D2.2 Technical requirements and high-level specifications v1

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Acronyms

API	Application Programming Interface
AQI	Air Quality Index
ASA	Azure Stream Analytics
ATMS	Advanced Traffic Management System
EEA	European Environment Agency
GPS	Global Positioning System
GUI	Graphical User Interface
HR	Heart Rate
HRV	Heart Rate Variation
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
ICT	Information and communication Technology
IoT	Internet of Things
ITS	Intelligent Transportations System
KPI	Key Performance Indicator
LoRaWAN	Long Range Low Power Wide Area Network
M2M	Machine-to-machine
OAQ	Outdoor Air Quality
OSS	Open Source Software
PM	Particle Matter
RF	Radio Frequency
RTU	Remote Telemetry Unit
SQL	Structured Query Language
STEM	Science, Technology, Engineering, and Mathematics

TCP	Transmission Control Protocol
TVOC	Total Volatile Organic Compounds
UI	User Interface
VLCi	Valencia smart City Platform
VOC	Volatile Organic Compounds

1. Introduction

This document (deliverable D2.2 Technical requirements and high-level specifications v1) presents the technical requirements and specifications for the use cases of ESTABLISH project. The major goal of this work package (WP) 2 is to provide definitions, requirements and specifications needed for the implementation of the ESTABLISH system. WP2 will collect and analyze the use case specific requirements to understand the motivation, interests, priorities and abilities of various stakeholders, establishing a context and concrete reference framework for the design and development of the technical solutions of the project. User needs and expectations towards defined use cases are explored via usability studies. Besides the requirements analysis, WP2 will codify the requirements in high-level technical specifications for the WPs 3-6. In those WPs, the requirements and specifications will be specified more in detail.

The work was started together with the partners in the kick-off meeting held in March 2017. There we brainstormed the use cases in groups. The ideas were discussed and prioritized together and the owners were chosen for the use cases. The use cases were developed further in smaller groups with the companies participating the certain use case. Use case definitions and user requirements together with state-of-the-art description has previously been reported in D2.1. This D2.2 specify the use cases and concentrate on technical specifications of them. ESTABLISH project includes three use cases with five pilots. The Korean pilot (Intelligent air quality management system) is described for the first time in this deliverable due to the later funding decision.

This deliverable describes the technical requirements and high-level specifications related to the use cases. The deliverable is divided in four sections. After Introduction, the ESTABLISH use cases and pilots have been shortly described in Section 2. Technical requirements related to these pilots have been defined in Section 3. Section 4 includes the conclusions and the next steps for WP2. Use case specific technical specifications and general use case requirements are presented in Appendixes.

2. ESTABLISH use cases and pilots

In this deliverable, three use cases of ESTABLISH project with five pilots are shortly described:

- Use case 1: Optimized City and Mobility Planning
- Use case 2: Developing smart HVAC systems that ensure a healthy indoor environment
    - Smart HVAC systems that ensure a healthy indoor environment
    - Intelligent air quality management system
- Use case 3: Promoting independence of specific vulnerable groups
    - Rehabilitation decision support, and
    - Indoor air quality improvement at school.

More specific use case and pilot descriptions can be found from D2.1 State-of-the-art, detailed use case definitions and user requirements. Korean *Intelligent air quality management system* pilot has been described for the first time in this deliverable due to the later funding decision. Each pilot has its own company owner. The owner is in responsible for the progress of the pilot; planning, implementing and reporting in co-operation with other partners. Table 1 summarizes the roles of the partners in the pilots.

Table 1. Summary of ESTABLISH use cases with partner roles.

Pilot	**Owner**	**Partners**
Optimized City and Mobility Planning	Prodevelop	Hi-Iberia, Tecnalia
Smart HVAC systems that ensure a healthy indoor environment	IMA	DEKPROJEKT, CUNI
Intelligent air quality management system	ETRI	Coway
Rehabilitation decision support	Siveco	BEIA
Indoor air quality improvement at school	VTT	Bigdatapump, Inspector Sec, Uniq Air

Two more pilots for use case 3 will be planned and described when the national funding has been received:

- Dementia air quality (owner: Turkgen), and
- Remote elderly lifestyle support (owner: ISEP).

2.1 Optimized City and Mobility Planning (Prodevelop)

Description and goal

Planning of urban development and traffic greatly affects air quality and consequently living conditions of a city. Based on environmental sensor data, complemented with other data sources (e.g., building footprints, demographics, traffic information, etc.) and geo-data analysis techniques, locations and/or routes will be profiled in terms of their environmental conditions and their impact on a healthy living environment.

Implementing smart transportation is a more durable way of raising the air quality in urban areas. Three key parameters will define smart mobility in urban areas:

- advanced traffic management system (ATMS),
- parking management, and
- intelligent transportations system (ITS) enabled transportation pricing systems.

In the use case on *Optimized City and Mobility Planning*, the Spanish consortium will build an advanced application for providing planning services and mobility information both for citizens and for city authorities considering relevant information such as contamination or traffic conditions (see Figure 1.). This pilot will also enable gamification methodologies to motivate people to improve efficiency of the transport system and promote sustainable habits in the context of transport mobility.

The use case includes the development of a dashboard that displays the status of metrics and key performance indicators (KPIs) related with it. The essential features of the dashboard include a customizable interface and the ability to pull real-time data. The dashboard will have two perspectives, the first for the authorities and the second for the citizens.

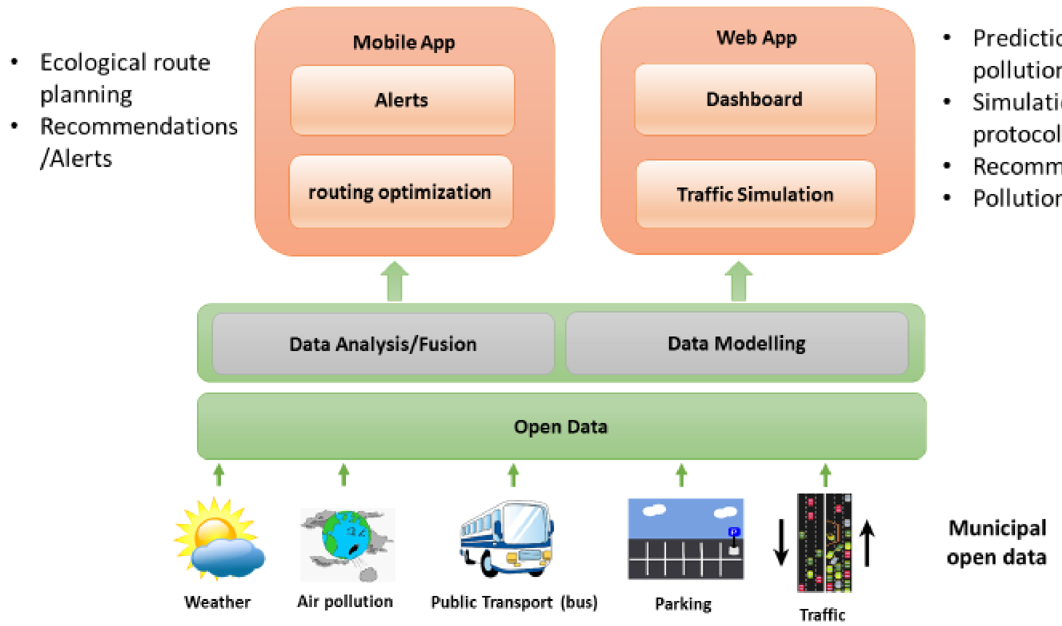


Figure 1. The idea of Optimized City and Mobility Planning use case.

The *Optimized City and Mobility Planning* will consider multi-modal mobility taking into account public and private transportation, awareness of energy usage, environmental conditions, pollution levels, travel costs and durations. The application will consider personalized preferences and constraints, the user may specify mobility problems, respiratory problems and allergies related to pollen suspended in the air, and these data will used to optimize the route to be calculated. Multi-Modal Mobility will not only improve the quality of life of individuals and, as a result, their health, but it will improve also the environment for society by reducing the air pollution produced by vehicle emissions.

Pilot

The pilot will be developed in Valencia (Spain), which is the third biggest city in Spain with 800,000 inhabitants. Valencia is investing many resources in its smart city platform and participates actively in many R&D projects and city networks (for example, Spanish Network for Smart Cities and The European Innovation Partnership on Smart Cities and Communities). Valencia is the first European city with a platform full FI-WARE compliant. Valencia Smart City Platform (VLCi) [1] contains nowadays more than 100 open data sources. These data sources are freely available for anybody, without copyright, patent or any other restriction. Valencia city council is not a partner of the Establish project but it is committed to collaborate with the pilot from the beginning and will provide support in the use of VLCi, access to new sources that will be incorporated into its platform in the future and validation of the use case. The partners involved in the use case will regularly review the new datasets and evaluate the possibility of incorporating them into the pilot.

Impact

The implementation of the use case will provide a series of benefits that will affect the increase in the quality of life of the citizens of Valencia and reducing the global pollution of the city. Thanks to the use of the application, the users will get several benefits such as reduction in average travel time in intra-urban movements, optimal routes personalized taking into account their preferences, mobility problems and health problems. The application will promote the use of greener and healthier means of transport, reducing energy consumption and pollution in cities. In order to carry out this system, it will use user information and data provided by different real-time data sources as well as weather forecasts. Through complex algorithms and forecasting models, the system will be able to predict future traffic congestion and elevated levels of pollution.

In addition, the system will provide feedback for cities and citizens. The application will show indicators on the use of different means of transport and roads. This information will be useful to detect needs of public services and to provide continuous improvement in these services.

The services for profiling geographic areas and routes in terms of their environmental conditions for city and route planning purposes will have the following impact:

- travel time reduction for individuals,
- energy savings on a city level,
- CO_2/NO_2 pollution decrease on a city level,
- reduction in overall queue lengths at public services, and
- proportion of people using Multi-Modal Mobility services.

2.2 Smart HVAC systems that ensure a healthy indoor environment (IMA)

Description and goal

In the deliverable D2.1, current system solutions developed in IMA was described. It has been taken as background of ESTABLISH platform in *Smart HVAC systems that ensure a healthy indoor environment* pilot. The basic architecture of simple local air quality monitoring system was explained. Two key system components were sensor devices and data aggregator, data were stored and interpreted using web-based interface for MAS DB data management, which has been developed on a Microsoft Silverlight platform. Applications developed on this platform offer a visually attractive and intuitive user-friendly interface to many database systems and fulfil all requirements to the user control comfort and data visualization. In this deliverable, we are going further in innovation of almost all system components described in D2.1.

[1] http://gobiernoabierto.valencia.es/en/

Pilot

The Czech *Smart HVAC systems that ensure a healthy indoor environment* pilot will develop such a HVAC system (focusing on automatic window opener and air handling unit) that will also autonomously learn behavior patterns of the users/inhabitants of the building and take advantage of this knowledge to get the building ready for the predicted needs. It will try to resolve the tension between energy efficiency and quality of indoor climates that occurs e.g. after retrofitting of existing buildings by offering an affordable solution.

Based on technical requirements given in Chapter 3.2, we will develop more than basic monitoring concept on how the air quality monitoring should be integrated at home or office environment management, in order to ensure elimination of negative aspects of sealed up homes (offices) and to contribute to quality of living, see Figure 2.

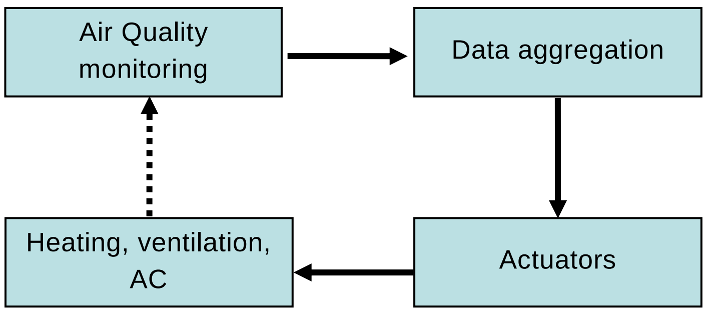


Figure 2. Usual management of home/ office environment.

Impact

Providing superior indoor air quality (IAQ) can improve health, work and school performance, as well as reduce health care costs, and consequently become a source of substantial economic benefits. While some see energy efficiency and IAQ as contradictory goals, an integrated design suggested in the pilot can bring on the market an affordable high performing control system for buildings or flats that will bring savings in energy consumption (up to 15%) while maintaining good IAQ. All stakeholders yearn for healthy environment either if they stay there as residents or if they design new components of HVAC.

Building up a new subsystem - environmental sensor network - on top of ID system platform will extremely speed up introduction of new air quality services and applications within the current systems since the main system components and communication channels are already verified on presently running ID and building services. Facilitation of the new sensor subsystem implementation makes faster market access possible and brings essential competitive advantage.

2.3 Intelligent air quality management system (ETRI)

Description and goal

On the industrialization and the climate change in the world, the living environment of people is being exposed to the external pollutions. The indoor air quality is more affected by the pollutants, because of proceeding the purification within the confined spaces. For instance, Korea peninsular is seasonally influenced by the contaminated dust that generated from the industrial complexes in China. At that time, most of the citizen in Korea cannot open the windows for ventilation of air and should wear a mask when going out. If some technologies can rapidly detect and clear the source of pollutants when the contaminants came into the building such as the house and the office, it will be one of the solutions to ensure the fresh and safe air quality in indoors.

The Korean *Intelligent air quality management system* pilot will contribute to developing the technologies and implementing the air purification system that can provide the clean and healthy spaces in the buildings, through connecting the information between the IAQ (Indoor Air Quality) / OAQ (Outdoor Air Quality) devices and the human activities. As the use case in the pilot, the ESTABLISH will assist the people residing in the buildings for a long time, e.g. patients, workers, senior citizens, children, by providing the comfortable environment.

Pilot

The *Intelligent air quality management system* pilot will contribute to developing a healthy indoor environment in the buildings that can automatically adjust its conditions to better temperature, air quality, humidity, etc. using the results analyzed by the environmental data, see Figure 3. The pilot will achieve the solution to generate the well-being, safe, comfortable indoor spaces for the people, especially the senior and the children.

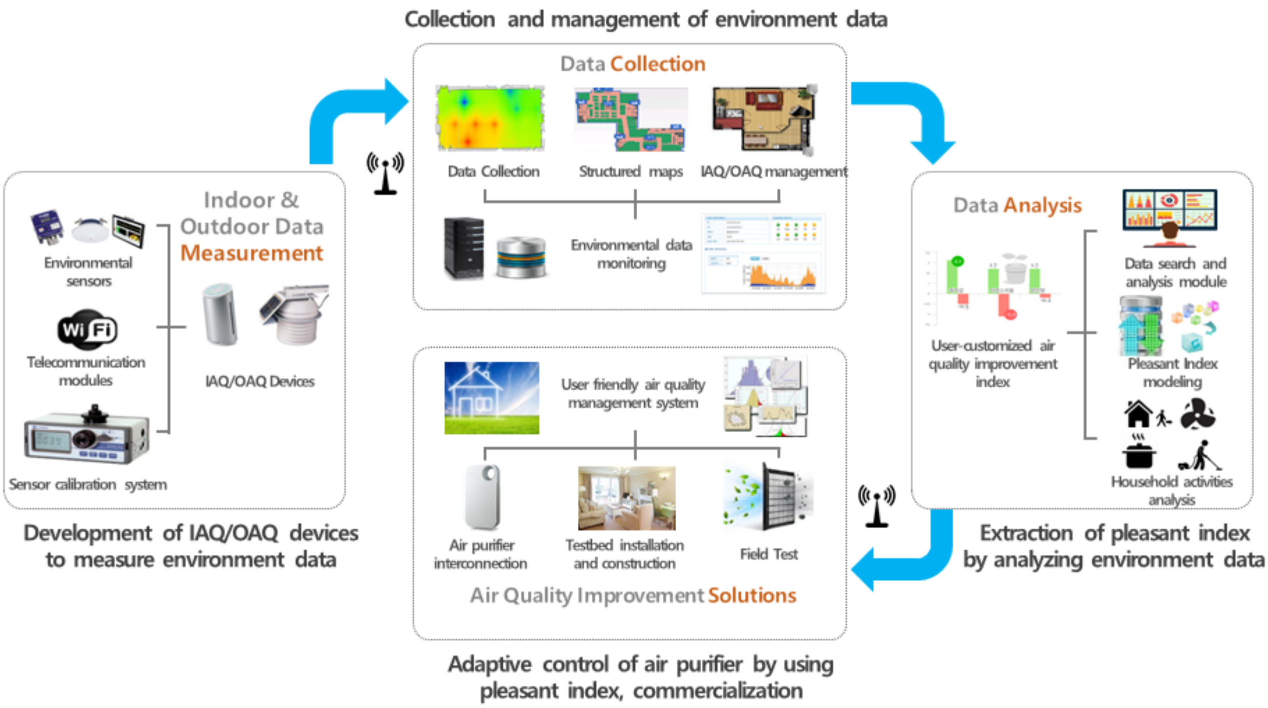


Figure 3. Intelligent air quality management system based on environmental data.

As shown in Figure 3, the pilot proposed the system architecture for data measurement, collection, analysis, and the solution in order to provide the clean air quality to the people by integrating the IAQ/OAQ devices, the server platform, and the air purifiers. The pilot is responsible for developing four major components to achieve the target goal of the system; data measurement, data collection and management, data analysis, and system solution.

Data Measurement: IAQ and OAQ devices integrate many kinds of sensors to measure the various environmental information into one hardware module. The devices also include the functions of the wireless communication to transmit the measured information.

Data Collection and Management: The server platform can manage the environmental data gathered by the IAQ and OAQ devices. Its main function is the extraction of the key information by analyzing the environmental data in the form of the big data.

Data Analysis: The algorithms such as the machine learning and data mining find out the indicators to improve the air quality by classifying the user life patterns and detecting the air pollution sources. It can improve the effectiveness and minimize the management cost of air purifiers by notifying the replacement cycle of filter parts, which are the core of the air purifier, through analyzing the contamination degree of the environment.

System Solution: The improvement indicators of the air quality are used for the program to interconnect the intelligent management system of the air quality and the air purifiers. The field test can improve the reliability of the developed system for the commercialization in the practical applications.

Impact

The pilot expects to achieve the positive effects in variety aspects. As the technical effect, the development of IAQ/OAQ devices can support to measure the various environmental data related to the air quality so that the air appliances such as air purifiers, air conditioner, humidifier, ventilator, etc. are used into the IoT technology ecosystem. In addition, as the economic and industrial effects, the developed system provides an opportunity to pre-empt the market related to the air quality through earlier commercialization since the people are more and more interested in the clean air of the living space according to increasing of the health threaten factor such as the fine dust, VOC, etc. Moreover, it contributes to improving the quality of life by providing the fresh air in indoors. Finally, as the social and cultural effects, the proposed system can improve the health of the people and minimize the social cost by preventing respiratory disease caused by the polluted air.

2.4 Rehabilitation decision support (SIVECO)

Description and goal

The ESTABLISH project appeared in the context in which wireless technologies have opened up new possibilities and applications in increasingly diverse areas of the medical field. Using medical devices together with communication technologies to monitor certain conditions and/or symptoms has laid the foundation for the integration of M2M technology in the medical industry, a phenomenon referred to as telehealth and e-health. eHealth services and mHealth applications contribute to improving the efficiency and coverage of programs for personal health monitoring, also facilitating communication between patients and medical professionals.

The Romanian *Rehabilitation decision support* pilot will combine environmental sensor data with physiological and behavioral sensor data to empower patients in a rehabilitation clinic with decision support tools for behavioral choices and treatment options.

The Romanian ESTABLISH pilot’s goals are to:

- monitor health parameters to constantly improve the health of the population through rehabilitation and spa care, specifically targeting the patient's functional aspect of integration in everyday life, environment and work,

▪ develop a decision support system and services based on the outdoors environment parameters and indoor location, and
▪ reduce operations costs and improve quality of the services provided.

We will use a first group of students from high school and a second pilot group of adults. We will register their physical activities, the cardiac rhythm, the burned calories, sleep patterns, in order to find links between the biological data and environmental conditions.

Pilot

The *Rehabilitation decision support* pilot will analyze the physical behavior of several high school students, while monitoring the environmental data, temperature, relative humidity, pressure, wind speed, together with the air pollutants concentrations, SO_2, CO, O_3, NO_2, PM2.5, and PM10.

In Figure 4 the proposed architecture for data collection and an experimental solution for monitoring functionalities[2] are presented.

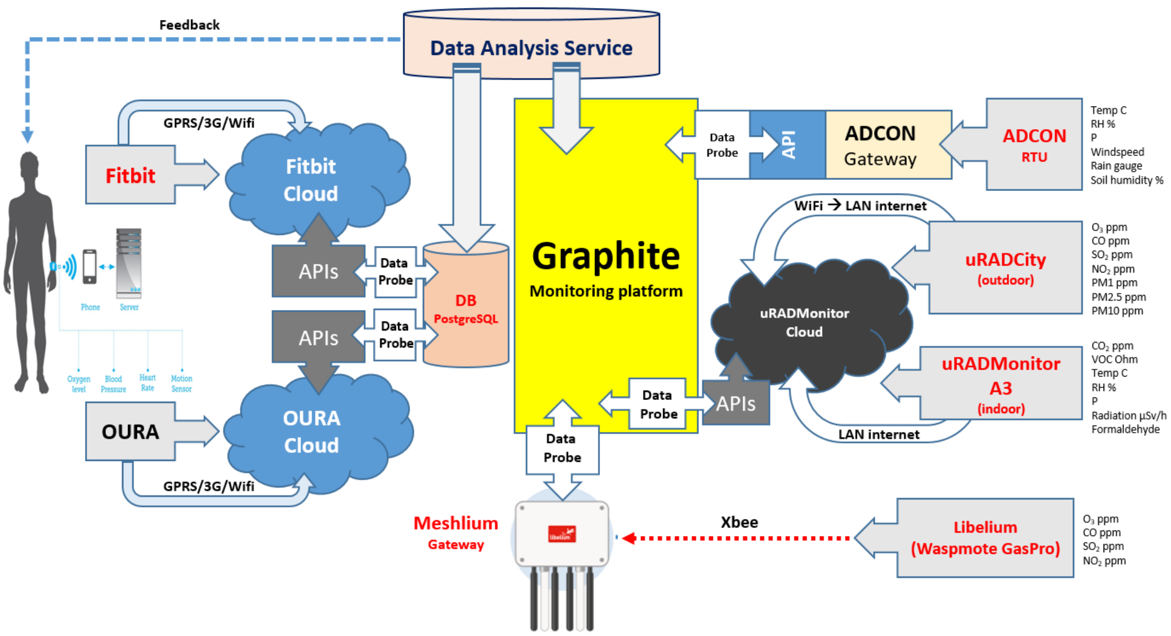


Figure 4. Sensors Architecture.

The environmental monitoring solutions, the ADCON meteorological station, and the air quality stations, Libelium, uRADMonitor City and A3, have been tested for several months to assure their functionality, mainly to test the air monitoring sensors, which have an use time between calibrations for around six months.

In addition, to achieve the objective in developing the rehabilitation decision support, we analyzed several available solutions for correlations over the impact of air pollution on human health.

In Figure 5 a sequence from the historical data available at the page of European Environment Agency[3] is presented. The data available includes air pollutants concentrations for various pollutants and cover

[2] *http://graphite.readthedocs.io/en/latest/*

[3] *https://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-2/#parent-fieldname-title*

period between 2004 and 2012. In the period 2013-2015, the monitoring station was not functioning properly and the measured data was not validated by EEA.

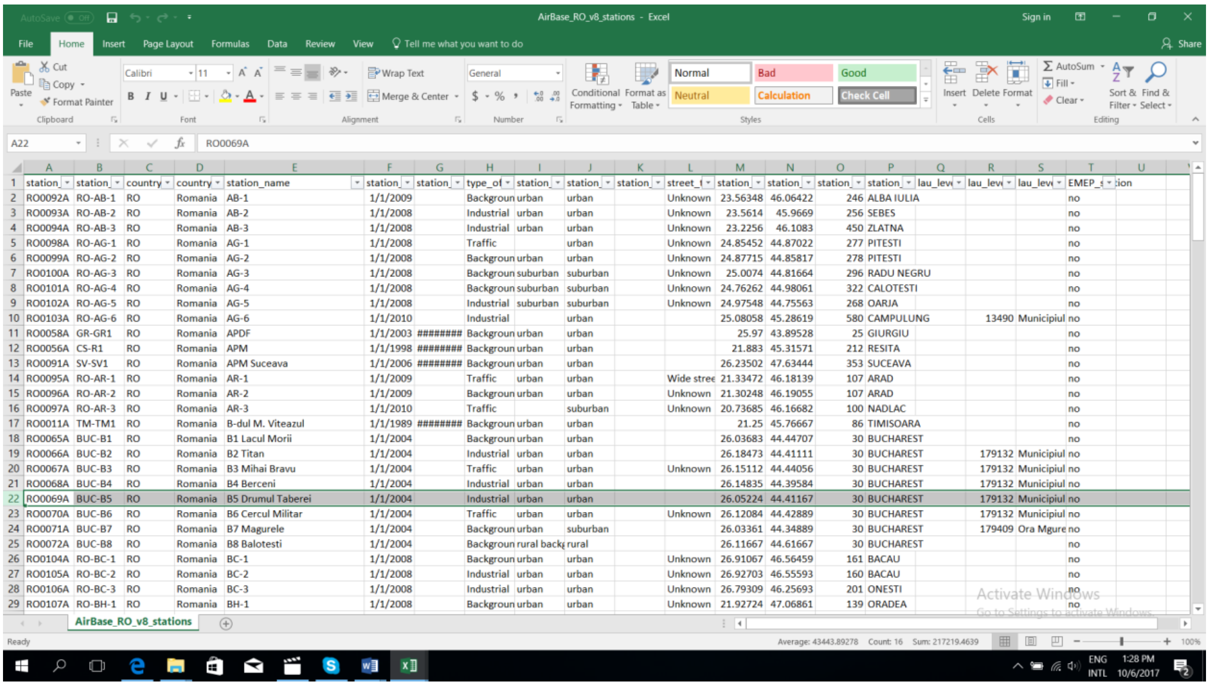


Figure 5. Airbase air pollutants historical data.

This dataset will be used to characterize the pollution level in the area where the high school pilot will take place. Statistical analysis will be performed to identify days/time periods with higher pollution level.

Links between air pollutants and health effects

For the establishment of the links between air pollutants and health effects we propose air quality indexes from various countries (i.e. U.K, U.S.A)[4].

UK air quality index[5] (UK – AQI) recommends breakpoints between the bands of Low, Moderate, High and Very High for each of the index pollutants (for SO2, O3, NO2, PM10 and PM2.5). The information that accompany the air quality index includes additional advice for susceptible individuals, together with advice for the general population. Short-term health effects of air pollution and action that can be taken to reduce impacts and health advice linked to each band to accompany the air quality index are presented. In addition, it is recommended the use of 'trigger' values to complement the air quality index and allow for the prediction of episodes of elevated air pollution in real time as they emerge.

U.S. air quality index (US- AQI) are estimated based on measured value for five pollutants (O3, PM10, PM2.5, CO, SO2 and NO2) and include the health effects messages, sensitive groups presentation, and cautionary statements for each pollutant. In Table 2, the pollutants specific sensitive groups are presented.

[4] *https://www3.epa.gov/airnow/aqi-technical-assistance-document-may2016.pdf*

[5] https://www.gov.uk/government/publications/comeap-review-of-the-uk-air-quality-index

Table 2. Pollutant-Specific Sensitive Groups[6].

Pollutant that had registered an AQI above 100	**Sensitive Groups**
Ozone	People with lung disease, children, older adults, people who are active outdoors (including outdoor workers), people with certain genetic variants, and people with diets limited in certain nutrients are the groups most at risk
PM2.5	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
PM10	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
CO	People with heart disease is the group most at risk
NO2	People with asthma, children, and older adults are the groups most at risk
SO2	People with asthma, children, and older adults are the groups most at risk

Figure 6 presents the location of the high school and the national air monitoring station. The map is provided by CalitateAer[7]. The web site displays air quality indices and measured values, updated hourly which are being validated and certified. Data source used in the pilot include values registered by local air quality monitoring station (code no. RO0069A, or B5 shown on the map) and stored in the European Air Quality Database – AIRBASE.

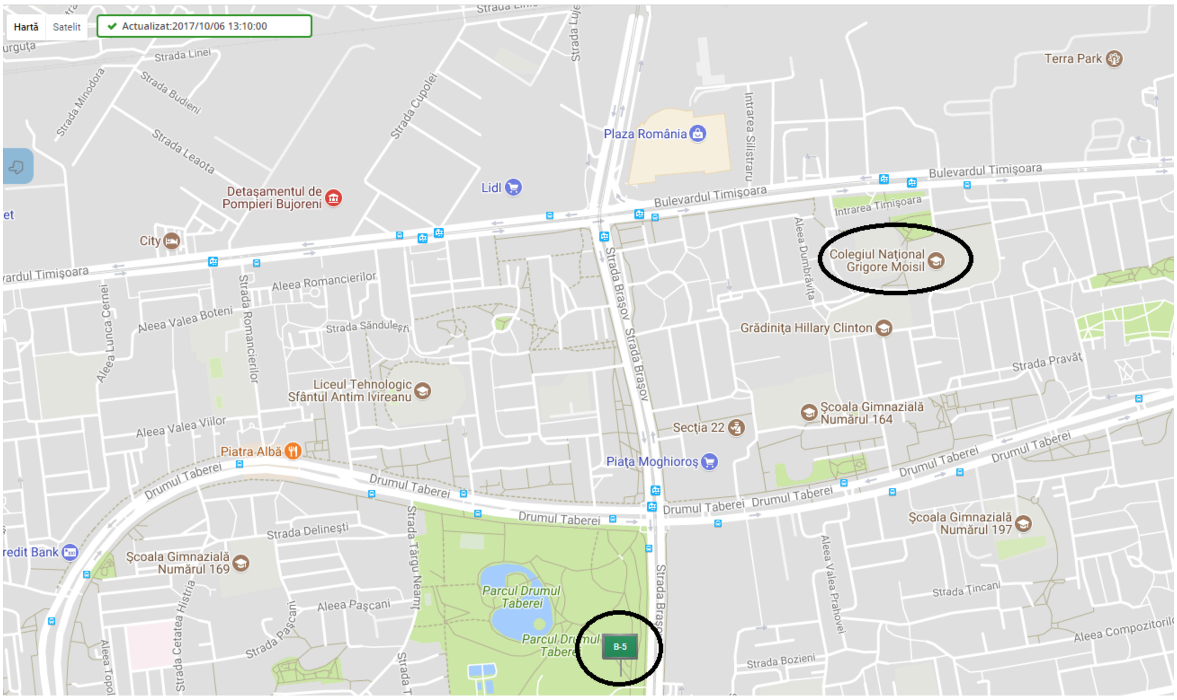


Figure 6. Location of the high school and air monitoring station.

[6] Source: Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI), U.S. Environmental Protection Agency, EPA-454/B-16-002, May 2016

[7] *http://www.calitateaer.ro/public/home-page/?__locale=ro*

The technical development for collecting the environmental and physiological data are detailed in section 3.4.

Impact

The pilot aims to offer people an innovative system, which will be their source of information on the environmental conditions in which they conduct daily activities. By analyzing this information and the decision support module, it will ensure the independence of vulnerable groups (children, women, elderly) from the health care professionals specialized in recovery and rehabilitation.

This system will reduce the negative effects that environmental conditions may have on the health of the people in these types of groups and will increase their independence and wellbeing.

Air quality monitoring studies conducted in Romania draw attention to the risk areas and hazardous substances, highlighting the link between air pollution and the effects of this phenomenon on health.

The number of people who do outdoor physical activities (jogging) or in special gyms is on the rise. Apart from those who intend maintaining their fitness levels and preventing obesity, there are people who have been prescribed physical activities related to recovery / the restoring of motor functionalities, both outdoors and indoors.

2.5 Indoor air quality improvement at school (VTT)

Description and goal

The Finnish *Indoor air quality improvement at school* pilot will study the use of a variety of indoor sensors and wearables combined with users' personal feedback and environmental sensing information to provide a healthier living environment for pupils, teachers, and other staff members at schools, see Figure 7. The idea is to learn from sensor data by means of combining different data streams and applying environmental models, machine learning, data mining and supported by big data ICT. This will enable optimization of power provision and self-adaptive HVAC control and air purification in the house. The users can get personalized recommendations based on measured data and feedback got from the users on the impact of air quality.

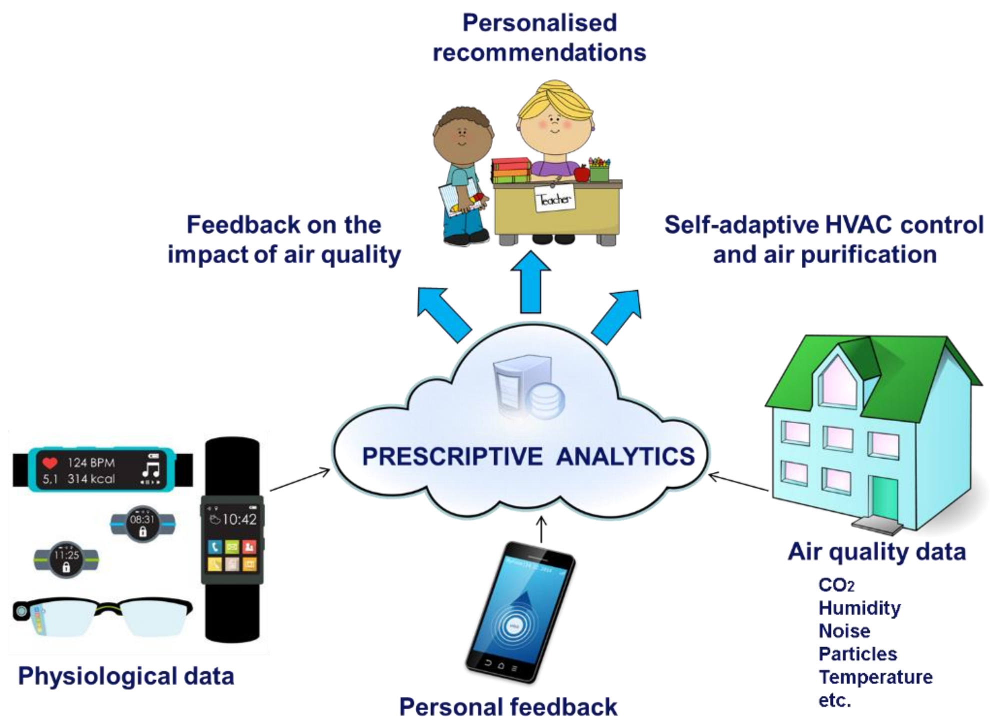


Figure 7. Idea of the Indoor air quality improvement at school.

Pilot

The pilot will be performed at two schools in Finland. Certain rooms at schools will be equipped with air quality control systems, determined in technical specifications. Sensors for indoor air quality measurements will include temperature, humidity, air pressure, carbon dioxide (CO_2), nitrogen dioxide (NO_2) and TVOC (total volatile organic compounds).

In the pilot, the staff members of the schools will receive suitable sensors for monitoring their health condition (physiological data) like heart rate (HR) or heart rate variation (HRV), activity and sleep. They are able to provide feedback about their wellbeing, and their feelings related to the air quality inside the house, by a mobile application and to control the system. The feedback data and data from the wearable devices and sensors will be collected to Azure cloud platform and stored, pre-processed and analyzed based on the time stamps. Based on the real-time analyses, users could get e.g. visualizations about the air quality (data from the sensors) compared to their wellbeing via the application. The need and possibility to utilize the air purifiers in the pilot at school will be evaluated.

The pilot consists of two phases. During the first phase, data will be collected to establish the connection between perceived and measured health and air quality. The second phase will utilize the understanding gained from the data of the first phase to provide the users with insight on the dependency of their wellbeing on air quality and allow for smarter control of their environment. The pilot will be implemented at the schools in autumn 2018.

Test environment. The setup of the pilot will be tested beforehand in VTT's premises in Oulu in autumn 2017. Ten offices (ten testees) and meeting rooms will be equipped with indoor air quality control systems (same sensors as mentioned above) and environmental motion sensors (depth cameras and/ or passive infrared motion detectors), and testees will get the wearable sensors to monitor their physiological data. The application will be developed during the test period so that in the first phase we will only collect the feedback about the air quality and personal conditions from the users, as “How do you feel”. These data will be used for research and development of automatic unobtrusive methods to evaluate user conditions. Other elements will be included before the real pilot after enough data has been gathered.

Available TePi environment will be utilized in the pilot including Azure cloud platform to data handling, as it has been planned in the real pilot. An unique TePi piloting environment at VTT comprises of an Internet of Things (IoT) platform, a data management & analysis platform and a demonstration facility. The Industrial internet platform exploits the latest advancements of 5G, IoT and cyber security technologies and methods. It consists of electronics pilot production and smart building research environments, and introduces 5G infrastructure to support the digital service and application piloting. In addition, related data management and analysis platform includes a server cluster for computationally intensive tasks for enabling lightning fast parallel computation, *e.g.* training deep learning neural networks and fast processing of huge datasets.

This setup will be tested during several months to collect data and to be sure, that it will work properly in the pilot at schools. Feedback from the testees will be utilized iteratively during the pilot to make some modifications before the real pilot at schools if needed.

User involvement. To understand the needs and expectations of the users, the work will be started to involve the users (VTT workers and staff members of the school) to the innovation process. Users will be interviewed to understand the present state and how would they like to improve the air quality and service related to it. These results will be utilized when planning the application and future services for the users.

Impact

The goal of this pilot is to research, co-innovate and develop a cloud-based air quality measurement, analysis and feedback system that provides information on the impact of indoor or limited outdoor (*e.g.* mine, tunnel) air quality on people’s health and wellbeing. The main application scope of ESTABLISH is products, services and solutions on an individual level utilizing environmental sensors (air quality, temperature) and combining the environmental input with other data sources, for example personal wearable sensors. This pilot will enable to go from *monitorin*g the indoor or limited outdoor to *managing* the environmental conditions on a personal level and thus improving the quality of life, reducing health costs and supporting vulnerable groups such as children.

The technological developments will lead to a wide range of new services and products that are all based on environmental sensors. Thus, ESTABLISH will create business opportunities for sensor manufacturers, service providers (*e.g.* facility management companies), software developers, health organizations, health insurance companies and HVAC manufacturers.

3. Technical requirements

3.1 Optimized City and Mobility Planning (Prodevelop)

The pilot *Optimized City and Mobility Planning* will build an advanced application for providing planning services and mobility information both for citizens and for city authorities considering relevant information such as contamination or traffic conditions. This pilot will also enable gamification methodologies to motivate people to improve efficiency of the transport system and promote sustainable habits in the context of transport mobility.

The pilot will provide a dashboard to display metrics and KPIs. The essential features of the dashboard product include a customizable interface and the ability to pull real-time data.

After the meeting between the Spanish consortium and the city council of Valencia, the scope of the pilot and the requirements have been defined.

Technical development

The use case will take into consideration the following technical aspects:

- Route planner:
  - Different means of transportation
  - Mono and / or multi-modal planning
  - Total flexibility in map definition and geographic scope
  - Fully configurable metrics (environmental impact, time, distance, mix, etc. ...)
  - Particularization according to habits of mobility and personal preferences. Integration of public and private transport modes (buses, bicycle and car exchange), others as electric vehicle, private vehicle, bicycle), and
  - Connection with environmental impact assessment and energy consumption systems.
- Precise prediction and forecasting of traffic loads and pollution, simulation of pollution protocols based on based on the information provided by the Traffic Simulation Platform.
- Recommendations for mobility and alerts about pollution in real time based on the fusion of different open data (such as air pollution, weather, traffic, etc.) using big data and machine learning techniques.
- Environmental impact assessment.
  - Estimation of environmental impact “air pollution” based on traffic, topographic and meteorological information,
  - Indicators by zones, and
  - Asynchronous notification of alarms against thresholds.
- Integration of different public data sources useful for the use case.
- Consideration of user preferences, fuel consumption and contamination of the user's vehicle and health problems.
- Provision of a web solution for city authorities and a mobile application for citizens.
- Develop a dashboard to analyze the information in real time.

Figure 8 presents a first approach for the implementation of *Optimized City and Mobility Planning use case*.

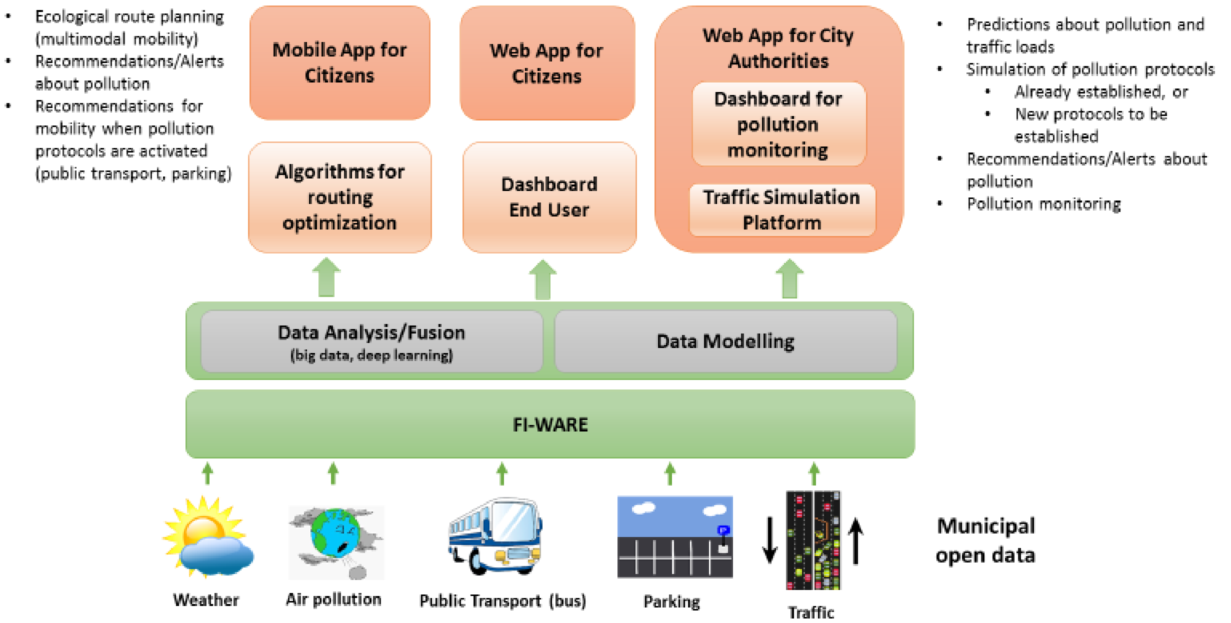


Figure 8. First approach for the implementation of Optimized City and Mobility Planning use case.

Technical requirements

Open data sources (Integration of different public data sources)

The use case will mainly use data obtained from the open data of the VLCi Platform. After the first analysis of the current data available on the platform, the following data sources have been preselected, as sources of data that can be incorporated into the demonstrator. Although the sources seem a priori to be of interest, these data should be analyzed deeply to determine whether data sources are finally selected. The criterion for choosing a data source would be based on the scope of data, reliability, and usefulness for the use case.

Data sources preselected are:

- Air pollution stations distributed throughout the city, to be able to know the pollution in the districts of the city
- Measuring Stations for Pollen
- Bike line
- Traffic cams
- Google Transit for public transport
- Parking
- Real-time traffic status
- Sense of circulation
- Intensity of bicycle
- Intensity of traffic
- Status of the Valenbici stations "public bike transportation".

The VLCi platform is based on Fiware, which is an open standard recommended by the European Commission for Smart Cities to ensure adaptation to the Internet of Things. The Main formats used by VLCi to expose the data are SHP, GML, WFS, WMS, KML, KMZ, CSV, JSON, JSON-LD, RDF XML/TURTLE /N3.

There are some means of public transport that go beyond the city of Valencia, as is the case of the metro that operates through several cities, for that reason the information of the metro is not included in the

VCLi, to obtain this information, the use case will use the open data of the Generalitat Valenciana, that provides this data.

In addition to the data obtained from the open data, the use case will make use of weather forecast systems; this information is relevant to make predictions of pollution levels.

To support the large amount of data required by the use case, the data will be stored in a non-SQL scalable database. It will provide a Restful API to manage data.

Data Fusion based on big data and deep learning techniques

This cloud platform for data fusion and data analysis based on big data and deep learning techniques intends to analyze the huge amount of heterogeneous information coming from the different municipal open data source (traffic, air pollution, weather, etc.) and to extract its meaning in order to infer and produce easily understandable higher-level information about mobility and pollution to the applications for stakeholders, allowing them to send recommendations and alerts for a dynamic urban mobility management to the citizens and city authorities in real time.

So, several specific technical requirements for this technical component have been identified as follows:

- This component should parse and process the heterogeneous data from the municipal open data source in order to homogenize them and so, to be able to infer new knowledge and higher-level information.
- This component should analyze historical municipal open data using big data and deep learning techniques to predict future problems related to mobility and pollution.
- This component should have learning capabilities using deep learning techniques.
- This component should produce recommendations and alerts about mobility and pollution in real time for the stakeholders.

This cloud platform for data fusion and data analysis follows the conceptual diagram shown in the Figure 9 below.

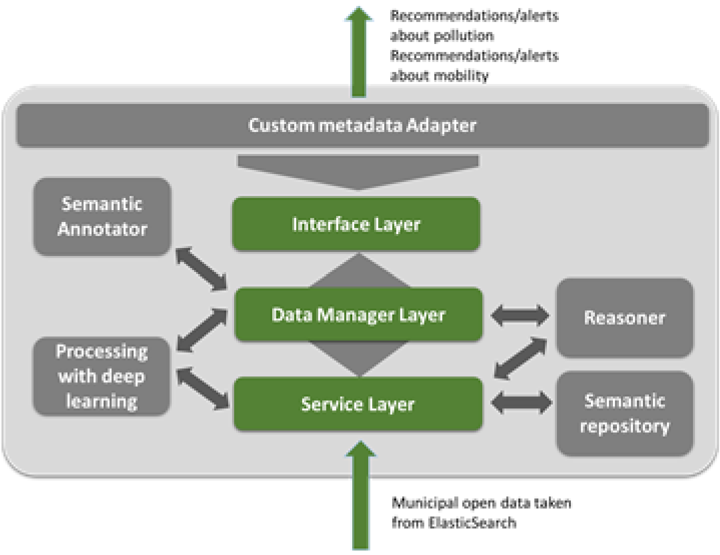


Figure 9. Data fusion and analysis in the pilot follow the conceptual diagram.

As observed, this technical component is a basic three-layered architecture made up of three layers:

- Interface Layer. The Interface Layer provides interfaces through which the cloud platform manages all of its input and output mechanisms.
- Data Manager Layer. The *Data Manager Layer* aims to annotate and store the incoming data in a unified model.
- Service Layer. The *Service Layer* is where semantics and reasoning are used to solve queries and to retrieve stored knowledge, and deep learning techniques are used to have learning capabilities.

Traffic Simulation Platform

Traffic Simulation Platform intends to predict the evolution of traffic loads and pollution levels in a city from historical municipal open data in order to optimize the mobility planning in a city allowing to the city authorities to make decisions on:

- the urban mobility planning based on the pollution levels,
- the contingency plans (protocols against the pollution), while simulating how such (new or already established) protocols could evolve along the time.

or to perform different analysis about:

- the future predictions of the pollution levels,
- the management between the pollution levels and the traffic in the city.

So, several specific technical requirements for this technical component have been identified as follows:

- This Traffic Simulation Platform should generate blocks of historical and real-time data, by simulating the behavior of different vehicles travelling on different routes under different boundary conditions.
- The Traffic Simulation Platform should support the definition and the simulation of various
- Traffic conditions, including light, heavy and very heavy traffic in parts of the road network.
- Road conditions, such as closed streets, congestion, etc.
- Weather conditions (this factor often affects time to reach a destination as well as the traffic conditions).
- The Traffic Simulation Platform should support the creation of multiple scenarios in order to setup and run different sets of repeatable boundary conditions for the underlying simulation tools
- The Traffic Simulation Platform should support extraction and extrapolation of macro (aggregated) volume data starting from the results of simulation in order to evaluate the ESTABLISH platform.
- The Traffic Simulation Platform should support the integration of additional plug-ins, in order to extend basic functionalities or to add specific features.

This Traffic Simulation Platform follows the conceptual diagram shown in the Figure 10 below.

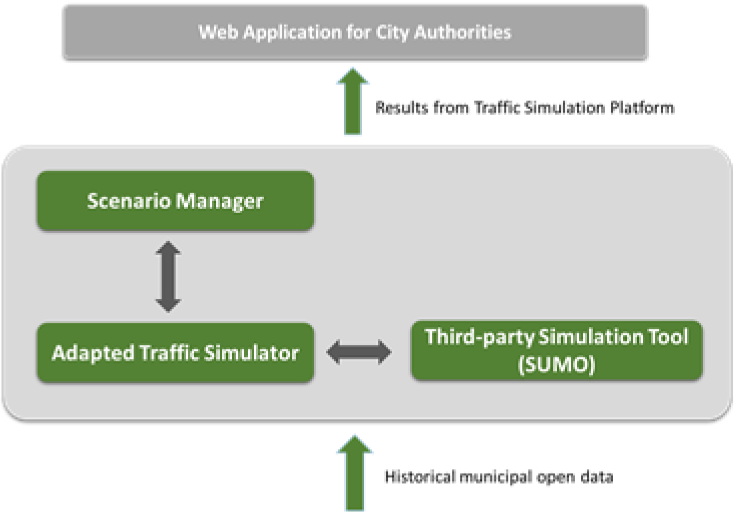


Figure 10. Traffic Simulation Platform.

As observed, this technical component is made up of three sub-components:

- Third-party simulation tool (SUMO). The Traffic Simulation Platform relies on an open source traffic simulator named as SUMO ("Simulator of Urban Mobility")
- Adapted traffic simulator. This subcomponent interfaces with SUMO for the execution of the simulation session. More specifically, it parses a simulation scenario, configures a simulation session according to the scenario, performs the simulation session of a configured scenario and, finally, processes raw simulation data in order to be more easily analyzed and delivered as simulation results.
- Scenario Manager. This subcomponent encapsulates all configuration procedures and post-processing functionalities. More specifically, it generates a simulation scenario, parses simulation results and interfaces with the web application for city authorities.

Mobile application for citizens

This mobile application intends to provide citizens with useful information about mobility and pollution in the city in real time, which has been produced by the cloud platform for data fusion and data analysis. Furthermore, this application also allows the citizens to have access to a route planner focused on the municipal open data.

So, several specific technical requirements for this technical component have been identified as follows:

- This mobile application should allow citizens to introduce a user profile with their preferences, their health problems, relevant information about their vehicles, etc.
- This mobile application should implement a notification management system in order to send recommendations and alerts about mobility and pollution to the citizens.
- This mobile application should allow citizens to calculate the most ecological route from any origin point to any destination point in the city.
- This mobile application should have an easy-to-use user interface that presents the information in a comprehensible way.
- In order to provide configurable and customizable routes, the system will consider the user's preferences when calculating the routes. These preferences include means of transport, heaths problems of the user and technical information (type of fuel, fuel consumption, gas emission) of the cars of the users.

It is important to remark that this mobile application will be an Android application and acts as the front-end side of the cloud platform for data fusion and data analysis and the route planner.

Web application for city authorities

This web application intends to help the city authorities in the decision-making about the urban mobility planning in terms of pollution levels, by showing them how the pollution is evolving in the city through a dashboard, and allowing them to analyze possible future situations/scenarios related to mobility and pollution through a traffic simulation platform.

So, several specific technical requirements for this application have been identified as follows:

- This web application should show the information on the pollution of the city in real time.
- This web application should allow the city authorities to create and configure different simulation scenarios.
- This web application should show the information related to the traffic loads and pollution levels according to the chosen simulation scenario.
- This web application should time responsiveness for basic user interactions.
- This web application should have an easy-to-use user interface that presents the information in a comprehensible way.

It is important to remark that this web application acts as the front-end side of the dashboard for pollution monitoring and the traffic simulation platform.

Multimodal Route planner

In the ESTABLISH project a route planner will be implemented in order to produce routes for different modes of transportation. Specifically the following modes are going to be considered for the Spanish pilot: walk, drive, bicycle, train (specifically the subway and light train handle by the MetroValencia, http://www.metrovalencia.es, company), bus (the network of buses of the metropolitan transportation company, the EMT, https://www.emtvalencia.es/). Figure 11 presents an example about multimodal routing.

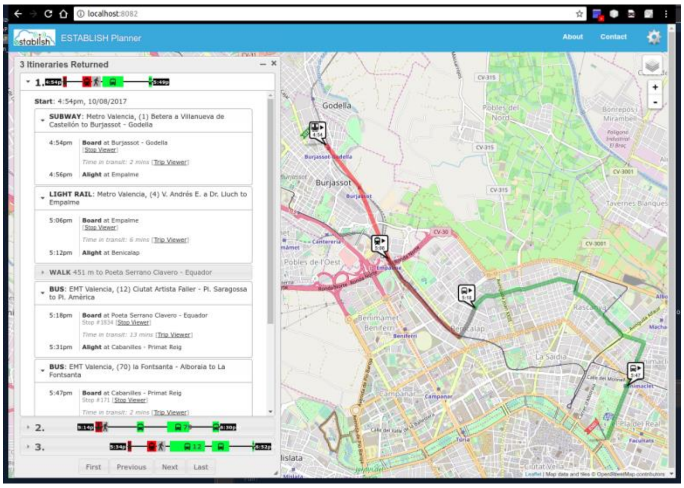


Figure 11. Example of a multimodal routing, which combines a leg by train, another walking and a final leg by bus.

These modes of transportation will be considered either in individual mode, usually referred as monomodal trip, or most likely in combinations of different modes multimodal routing. Multimodal routing has many different combinations, one of the most basic and most useful one is to consider public transit as the example shown in Example of a multimodal routing, which combines a leg by train, another walking and a final leg by bus. , this case considers travelling by bus, train or walk. Other types of multimodal travelling are also considered:

- “park and ride”, which implies using a private car up to a designated parking lot and from the using public transportation, and
- “kiss and ride” which implies that the first leg is realized as a passenger in a private car and therefore there is no need for a parking place, a designated area for performing the drop off is needed instead.

The geographic scope for the routing (Figure 12) engine englobes all of the metropolitan area of Valencia and beyond including the region where the buses belonging to the EMT give service.

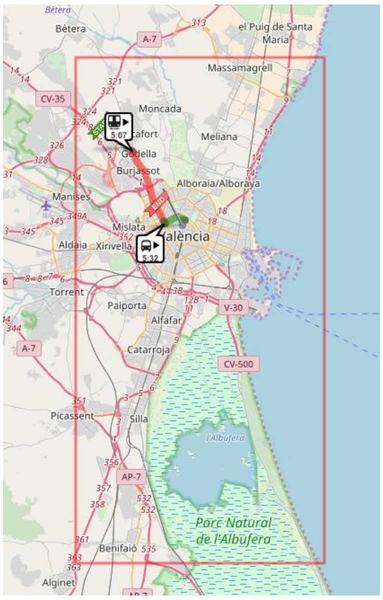


Figure 12. The considered area for the routing engine will include all the metropolitan area of Valencia and beyond.

The routing engine provides different metrics, which can be selected by the user in order to obtain the best route. For example, for the bicycle mode of transportation user will have the ability of choosing the shortest route, the easiest or the cleanest, i.e. the less pollute route or a combination of different metrics as it can be shown in Figure 13.

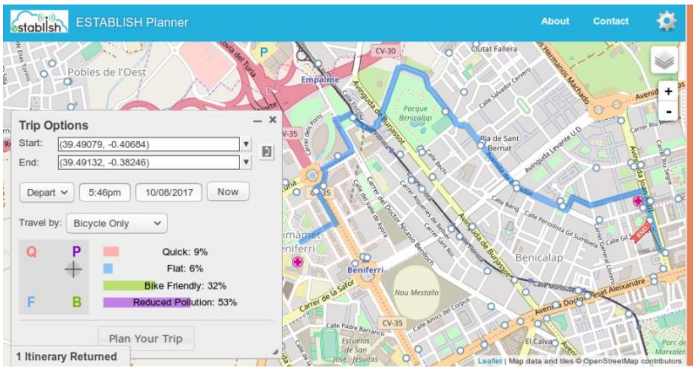


Figure 13. Metric configuration diagram for the bicycle mode of transportation.

The planner also will take into consideration the personal user preferences while providing a specific route. One specific way in which these preferences will be considered to consider the type of car the user will drive in order to gauge the impact in the pollution of a particular suggested route.

- Precise prediction and forecasting of traffic loads and pollution, simulation of pollution protocols based on based on the information provided by the Traffic Simulation Platform.
- Recommendations for mobility and alerts about pollution in real time based on the fusion of different open data (such as air pollution, weather, traffic, etc.) using big data and machine learning techniques.
- Environmental impact assessment
  - Estimation of environmental impact "air pollution" based on traffic, topographic and meteorological information,
  - Indicators by zones, and
  - Asynchronous notification of alarms against thresholds.

Real time Dashboard

The dashboard to be develop will use the latest technological advances and will be able to process data in real time and provide useful metrics and indicators for users, incorporating advanced visualizations of information on maps.

The dashboard will allow municipal technicians/politicians to have access to different visualizations where they can consult relevant information to obtain KPI and take decisions in real time. This dashboard will be configurable by municipal technicians to adapt the visualizations to the user needs. In addition, the dashboard will have a second perspective for citizens, so users will have access to information provided by the city as operational decisions, strategic planning, real-time measurements, automatic alerts and reports. The following images shows an example of a dashboard. Figure 14 presents an example of the dashboard for citizens.

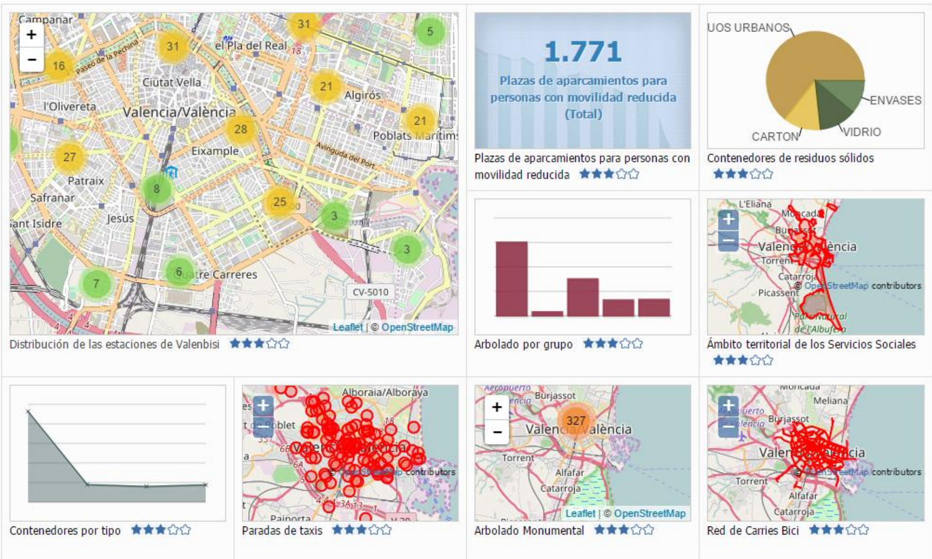


Figure 14. Example of a dashboard for citizens.

Technical specifications of the use case are presented in Appendix 1A. Use case requirements are presented in Appendix 1B.

3.2 Smart HVAC systems that ensure a healthy indoor environment (IMA)

The use case *Smart HVAC systems that ensure a healthy indoor environment* will consist of hardware and software components, customer services and applications, running on specific cloud platform. The main requirements on hardware components are identified, partners will develop various sensors monitoring indoor air-quality, typically temperature, relative humidity and CO2 (IMA); Dekprojekt will develop ventilation actuators. The hardware components will be provided by control software. As for the software components, CU will develop edge cloud server and algorithms processing big data from sensors resulting in control processes at ventilation systems considering customer profiles and desired optimization schemes.

The use case will provide human interface and customer application to allow customer either feedback monitoring or/and active impact on the algorithm when optimization processed. Dekprojekt acts within the use case in role of system integrator and in role of technology user since its company business model.

All partners will participate at requirements elicitation and testing/validation. Test components of the use case will be deployed at IMA and Dekprojekt premises.

Technical development

Technical development will be concentrated to both new use case components and innovation of currently available components. Depend on partners' objectives the development is directed towards

- sensors, their interfaces and data gathering (gateway) (IMA),
- data processing on the cloud framework, algorithms, assessment, data interpretation (CU),
- control and act of HVAC components based on sensor data assessment (DEKPROJEKT).

The use case will demonstrate components running in the whole value chain when special interest is given on feedback control functions and services. Even though fully automatic process is intended, all the stakeholders will be able to influence the component behavior via their mobile devices and user profile can be employed.

Technical requirements on new HVAC pilot

Use case requirements list is built on current system experience.

Technology for data collection devices, sensors:

- low range wireless technology.
- low power,
- stabile and robust,
- easy to implement, operate and maintain,
- bi-directional communication,
- data encryption, and
- peripherals for various sensor integration.

Technology for data aggregation, gateways:

- industrial features,
- OSS (Open Source Software, e.g. Linux, MySQL, Apache etc.),
- full LoRa standard,
- GPS (Global Positioning System), and
- reliable casing for optional outdoor usage.

Application platform, data management & user services, interpretation:

- cloud like conception,
- availability and scalability,
- strong focus on security,
- enterprise volume,
- reputable platform,
- reliable with strong support,
- combining services IaaS and PaaS,
- user & device management, and
- advanced GUI (Graphical User Interface).

High-level HVAC specification

Compiling partners' technological contribution and potential user feedback, we will result in specification of new Establish smart HVAC use case. We went through two steps of development achieving detail system architecture as planned in D3.1. First, we drafted high-level function specification of HVAC pilot expressed by process V-diagram, see Figure 15. On the diagram are shown four system stages the system will go through, system initialization, events detection and monitoring, execution and system stabilization. These stages repeat at the system runtime.

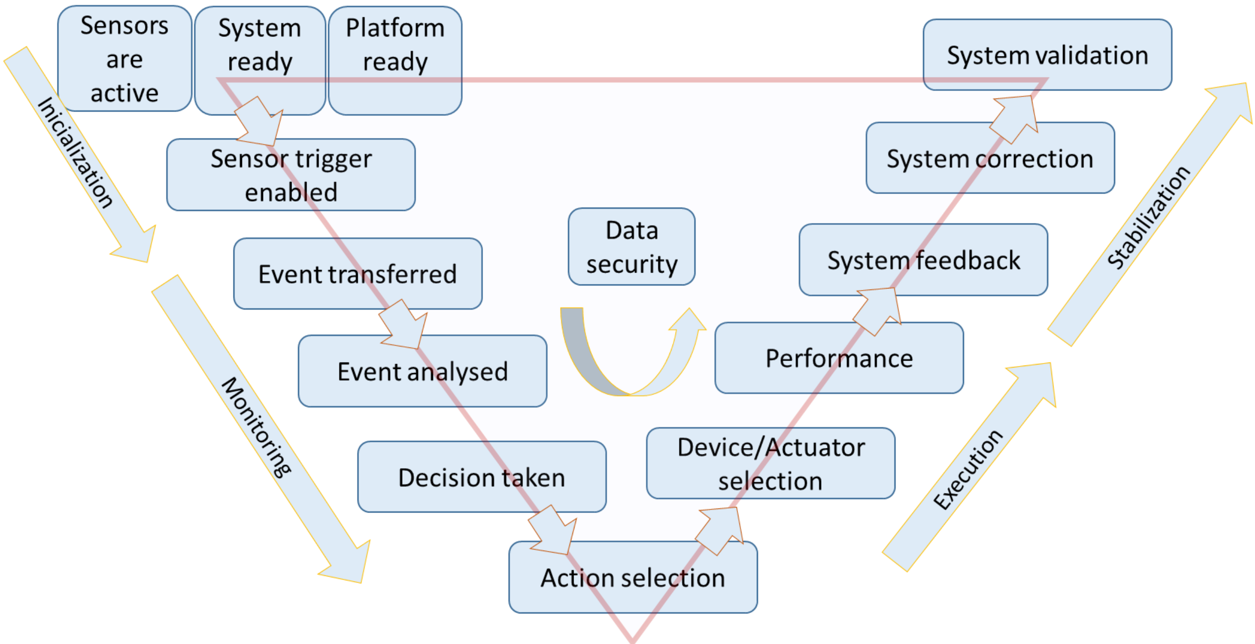


Figure 15. High-level function specification on the HVAC use case expressed by process V-diagram.

In order to provide all shown system functions, we need to design system components able to perform them. The Figure 16 with a high level HVAC system components specification is depicted. In the center of gravity is the cloud system platform involving system web application and services ensuring management of data, users and devices. This is the main role of the platforms. Beside this role, the platform needs to ensure system configuration, security, scalability, reporting and other services. The system runtime starts by sensors connected to gateway(s), gateways pre-process and transfer data to web platforms. The platform evaluates system behavior, takes decision and then control infrastructure usually requiring for a system change. To do that the infrastructure applications need to require actuation devices to take actions like open window, enable ventilation etc. The components specification correspond the list of requirements in the text above.

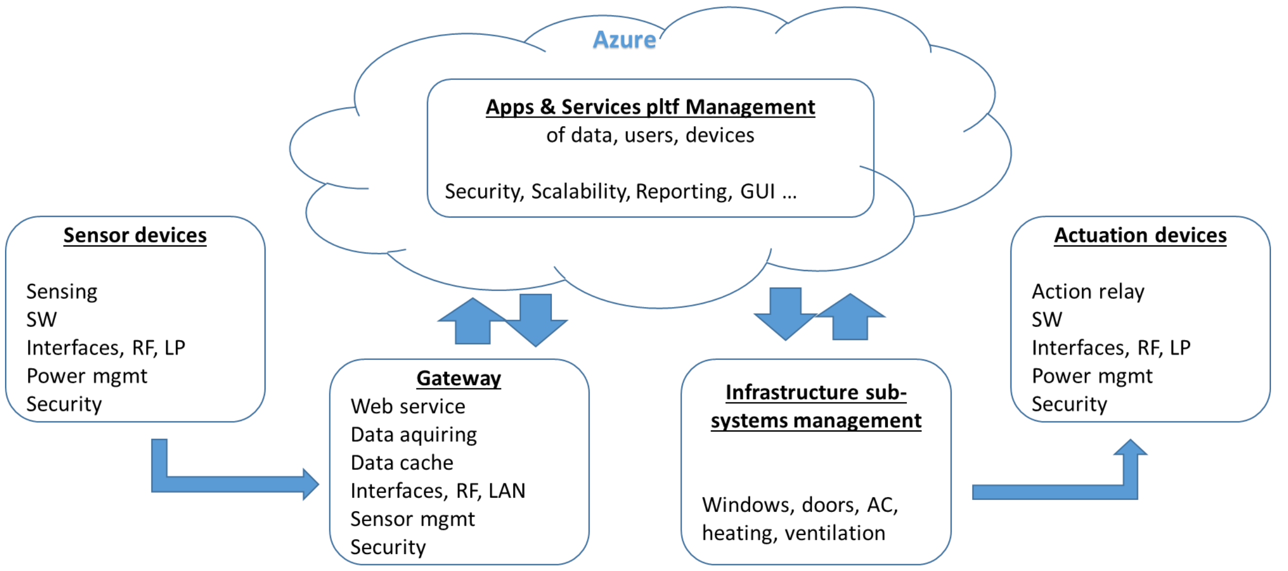


Figure 16. High-level component specification on the HVAC use case.

Technical specifications of the use case are presented in Appendix 2A. Use case requirements are presented in Appendix 2B.

3.3 Intelligent air quality management system (ETRI)

The Korean pilot consists of key technologies to develop a healthy indoor environment in the buildings that can automatically adjust its conditions to better temperature, air quality, humidity, etc. using the results analyzed by the environmental data. As the indoor environments are affected by the outdoor pollutants as well as the indoor pollutants, Coway will develop the IAQ (Indoor Air Quality) and the OAQ (Outdoor Air Quality) devices in order to gather environmental data related to the air quality. Basically, the IAQ and OAQ devices will be equipped with the telecommunication modules based on Wi-Fi and the various environmental sensors. In addition, Coway will operate on the indoor testbed to evaluate the intelligent air quality management system interconnecting with the air purifiers. ETRI will build a server platform to manage and analyze the environmental data measured from the IAQ and OAQ devices. ETRI will also develop some machine learning algorithms to detect and classify the user behaviors and the analyzed results will be applied to air purifier to clean the indoor air quality in home and office buildings.

Technical development

In this pilot, Coway will contribute to the development of the IAQ/OAQ sensors for acquiring the environmental data and the adaptive control of air purifiers. ETRI will develop a data server to store the environmental data and efficiently access the data for further monitoring and analysis. In addition to that, ETRI will analyze the data from the sensors to automatically find pleasant index and user activity patterns that lead to the adaptive control of air purifiers to improve the environmental conditions. The technical development of the pilot will be concentrated on the development of four technologies as shown in the following Figure 17.

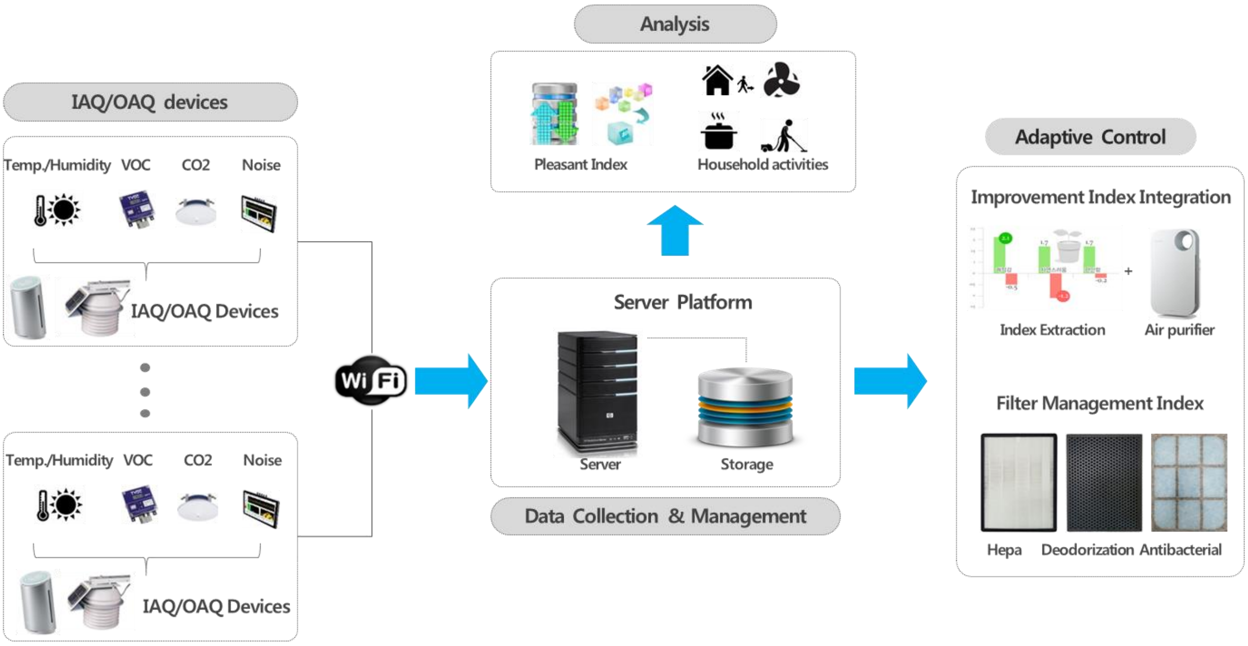


Figure 17. Main components consists of intelligent air quality management system.

The contributions of each partner will take into consideration the following technologies depending on their objectives:

- Development of IAQ/OAQ devices to measure environmental data (Coway),
- Collection and management of environmental data (ETRI),
- Analysis of environmental data to extract pleasant index (ETRI), and
- Adaptive control of air purifier by using pleasant index and commercialization of the integrated product (Coway).

The pilot has a yearly concrete development plan as the following Figure 18.

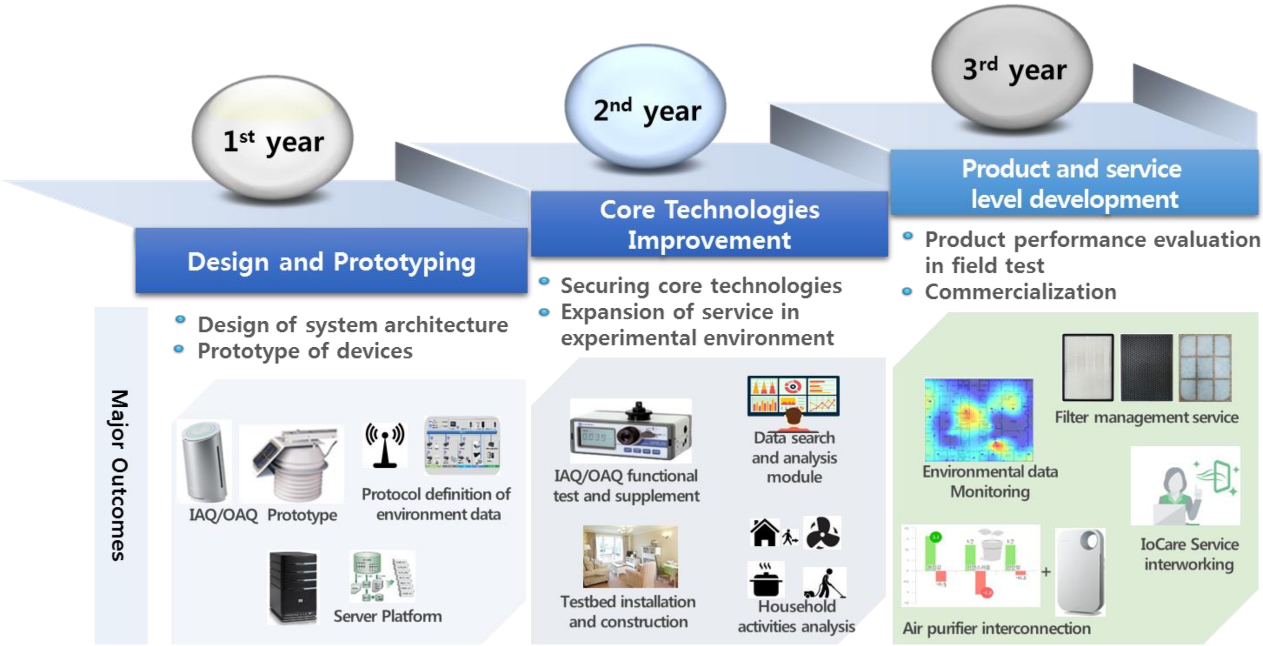


Figure 18. Contents of technology development by year for intelligent air quality management system.

In terms of the development plan, the pilot will carry out the following technical developments:

- First Year : Design and prototyping
  - Determination of the specification of IAQ/OAQ sensors,
  - Prototype development of IAQ/OAQ devices,
  - Development of the communication module between sensors and the management server,
  - Development of data structure for managing environmental data,
  - Development of search interface for efficiently accessing the stored data,
  - Development of data exporting module, and
  - Installation of IAQ/OAQ device test environment.

- Second Year : Core technologies improvement
  - Development of IAQ/OAQ devices,
  - Development of IAQ/OAQ device management module,
  - Development of IAQ/OAQ device displacement optimization module,
  - Development of pleasant index extraction technology,
  - Analysis of user activity patterns based on IAQ sensor data, and
  - Development of application interface for interoperating with air purifiers.

- Third Year: Product and service level development
  - Commercialization of IAQ/OAQ devices,
  - Development of environment data monitoring and statistics module,
  - Analysis of improvement index of air purifier filters,
  - Air pleasant index monitoring, and
  - Commercialization of the integrated system and services.

Technical requirements

The following Figure 19 shows the basic technical requirements of the pilot.

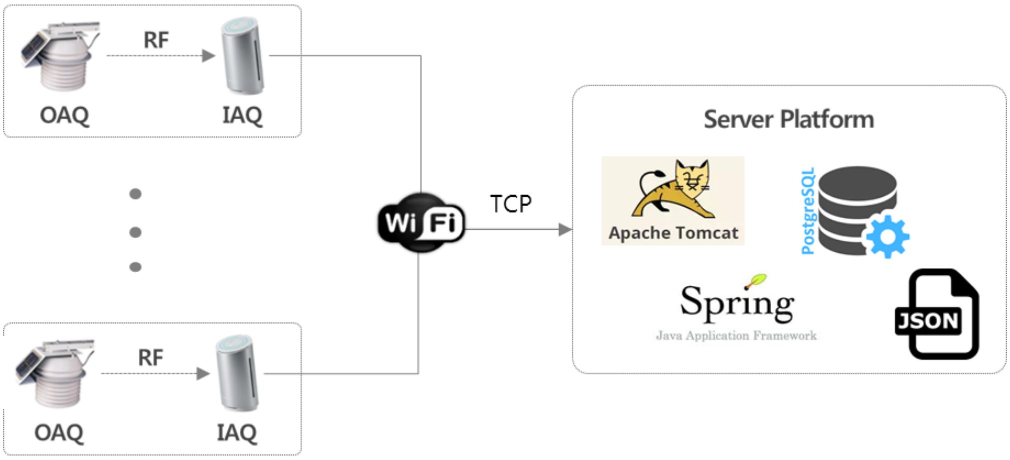


Figure 19. Basic technical requirement of intelligent air quality management system.

IAQ sensors for indoor air quality measurements will include temperature, humidity, CO_2, illuminance, noise, VOC (volatile organic compounds), Formaldehyde and dust sensors. OAQ sensors for outdoor air quality measurements will include temperature, humidity and dust sensors. An OAQ sensor will be developed to use solar energy as its battery charging and designed to endure the tough outdoor weather. An IAQ sensor communicates with its subordinate OAQ sensor through Radio Frequency (RF) to gather both IAQ and OAQ environmental data and send it to the backend data server via Transmission Control Protocol (TCP). The backend server platform communicates with the IAQ sensors via TCP in order to collect and store the data. In addition, the server provides data access service with JSON query format describing various query constraints over HTTP. The server will be implemented with Spring framework over Apache Tomcat for HTTP processing and PostgreSQL for environmental data storage.

Technical specifications of the use case are presented in Appendix 3A. Use case requirements are presented in Appendix 3B.

3.4 Rehabilitation decision support (SIVECO)

The *Rehabilitation decision support* pilot, developed in Romania, will use data from ambient sensors (air quality, atmospheric pressure, temperature, humidity) and the biometric, physiological and behavioral sensors (heart rate and respiratory number of steps), to provide patients in clinical rehabilitation/ keeping fit programs with decision support tools related to behavior and treatment options.

The pilot will test mobile and web applications that offer users/clients data regarding decision support and location information. The system will be integrated with handheld devices like Fitbit bracelet that record the steps distance and calories burned during the day and monitor sleep quality at night.

The first pilot activities within ESTABLISH started in November 2016 with the study of sensors and applications that will monitor the physical activity, physiological parameters and environmental conditions in which the running / walking exercises meant to keep fit the students of "Grigore Moisil" National College in Bucharest are carried out. These extracurricular activities are part of the thematic area of interdisciplinary STEM (Science, Technology, Engineering, and Mathematics) designed to revive the interest of Romanian students for the combined study of science, technology, engineering and mathematics. Furthermore, a study among employees at BEIA Consult office will be conducted using the aforementioned methodology.

Technical development

The technical development section will summarize the achievements regarding the APIs for data collection from the meteorological station, air quality stations, and wearable devices.

Meteorological data collection addUPI

This section describes the communication protocol between the different TCP / IP components of Adcon Telemetry (addUPI – URL Programming Interface). Below are some examples of components that can implement this protocol:

- An addVANTAGE Pro client and an addVANTAGE Pro server;
- An addVANTAGE Pro client and a telemetry gateway (e.g. an A850 Gateway);
- A Telemetry Gateway and a Remote Telemetry Unit (RTU).

As shown also in Figure 20 below, the addUPI protocol requests a client and a server. The client will issue HTTP requests to the server and the server will respond to these requests. Client requests use the GET method, while responses return an XML document.

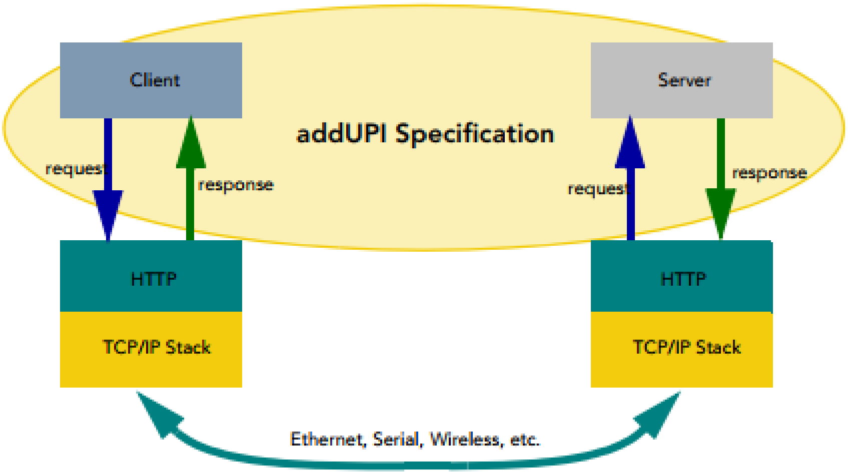


Figure 20. addUPI specification.

A typical session between a client and a server that communicates via addUPI follows the steps described below:

1. The client identifies the server: the server name (or IP address) must be known
2. Authentication of the customer (by authentication key, see example below)
3. The client asks the server to return its capabilities: in this context, the capability can be a list of proxy nodes
4. Each node is interrogated, which assumes the list of attributes and / or functions that the node has and / or can execute (this step can be done simultaneously with step 3 by requesting the node configuration, "getconfig"). Below are the authentication requests and "getconfig".

A request submitted by a client has the generic formula presented below:

```
http://hostname:port/addUPI?function=fn&session-id=nnnn&param1=p1&
    param2=p2&...paramn=pn
```

where:

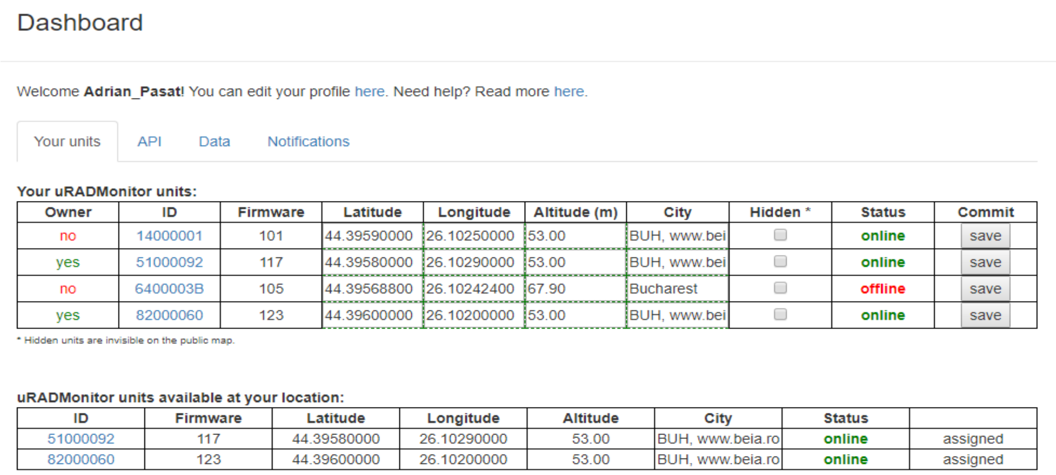
- `hostname` is the address of the server,
- `port` is the port number to the server listens upon (if not specified, it is standard 80; it is recommended to use the port 80 for Telemetry Gateways and 8080 for addVANTAGE servers),
- `addUPI` is the name of the handler on the server that will be invoked to handle the request; this may be a servlet, a cgi, etc.
- `function` is the name of the invoked method,
- `session-id` is a number identifying a certain client (obtained after authentication),
- `param<i>=pn` are the parameters requested by a particular function.

An XML example is shown below.


```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE response SYSTEM "/xml/rs_getconfig.dtd">
<response>
    <node id="1" template="A850_SERVER_V8" name="Adcon A850 - 104399" class="SERVER"
subclass="GATEWAY">
            <attribs>
            <attrib name="manufacturer">
            <string>Adcon Telemetry</string>
            </attrib>
            <attrib name="type">
            <string>A850</string>
            </attrib>
            <attrib name="version">
            <string>3.4.10</string>
            </attrib>
            <attrib name="serialNr">
                    <string>104399</string>
            </attrib>
            <attrib name="timeZone">
                    <string>Europe/Bucharest</string>
            </attrib>
            <attrib name="date">
                    <date>20170523T14:36:17</date>
            </attrib>
            <attrib name="uptime">
                    <string>102 days, 21 hours, 21 minutes</string>
            </attrib>
            <attrib name="getdataMaxSlots">
                    <int>10000</int>
                    </attrib>
                    <attrib name="getdataMaxNodes">
                            <int>200</int>
                            </attrib>
                    </attribs>
                    <functions />
                    <nodes>
            <node id="34" template="A850_AREA" name="Beia" class="AREA" subclass="DEFAULT">
            <attribs />
            <functions />
            </node>
            </nodes>
            </node>
</response>
```

Air quality data collection

To access the uRADMonitor Data we used the uRADMonitor API presented on the dashboard menu (Figure 21 shows the list of devices attached to the user account), after creating an user account.


Dashboard

Welcome **Adrian_Pasat**! You can edit your profile here. Need help? Read more here.

Your units API Data Notifications

Your uRADMonitor units:

Owner	ID	Firmware	Latitude	Longitude	Altitude (m)	City	Hidden *	Status	Commit
no	14000001	101	44.39590000	26.10250000	53.00	BUH, www.bei		online	save
yes	51000092	117	44.39580000	26.10290000	53.00	BUH, www.bei		online	save
no	6400003B	105	44.39568800	26.10242400	67.90	Bucharest		offline	save
yes	82000060	123	44.39600000	26.10200000	53.00	BUH, www.bei		online	save

* Hidden units are invisible on the public map.

uRADMonitor units available at your location:

ID	Firmware	Latitude	Longitude	Altitude	City	Status	
51000092	117	44.39580000	26.10290000	53.00	BUH, www.beia.ro	online	assigned
82000060	123	44.39600000	26.10200000	53.00	BUH, www.beia.ro	online	assigned

Figure 21. uRADMonitor dashboard.

The API protocol for retrieving data from uRADMonitor devices is described below:

- Method: **GET**
- Get devices list
  `//data.uradmonitor.com/api/v1/devices`
- Get device sensors list
  `//data.uradmonitor.com/api/v1/devices/[ID]`
- Get device data
  `//data.uradmonitor.com/api/v1/devices/[ID]/[sensor]/[interval]`
- Authentication:
- All calls must be authenticated with user-id and user-key sent in the headers section of the GET call as key-value pairs of the following format: `X-User-id:xxx, X-User-hash:xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.`
- Response: JSON formatted answer, containing error message in case of failure or the requested data.

Figure 22 presents an API implemented on BEIA's website, www.beia-telemetrie.ro/livedata.

Figure 22. uRADMonitor API.

Wearable devices data collection. Fitbit API

Following the steps described at https://github.com/simonbromberg/googlefitbit, we managed to upload the data from a Fitbit Charge wearable device to a Google Spreadsheet. To retrieve the data in a Google Spreadsheet we followed the steps described below:

- firstly, we integrated the script available at https://github.com/simonbromberg/googlefitbit/blob/master/heartrate.gs;
- we added the OAuth 2.0 resources in the Libraries menu (Figure 23);

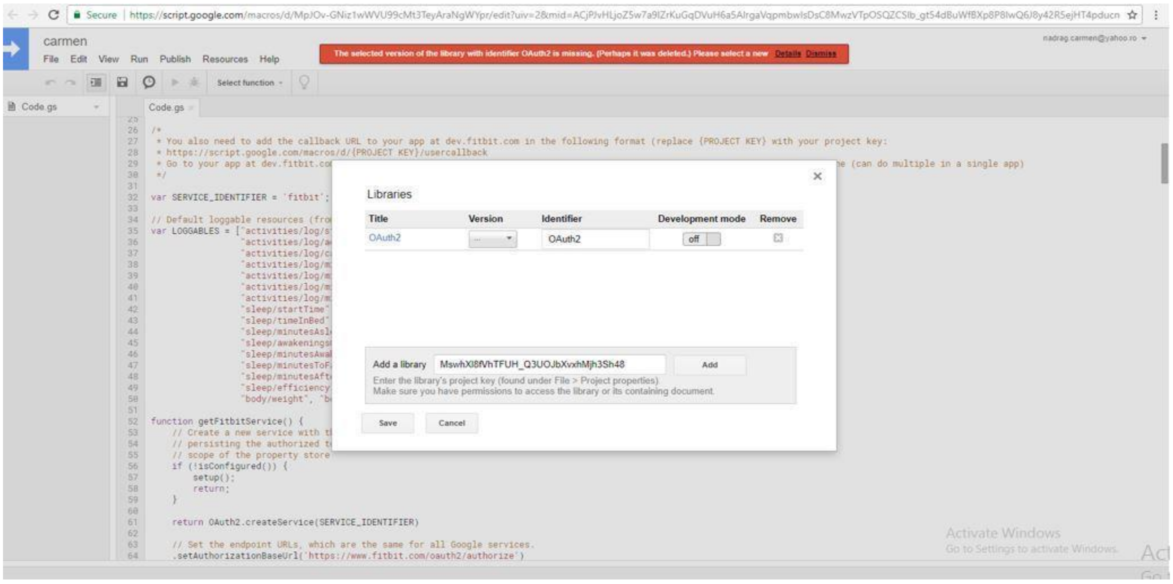


Figure 23. Google spreadsheet Libraries menu.

- we created the developer account at https://dev.fitbit.com/apps (Figure 24);

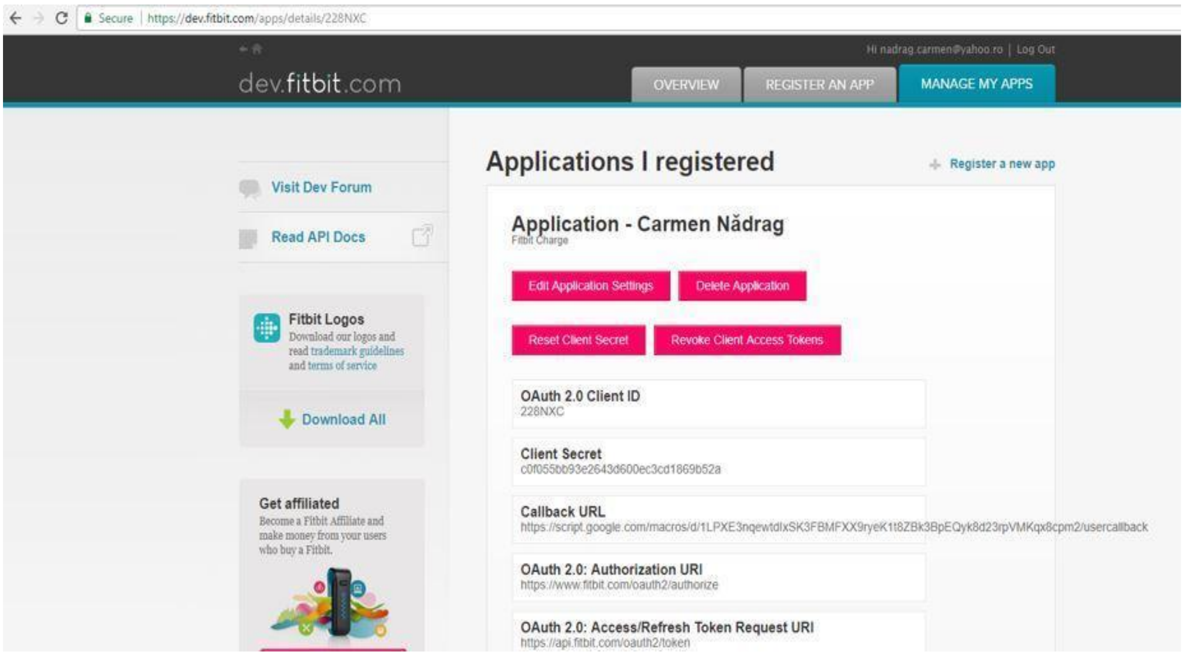


Figure 24. Fitbit developer account registration.

- in order to sync the data, we authorized the Fitbit application (Figure 25);

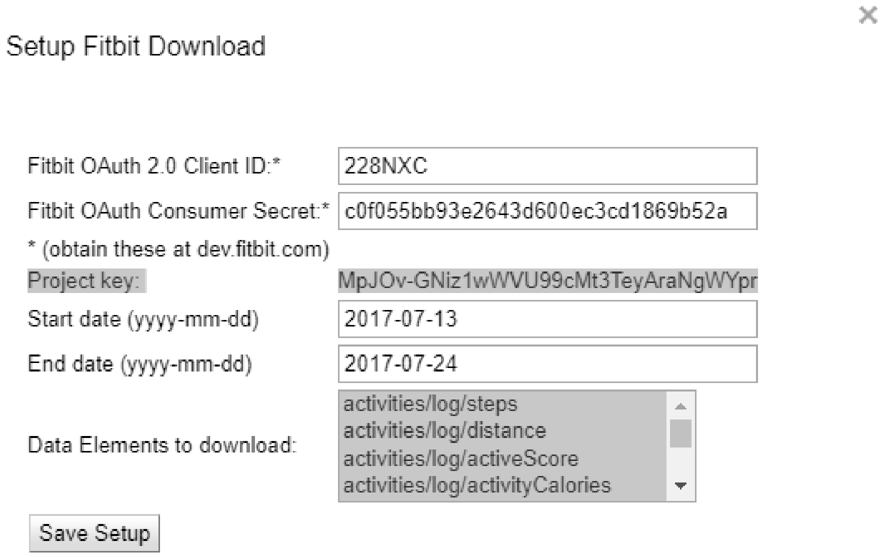
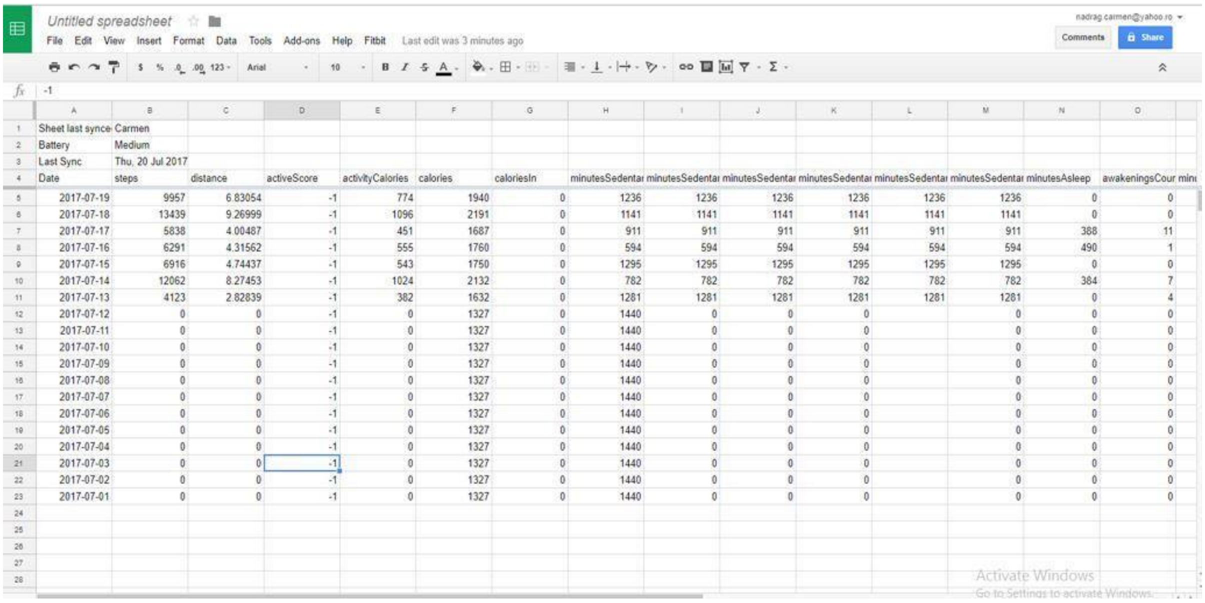


Figure 25. Authorizing Fitbit application.

- Returning to the spreadsheet, uploading and viewing data was done by selecting "Fitbit> Sync". In Figure 26, is presented the information retrieved from the Fitbit account.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Sheet last synce	Carmen													
2	Battery	Medium													
3	Last Sync	Thu, 20 Jul 2017													
4	Date	steps	distance	activeScore	activityCalories	calories	caloriesIn	minutesSedentar	minutesSedentar	minutesSedentar	minutesSedentar	minutesSedentar	minutesSedentar	minutesAsleep	awakeningsCour
5	2017-07-19	9957	6.83054	-1	774	1940	0	1236	1236	1236	1236	1236	1236	0	0
6	2017-07-18	13439	9.26999	-1	1096	2191	0	1141	1141	1141	1141	1141	1141	0	0
7	2017-07-17	5838	4.00487	-1	451	1687	0	911	911	911	911	911	911	388	11
8	2017-07-16	6291	4.31562	-1	555	1760	0	594	594	594	594	594	594	490	1
9	2017-07-15	6916	4.74437	-1	543	1750	0	1295	1295	1295	1295	1295	1295	0	0
10	2017-07-14	12062	8.27453	-1	1024	2132	0	782	782	782	782	782	782	384	7
11	2017-07-13	4123	2.82839	-1	382	1632	0	1281	1281	1281	1281	1281	1281	0	4
12	2017-07-12	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
13	2017-07-11	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
14	2017-07-10	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
15	2017-07-09	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
16	2017-07-08	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
17	2017-07-07	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
18	2017-07-06	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
19	2017-07-05	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
20	2017-07-04	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
21	2017-07-03	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
22	2017-07-02	0	0	-1	0	1327	0	1440	0	0	0		0	0	0
23	2017-07-01	0	0	-1	0	1327	0	1440	0	0	0		0	0	0

Figure 26. Data retrieved from the Fitbit account.

Technical requirements

Technical specifications of the use case are presented in Appendix 4A. Use case requirements are presented in Appendix 4B.

3.5 Indoor air quality improvement at school

In the *Indoor air quality improvement at school* pilot, data from of indoor and outdoor sensors and wearables is combined with users' personal feedback and environmental sensing information to provide a healthier living environment for pupils, teachers, and other staff members. The idea is to learn from sensor data by means of combining different data streams and applying environmental models, machine learning, data mining and supported by big data ICT. This will enable optimization of power provision and self-adaptive HVAC control and air purification in the house.

The users have a remarkable role during the pilot. First, they are informed about the idea of the pilot and their role in it. Users are involved in the planning of the pilot and the future mobile service to really understand their needs and expectations. The idea is that the users can get personalized recommendations based on measured data and feedback got from the users on the impact of air quality. Feedback is collected regularly during the pilot by using different methods.

Technical development

In the *Indoor air quality improvement at school* pilot a variety of indoor sensors (temperature, humidity, air pressure, carbon dioxide (CO_2), nitrogen dioxide (NO_2) and TVOC) will be implemented at school environment. The data from indoor conditions monitoring will be combined with outdoor weather and air quality sensors (temperature, air pressure, humidity, CO_2, precipitation, wind speed and direction, particulates, NO_2, SO_2, CO, O_3) and wearable sensors (heart rate (HR) or heart rate variation (HRV), activity and sleep). Participants are also able to share their feedback related to air quality and well-being by a mobile application.

The feedback data and data from the wearable devices and sensors will be collected to Azure cloud platform, and stored, pre-processed and analyzed based on the time stamps. Based on the real-time analyses, users could get e.g. visualizations about the air quality (data from the sensors) compared to their health via the application. A mobile application for the users to visualize the results and control the indoor air quality will be created based on their needs. The need and possibility to utilize the air purifiers in the pilot at school will be evaluated.

Technical requirements

The following describes the technical solutions and components intended to be used in the pre-pilot and the actual pilot. Unless stated otherwise, the same solutions are used for both. A separate Azure instance with the desired components is created for the pre-pilot and the actual pilot; this way, data from the two pilots can be kept separate.

Environmental data collection and storage

Environmental data collection in the Finnish pilot relies heavily on the Microsoft Azure platform and its services. The collection and processing setup is described in Figure 27.

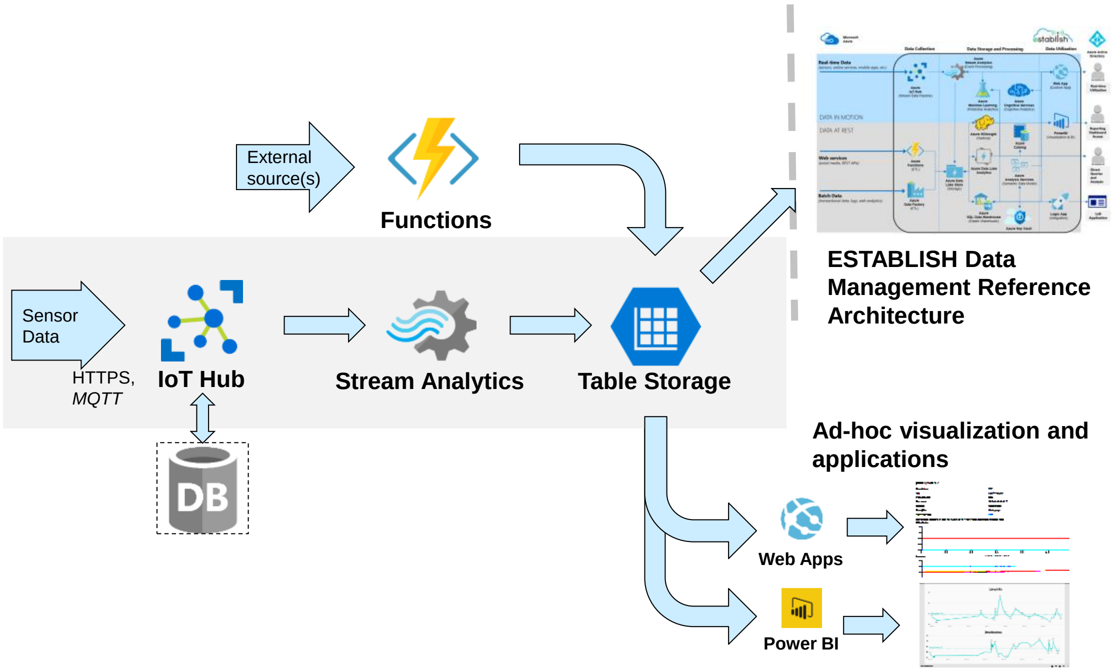


Figure 27. The reference implementation for environmental data collection and processing in the Finnish pilot.

Sensors and Data Collection

Data collection from various types of wireless sensor nodes into common storage is done using mains-powered gateways that communicate with the backend system (Microsoft Azure IoT Hub). Device management and end-to-end encryption of telemetry data is handled by Azure. Device management is applied at gateway level, whereas data itself will be made available on a node-by-node basis.

For the pre-pilot, VTT Nodes and Ouman Wireless nodes can be used interchangeably. Each office is equipped with at least one node sensing temperature, relative humidity, and CO_2 level. Pressure difference with respect to outside environment is measured where feasible. Libelium or uRADMonitor units are used in the monitored offices (not necessarily in every office all the time). The devices measure, to a varying degree, CO, CO_2, NO_2, SO_2, Particle Matter (PM_1 / $PM_{2.5}$ / PM_{10}), VOC, and Formaldehyde.

For the actual pilot, VTT Nodes are used for classrooms. Other sensors to be used (e.g. VOC, gasses, particle matter) can be decided partially based on experiences gained from the pre-pilot.

Data transfer to the cloud backend is done using gateways, which may need to be tailored for each new type of sensor node. The gateways are built on proto boards such as BeagleBone Black, Raspberry Pi 2/3/Zero, etc., with cloud connectivity from 3G/4G modems and/or WiFi. In the pre-pilot, LoraWAN is used for Libelium and uRADMonitor, with a dedicated / common LoraWAN gateway at VTT.

Data processing and storage in the cloud

The incoming data, which comes from a variety of sources, needs to be ingested and routed into source specific tables for storage. The components used for this in the Finnish pre-pilot and actual pilot is the Azure IoT Hub, Azure Stream Analytics (ASA), and Azure Functions. In practice, processing rules need to be specified for each different type of data source to determine the mapping of source data fields into database table fields. The rules are specified in the data processing component, be it in the ASA query that processes the inputs to outputs, or in the Azure Function that is triggered by each new data event.

All telemetry data is stored in Azure Table Storage, which is a simple NoSQL storage. Division of the data into separate tables may be based on, e.g., data similarity or source; for example, all data from one gateway may be stored into one table.

Data is expected to be processed at rest, i.e., by querying the data from the tables, and running analyses on it. Analysis is supported via both ad-hoc style querying within the Azure instance, and after exporting to the ESTABLISH general architecture solution. Live processing is also possible, using, e.g., Stream Analytics.

Metadata management

Especially when the number of data sources grows, it becomes necessary to record metadata on the location, measurement unit, accuracy, calibration data, etc. regarding the sensors and recorded sensor data. In the Finnish pilot and the pre-pilot, metadata storage will be implemented in Azure either as a purpose-built SQL DB with a REST API for managing the metadata, or using the Azure Data Catalog service.

Either as a separate entity or as a part of the metadata system, dynamic device status info is also recorded for monitoring purposes. The status information may include, e.g., battery level, last battery change date, current signal strength, etc.

Analytics and applications

The cloud backend needs to support both “in motion” and “at rest” approaches for data usage. The exact analytics solution(s) to be used are not defined at the time of writing. Both “at rest” and “in motion” routing of the data, and any analytics applications implemented utilizing the routes, must provide flexible interfaces to other (backend) applications such as visualization and other types of decision support.

Physiological data collection

The physiological data collection scheme differs from environmental data collection in that it is based on a mobile client and an infrastructure-as-a-service backend where the collection architecture is built on a virtual machine. The virtual machine is deployed on Azure, although any other IaaS provider could do. Data storage is in Azure. The overall scheme is depicted in Figure 28.

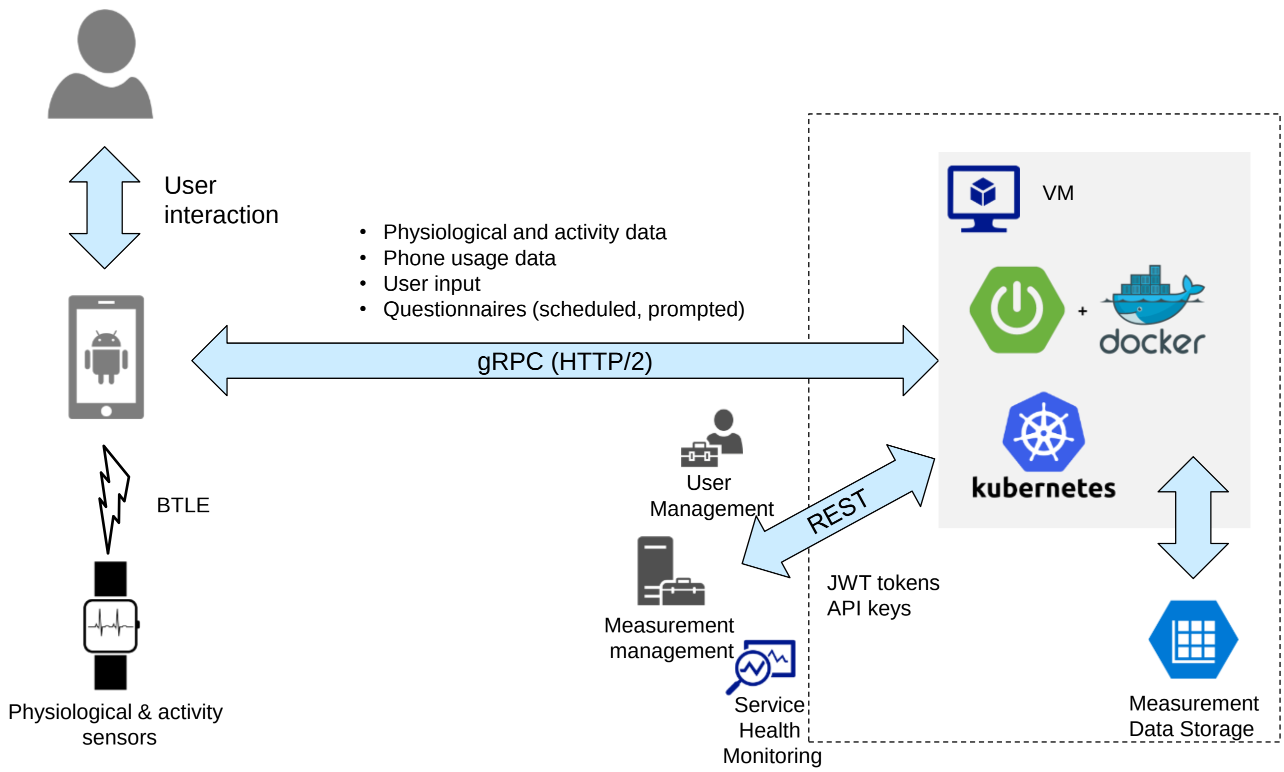


Figure 28. The overall scheme for physiological and activity data collection in the Finnish pilot.

Mobile client

The mobile client is running on an Android device. The client may consist of several applications running at once. The client application(s) has four distinct tasks:

- Activity and phone usage data collection
- Physiological and activity data collection from wearable devices
- User feedback and questionnaires, and
- Data visualization.

Activity data from, e.g., accelerometer may be collected from the phone. In addition, phone usage data may also be collected in order to determine the user's stress level. The need for this data in the actual pilot will be decided after the pre-pilot. For example, phone usage data will not likely be available from teachers during classes. Positioning data may also be provided by the mobile application, either via phone GPS and other positioning methods (e.g., via Google APIs), or via a yet unspecified coarse indoor positioning solution such as raw Bluetooth beacon RSSI (Received Signal Strength Indicator) data. The application needs to timestamp the data, accumulate it into suitable batches and send the data to the backend application via a REST API.

The phone acts as a gateway for relaying measurement and activity data from various wearable devices, such as a heart rate monitor. The phone may also store at least part of the data instead of transmitting it over a radio link. In addition, the application may group the accumulated data into bigger chunks for transmission in order to save phone battery. The mobile application connects to the backend application via a REST API. The mobile phone may also act as a gateway for third party applications for collecting physiological data (i.e., via a device vendor provided app); in that case, the data needs to be made available to the ESTABLISH platform via backend operation, e.g., by connecting to the vendor's data API.

The client also provides an user interface (UI) for the user to give spontaneous feedback over his/her feelings and any symptoms. The same application could also be used for answering scheduled questionnaires and, if implemented, to prompt the user to answer a more immediate questionnaire when the backend analytics applications detect some change in the user's behavior or physiological data.

The application may also be used as the user's point of entry into seeing the recorded data. Visualization itself is done on the backend. Thus, the user could alternatively view the visualizations via a web browser. However, it is not entirely certain whether the users should see their data, at least very soon after being collected, as it may affect their behavior and symptoms.

Android Wear application

An optional Android Wear application may optionally be used in conjunction with compatible wearable devices, e.g., in order to gain access to raw physiological measurement data. In the VTT pre-pilot, a Polar M600 device will be evaluated with respect to usability of raw PPG data gained from it in the context of ESTABLISH.

Backend data collection and storage

The backend for collecting and storing the data sent by the mobile client is done via a dedicated server based on Docker services, running on a virtual machine. The server communicates with the client via gRPC over HTTP/2, and provides a REST API for all data operations. The measurements are configurable at the server (e.g., granularity of location data). The server provides the necessary services to pre-process the data before storage to comply with the measurement configuration. For example, if location collection granularity is set to distinguish between a set of user-specified locations only, a service will convert the raw geolocation info (GPS coordinates) into one of the specified locations (e.g., "home").

All physiological, activity, and phone usage data is stored in Azure Table Storage. The server also implements API key and JWT token-based access control for the users and data. In addition, service health monitoring will also be provided. The server is built as Docker (micro)services deployed in a Kubernetes container orchestrator.

More detailed technical specifications of the use case are presented in Appendix 5A. More detailed use case requirements are presented in Appendix 5B.

4. Conclusions and next steps

Five different pilots have been defined for ESTABLISH project: 1) Optimized City and Mobility Planning, 2) Smart HVAC systems that ensure a healthy indoor environment, 3) Intelligent air quality management system, 4) Rehabilitation decision support, and 5) Indoor air quality improvement at school. Two more use cases will be planned and described when the national funding has been received.

The first pilot, Optimized City and Mobility Planning, concentrates on outdoor air quality; planning of urban development and traffic greatly affects air quality and consequently living conditions of a city. Based on public open data e.g. about environment, building footprints, demographics, and traffic information, precise prediction and forecasting of traffic loads and pollution in the city can be provided. Recommendations for route planner and alerts about pollution in real time will be shared to the users by mobile and/or web applications.

The use case *Developing smart HVAC systems that ensure a healthy indoor environment,* including two pilots, the *Smart HVAC systems that ensure a healthy indoor environment, and* the *Intelligent air quality management system,* will develop a HVAC system that will also autonomously learn behavior patterns of the users/inhabitants of the building and take advantage of this knowledge to get the building ready for the predicted needs. A smart application developed in the pilot, will automatically adjust indoor conditions to better temperature, air quality, humidity, etc. using the data analyzed from different air quality sensors.

The third use case *Promoting independence of specific vulnerable groups* includes two pilots, both focusing at schools. Both pilots, the Rehabilitation decision support, and the *Indoor air quality improvement at school,* will combine environmental sensor data (indoor and outdoor) with physiological and behavioral sensor data from wearable devices to empower decision support tools for behavioral choices. Applications to visualize the indoor air quality and wellbeing will be developed in both pilots.

All the pilots of the ESTABLISH project are progressing at the moment, and technical specifications has been planned and reported carefully. Now, the pilots will be implemented in different countries.

This deliverable concentrated on technical specifications of pilots of the ESTABLISH project. These pilots have been described more in detail with state-of-the-art description in the previous deliverable D2.1. Deliverable D4.1 will concentrate on data management platform architecture to be used in ESTABLISH project and D3.1 will concentrate more on architectural and design specification of the pilots. In WP2, the second version of technical requirements will be published after one year, and usability of ESTABLISH solutions at the end of the project.

Appendixes

Appendix 1A. Optimized City and Mobility Planning, technical requirements

	Discription
Devices, sensor management (WP3 System architecture)	
Other data sources	Open data from Valencia City Council - Valencia Smart City Platform (http://gobiernoabierto.valencia.es/en)
Data (WP4 Connecting and managing sensors)	
Data sources	
Storage	Cloud platform
Recording of data	Air pollution from weather stations Traffic data in real time Static data of public transport (buses) Bike lanes Public and private parkings Information about regulated parking service
Monitoring	Air pollution from weather stations Traffic data in real time Static data of public transport (buses) Bike lanes Public and private parkings Information about regulated parking service
Gateways	FI-WARE
Integration	Open Data from Valencia Smart City Platform analyzed and integrated in the ESTABLISH platform
Analytics (WP5 Data analytics and adaptive control)	
	Data fusion based on big data and deep learning techniques in order to provide recommendations for mobility and alerts about pollution in real time
	Data analysis with algorithms using geographical aware complex event processing (geoCEP) in realtime situations.
Privacy and Security	
Application	
User needs	Applications providing planning services and mobility information considering all relevant information about traffic conditions and pollution
Front end	Mobile application with multimodal route planning and alerts/recommendations about pollution. Web application with dashboard and traffic simulation platform
Back end	Algorithms for ecological route optimization Dashboard Traffic Simulation Platform
Pilot Implementation	
Implementation	In progress
Integration	To be done
Testing	To be done

Appendix 1B. Optimized City and Mobility Planning, use case requirements

PILOT	Optimized City and Mobility Planning
COUNTRY	Spain
DESCRIPTION	The pilot will build an advanced application for providing planning services and mobility information both for citizens and for city authorities considering relevant information such as contamination or traffic conditions..
OWNER, CONTACT PERSON (in the project)	Ismael Torres (Prodevelop)

	Description
Use case preparation	
Brainstorming	Kick-off of spanish partership (20/02/2017).
User scenario development	Plan for scenario writing D2.1, preliminary of work structure and invovement of partners, candidate technologies, etc.
User experience planning	User experience viewpoints in the pilot / how / how often... Aproach based on an iterative process with mockups, to be refined once the use case definition is concluded
Contacting the users, recruitment	User community building. Check use case with final users (City interface and responsables (mobility, infrastrcture, smart city and innovation)). Revent communities, associations and relventa users (citizen view)
Informing about the pilot	Contrast meetings with Valencia City responsables
Business modeling	At this stage identification of relevant stakeholders and partners. Business Model Canvas to be developed duirng the project lifecycle
Evaluation criterias	When we have succeeded. Brainstorming around the initial proposal (KPIs and relevant data acquisition processes)
Use case specification	
Use case definition	Definition of the spanish use case according the common template defined for the project.
Business modeling	At this stage identification of relevant stakeholders and partners. Business Model Canvas to be developed duirng the project lifecycle
Feedback from stakeholders	Meetings with Las Naves-InnDEA, entity of the Valencia City for innovation issues (representants for Smart City and mobility innitatives). To prepare questionnaires and groups dynamics to refine and evaluate in an incemrental way the different developments.
Feedback from advisory board	To define and involve reference compies and organizations to complete the spanish chapter. To prepare: formal invitation, questionnaires, interviews, group discussions, co-creation tools...
Technical specifications	See Technical specifications sheet

Use case design	
Concept visualization	Adopting a lean or incremental development lifecycle, different tools and methods will be used to align work among partners under a common picture (paper prototyping, mock-ups…)….
Feedback from stakeholders	Concept evaluation, iterative meetings with relvant staksholders (city and final users associations, if applies)
Feedback from advisory board	Concept evaluation
Implementation	
Contacting the users	A common plan to contact and involve users (How, how often, what to inform…). With the City, a communication and coordination scheme have been established during the first weeks of the project (see KoM minutes); with other users, this plan will be defined once user engagement is running and a clear concept of the pilot available
Review meetings	Meetings (F2F or teleconference) involving all the pilot partners are expected each two weeks or monthly at latest. Minutes will be prepared and agred among partners.
Detailed architectural specifications	Detailed architectural specifications
Detailed architectural design	Detailed architectural design
Integration plan	Integration plan
validation plan	validation plan
During the pilot	
Contacting the users	According the common plan to contact and involve users (how, how often, what to inform…), involve the city on the pilot expoitation, KPI monitoring and evoluation, risks and integration on the public strategy. Contact channels with users will keep alive during the piloting stage, by means of questionaires and working gruops dynamics if possible.
User experience	Selection of tools for Questionnaires, interviews, group discussions, co-creation). Involvement of users.
After the pilot	
Evaluation of the pilot	Evalaution with final users: KPIs final evaluation, sucess of project according just defined criteria
Contacting the users	By using previous tools, acquire feedback of users
Conclusions and recommendations	Extract conclusions, best practices, guidelines from user, stakeholders and advisory group feedback for next steps of the consortium and European community.
Feedback from stakeholders	Specific working meetings to analyze business and co-deisng nof business oportunities, technology evalaution and new lines of work opening
Feedback from advisory board	Evalaution with final users: KPIs final evaluation, sucess of project according just defined criteria and bsuienss opportunities.
Feasibility check	Assessing the feasibility of the concept to go to market and defining the necessary steps
Business model update	Finalisation of the business model canvas

Appendix 2A. Smart HVAC systems that ensure a healthy indoor environment, technical requirements

	Description
	Devices, sensor management (WP3 System architecture)
Sensor 1	Temperature sensor(s)
Sensor 2	Humidity sensor(s)
Sensor 3	CO2 sensor(s)
Sensor 4	Radon gas sensor(s) (optional)
Sensor 5	Illuminance sensor (s)
Sensor 6	Noise sensor(s)
Actuator 1	Window opener
Actuator 2	Local AHU with heat recovery
Actuator 3	Thermostat / Heater valves
Data source	Online weather data (e.g. CHMI)
	Data (WP4 Connecting and managing sensors)
Storage	MS Azure cloud platform
Recording of data	Location-fixed indoor conditions data (temperature, humidity, CO2, pressure difference w.r.t outdoors) every 5 minutes.
Recording of data	Outdoor conditions data; every 5 minutes
Recording of data	Indoor air quality data from fixed sensors every 5 minutes or according to sensor specification (to be defined)
Recording of data	Physiological sensors; maximum rate available by sensors for one-day operation between charging.
Recording of data	User-defined labels; user initiated (any time) and scheduled (three times during working day; morning, midday, when leaving work). Option for backend-originated querying of user label based on observed physiological data.
Recording of data	Air purifier; filtering efficiency (e.g., power vs airflow and/or purification efficiency). Optional: Incoming air quality (if not available via the external indoor air quality sensors)
Monitoring	Visualizations updated at least once a day for participants.
Monitoring	Air purifier filter status; daily
Gateways	Location-fixed indoor sensors connect via IMA gateways and/or vendor specific selected cloud IoT Hub. Mobile phone may be used as gateway for pilot participants' physiological sensors.

Connectivity	Sensor <=> gateway via LoRa and/or BLE Gateway <=> cloud via 3G/4G cellular, Wi-Fi and/or Ethernet
Integration	IMA indoor conditions data are made available to project consortium.
	Analytics (WP5 Data analytics and adaptive control)
Mathematical model	A mathematical representation of the building will be used to control the HVAC system in the pilot. Model will be able to use the measured data to predict optimal parameters of the HVAC system in the future.
	Privacy and Security
	Privacy and security provisions will be performed within WP4 and WP5. Main focus on – protect sensor data (values, placement, type) against misuse, gateway encrypted protocols, user identity and user activity protection, actuators breaking, infrastructure misuse and user authentication on applications.
Application	
User needs	Interviews / questionnaires / focus group discussions to understand users' needs.
Front end	Sensor data collection; visualizations of collected and predicted data. Visualization of actuators settings.
Back end	Data aggregation for analytics, visualization and prediction. Connecting the measured date with mathematical model.
System feedback	Adjustment of actuators based on observed environmental conditions and predicted conditions. Feedback loop validation process, auto-reconfiguration proposition.
	Pilot Implementation
Implementation	Implementation steps come out of description of use case development and main actors of Step 1 to Step 5 will take part the implementation process regardless of either administrative or technical provisions are taken.
Testing	Based on the use case development and deployment definition. Phase 1: At IMA premise, limited number of users/testers, supported by development sources in order to ensure fast system corrections. Phase 2: Depending on stakeholders' involvement, industrial partners will deploy tested components of the phase 1, Dekprojekt operational environment.

Appendix 2B. Smart HVAC systems that ensure a healthy indoor environment, use case requirements

Use case requirements and technical specifications	
PILOT	Smart HVAC systems that ensure a healthy indoor environment
COUNTRY	Czech republic
DESCRIPTION	The pilot will show up defined technical as well as formal aspects of Czech use case. Partners will develop HW and SW components of the use cases - sensors, gateways, coordination platform, SW services, applications including data interpretation interfaces. Determined stakeholders will be familiar with functionalities and expected results. Use cases will be deployed at selected test sites in Czech. The focus of the pilot is to assess the impact of smart HVAC technologies on health status improvement.
OWNER, CONTACT PERSON (in the project)	Jiri Havlik (IMA)
	Description
	Use case preparation
Brainstorming	Discussing with partners involved.
User scenario development	Step1 – use case components specified in D2.2 collection in laboratory conditions both at development partner (IMA) and industry partner (Dekprojekt). Step 2 – setup and configuration of HVAC system, debugging, requirements revision Step 3 – first run of the use case, limited number of users, system monitoring Step 4 – second run based on feedbacks, preparation for real operation Step 5 – real operation of demonstrator, deployment at Dekprojekt and premise.
User experience planning	User experience viewpoints in the pilot / how / how often etc. will be planned together with use case developers - IMA, CU, DEKPROJEKT..
Contacting the users, recruitment	The contact person will be contacted and a planning meeting will be arranged.
Informing about the pilot	Informative meetings will be arranged before, during and after the test period.
Business modelling	Business model canvas will be created when the pilot will be defined. The canvas will be discussed in the steering group meeting also.

Evaluation criteria	TBD
	Use case specification
Use case definition	The Czech pilot will develop such a HVAC system that will also autonomously learn behavior patterns of the users/inhabitants of the building and take advantage of this knowledge to get the building ready for the predicted needs. It will try to resolve the tension between energy efficiency and quality of indoor climates that occurs e.g. after retrofitting existing buildings by offering an affordable solution.
Business modelling	Business model canvas will be developed during the pilot.
Feedback from stakeholders	Questionnaires, interviews, group discussions, co-creation tools will be utilized to collect feedback. It will be determined together with testees how the feedback will be collected during the pilot.
Technical specifications	See the other sheet: Technical specifications
Use case design	
Concept visualization	Paper prototyping, mock-ups will be utilized. The real application will be developed iteratively based on the feedback got from the users.
Feedback from stakeholders	UC concept and design will be validated using stakeholders' feedback and with DEKPROJEKT support. The feedback will be assessed by US developers.
Implementation	
Contacting the users	The contact person will be contacted and a planning meeting will be arranged. All testees will be informed about pilot.
Review meetings	The stakeholders will be informed at the meeting before the pilot. At the end of the pilot, a feedback event / group discussion meetings will be arranged.
During the pilot	
Contacting the users	TBD
User experience	Questionnaires, interviews, group discussions, co-creation tools will be utilized to collect feedback. It will be determined together with testees how the feedback will be collected during the pilot.
Analytics	Differences between predicted and measured indoor air quality will be evaluated during the pilot. Measures to maximally closing the gap will be developed.

After the pilot	
Evaluation of the pilot	The pilot will be evaluated with the stakeholders by the criteria defined before the pilot.
Contacting the users	The results of the pilot will be shared with the users in a meeting / by email.
Conclusions and recommendations	The results of the pilot will be analyzed and shared with the stakeholders in a meeting.
Feedback from stakeholders	Feedback from the stakeholders will be collected in a meeting. They are also able to comment and update the report of the results.
Feasibility check	Assessing the feasibility of the concept to go to market and defining the necessary steps.
Business model update	Finalization of the business model canvas with the stakeholders.

Appendix 3A. Intelligent air quality management system, technical requirements

	Description
Devices, sensor management (WP3 System architecture)	
Sensor 1	Temperature and humidity sensor(s) in IAQ and OAQ
Sensor 2	CO2 sensor(s) in IAQ
Sensor 3	Illuminance sensor(s)
Sensor 4	Noise sensor(s)
Sensor 5	VOC sensor(s) in IAQ
Sensor 6	Formaldehyde sensor(s) in IAQ
Sensor 7	Dust (PM2 and PM10) sensor(s) in IAQ and OAQ
Battery 1	Battery pack in OAQ
Battery 2	Solar module in OAQ
Communication 1	Wi-Fi module in IAQ and Server
Communication 2	RF module(Sub-GHz) in IAQ and OAQ
Actuator 1	Air purifier
Data (WP4 Connecting and managing sensors)	
Storage	Server Platform
Storage of additional research data in Korean pilot	Structural map in the building
Recording of data	Indoor conditions data (temperature, humidity, CO2, Illuminance, Noise, VOC, Formaldehyde, Dust) every 1 minutes.
Recording of data	Outdoor conditions data (temperature, humidity, Dust, Battery) every 1 minutes
Monitoring	Indoor air quality data every 20 minutes or according to sensor specification (TBD)
Monitoring	Outdoor air quality data every 20 minutes or according to sensor specification (TBD)
Monitoring	Air purifier filter status; daily
Connectivity	IAQ <=> Server via Wi-Fi OAQ <=> IAQ via RF(Sub-GHz)

Integration	Indoor and outdoor conditions data are made available to project consortium
Analytics (WP5 Data analytics and adaptive control)	
Mathematical model	The mathematical algorithms will be used to estimate the current air quality in indoors and outdoors. Moreover, the mathematical methods such as machine learning and the data mining will contribute to finding out the indicators to improve the air quality by classifying the user life patterns and detecting the air pollution sources.
Privacy and Security	
	The collected private information will be anonymized by hashing the person identifier, and not save the unhashed identifier in the server platform and processing system.
Application	
User needs	Interviews / questionnaires / focus group discussions will be opened to collect the user requirements for the target or the current customers.
Front end	IAQ/OAQ devices; sensor data collection; visualizations of collected data; visualization of actuators settings
Back end	Data aggregation for analytics; visualization of the space conditions; field of outdoor air quality analysis; advanced air purifier
System feedback	Adjustment of air purifiers based on the indicators extracted by using the environmental data. Feedback loop control and validation to automatically improve the air quality in indoors.
Pilot Implementation	
Implementation	The implementation works are performed according to the progress of the use case development from step 1 to step 5.
Testing	Each partner will perform the evaluation on a module-by-module basis about the key components such as "IAQ/OAQ devices", "Server Platform", "Algorithm", "Interconnection to Purifiers". After each module is completed at the prototype level, the partners try to integrate and evaluate the whole system on the testbed similar to the real field.

Appendix 3B. Intelligent air quality management system, use case requirements

PILOT	Intelligent air quality management system
COUNTRY	Korea
DESCRIPTION	The pilot will implement the intelligent air management system for providing the fresh and healthy air to the users residing in the buildings for a long time. For the successful R&D, the partners should survey the user requirement, design the system architecture, implement the hardware and software, and evaluate the performance in the testbed.
OWNER, CONTACT PERSON (in the project)	Yu-Cheol Lee (ETRI)

	Description
Use case preparation	
Brainstorming	Generation of the ideas through the regular meetings once a month in Korea
User scenario development	Step 1) survey and collect the requirements for the air purifier users Step 2) define the technical specifications corresponding to the user requirements Step 3) develop the hardware (IAQ/OAQ devices, air purifier) and software (server platform and algorithms) Step 4) evaluate the performance in the laboratory level and reflect the feedbacks Step 5) evaluate the performance in the real operation level and stabilize the components
User experience planning	User experience viewpoints in the pilot / how / how often etc. will be planned together with the use case partners - ETRI and Coway.
Contacting the users, recruitment	Staff members managing the end customers in the air purifier business
Informing about the pilot	Opening the workshops to prepare and perform the evaluation of use case
Business modeling	Designing the business model canvas based on expansion application of the air purifier through rental and sales

Evaluation criteria	Performance test of the developed technologies to implement the use case, Survey results of the function satisfaction corresponding to the end-customers
Use case specification	
Use case definition	The Korean pilot will contribute to developing a healthy indoor environment in the buildings that can automatically adjust its conditions to better temperature, air quality, humidity, etc. using the results analyzed by the environmental data. It will achieve the solution to generate the well-being, safe, comfortable indoor spaces for the people, especially the senior and the children.
Business modeling	Designing the business model canvas based on expansion application of the air purifier through rental and sales
Feedback from stakeholders	Questionnaires, interviews, group discussions, conference, and co-creation tools will be used for collecting the feedbacks from the various sources such as customers, technical experts, and business partners. The feedback will be periodically reflected in the implementation of the use case.
Technical specifications	See the other sheet: Technical specifications
Use case design	
Concept visualization	Paper publication and the mock-up prototyping will be used to describe the concept of the use case. The real application will be developed iteratively based on the feedback received from the users.
Feedback from stakeholders	The concept will be evaluated in the regular meetings with the partners in the pilot. The co-work with other pilots will be defined during the project.
Implementation	
Contacting the users	Staff members managing the customers in the air purifier business will be arranged the interviews and survey meeting with the target users.
Review meetings	The stakeholders will be informed at the meeting before the pilot. At the end of the pilot, a feedback event / group discussion meetings will be arranged.
During the pilot	

Contacting the users	Staff members managing the customers in the air purifier business will explain the effect and the functions about the use case to the users.
User experience	Questionnaires, interviews, group discussions, conference, co-creation tools will be utilized to collect feedback. It will be determined together with testees how the feedback will be collected during the pilot.
Analytics	Evaluating the effectiveness of the use case based on the user experiences. The gap between the predicted and collected results of the responders will be used for refining the questions and the survey methods.
After the pilot	
Evaluation of the pilot	The pilot will be evaluated with the stakeholders by the criteria defined before the pilot.
Contacting the users	The results of the pilot will be shared with the users through the report in the meeting.
Conclusions and recommendations	The results of the pilot will be analyzed and shared with the stakeholders in a meeting.
Feedback from stakeholders	Feedback from the stakeholders will be collected in a meeting. They are also able to comment and update the report of the results.
Feasibility check	Assessing the feasibility of the concept to go to the market and defining the necessary steps.
Business model update	Finalization of the business model canvas with the stakeholders.

Appendix 4A. Rehabilitation decision support, technical requirements

	Description
Devices, sensor management (WP3 System architecture)	
Sensor 1	Air Quality Sensors (posibil Aeroqual series 500): sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O_3), particulate matter (PM10 and PM2)
Sensor 2	Weather sensors (pressure, temperature, humidity, CO_2)
Sensor 3	FitBit Bracelet (heart rate, pedometer, calories burned)
Data (WP4 Connecting and managing sensors)	
Data sources	
Storage	Cloud platform
Recording of data	sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O_3), particulate matter (PM10 and PM2)/ once at 3 minutes
Recording of data	pressure, temperature, humidity, CO_2/once at 15 minutes
Recording of data	heart rate, pedometer, calories burned/once in a minute
Monitoring	sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O_3), particulate matter (PM10 and PM2)/ once at 3 minutes
Monitoring	pressure, temperature, humidity, CO_2/once at 15 minutes
Monitoring	heart rate, pedometer, calories burned/once in a minute
Gateways	FIWARE (?) to be done after sensors purchasing
Connectivity	Sensors -M2M Platform -Decision Expert System - Mobile Apps (for notifications)
Integration	Weather and air quality data will be available for al the users of the integrating platform
Analytics (WP5 Data analytics and adaptive control)	
	to be done after sensors purchasing
Privacy and Security	
	Users personal data will be seen only for doctors and rehabilitation stuff
Application	
User needs	Maintaining their physical condition and performing exercises for physical activity in order to recovery/restoring of motor functionalities, both outdoors and indoors.
Front end	Personal data, medical data, sensors data entries
Back end	Air quality, weather, behavioral data and notifications from the expert system.
Pilot Implementation	
Implementation	Work in progress
Integration	to be done
Testing	to be done

Appendix 4B. Rehabilitation decision support, use case requirements

PILOT	Promoting independence of specific vulnerable groups
COUNTRY	Romania
DESCRIPTION	The pilot will study the use of variety of indoor sensors combined with inhabitant's personal feedback and environmental sensing information to provide a healthier living environment for elderly people in their homes or in a care facility.
OWNER, CONTACT PERSON (in the project)	Ana-Maria Baldea (Siveco)
	Description
Use case preparation	
Brainstorming	Done with **BEIA, Premium Wellness Institute** and **National Institute of Rehabilitation, Physical Medicine and Balneoclimatology Bucharest**
User scenario development	Done
User experience planning	User experience viewpoints in the pilot / how / how often…
Contacting the users, recruitment	The first pilot activities will take place with two volunteers groups: students from a high school from Bucharest and corporates from SIVECO. They intend to maintain their fitness and prevent obesity. After this we will choose people who have prescriptions for physical activity for the recovery/restoring of motor functionalities, both outdoors and indoors.
Business modeling	Business model canvas
Evaluation criterias	When we have succeeded

Use case specification	
Use case definition	The Romanian pilot will combine environmental sensor data with physiological and behavioural sensor data to empower patients in a rehabilitation clinic with decision support tools for behavioural choices and treatment options. The Romanian ESTABLISH project's goals are: - to monitor health parameters to constantly improve the health of the population through rehabilitation and spa care, specifically targeting the patient's functional aspect of integration in everyday life, environment and work. - to develop a decision support system and services based on the outdoors environment parameters and indoor location. - to reduce operations costs and improve quality of the services provided. We will use a first group of students from highschool and a second pilot group of adults. We will register their physical activities, the cardiac rithm, the burned calories, in order to find links between them and the air conditions.
Business modeling	Business model canvas
Feedback from stakeholders	Questionnaires, interviews, group discussions, co-creation tools…
Feedback from advisory board	Questionnaires, interviews, group discussions, co-creation tools…
Technical specifications	See the other sheet: Technical specifications
Use case design	
Concept visualization	Paper prototyping, mock-ups… (WYP)
Feedback from stakeholders	Concept evaluation
Feedback from advisory board	Concept evaluation
Implementation	
Contacting the users	How, how often, what to inform…
Review meetings	Who to involve, when, how often…
During the pilot	
Contacting the users	Users will receive notifications everytime is necessarily: overcoming their concentration level of sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O3), particulate matter (PM10 and PM2)
User experience	Questionnaires, interviews, group discussions, co-creation tools…
After the pilot	
Evaluation of the pilot	to be done
Contacting the users	How, how often, what to inform…
Feasibility check	Assessing the feasibility of the concept to go to market and defining the necessary steps
Business model update	Finalisation of the business model canvas

Appendix 5A. Indoor air quality improvement at school, technical requirements

	Description
Devices, sensor management (WP3 System architecture)	
Sensor 1	Indoor conditions monitoring; temperature, humidity, CO2, pressure difference. E.g., VTT TinyNode and/or Ouman WL-TEMP-RH
Sensor 2	Outdoor weather / air quality sensors at VTT; temperature, air pressure, humidity, CO2, precipitation, wind speed and direction, particulates, NO2, SO2, CO, O3
Sensor 3	Indoor VOC sensor(s) (portable), reference device
Sensor 4	Indoor particulate sensor, reference device
Sensor 5	Wearable activity sensors (e.g. FitBit)
Sensor 6	Physiological activity sensors with heart rate, HRV, breathing rate; e.g., Polar M600 (can be the same device as Sensor 5)
Sensor 7	Oxygen saturation and skin conductivity sensors
Sensor 8	(within air purifier) - optional: incoming air quality, purification efficiency
Sensor 9	Environmental activity sensors (depth cameras and/ or passive infrared motion detectors (PIR) for VTT pilot, maybe PIR can be used at school too
Sensor 10	Indoor air quality monitoring devices (particulates, VOC, Formaldehyde, gases (CO, CO2, SO2, NO2)), e.g. Libelium or uRAD, reference devices (accurate)
Sensor 11	Low-cost indoor air quality monitoring devices (particulates, VOC, gases), to be defined. E.g., Raspberry PI or Arduino based, multiple sensors
Sensor purchasing	Sensors 1-4 and 10 and part of sensors 9 (depth cameras) are already available for VTT pre-pilot. Personal sensors, indoor conditions, air quality monitoring sensors, and PIR sensors need to be purchased for the pilot.
Implementation	Design and coding of the backend applications for environmental, air quality and physical data collection. Implementation of necessary APIs for data retrieval for analysis & further visualization.
Computing platforms for environmental activity sensors	Laptops or Raspberry PI for some of VTT rooms (we have 2 laptops, and we might get couple of loan laptops from PC support, TBD)
Mobile phones	Phones are purchased for development purposes; no specific requirements (stock Android smartphone). In case separate phones are decided to be used by pilot participants, similar phones may be purchased. Otherwise, pilot participants may use their own (Android) phones. It is highly preferable that pilot participants use their own phones because in this case we can evaluate human condition also based on mobile phone usage data.
Mobile application	Design and coding of the application. See Application part from this document.
Keyboard/ mouse data collecting application for VTT pilot	TBD: if some open source SW can be reused, and we can get this application in little time for VTT pilot

Data (WP4 Connecting and managing sensors)	
Storage	MS Azure cloud platform
Storage of additional research data in VTT pilot	On local machines or MS Azure platforms, TBD depending on nature of data and consent of test subjects
Recording of data	Location-fixed indoor conditions data (temperature, humidity, CO2, pressure difference) every 5 minutes.
Recording of data	Outdoor conditions data; every 5 minutes
Recording of data	Indoor air quality data from movable sensors (VOC, particulates) and/or (semi)fixed air quality monitoring reference devices and/or room specific low-cost air quality monitoring devices every 5 minutes or according to sensor specification (to be defined)
Recording of data	Physiological and activity sensors; maximum rate available by sensors for one-day operation between charging.
Recording of data	Category-wise mobile phone application usage data in VTT pilot (timestamps when user started and stopped applications of each category, such as business, social etc.)
Recording of data	User-defined labels; user initiated (any time) and scheduled (three times during working day; morning, midday, when leaving work). Option for backend-originated querying of user label based on observed physiological data.
Recording of data	TBD: certain features of keyboard and mouse usage in VTT pilot, e.g., speed of mouse movement - if we can develop data collection SW in time for VTT pilot
Recording of data	Air purifier; filtering efficiency (e.g., power vs airflow and/or purification efficiency). Optional: Incoming air quality (if not available via the external indoor air quality sensors)
Monitoring	Visualizations updated at least once a day for participants.
Monitoring	Air purifier filter status; daily
Gateways	Location-fixed indoor sensors connect via VTT gateways and/or vendor specific (e.g., Ouman WL-Base) to MS Azure IoT Hub. Mobile phone may be used as gateway for pilot participants' physiological sensors.
Connectivity	Sensor <=> gateway via BTLE, ZigBee, LoRA. Gateway <=> cloud via 3G/4G cellular and/or WiFi
Integration	VTT indoor conditions and outdoor conditions are made available to project consortium.
Analytics (WP5 Data analytics and adaptive control)	
	Started during VTT pre-pilot; seek to find correlation between user-defined labels (feelings, symptoms, and activity), physiological measurements (e.g., heart rate, breathing rate) and behavioral data. Find correlation between symptoms and spaces the participant visits. Seek to classify sources of indoor air quality problems by correlating symptoms (user-specified and physiological), indoor and outdoor air quality measurements, questionnaire

Privacy and Security	
	Selection of pilot (and VTT pre-pilot) participants according to ISEC questionnaire & policy; selection criteria or personal data will not be available to project members (even at ISEC). Collected physiological data will be anonymized by hashing the person identifier, and not storing the unhashed identifier in the data collection and processing system.
Application	
User needs	Interviews / questionnaires / focus group discussions to understand users' needs. User needs the application for labelling data (feelings, symptoms, etc.) and in order to see their personal collected data (visualizations). If location cannot be determined otherwise, ask the user.
Front end	User data collection (labels); visualizations of collected physiological data. Positioning / location tracking.
Back end	Data aggregation for analytics and visualization. Option for querying users for data labels based on observed physiological reactions. Location / positioning (e.g., combine BT beacon data, WiFi identifiers, etc. to determine location). Collection of mobile phone usage data at least in VTT pre-pilot, such as for how long the user used applications of different categories (social, business, etc.)
Front end / Back end (division TBD)	Adjustment of air purifier operation based on observed environmental conditions, and determination + indication of need for filter cleaning & replacement.
Pilot Implementation	
Implementation	VTT pre-pilot
Testing	At VTT pre-pilot

Appendix 5B. Indoor air quality improvement at school, use case requirements

PILOT	Indoor air quality improvement at schools
COUNTRY	Finland
DESCRIPTION	The Indoor air quality improvement at school pilot will study the use of a variety of indoor sensors and wearables combined with users personal feedback and environmental sensing information to provide a healthier living environment for pupils, teachers, and other staff members.
OWNER, CONTACT PERSON (in the project)	Heidi Similä (VTT)

	Description
Use case preparation	
Brainstorming	Branstorming with researchers, discussing with companies involved.
User scenario development	Scenario writing for D2.1, and D2.2. Discussion and planning with researchers.
User experience planning	User experience viewpoints in the pilot / how / how often etc. will be planned together with researchers and pre-testee at VTT.
Contacting the users, recruitment	Contacting potential users from VTT by email. In the case of school, the contact person will be contacted and a planning meeting will be arranged.
Informing about the pilot	More information about time pilot will be shared to the users by email including all practical information, contact person of the project etc. Also, an information meetings will be arranged before the test period.
Business modeling	Business model canvas will be filled in by researchers. The canvas will be discussed in the steering group meeting also.
Evaluation criterias	TBD by researchers before the pilot.
Use case specification	
Use case definition	The Finnish pilot targets users of buildings with confirmed or suspected indoor air quality problems. The aim is to improve and simplify the detection of the type and severity of indoor air quality problems, location affected by them (e.g., classrooms or offices) by correlating questionnaire data, environmental data, user-provided data of their symptoms and mood, and physiological data collected of the pilot participants. The air purifiers will be utilized if needed. Suitable participants are screened by a structured questionnaire (ISEC) and/or volunteers. The participants wear physiological sensors (bioharness, wrist-held device(s)) and report their feelings (symptoms, mood, tiredness etc.) on a mobile application. Environmental data is simultaneously collected of the locations and outside conditions. Location data is either user provided, derived on a coarse level by, e.g., GPS signal, and/or using indoor locationing/positioning. Data from different soursen will be analysed and visualised for the users by a mobile application.
Business modeling	Business model canvas will be filled in by researchers. The canvas will be discussed in the steering group meeting also.
Feedback from stakeholders	Questionnaires, interviews, group discussions, co-creation tools will be utilized to collect feedback. It will be determined together with testee how the feedback will be collected during the pilot.
Technical specifications	See the other sheet: Technical specifications

Use case design	
Concept visualization	Prototyping, mock-ups (proto.io) will be utilized e.g. to visualize the mobile application for testees. The real application will be developed iteratively based on the feedback got from the users.
Feedback from stakeholders	Concept evaluation with companies involved and project partners in the meetings. Co-operation possibilities with other partners will be discussed during the project.
Implementation	
Contacting the users	The testees at VTT and at schools will be informed by email about e.g. the time tables, their role in the pilot and sensor implementations beforehand. Also, a f2f meetings will be arranged both at VTT and at schools.
Review meetings	The testee at VTT and at school will be informed in the meeting before the pilot. At the end of the pilot, a feedback event / group discussion meetings will be arranged.
During the pilot	
Contacting the users	The contact person from the schools will be contacted at least weekly to understand how everything is going in the pilot.
User experience	Questionnaires, interviews, group discussions, co-creation tools will be utilized to collect feedback. It will be determined together with testees how the feedback will be collected during the pilot. It will be clarified if it could be possible to get some feedback also from the pupils.
Analytics	Pursue to find correlation between user input, air quality monitoring and physiological sensors; determine need for additional measurements and/or adjust user app (add/change/remove questions, change questioning interval).
After the pilot	
Evaluation of the pilot	The pilot will be evaluated with the stakeholders by the criterias defined before the pilot.
Contacting the users	The results of the pilot will be shared with the users in a meeting.
Conclusions and recommendations	The results of the pilot will be analysed and shared with the stakeholders in a meeting.
Feedback from stakeholders	Feedback from the stakeholders will be collected in a meeting. They are also able to comment and update the report of the results.
Feasibility check	Assessing the feasibility of the concept to go to market and defining the necessary steps.
Business model update	Finalisation of the business model canvas with the stakeholders and researchers.