UCaDdfpvLONuybNBV9cNGIbQ

1. CITIZENS' OBSERVATORIES WEB PORTAL

What is it about?

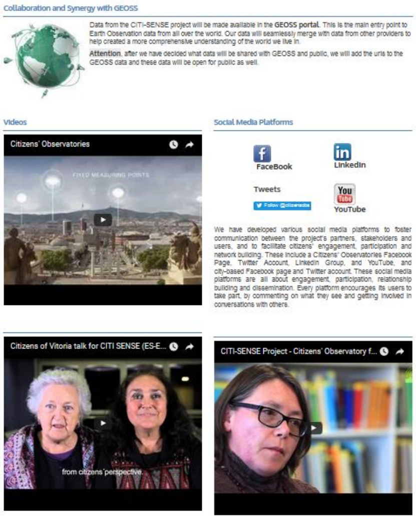
The CITI-SENSE Citizens' Observatories Central Web Portal is a gateway to the Citizens' Observatories Toolbox (COT). It provides interested parties access to our products and services, e.g., mobile apps and air quality perception surveys, and serves as a forum for discussion, debate and sharing of the citizens' own personal observations. The products and services include those based on outputs from several sensor platforms for air quality monitoring, and those based on subjective perceptions contributed by the public.



The CITI-SENSE Citizens' Observatories (CO) Web Portal is a gateway to the COs developed within the project. It has three layers - the CO central web portal, thematic areas, and individual web portals of participating cities. The thematic areas are Air Pollution Perception, Outdoor Air Quality in Cities, Indoor Air Quality in Schools and Environmental Quality in Public Spaces, The portal is structured in an intuitive and easy to navigate manner:

- Home
- The project
- Citizens' Observatories Toolbox
- Developers & Users
- Usage Examples
- FAQ
- Useful Links
- Contact Us.

The home page describes also the CITI-SENSE relationship to the Global Earth Observations (GEO) and gives a link to the GEO System of Systems (GEOSS).



More information is accessible using the embedded videos, hosted on YouTube. Social media platforms are presented with links as well.

How to use it?

The user can:

- View and access the CITI-SENSE data and products using the ‘Citizens’ Observatories Toolbox’;
- Access information for developers and those who are using the CITI-SENSE products and services from the ‘Developer & Users’ page ;
- Complete the air pollution perception surveys and social media platforms;
- Link to the information and data from the thematic CITI-SENSE COs;
- Access the GEOSS data, including the data by CITI-SENSE;
- Watch videos developed by the CITI-SENSE project;
- Get overviews of examples from real-life campaigns in the ‘Usage Examples’;
- Check out similar projects in the world, other types of sensor devices and monitors, air quality information, and collaboration and synergy with GEOSS, under ‘Useful Links’;
- Contact us and the tools providers through the ‘Contact Us’ page.

Where to look for data?

For data from each of the thematic COs, there are the following options:

- To click the link ‘View and download data’ in each tab of the three COs in the front page.
- To click on the ‘Web portals’ under ‘Citizens’ Observatories Toolbox’ for the thematic COs web portals.
- To click on ‘Data’ on the page ‘Citizens’ Observatories Toolbox’, where a link to each of the thematic COs data is available.

For all data from the CITI-SENSE project, there are the following options:

- To click on the tab ‘Collaboration and Synergy with GEOSS’ on the front page
- To click on ‘Data’ in the figure that is presented on the page ‘Citizens’ Observatories Toolbox’.

For data from each of the nine participating locations/cities, these are the ways to do so:

- To click the sub-page ‘Web portals’ under ‘Citizens’ Observatories Toolbox’, find each of the three COs web portals, and then each location-based web portal.
- To click on ‘Data’ in the figure that presents the COT at the page ‘Citizens’ Observatories Toolbox’, find the link to each of the three COs data, and find the link to each-location based COs data.

How to find it?

Please go to the web portal http://co.citi-sense.eu/, and find the detailed contact information there or contact Hai-Ying Liu from NILU-Norwegian Institute for Air Research, hyl@nilu.no.

2. PERSONAL AIR MONITORING TOOLKIT

What is it about?

This toolkit includes three different tools that when combined, allow to measure and visualize personal air quality in the user's immediate surroundings:

- Mobile sensor unit LEO (Little Environmental Observatory)
- Android app that connects to the sensor unit, reads and upload data to a server (ExpoApp)
- Computer application for sensor management (firmware upgrade).

Technical elements

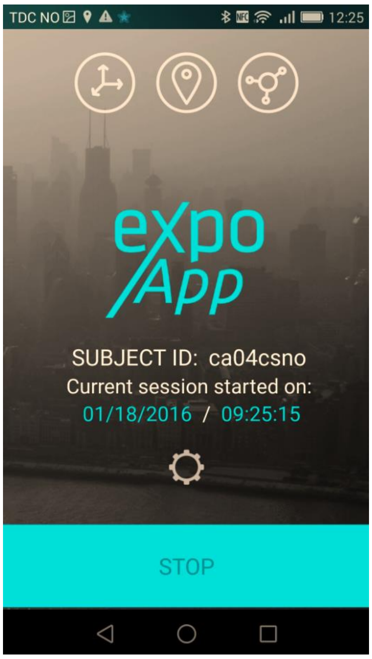
LEO - Little Environmental Observatory

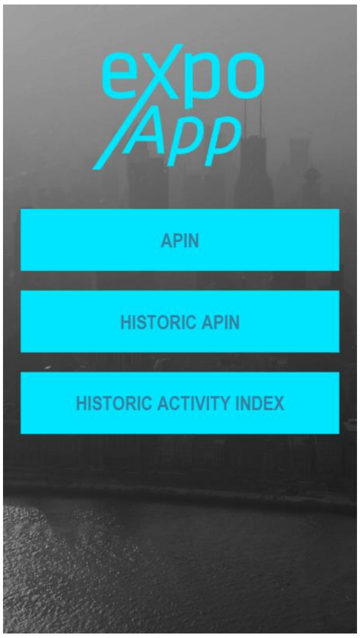
The LEO is a portable sensor pack. It measures NO, NO_2 and O_3 using electrochemical sensors. It also provides information about the current temperature and relative humidity. It can be used both, outdoors and indoors, but its primary use is for outdoors.

ExpoApp smartphone application for Android

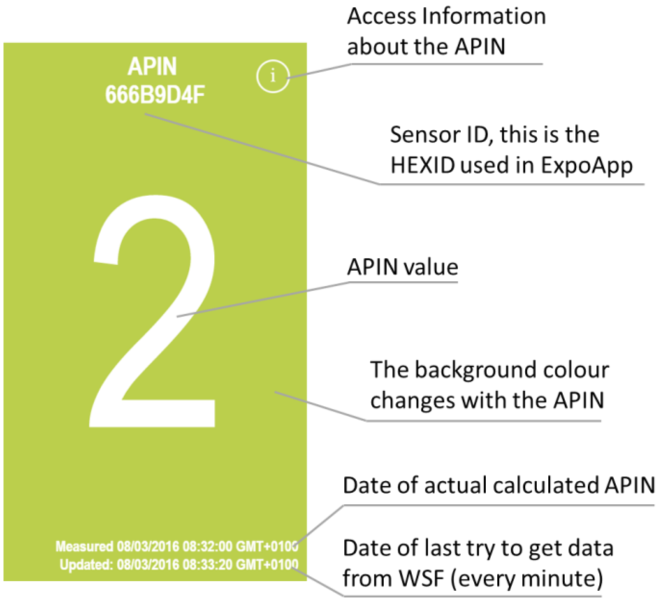
ExpoApp is an application for Android devices that communicates with the LEO. It reads and uploads the observations from the LEO and it also reads and uploads information from the user's smartphone about location and physical activity recorded by the so called accelerometer that is already built-in in each smart phone.

The ExpoApp allows the user to establish the connection between the LEO device and the smartphone via Bluetooth (left). It also provides a quick access to information about the status of the communication between smartphone and the sensor (Last Message) and the smartphone and the server (Last Upload) (right).



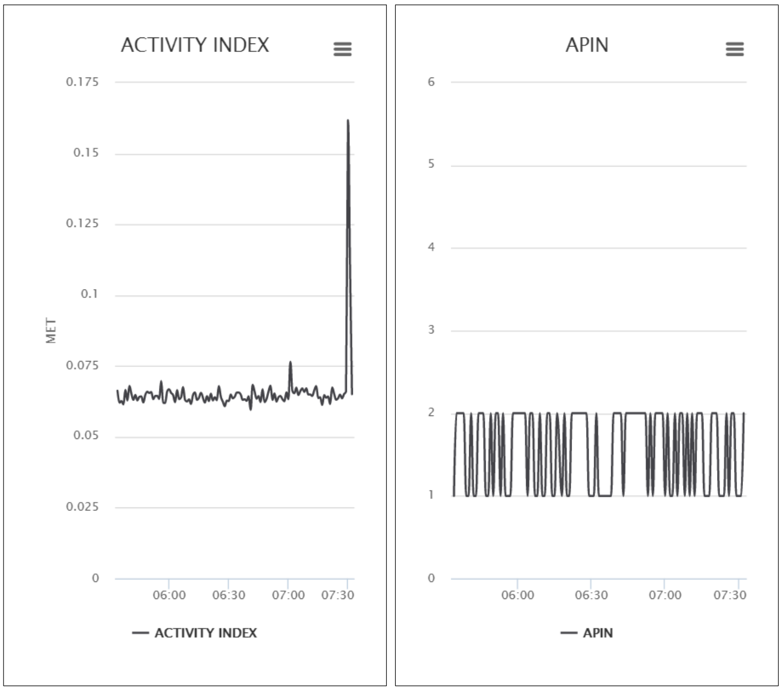


CITI-SENSE, www.citi-sense.eu, is a collaborative project co-funded by the European Union's Seventh Frame-work Programme for Research, Technological Development and Innovation, grant agreement no 308524.



The results are displayed as an APIN - air pollution indicator value (left). This indicator is related to a Common Air Quality Index CAQI, but cannot directly be compared as the air quality monitoring methods underlying the measurements differ.

The user can also check for the last 2 hours of data. The historic plots display the APIN, and the ACTIVITY Index calculated with the smartphone.



A computer application for sensor management

Ateknea Sensor Tool is used by the technical support to update the LEO, and not directly by the user. It has also functionalities for reading the raw data from the sensor unit, and for adding calibration values.

How to use it?

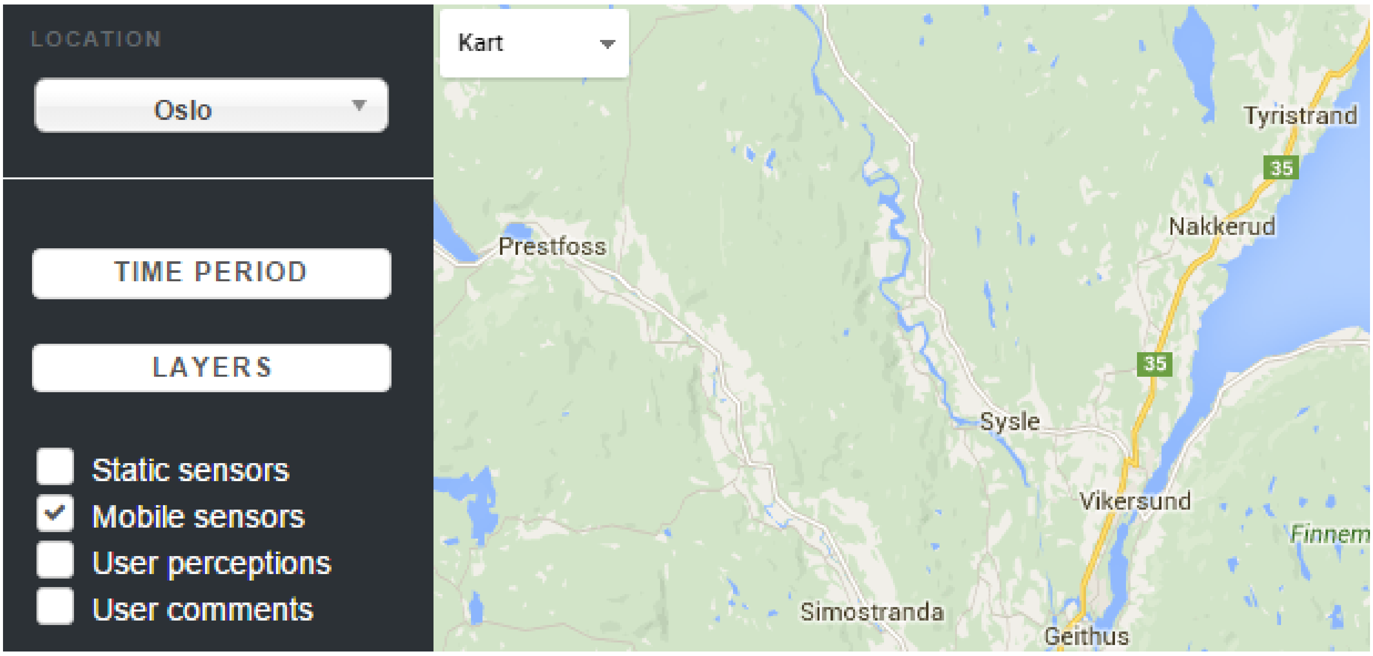
The **Personal Air Monitoring Toolkit** provides an opportunity to monitor personalized levels of air pollution and their changes in time and place. The LEO sensor unit can be carried on the outside of a jacket or on a belt. The user's android smartphone can then be paired with the sensor unit via the mobile's Bluetooth. Once paired, the ExpoApp can be set up to read and store the data from the device. Processed data from all users, without personal identification, are publicly available.

The measurements give an indication of pollution levels and their changes, as the user moves through different locations and types of environments. They help to identify where (and when) the pollution is higher than other places, as such situations sometimes can be avoided. The project team takes great care to provide measurements of good quality, but as the methods are not the same as methods used in air quality monitoring by the authorities, the official air quality information should be consulted on air quality levels.

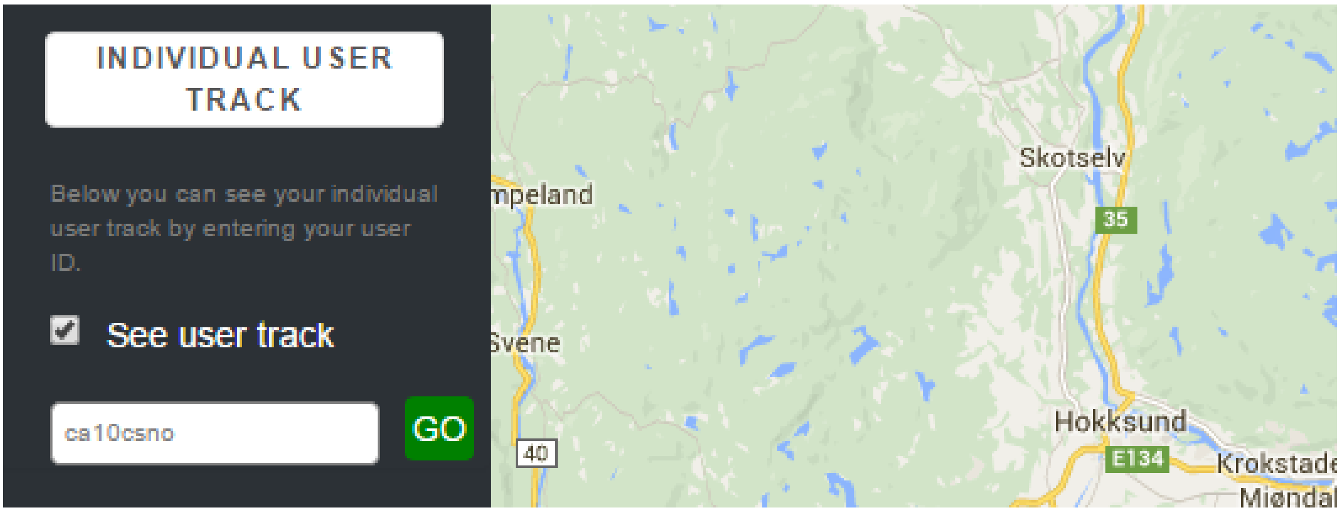
Where to look for data?

The user can **view** data at http://srv.dunavnet.eu/new/citisense/OutdoorDataPortal.

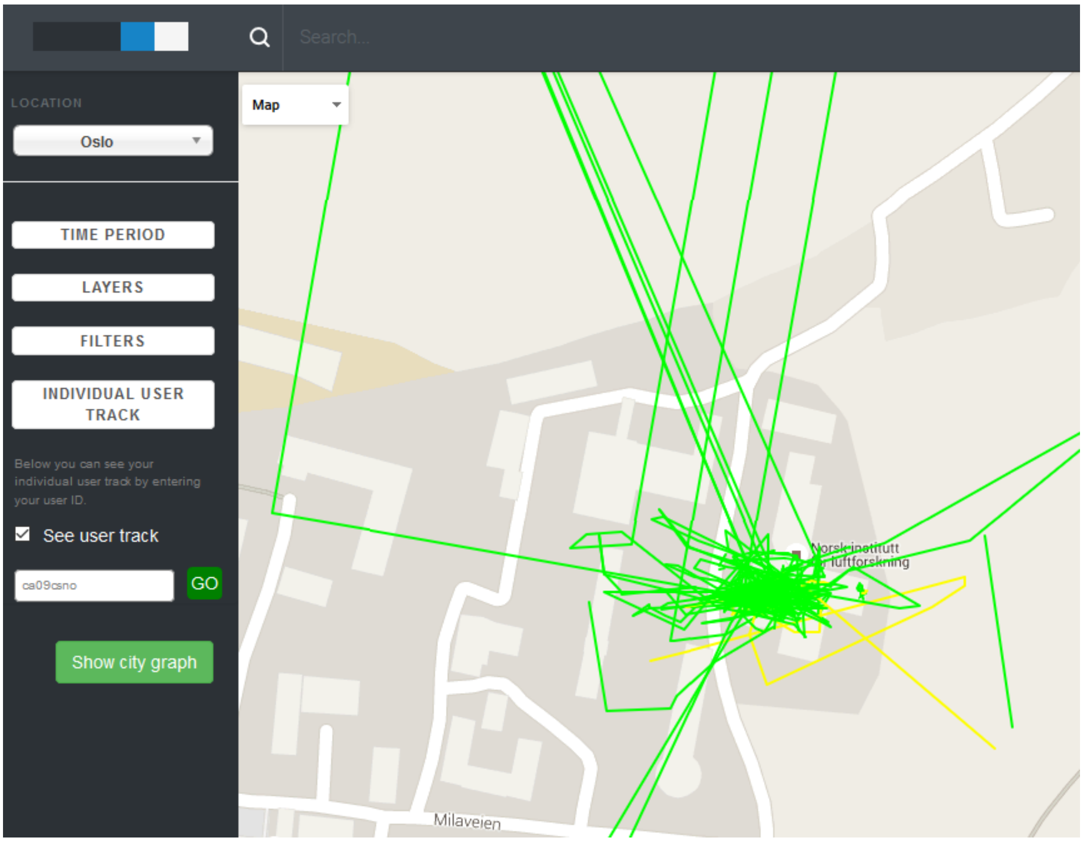
To **check for the last measured values** of all mobile sensors in a city, add filter criteria:



To **follow the user's own sensor unit**, add the user id registered on the ExpoApp:



After that, you will be able to track the sensor in a geographic area:



How to get it?

The package has been developed in the CITI-SENSE project, co-funded by the European Commission Seventh Framework Programme for Research, Technological Development and Innovation under grant agreement no 308524, active between October 2012 and September 2016.

More information about the package is available at: http://citisense.ateknea.com/

ExpoApp is available on Google Play
https://play.google.com/store/apps/details?id=ateknea.eu.expoapp2

Documentations, links to video tutorials, PC application download and user guides can be found here:
http://citisense.ateknea.com/sensors/downloads
http://co.citi-sense.eu/CitizensObservatoriesToolbox/Sensorandsensorplatforms.aspx

Until May 2016, interested users in Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava and Vienna can contact the project using the contact information provided in:
http://co.citi-sense.eu/ContactUs.aspx

After May 2016, The **LEO** sensor device can be purchased upon request from
Ateknea Solutions, Carrer de Víctor Pradera, 45, ES-08940 CORNELLÀ DE LLOBREGAT
+34 932049922**; info.barcelona@ateknea.com;** ateknea.com/es; ateknea.com/ct

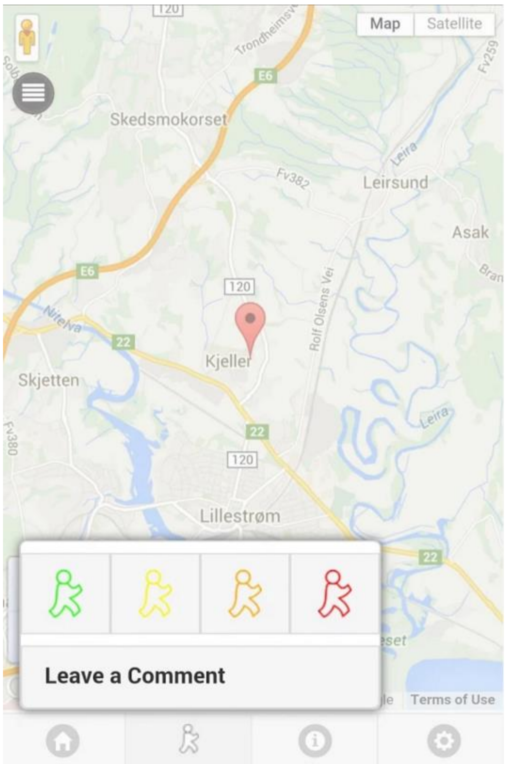
3. CityAir SMARTPHONE APP

What is about?

CityAir is a smartphone application (App) for the public to express their perception of the outdoor air quality at their location. It allows users to collect and display individual perceptions of air quality, irrespective of where they are in the world. It also allows users to indicate the assumed source of the air pollution and write a comment.

CityAir gives the user the possibility to rate the air quality in their immediate surrounding by using a code of four colours:

Green – very good air quality;
Yellow – good air quality;
Orange – poor air quality;
Red – very poor air quality.



How to use it?

When the user has access to network and GPS signals, the App will display a map and mark the users' current position. When the user moves into another area, the home-button will re-position the marker onto the correct place at the map.

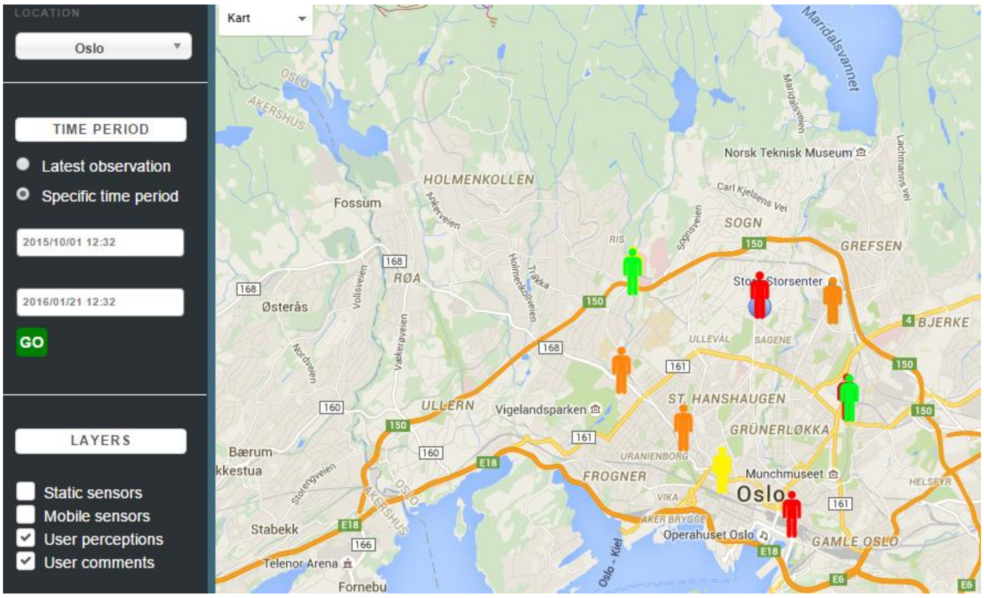
The user can add a perception marker for the current air quality, and suggest a pollution source or leave a comment. When the preferred network is available (chosen by the user), the App will upload the information provided by the user into the CITI-SENSE platform.

Before the first use of the App, the user can select a preferred language from a list. S/he will also be asked some personal information (gender, year of birth and education) for statistical purposes.

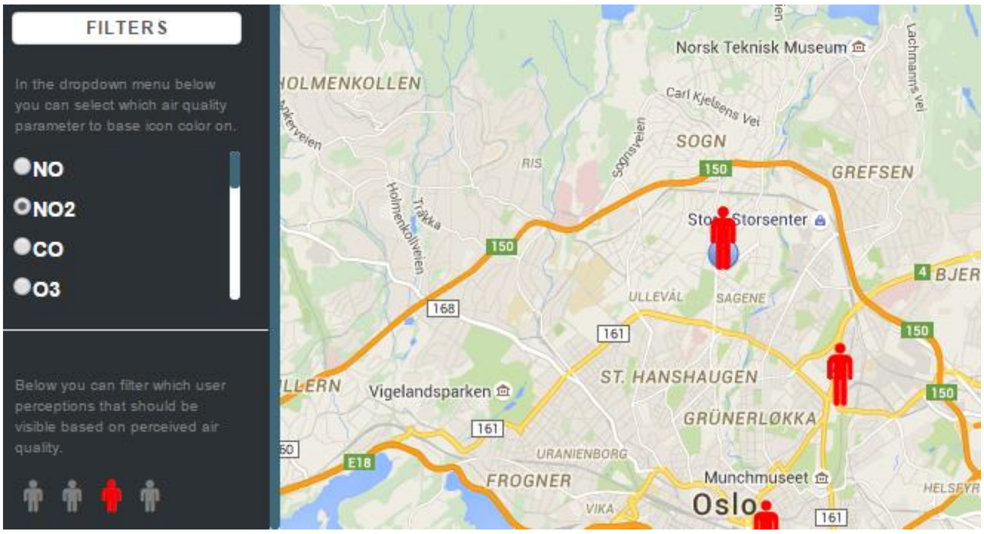
Where to look for data?

The user can choose to download other users' perceptions reported through **CityAir** for the same day, the last week or the last month, directly into the **CityAir** App on their smartphone.

CITI-SENSE Data Web Page



http://srv.dunavnet.eu/new/citisense/OutdoorDataPortal allows viewing the collected perceptions reported by all contributing users. The web page allows also for viewing the reported perceptions from a specific location, to only get the last observations, or observations made in a specific time period.



All perceptions can be found under the **User perceptions** and **User comments** layers. The user can also choose to filter the markers on the map according to perceived air quality (the pollution components in the picture do not apply).

How to get it?

	Available on Google Play: https://play.google.com/store/apps/details?id=io.cordova.CityAir	*Available on AppStore:* https://itunes.apple.com/no/app/cityair-perception/id1045646666?mt=8

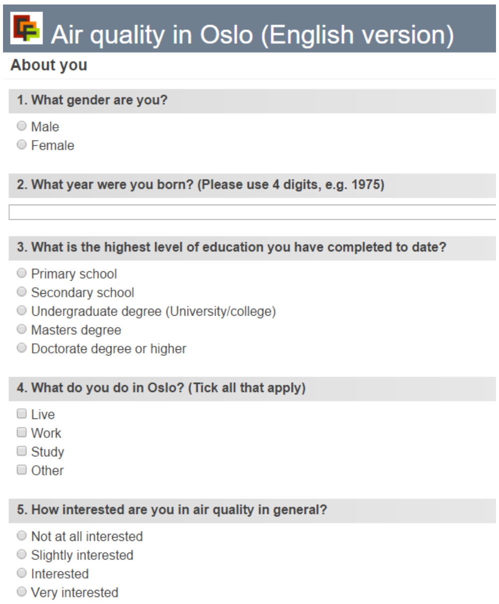
4. ON-LINE AIR QUALITY PERCEPTION QUESTIONNAIRE

What is it about?

The CITI-SENSE **Online air quality perception questionnaire** is a tool for collecting and analysing how users perceive air quality issues. The tool is being used in the nine participating cities/locations.

The quesionnaire can be answered by anybody anywhere. Instances for new cities can be easily created for free using the CIVICFLOW platform. At the moment, the questionnaire is active for the participating sites.

The questionnaire includes three seections: participants' personal information, specific questions on the participants' air quality perception, and feedback from the participant. The questionnaire has also an optional part to collect user preferences on what information on air quality shall be fed back to the user. The data collected is seamlessly available for visualization and analysis through the CITI-SENSE platform.



Air quality in Oslo (English version)

About you

1. What gender are you?
- Male
- Female

2. What year were you born? (Please use 4 digits, e.g. 1975)

3. What is the highest level of education you have completed to date?
- Primary school
- Secondary school
- Undergraduate degree (University/college)
- Masters degree
- Doctorate degree or higher

4. What do you do in Oslo? (Tick all that apply)
- Live
- Work
- Study
- Other

5. How interested are you in air quality in general?
- Not at all interested
- Slightly interested
- Interested
- Very interested

How to use it?

The questionnaire can be answered from any web browser; for mobile phone users a QR code for accessing the survey is also provided. The questionnaire can be seamlessly integrated into existing proprietary mobile applications or web portals. Currently the online perception questionnaire is available in different languages for each city that is involved in CITI-SENSE.

Where to look for data?

After the local campaigns, the results will be available on the CO web page of each site, and through the citizens' observatories web portal http://co.citi-sense.eu .

Oslo	http://oslo.citi-sense.eu/Browsedata.aspx
Vienna	http://vienna.citi-sense.eu
Ljubljana	http://ljubljana.citi-sense.eu
Haifa	http://haifa.citi-sense.eu
Barcelona	http://barcelona.citi-sense.eu
Belgrade	http://belgrade.citi-sense.eu/
Edinburgh	http://edinburgh.citi-sense.eu/
Ostrava	http://ostrava.citi-sense.eu

How to get it?

City	*Web page questionnaire*	*QR access code*
Oslo	**Norwegian**: http://w.civicflow.com/task/participate/153 **English**: http://w.civicflow.com/task/participate/150	Norwegian English
Vienna	**German:** http://w.civicflow.com/task/participate/159	
Ljubljana	**Slovene**: http://w.civicflow.com/task/participate/157 **English**: http://w.civicflow.com/task/participate/162	Slovene English
Haifa	**Hebrew:** http://w.civicflow.com/task/participate/158	
Barcelona	**Castellano**: http://w.civicflow.com/task/participate/156 **Català**: http://w.civicflow.com/task/participate/154 **English**: http://w.civicflow.com/task/participate/161	Castellano Català
Belgrade	**Serbian:** http://w.civicflow.com/task/participate/151	
Edinburgh	**English**: http://w.civicflow.com/task/participate/144	
Ostrava	**Czech:** http://w.civicflow.com/task/participate/155	

5. ENVIRONMENTAL MONITORING TOOLKIT for PUBLIC PLACES

What is it about?

The toolkit for public places is a collection of tools for subjective and objective monitoring of environmental quality and satisfaction, and for giving feedback at all kinds of public places. It consists of a Kestrel 4000 Pocket Weather Meter, Sensor Data Storage, Sense-It-Now app, a dedicated noise sensor and CityNoise app. The main use of this toolkit is in dedicated campaigns.

Technical elements

The Kestrel® 4000 Pocket Weather Meter

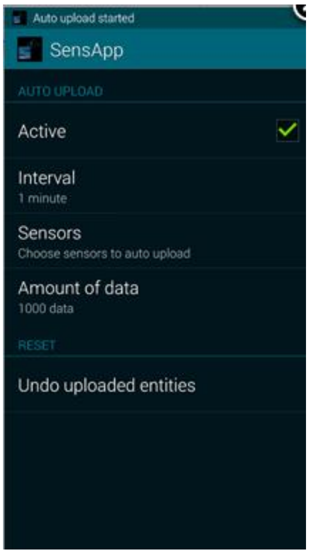
Kestrel® Pocket Weather Meter is a commercial sensor unit that measures wind speed, temperature, relative humidity and air pressure. To read data, it is connected to a smartphone via Bluetooth

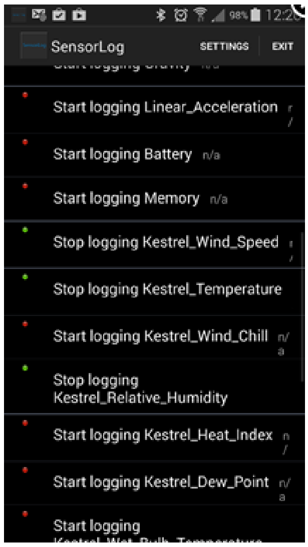
Sensor Data Storage

To read data from the Kestrel sensor and upload the data to server for storage, this toolkit combines three different elements. **SensorLog** is an android smartphone application for reading the Bluetooth stream from the sensor unit. **SensApp Android** is an android smartphone application that pushes the data read by SensorLog into the SensApp web services for storage and management**. SensApp Web Services** enable storage and retrieval.

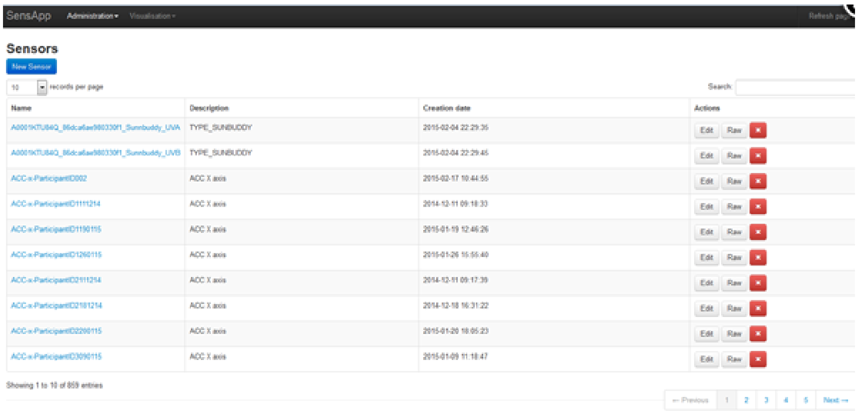
SensorLog is an Android application which establishes communication with sensors and then pushes these data to the SensApp Android application. The client can find any referenced sensor contained in the Android host system and a predefined set of Bluetooth sensors.

The **SensApp Android** smartphone application provides a database shared with client applications on the android device. While the client applications can easily insert sensors and measures in the database, the **SensApp** android maintains and uploads data to remote SensApp server instances.





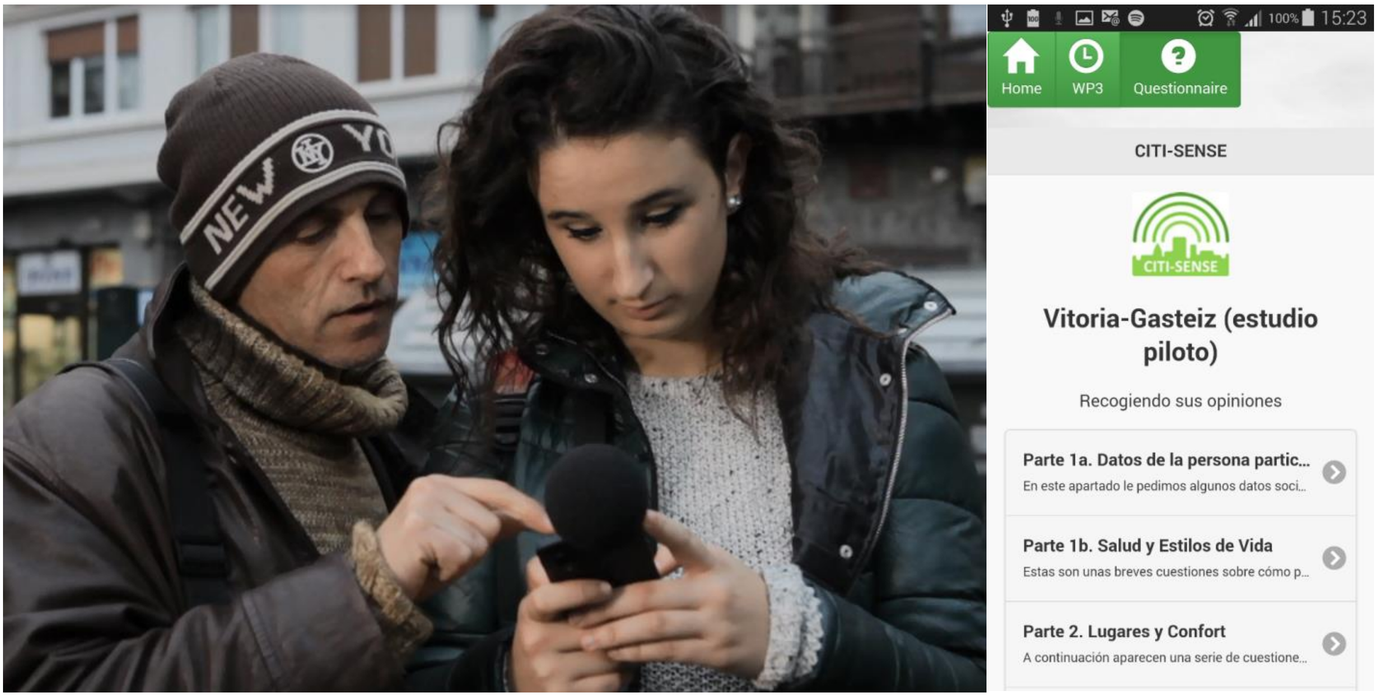
SensApp web services is composed of a set of web services that enable retrieving and storing sensor data. SensApp has a web page for sensor data management.



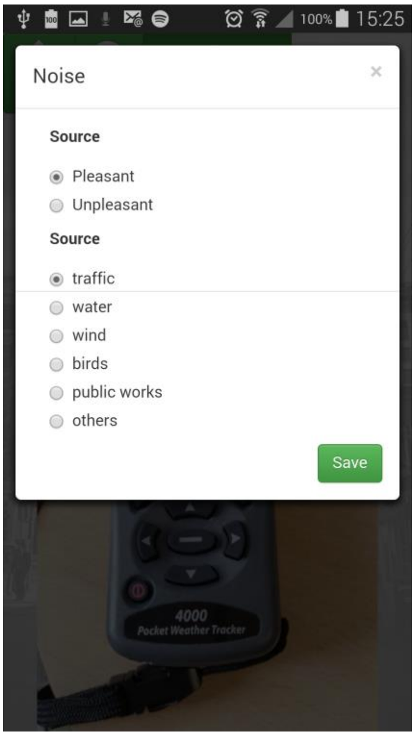
SENSE-IT-NOW

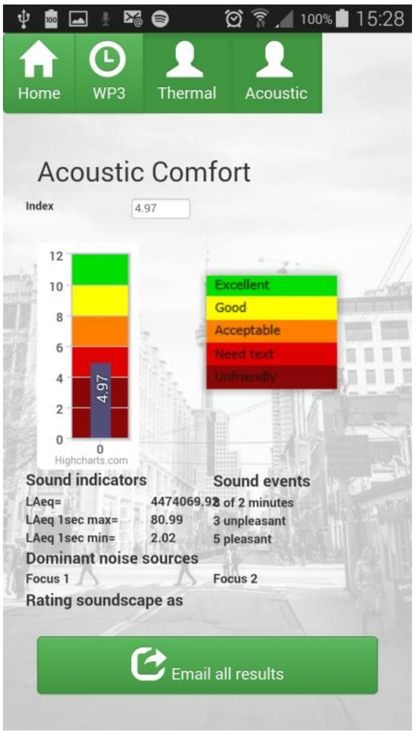
SENSE-IT-NOW is a smartphone application developed for Android devices that provides the following options:

- carry out online surveys;
- collect user provided information about their personal perceptions of the environmental quality by taking a photo and mark it with “Pleasant” or “Unpleasant”;
- show in real time the measurements of temperature, humidity and wind speed from the Kestrel sensor, and sound pressure levels from the microphone and the CityNoise App;
- calculate personal thermal and acoustic comfort;
- taking a photo of the area and reporting its perception (pleasant or unpleasant) .



CityNoise





CityNoise is a smartphone application/service developed for android devices to detect noise in the user's surroundings. It runs in the background but provides feedback to the SENSE-IT-NOW application when changes in the soundscape are detected.

Based on the user feedback of the source, perception of the detected sounds, and specific questions answered through the SENSE-IT-NOW App, CityNoise will calculate an acoustic index and provide it to SENSE-IT-NOW.

The service provides a sound pressure measurement and detects sound events.

How to use it?

The toolkit can be used in dedicated campaigns. Prior to the user involvement, the team responsible for the campaign will initialize the toolkit, and give the users a short training.

Each user will carry out a monitoring session of about 15 minutes. The user will carry a Kestrel sensor that is connected to an android smartphone with the four necessary apps and an external microphone attached. The user will first start a measuring session of noise levels, wind speed, humidity and temperature with the Kestrel sensor. While the measurements are ongoing, the user will complete a survey about her/his perception of the place. At the end of the measurements, the user can take pictures of the surroundings.

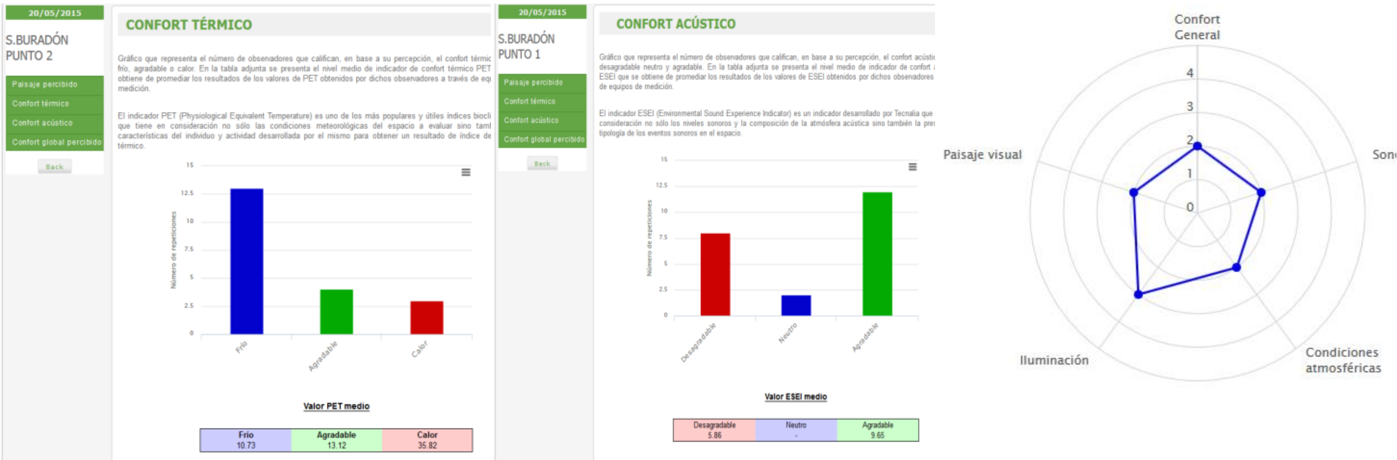
During the measurements, if the CityNoise App detects a noise event, the user will be alerted and will be able to provide feedback about the perception of the sound and possible source.

When the user chooses to end the measuring session, the information will be used to calculate an acoustic and a comfort index.

Photos and perceptions taken by other users can be also viewed. Additional visualization of data can be offered by the App in the smartphone.

Where to look for data?

The SensApp web services can be used for downloading the collected data. The data is displayed at the web page http://vitoria.citi-sense.eu/en-gb/citisense.aspx :



As a final step, the users can gather for a workshop to discuss their suggestions for area improvements.

How to get it?

Please contact:

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Área Sostenibilidad Urbana y Territorial/ Urban and Territorial Sustainability Area
División Energía y Medio Ambiente / Energy and Environment Division
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Parque Tecnológico de Bizkaia; C/Geldo, Edificio 700
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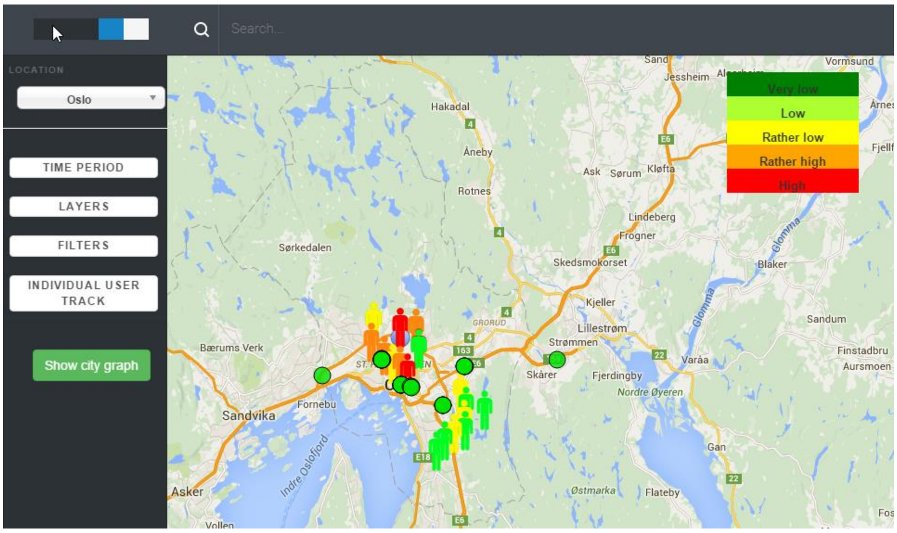
6. DATA VISUALIZATION WEB PAGE

What is it about?

The CITI-SENSE project collects numerous types of data, and provides varied information. A dedicated web site, operating on input from the CITI-SENSE central data platform, allows to visualize this information.

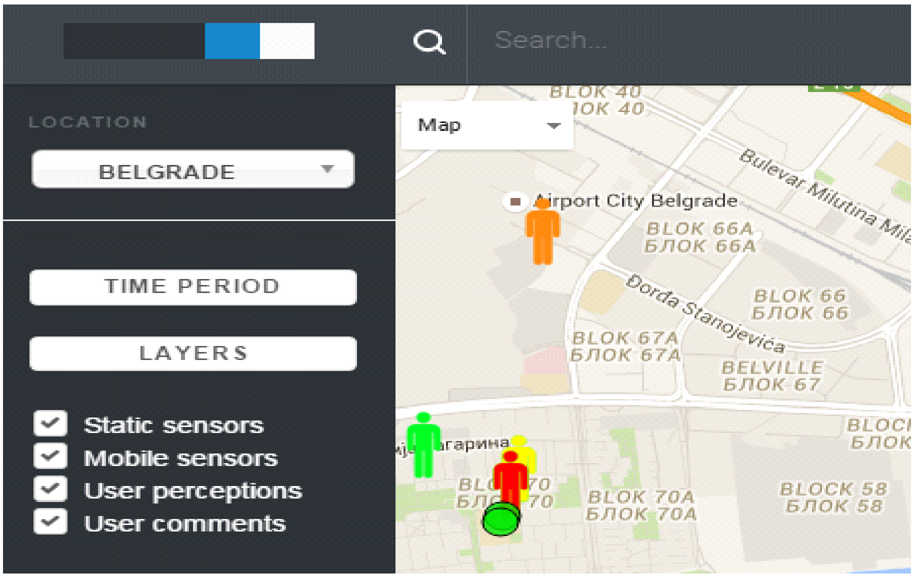


The CITI-SENSE data web page is a web tool for viewing collected data. It is based on input from the CITI-SENSE platform that collects anonymized information.
The user can choose to look at different data types and to combine these in a simple map.

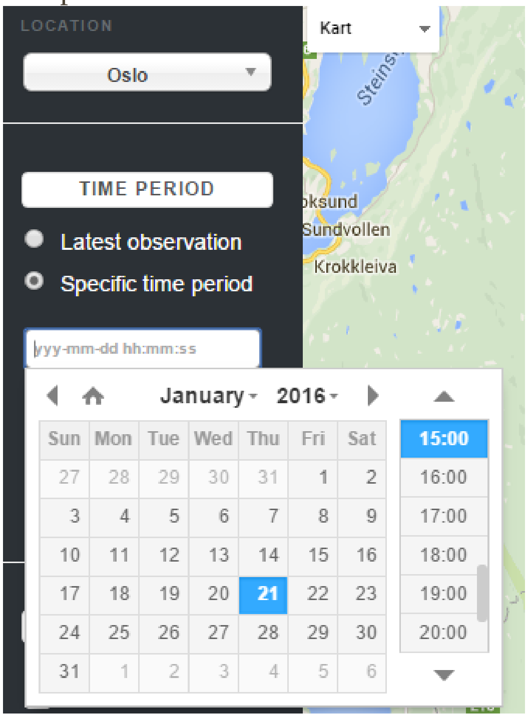
How to use it?

The user starts off by selecting a location from a predefined set of locations registered in our CITI-SENSE platform. When the location is chosen, the web page will upload as a default the last measured values on the following inputs:

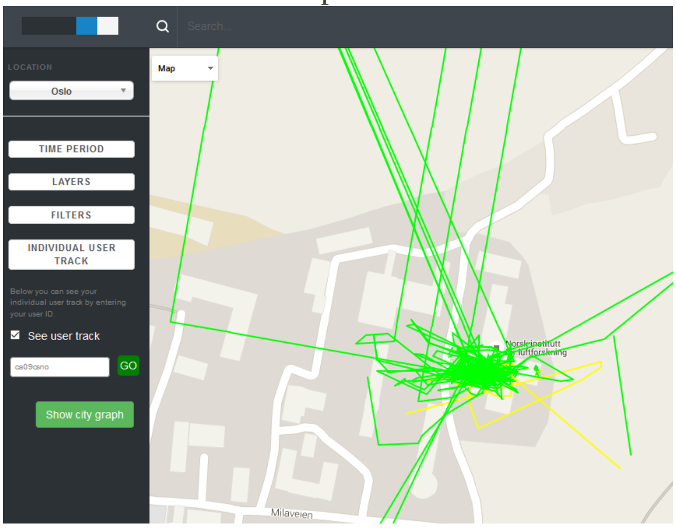
- Static sensors
- Mobile sensors
- User Perceptions
- User Comments



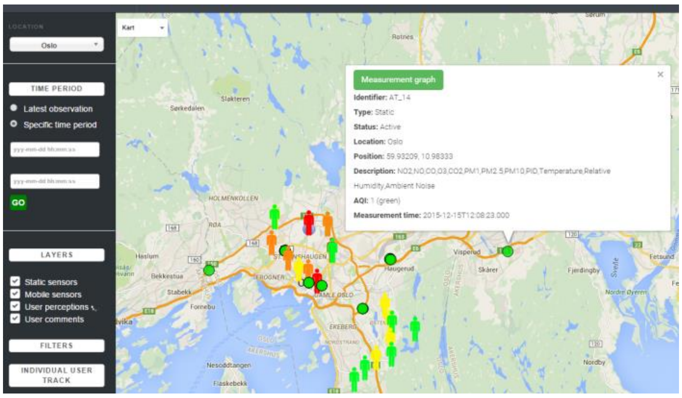
The user can choose to view data within a specific time period:



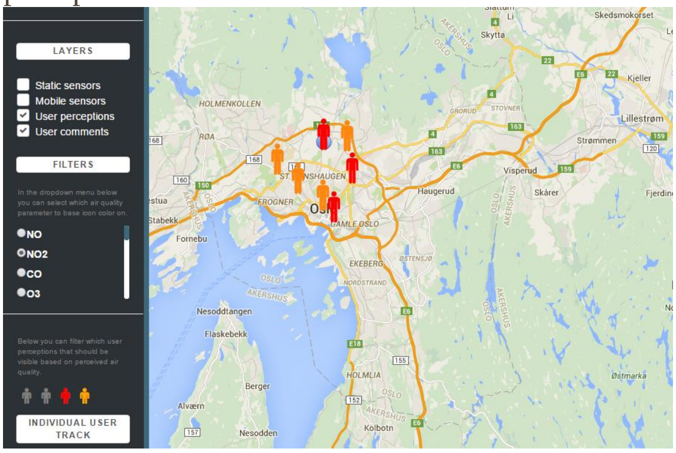
For mobile sensors, the user can fill in the unit's user ID from the ExpoApp and track their measurements on the map.



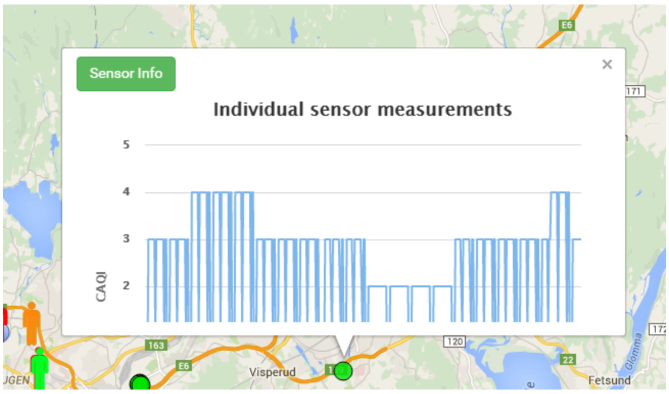
After clicking on a sensor on the map, the user will see more information:



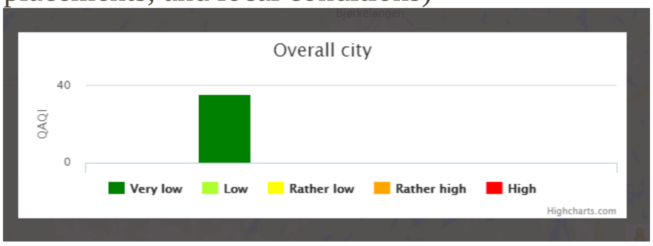
Several options are available for removing layers, or viewing individual air quality parameters and perception markers:



And the individual sensor`s measurements:



For each city, a summary graph indicates air quality as measured by the sensor units (please note that this may differ from the information from the public air quality information systems, due to differences in monitoring methods, device placements, and local conditions)

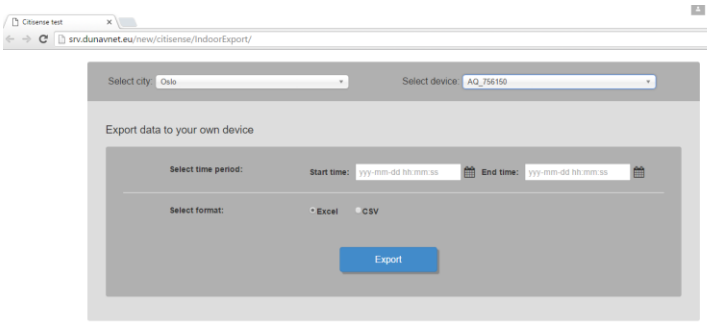


How to get it?

The web page can be found at this address: http://srv.dunavnet.eu/new/citisense/OutdoorDataPortal/

CITI-SENSE, www.citi-sense.eu, is a collaborative project co-funded by the European Union's Seventh Frame-work Programme for Research, Technological Development and Innovation, grant agreement no 308524.

7. DATA DOWNLOAD WEB PAGE



What is it about?

The CITI-SENSE **Download Data Web Page** is a web tool for downloading sensor device data from the CITI-SENSE platform in CSV format or directly into an Excel sheet. It is intended for use within the CITI-SENSE project, but can be used by any interested party.

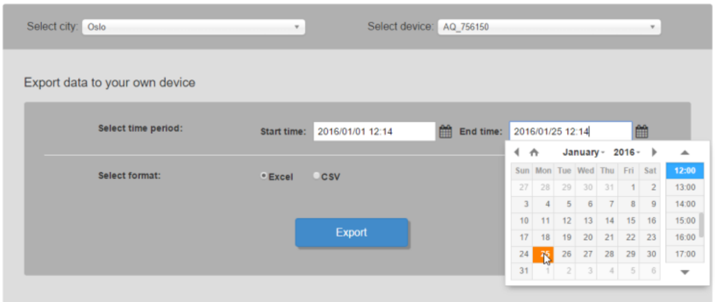
Participants in the CITI-SENSE school use cases can access data at http://schools.citi-sense.eu/ (password-protected).

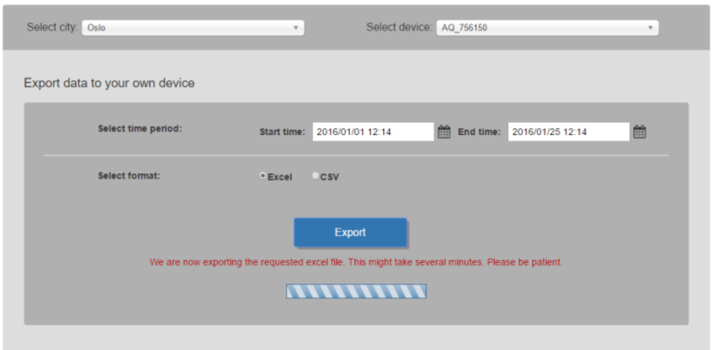
The **Download Data** web page has the following five mandatory filter criteria:

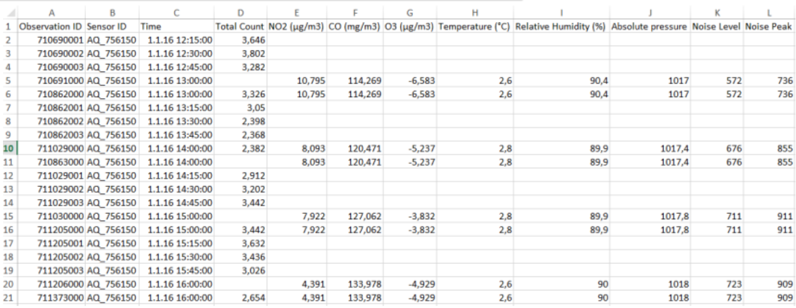
(1) Location, (2) Sensor device, (3) Start time, (4) End time (5) Format CSV/Excel).

How to use it?

The user selects from a drop-down menu the area (city), and chooses the device to view. Then s/he defines the start and end of the measuring period, chooses the output format, and clicks the Export button:







	A	B	C	D	E	F	G	H	I	J	K	L
1	Observation ID	Sensor ID	Time	Total Count	NO2 (µg/m3)	CO (mg/m3)	O3 (µg/m3)	Temperature (°C)	Relative Humidity (%)	Absolute pressure	Noise Level	Noise Peak
2	710690001	AQ_756150	1.1.16 12:15:00	3,646								
3	710690002	AQ_756150	1.1.16 12:30:00	3,802								
4	710690003	AQ_756150	1.1.16 12:45:00	3,282								
5	710691000	AQ_756150	1.1.16 13:00:00		10,795	114,269	-6,583	2,6	90,4	1017	572	736
6	710862000	AQ_756150	1.1.16 13:00:00	3,326	10,795	114,269	-6,583	2,6	90,4	1017	572	736
7	710862001	AQ_756150	1.1.16 13:15:00	3,05								
8	710862002	AQ_756150	1.1.16 13:30:00	2,398								
9	710862003	AQ_756150	1.1.16 13:45:00	2,368								
10	711029000	AQ_756150	1.1.16 14:00:00	2,382	8,093	120,471	-5,237	2,8	89,9	1017,4	676	855
11	710863000	AQ_756150	1.1.16 14:00:00		8,093	120,471	-5,237	2,8	89,9	1017,4	676	855
12	711029001	AQ_756150	1.1.16 14:15:00	2,912								
13	711029002	AQ_756150	1.1.16 14:30:00	3,202								
14	711029003	AQ_756150	1.1.16 14:45:00	3,442								
15	711030000	AQ_756150	1.1.16 15:00:00		7,922	127,062	-3,832	2,8	89,9	1017,8	711	911
16	711205000	AQ_756150	1.1.16 15:00:00	3,442	7,922	127,062	-3,832	2,8	89,9	1017,8	711	911
17	711205001	AQ_756150	1.1.16 15:15:00	3,632								
18	711205002	AQ_756150	1.1.16 15:30:00	3,436								
19	711205003	AQ_756150	1.1.16 15:45:00	3,026								
20	711206000	AQ_756150	1.1.16 16:00:00		4,391	133,978	-4,929	2,6	90	1018	723	909
21	711373000	AQ_756150	1.1.16 16:00:00	2,654	4,391	133,978	-4,929	2,6	90	1018	723	909

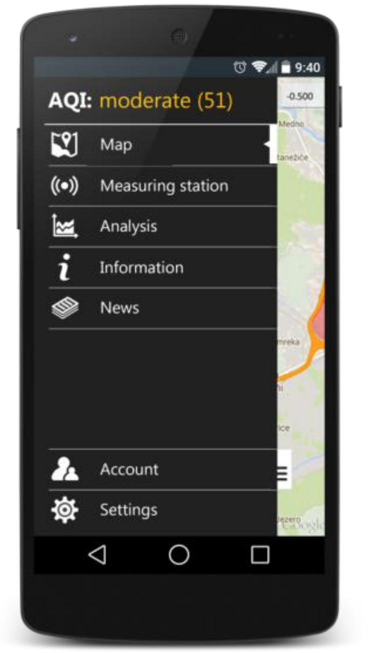
How to find it?

The web page can be found at this address: http://srv.dunavnet.eu/new/citisense/IndoorExport/

8. EXTERNAL CONTRIBUTION: Phone application to display air pollution in Cities

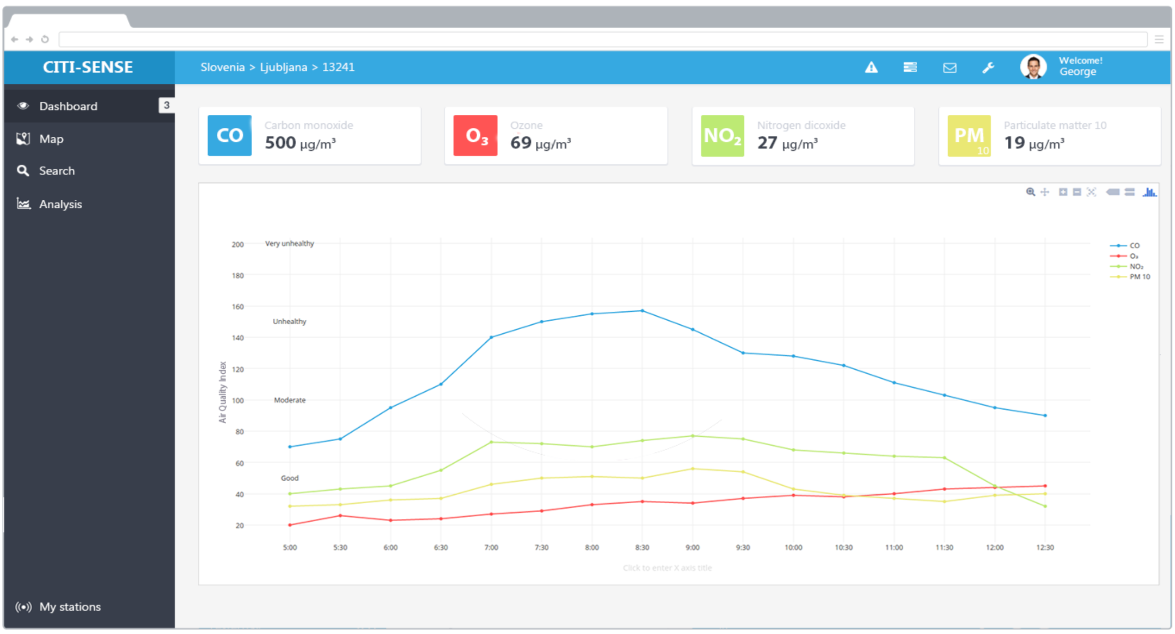
What is it about?

A centralized open source phone application for Android and iOS which visualizes air quality by using effective colour schemes. Semi-transparent overlays of pollution are generated according to Air quality index (AQI) scale (only for areas with sufficient number of measuring points per area) which is displayed as layers over Google maps.



How to use it?

The application will be accessible from any modern device, whether from a native app or via web interface. On areas with several measuring stations, AQI heat maps of pollution will be generated. The Android and iOS app will also support portable measuring units. With the portable units, the user will get information at any location he is staying during the day. The application is designed to interpret the data from the available measuring units from the CITI-SENSE project, but it also enables inclusion of data/measurements from any amateur weather station as well as any commercially available air monitoring products (e.g. Netatmo, Cubesensors).



How to get it?

The app will be available on Google Play on June 2016 at the latest.

CITI-SENSE, “Development of Sensor-Based Citizen’s Observatory Community for Improving Quality of Life in Cities”, aims to strengthen the ability of citizens to participate in environmental decision making. It provides citizens with tools to ‘sense’ and appraise their environment through new devices, at the same time raising awareness about pollution issues, and allowing to communicate valuable environmental information between various stakeholders.

To address its objective, CITI-SENSE builds on an intensive dialogue between the technical, scientific, and social aspects of environmental information, its production, and its use. The project is building a technical infrastructure that allows to collect data from numerous information providers (sensor devices, citizens, environmental databases), and to develop information products partly using co-design techniques.

As one of the aims is to provide information to GEOSS, our infrastructure complies with the necessary standards. Own data collection using microsensor devices gives substantial attention to quality assurance and control issues. The potential for the use of the data, ultimately aiming at empowerment, is investigated in case studies in nine European cities.

The project, www.citi-sense.eu, is a collaborative project co-funded by the European Union's Seventh Framework Programme for Research, Technological Development and Innovation, grant agreement no 308524, and is executed by a consortium of 30 partners.