LIFE13 ES/ENV/417

Final Report
Covering the project activities from 01/06/2014 to 31/12/2017

Reporting Date
28/6/2018

LIFE+ RESPIRA Reduction of exposure of cyclists to urban pollutants

Project Data

Project location	Navarra, Spain
Project start date:	01/06/2014
Project end date:	31/05/2017 **Extension date:** <31/12/2017 >
Total Project duration (in months)	43 months (including **Extension of** <7> **months**)
Total budget	2.333.685 €
Total eligible budget	2.245.060 €
EU contribution:	1.122.530 €
(%) of total costs	48,16 %
(%) of eligible costs	50 %

Beneficiary Data

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2. Executive summary

2.1. Project objectives

The main goal of Life+Respira project is to demonstrate that it is possible to improve the quality of life in European cities through the use of new technologies, along with urban planning and management measures such as promoting sustainable mobility.

The project relies in an enthusiastic backbone of more than 200 urban cyclists supporting a much smaller research team. It can thus be considered an example of citizen science, where volunteers provide experimental data for researchers by using cutting-edge technologies. As a result of this open, networked and trans-disciplinary scenario, science-society-policy interactions can be improved leading to a more democratized and evidence-informed decision-making, based on scientific research enhanced and supported by amateur or non-professional scientists.

Besides this general target Life+Respira aims at reaching the following specific objectives:

- To quantify the amount of pollutants that cyclists (and pedestrians) inhale under actual traffic conditions and in real, representative rides, assessing the potential health hazards such intake poses for them according to how and where they ride through, and for how long.

- To demonstrate the effectiveness of innovative technologies, design features and riding pattern options under real-life conditions, obtaining reliable conclusions readily transferable to other, similar cities.
- To demonstrate how other existing, correctly integrated systems for urban planning and management can help reduce urban air pollution.
- To develop a model allowing extrapolation of results to improve air quality control strategies, thus contributing towards urban sustainability.
- To develop a tool to produce realistic, fine-scale, near-real-time urban pollutant maps that can help improve urban planning and management.
- To develop a route planner that would help the user select healthier routes as respects to air pollution.
- To help assessing the environmental, social and economic benefits of increased cycling as transportation means in cities and the corresponding economic impact.
- To engage citizens through an outreach campaign into the project development, making them the main drivers and raising awareness about their responsibility in air quality and in their own health.
- To educate about, and disseminate information on, air quality and urban air pollution, promoting the development of actions for a healthier environment.

2.2. Key deliverables and outputs

Life+Respira is an ambitious and complex project that has developed 26 actions to achieve the objectives set out above. Perhaps one of the greatest strengths of this project has been its multidisciplinary nature, involving 34 researchers from such different fields as biology, chemistry, physics, engineering, meteorology, architecture, geography, sociology, medicine or journalism. This has entailed addressing the issue of air pollution in cities from very different perspectives, fostering the acquisition of a comprehensive view of the problem and proposing more objective solutions.

The main outputs at the end of the project have been:

- Precise knowledge of the small-scale time- and space- distribution of air pollutants in cities.
- Estimation of the health risks associated to traffic pollution specifically for cycle riders according to weather, time, traffic conditions, and especially riding options.
- Assessment of the effectiveness of pollutant-reduction technologies and management options at reducing breathed pollutants.
- Estimates of the environmental, health, carbon footprint, and economic benefits of a shift to bicycling as transportation means.
- Development of a spatially explicit model for air pollutants under various scenarios that can be adapted to other, similar cities.
- Development of information tools (GIS, data management plan) for data processing and application.
- Development of a “healthy route planner” enabling citizens to select the healthier route for a ride between two points.
- Transfer to citizens and city planners of results for enhanced awareness about air quality, and about the benefits of healthy transportation, the risks associated to air

pollution, and options for sustainable life.
- A guide for official use detailing actions, management options, and planning features that can help achieving better breathable air quality in cities.
- An increase in the public awareness about the benefits of environmentally sustainable transportation options and the risks associated to air pollution.
- Experimental data that can be used by lawmakers and other stakeholders to draft or improve policies and regulations towards achieving better urban air quality.

2.3. Main conclusions of the project

Once the project has finished, and despite several initial unforeseen setbacks in carrying out some actions, we can say that the Life + Respira project has been a success. Undoubtedly, the greatest milestone of the project has been to involve society through a large number of volunteers (200), making them participate in a set of scientific activities that has allowed citizens to become aware of the problem of urban air pollution. Thanks to this citizen science project a link between the world of research and society has been established, obtaining results that can contribute to improving the quality of life in cities.

From the technical point of view, the most relevant challenge of the project was the construction of air quality prototypes, since the existing equipment in the market did not have the precision required to accurately determine the concentrations of the main urban air pollutants. Therefore, we had to design our own prototypes, also developing complex algorithms and calibration and correction procedures to obtain reliable data.

The millions of data generated during the project were uploaded to the European EUDAT platform for long-term archiving. This was possible thanks to a pilot project granted during the execution of Life+Respira by EUDAT, called PAIRQURS (Public Access to Air Quality Urban data from Roaming Sensors), which enabled the creation of a data flow to facilitate the storage and permanent archiving and also release the result for public use.

Concerning results, the distribution of pollutants was strongly linked with the emission sources (mainly traffic) and their temporal variations, and to a lesser degree the weather circumstances and topographic layout of the city. Important variations in the exposure of cyclists to air pollutants were found as a function of distance to the road. Travelling on roads increased between 37 and 54% the exposure to traffic-related air pollutants. The inhalation of pollutants by cyclists was calculated according to several variables: sex, age, velocity and slope of the routes. The results indicated that the inhalation of contaminants was greatest when cyclists were traveling on steep slopes, thus requiring a greater effort that significantly increases their breathing rate.

Another important milestone of the project was the application of a high-resolution model. In this regard, and as far as we know, this is the first time in the world that a complete city has been modelled to determine the variation of atmospheric pollutants, and this is also the longest study related to air quality in a city thanks to the participation of citizens (1,463,090 sampling points with information on air pollution were recorded by volunteers). This model was also the basis for estimating the economic costs associated to the damage caused by air pollution. The results obtained amounted to a total of 5.7 M€ per year in the city of Pamplona, being the reduction in life expectancy the most important external cost.

Apart of distance, vegetation was observed to be very efficient in the reduction of air pollutants. The use of vegetation barriers, like hedgerows, helped to reduce the exposure of cyclists and pedestrians to air pollution by up to 30%. However, we observed that urban trees can also prevent the dispersion of pollutants emitted by traffic, depending on a series of factors that must be taken into account. Narrow streets with heavy traffic need detailed studies to design a suitable vegetation distribution that offer climatic comfort without worsening air quality through decreasing street ventilation.

The communication and dissemination actions showed that the media impact of the project was much higher than initially planned. The strategy to make a "transmedia" communication, in which traditional media, radio and television are used, along with digital media (short videos and social networks), caused a spectacular spread of the project awareness. Indeed, an estimated global audience of over 10 million people was reached.

The education programme developed in Life+Respira was also an example of success. A total of 10 schools and more than 1.200 students participated in the educational activities organized by Life+Respira in collaboration with MancoEduca, a prestigious environmental education program created 25 years ago by the local public institution "Mancomunidad de la Comarca de Pamplona".

Finally, the actions directed to the management and monitoring of the project, as well as the final audit carried out at the end of Life + Respira, confirmed that the project was carried out with great meticulousness, fulfilling the initially planned objectives.

3. Introduction

Cities produce a wide array of air pollutants, mainly linked to fuel burning in heating and motor vehicles. But despite significant impacts on human health and climate, we lack large scale systematic measurements of air pollution in cities, leading to a misunderstanding of the real situation of urban air quality.

Given the steady growth of cities and the increasing problems associated to traffic there is a need to develop new transportation alternatives contributing to improve air quality. An effective way to contribute to urban sustainability is to encourage the use of "friendly" environmental transport, such as cycling. Paradoxically, this healthy activity may pose a risk to cyclists themselves because of their increased exposure to air pollutants emitted by traffic while riding.

Life+Respira project has sought to shed light on these unknowns, demonstrating that air pollutants intake by cyclists and pedestrians can be reduced by using new technologies and implementing other options in urban planning, urban design and mobility management. These new technologies include the use of low cost sensors for measuring air pollutants, and testing a photo catalytic pavement active in the destruction of air pollutants.

Key to achieve this goal has been a group of citizen volunteers that has provided extensive field data to establish a realistic distribution of air pollutants in a city archetypical of 80% of all European cities. Through the use of cutting edge sensors, cyclists have recorded air pollution concentrations on a large scale but at very fine resolution in the city of Pamplona, helping solve the problem of low representativeness of data provided by the low-density, static air quality networks, which are typical in cities.

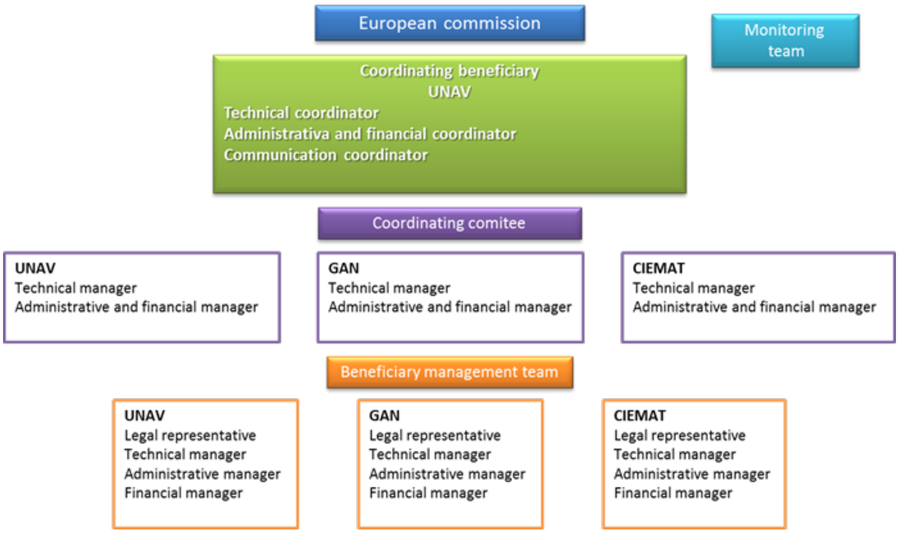
This project has had an important influence on society, providing environmental benefits for the city of Pamplona. These include an improvement of urban air quality thanks to the adoption of different management measures, an increase of citizen awareness regarding air pollution problem and an increase of urban cycling promotion. However, its usefulness may not stay local. In the short term it is expected that this project can be replicated in other Spanish and European cities. The experience accumulated during this project has encouraged us to export the idea of replicating Life+Respira in other cities, for which we have held several meetings with City Councils and Autonomous Communities, as well as with companies interested in managing the data that can be generated. Thanks to this, it is almost certain that in the next few months we will apply the methodology developed in Life+Respira in another Spanish city.

4. Administrative part

4.1 Description of the management system

Action E1: Project management

The project management system has been structured by the coordinating beneficiary and supported by the associated beneficiaries. The organization chart with the role of beneficiaries is given in this figure:



This information has been already described in the Inception Report and explained in the deliverable "Documento órganos de gestión" where the roles, responsibilities and actions developed by each partner are detailed, attached as. Annex 7.1.a_E1-Management board.

Dr. Jesús Miguel Santamaría is the technical and overall responsible for the project supported by Helena Baigorri, the financial and administrative manager also in charge of the communication with the Commission and the Monitoring team. Due to the important role of the communication on the LIFE project Dr. Bienvenido León has been designed as Communication and diffusion manager coordinator. The Coordination committee is composed of Technical and Administrative-Financial manager of every partner and is responsible of the evaluation, implementation and decision making in the different project phases. The beneficiary management team is constituted by the Legal representative and the technical and administrative and financial manager.

The project has had an amendment to the Grant Agreement approved the 19th of April 2017 in order to extend the project duration 7 month to the 31of December 2017 an to readjust the budget. The Partnership agreements have been signed on January 2015 and submitted with the Inception report on February 2015. A copy of them is attached as Annex 7.1b_E1-Consortium Agreement. The agreements have been established following the document "Guidelines for LIFE + Partnership Agreements" and the Common provisions 2013 and reviewed and agreed by all beneficiaries. The document outlines the role and obligations of the coordinating and associated beneficiaries, the technical and financial reports required by the European Commission and the financial conditions.

Reports delivered:

- Inception report covering the activities of the Project from 1/06/2014 to 31/01/2015
- Midterm report covering the activities of the Project from 1/06/2014 to 31/03/2016
- Progress report covering the activities of the Project from 1/04/2016 to 30/06/2017

Action E2: External Audit.

The coordinating beneficiary has contracted "CET Auditores", as external auditor before the end of the project according with the planned chronogram and the audit report is attached together with the final financial report as explained on the Financial Part.

Action E3: Networking with other projects/entities.

- 17 July 2014. Pamplona. Infoday Life call 2014. Organized by the University of Navarra, the Government of Navarra and the Spanish LIFE contact point.
- 22-24 September 2014, Amsterdam, and 23-25 September 2015, Paris. Plenary meetings of the Research Data Alliance (RDA).
- 3-5 February 2016. Rome. Invited participation in the EUDAT User Forum and the European Open Science Cloud for Research (EOSC).
- 4-5 February 2016- Valencia. Participation in the Life AIRUSE meeting on air quality.
- 19 February 2014. Peralta (Navarra). Meeting with representatives from LIFE Factory Microgrid and Life+ REWIND projects.
- 25 February 2016. Madrid. Invited Participation in the meeting organized in the frame of the project TECNAIRE.
- 20 September 2017. Madrid. Invited participation in the meeting: Thinking of mobility, thinking on the road:
    - Asociación Española de la Carretera.
    - Ayuntamiento de Valladolid.
    - WWF
    - Seguridad Vial 3M Iberia
- 12-13 December 2017. Pamplona (Navarra). Urban Air Pollution: Life+Respira final meeting:
    - Andalucía Smart City.
    - LifeWatch-ERIC.
    - IMPROVE-LIFE.
    - BREATHE.
    - Universidad de Lisboa.
    - TECNAIRE.
    - AIRUSE LIFE.
    - LIFE Factory Microgrid.
    - LIFE PhotoCityTex.
    - HEIRRI.

Networking with Life Factory Microgrid and Life Rewind projects (left) and TECNAIRE (right)

Action E4: After LIFE communication plan.

The After LIFE communication plan has been written by the end of the project to set out in detail how the project will continue disseminating and communicating the results after its end and it has been presented in the final conference. A pdf copy is attached as deliverable in the Dissemination annexes E4-After Life communication plan and can be downloaded on the project web page www.liferespira.eu

4.2 Evaluation of the management system

The management system is being successful. Each action has a responsible and the communication between the different partners is fluid and constant. As reported on the Midterm report, the problems with the new City Council have been overcome and it now shows a full involvement at the technical level. Annex 7.1.c_Commitment Pamplona Council.

Meetings were organized every six months in order to involve all the partners and to have time enough to present, discuss and solve any technical, financial or administrative problem eventually encountered. All the materials presented in the meeting are uploaded and shared in the project repository.

Since the project start eight meetings were organized in the Coordinating beneficiary premises.

- Kick off meeting. 17 July 2014. Pamplona. The consortium team met and all the partners presented their planned actions.
- 2nd Meeting. 30 November 2014. Pamplona. The first Coordination committee. Each project Action responsible showed the first results and discussed any relevant information about the project.
- 3rd Meeting and 1st Monitor visit. 17 February 2015. Pamplona. The project team presented the Monitor a general overview of the project and the different actions implementation.
- 4th Meeting. 15 October 2015. Pamplona. Presented the project implementation status.
- 5th Meeting and 2nd Monitor visit. 15 March 2016. Pamplona. Presented the project implementation and financial status and the schedule for the Midterm report.
- 6th Meeting: 16 November 2016. Pamplona. Presented the project implementation status and approved the request for an amendment.

- 7th Meeting and 3rd Monitor visit. 29 March 2017. The project team presented the current status of the project and received the approval of the amendment.
- 12th and 13th December 2017. Final Seminar. Presentation of the final results of the project and Coordination meeting for the schedule for the Final report.

In the Annex 7.1.d. the general meeting information is provided.

Communication with the Commission and Monitoring team

The communication with the Commission and the Monitoring team has been carried out by the coordinating administrative and financial manager. Mr. Iñigo Ortiz de Urbina, representative of the NEEMO Monitoring Team, has joined twice the LIFE+RESPIRA consortium meetings in the framework of the project progress control.

The 1st monitoring visit took place on February 17th 2015 in Pamplona and he met the project members. The technical coordinator made a general project presentation and every Action coordinator described the progress and implementation of the actions.

In the 2nd monitoring visit on March 15th 2016, the LIFE+RESPIRA team offered a detailed view of the status of the project. The monitor could examine the air quality monitoring prototypes and check the financial and administrative information.

In the 3rd monitoring visit on March 29th 2017, the LIFE+RESPIRA team presented the status of the project's implementation and the financial updated information.

In the 4th monitoring visit, the coordinator project responsible Dr. Jesús Miguel Santamaría presented the final results and the monitor could check the financial and administrative information.

During the development of the project, the communication with the monitor has been fluid and the project team has really appreciated his support.

5. Technical part

5.1. Chronogram

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2014 | 2015 | 2016 | 2017

Año 1 | Año 2 | Año 3 | Año 4

	Tarea	
A. PREPARATORY ACTIONS		
A1	Desarrollo de prototipos de monitorización de calidad del aire	Inicial / Modificación
A2	Plan de gestión de los sensores y adquisición de equipos complementarios	
A3	Análisis del marco urbano	Inicial / Modificación
A4	Caracterización de la movilidad ciclista en el contexto general de movilidad urbana de Pamplona	Inicial / Modificación
A5	Formación y constitución de los equipos de voluntarios	Inicial / Modificación
B. IMPLEMENTATION ACTIONS		
B1	Calibración de los sensores electroquímicos de medida de contaminantes	Inicial / Modificación
B2	Modelización de alta resolución de la calidad del aire urbano	Inicial / Modificación
B3	Instalación de pavimento fotocatalítico y demostración de sus efectos en la calidad del aire	Inicial
B4	Cuantificación y modelización de la mejora de calidad del aire por acción de la vegetación urbana	Inicial / Modificación
B5	Desarrollo de un planificador de "Rutas saludables"	Inicial / Modificación
B6	Demostración de la eficacia de las mascarillas anti-contaminación	Inicial / Modificación
B7	Plan de movilidad ciclista en el contexto general de movilidad urbana, conforme a criterios de calidad del aire	Inicial / Modificación
B8	Red de sensores post-proyecto	Inicial / Modificación
C. MONITORING OF THE IMPACT OF THE PROJECT ACTIONS		
C1	Medida a gran escala de los contaminantes a los que están expuestos los ciclistas	Inicial / Modificación
C2	Cuantificación de la inhalación de contaminantes por los ciclistas	
C3	Determinación de los nivels de COVs a que están expuestos los cilistas y de las concentraciones presentes en su aliento exhalado	Inicial / Modificación
C4	Valoración económica de los impactos ocasionados por la contaminación, y estimación de beneficios derivados de las medidas de reducción	Inicial / Modificación
C5	Programa de gestión y tratamiento de datos	Inicial / Modificación
D. COMMUNICATION AND DISSEMINATION ACTIONS		
D1	Plan y herramientas de comunicación y difusión	Inicial / Modificación
D2	Seminario Internacional y acciones formativas	Inicial / Modificación
D3	Dinamización dirigida al público general	Inicial / Modificación
D4	Medios de Comunicación	Inicial / Modificación
E. PROJECT MANAGEMENT AND MONITORING OF THE PROJECT PROGRESS		
E1	Gestión del proyecto	Inicial / Modificación
E2	Auditoría externa	Inicial / Modificación
E3	Redes con otros proyectos	Inicial / Modificación
E4	Plan de Comunicación after-LIFE	Inicial / Modificación

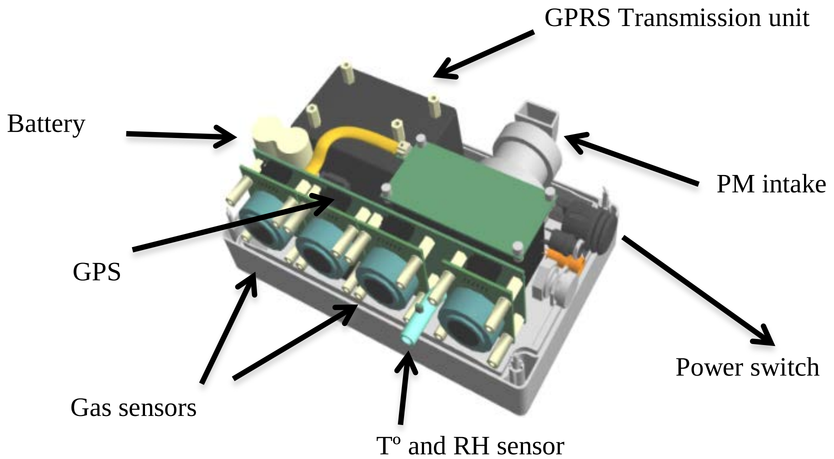
5.2. Technical progress, per task

ACTION A1	Development of air quality monitoring prototypes		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	6/14	Planned completion date	8/14
Start date	6/14	Completion date	3/15-31/12
Description of the tasks:			

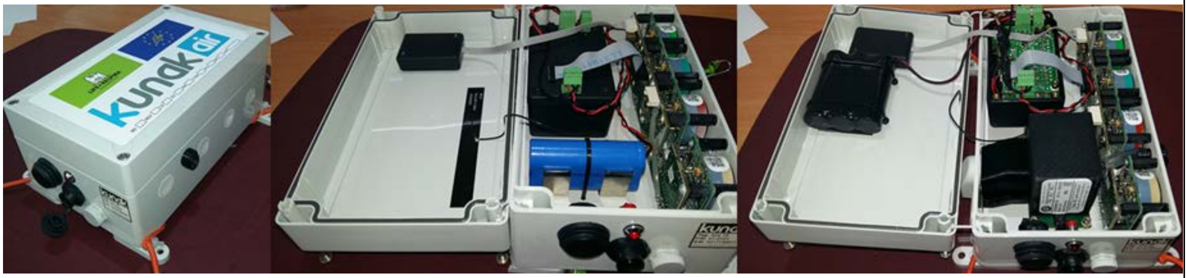
Despite the delay in the construction of the prototypes (the new sensors manufactured by Alphasense arrived late), this action was not compromised. Over the first few months of the project, we developed the sensor/transmitter suites (hereinafter “devices”) used by volunteers for air quality monitoring. The work was carried out in close collaboration with Kunak, a remote sensing company that was responsible for the sensor integration as a contractor.

1. Design and construction of the sensor suites

A prototype was designed including electronics motherboard, GPRS transmitter-receiver, sensor drivers, power supply, pluggable sensors, GPS receiver, and all accessory components within a polycarbonate enclosure IP67. Models were created in AutoCAD to optimize sensor and component distribution and account for factors that could affect reliable measurements. Several sensor configurations were tested. Although unavoidable, a main design factor was minimizing cross-sensor interference. This was achieved through optimal spacing, positioning and electronic current control, although it was not possible to completely shield sensors from variable-power capacitive coupling from the GPRS unit under low signal (high-transmitting power) conditions. This coupling adversely affected sensor readings and was treated at post-processing (see Action B1).



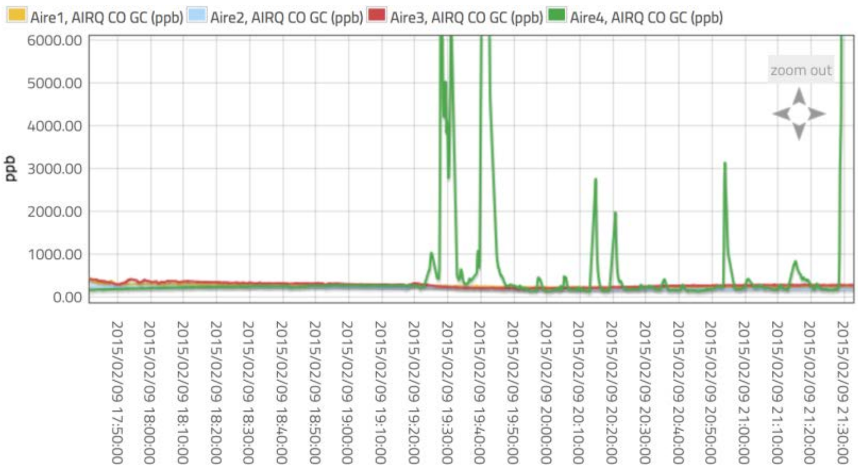
Although the IP67 enclosure is watertight, we drilled gas and sensor windows to allow gas entrance and readings. These were shielded from rain, splashes and insects by cowlings and gas-permeable Teflon membranes. Pressure-equalizing valves were also fitted. An installation protocol was drafted specifying how the devices should be attached to moving vehicles to ensure no effect from impact, dynamic pressure, rainfall or splashes on the sensor entrances. Four prototypes were built and thoroughly tested. Minor design flaws were corrected and 46 production devices were built (total 50 devices). Two configurations were fielded: with (type II) and without (type I) OPC particle counters. Those with OPC had less uptime on account of a higher battery drain, but could nonetheless be used for several hours in continuous operation before requiring recharge.



External and internal views of operating prototypes. Center: Type I (device #15), right: Type II (device #45)

2. Sensor configuration

Individual sensors can be configured independently. We tested several configurations over several weeks of data collection. Sensor operation is divided between "collection time" (CT) and "transmission time" (TT) when data are not read to avoid GPRS interference. CT is split into discrete chunks that average all electronic readings, actually occurring at a 5-Hz frequency. Initial configuration was 10-sec (50-readings) chunks, 10-min CT, 2-min TT. Experiments showed that this tended to interrupt average runs and risked data loss under low GPRS signal conditions, so the times were increased to 30/5 min to fully record most runs with minimal data loss. Averaging time was retained at 10-sec except for fixed (reference) device where integration times were set at 1-min to 5-min to better match the reference readings from certified sensors.



Comparison of CO concentration values supplied by two prototypes located in a clean room (red line) and on a bike cycling through the city (green).

3. Preliminary calibration and field tests

Before starting the monitoring campaign we performed several laboratory and field tests to check the operation of the sensors. Concentrations of the different pollutants read by sensors varied depending on the air conditions, responding consistently to different contamination levels. However, the concentrations directly supplied by the sensors differed among prototypes and from values supplied by officially-certified instruments. This was expected behavior as sensors required calibration (see Action B1), but the consistent readings ensured that calibration was achievable.

4. Checking data transmission

The performance of the data-receiving platform kunakcloud.com was checked, confirming that it operated properly and data could be reliably retrieved. The platform provided plots to check the incoming data, sensor health, and device location, and services to remotely set various parameters.

The platform provided both converted (concentration) data using factory-set parameters, and actual voltage readings. We observed consistent behavior in the raw sensor data (see above) but conversions were inconsistent with calibrated data from certified sources. We set a calibration program to achieve accurate conversions outside the platform. We also observed capacitive coupling at TT, and thus designed a spike filter to remove extraneous data (see Action B1). Both filter and calibration algorithms work on raw readings to deliver usable, accurate concentration levels.

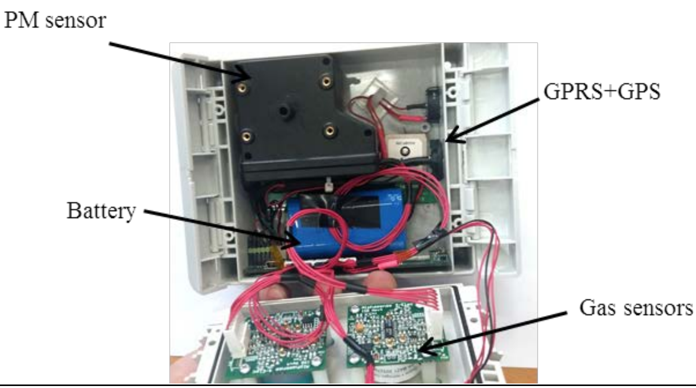
5. **Design and manufacture of the new sensor suites**

Throughout the development of the project, LIFE + RESPIRA researchers have gained considerable experience in the use of air quality prototypes. During this time, we have introduced some technical improvements and developed complex algorithms to correct the influence of the variables that affect the performance of sensors. Taking advantage of this experience, and considering that almost all prototypes already reached the end of their life-span by the end of the monitoring campaign, we decided to reopen this action to construct new prototypes (to be used in the post-project monitoring network) that would include both hardware and software improvements in order to reduce the problems that we faced during the project. This would allow obtaining much more precise pollutant readings as well as making data processing simpler and safer. With these premises, in the last months of the project we worked on the design and construction of the new prototypes. This action involved a constant collaboration between the University of Navarra and the company AICIA (Andalusian Association for Research and Industrial Cooperation), which was the company to which the contract for this activity was awarded.

One of the main challenges of this action has been to significantly reduce the size of the new prototypes. In this way AICIA has carried out a very important miniaturization work, both at the level of acquisition and power electronics and in wireless communication, improving the integration between the set of elements. Thanks to the new design and the use of a miniaturized transmission unit, a 50% reduction in the size of the new prototype has been achieved.

External and internal views of new prototypes.

The miniaturization has involved a conscientious analysis of the protective envelope (Bopla model B141306), taking into account its ergonomics and the location of the sensors to favor the manageability of the equipment without altering the measurement conditions. Thanks to this, it has been possible to include in the new prototype the B series sensors (last version) of the company Alphasense, which are currently the most reliable sensors on the market.



Internal layout of the different components of the new prototype.

In addition to the reduction in size, the main improvement of the updated version has consisted in the isolation of the electronics, avoiding cross-sensor interferences as well as signal alterations produced during the transmission of data to the cloud. Thanks to this it has been possible to completely shield sensors from variable-power capacitive coupling from the GPRS unit under low signal (high-transmitting power) conditions. As we had the opportunity to verify throughout the project, this coupling adversely affected sensor readings, so it was necessary to perform a tedious post-processing treatment of data.

Another significant improvement implemented in the new prototype has to do with the behavior of the Optical Particle Counter (OPC) sensor. One of the problems observed during the Life+Respira project and that has involved the elimination of a significant amount of data was the effect of the speed of cyclists on the operation of the OPC. After analyzing all data generated by the project we observed that above 25 km/h the aspiration of the OPC pump was compromised, so that the equipment became saturated and the reading of particles failed in an ostensible way, giving readings close to zero. To avoid this problem the design of the pump outlet has been modified and also a small isokinetic probe has been included at the inlet of the suction pump, thus avoiding the influence of wind on the air flow.

Finally, another of the improvements introduced in the new prototypes has been the coupling of a solar panel to the equipment, which will allow a continuous operation of them. Logically, this is intended for the deployment of prototypes at fixed points, which is the objective of the post-project monitoring network.

ACTION A2	Sensor Management Plan and acquisition of additional equipment		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	6/14	Planned completion date	9/14
Start date	6/14	Completion date	10/16
Description of the task undertaken:			

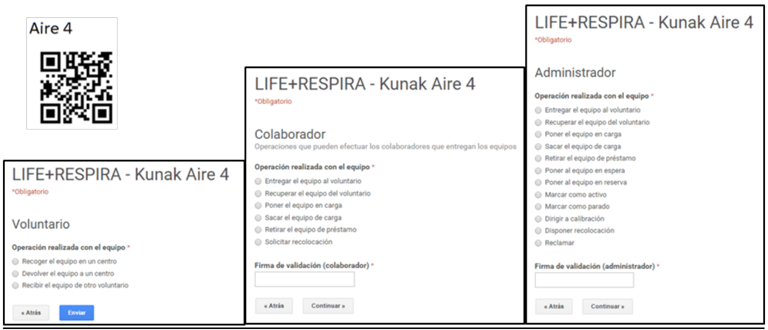
This action consisted of two sub-actions: development of a sensor management plan and acquisition of complementary equipment.

1. Development of a sensor management plan

A management plan was designed for the using of sensor suites (devices) by volunteers. Due to the delay in the construction of the devices (A1 Action), this action ended belatedly but still in time for the data collection campaign.

The sub-action included the following activities:

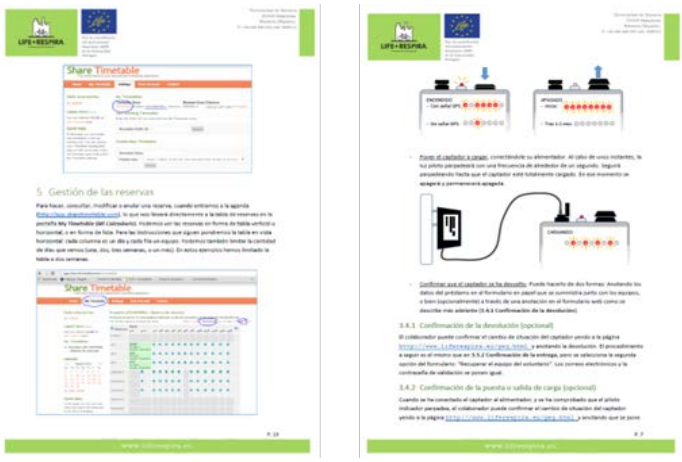
1.1. Identification and inventory of devices. All devices were electronically and visually identified with tags and external QR codes. QR codes link directly to each device control form and allow immediate status update through a smartphone.



QR code sticker of device #4 and the called operation page for 3 profiles (volunteer, collaborator and administrator)

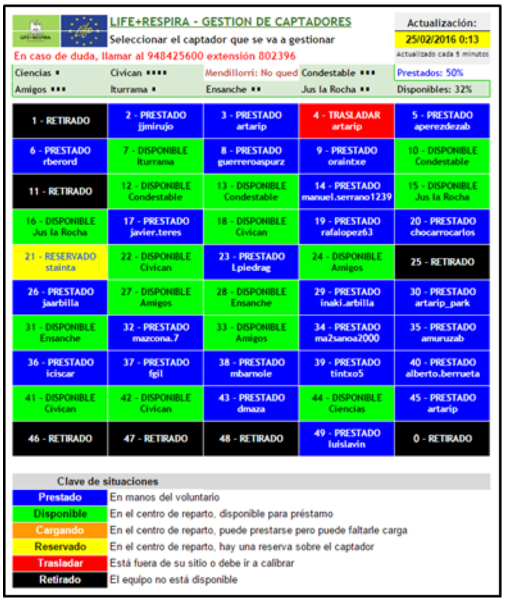
1.2. List of exchange nodes. Nine “front desk” sites were set up as exchange bases for device operations (loan, return, charge, custody, etc.) at venues belonging to University of Navarra, CIVICAN, Civivox, and from 2016 onwards UPNA and UNED. Staff at these centers received a training course in order to correctly perform the delivery and collection of the devices, as well as storage/charging units and codes.

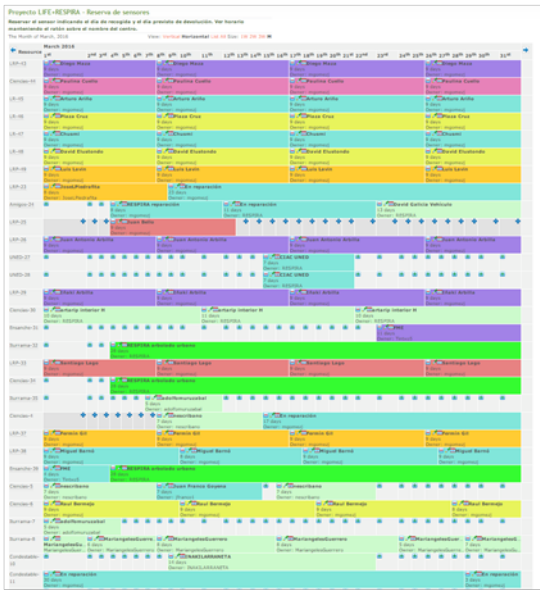
1.3. Operation manuals. Tailored manuals describing all operation and procedures and containing all information necessary for the proper use of the monitoring devices were handed out to all collaborators and volunteers at the training events.



Pages #7 and #13 of the operations manual for node collaborators.

1.4. Device tracking database. All operations with device such as loan, retrieval, removal, return, calibration, etc. are tracked through either QR reading or direct access to a web app that doubles as status and control panel for all devices. Clicking the corresponding control panel button (or reading the QR code on a device’s box) links to a menu of allowable actions for that device. The database and status control were implemented in Google Apps.





Device status and control panel (left) and partial view of the reservation table for March 2016 (right)

1.5. Reservation Service. Volunteers book a device for use for a limited time through a web reservation service (http://app.sharetimetable.com/guest/LIFERESPIRA). The agenda list all devices, their locations, and their availability or loan timeframes. It also allows for a visual inspection of the loan history of the devices and facilitates a follow-up of volunteer time.

Statistics can be derived from the agenda; e. g., about 80 loans per month have been recorded.

2. **Acquisition of additional equipment.**

Measuring equipment WAS acquired by UNAV and GAN to ensure reference data to work with the devices.

2.1. UNAV acquisitions:
   2.1.1. Three AethLabs portable aethalometers for black carbon.
   2.1.2. Three Grimm spectrometers for the analysis of particulate matter.
   2.1.3. 50 Polar band-type heart rate sensors of types RC3 and RCX3.

Both aethalometers and spectrometers were used for calibration and for reference measurements through special fitting in protective, adapted Pelikase cases on bikes. As these devices are rather expensive these were restricted to the research team.

Heart rate sensors were assigned to the most active volunteers after several months of follow-up to determine the best suitable candidates. The activity was synchronized to Action C2 (thence a delay in the start of the activity, scheduled for May 2016).

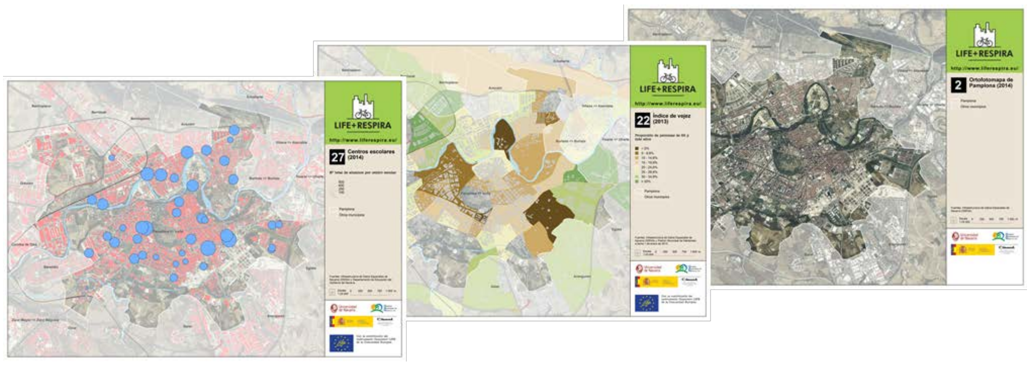
2.2. GAN acquisitions:

GAN acquired the following instruments from ENVIRONMENT, S.A. to provide fixed-point reference data. Instruments were installed by IZASA SCIENTIFIC S.A. at GAN's background analysis stations where calibrations were performed for the project's devices. To ensure that reference equipment provide reliable data, these are verified every two weeks and calibrated quarterly. A linearity study is also performed twice a year. Tasks are carried out by an external contractor (ANALYZERS of GAS, S.L., calibration laboratory No. 145/LC10.103 with ENAC accreditation) under the supervision of technical staff of GANASA. Likewise, a low flow gravimetric equipment was acquired for the measurement of PM_{10} in compliance with the UNE EN 12341 Standard, necessary for the verification of the proper functioning of the automatic particle analyzers.

Instrument & type	Parameter	Serial number	Calibration certificate	International standard system
CO12M - CO analyzer, gas filter correlation	CO	1965	P-5317-1	ISO 4224, EN14626
O342 - O_3 analyzer, UV photometry	O_3	1707	P-5317-3	ISO 13964, EN 14625
AF22M - SO_2 analyzer, UV fluorescence	SO_2	2392	P-5317-4	ISO 10498, EN 14212
AC32M - NOx analyzer, chemoluminescence	NOx	2726	P-5317-2	ISO 7996, EN 14211
MP101M – Suspended PM10, β-gauge monitor	PM10	4783	--	EN 12341

ACTION A3	Analysis of the urban framework		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	6/14	Planned completion date	11/14 (1/17)
Start date	6/14	Completion date	1/15 -31/12
Description of the task undertaken:			

During the first months of the project a wide swath of urban data about the city of Pamplona was collected for uptake into a geographic information system (GIS). The ArcGIS © platform was used. In collaboration with the CIEMAT team in charge of developing the CFD model and calculating the economic cost of pollution, a set of information layers deemed critical for the project's development was defined. These layers included several aspects directly or indirectly related with the cyclist mobility or the quality of the air. The layers were grouped by topics such as relief, climate, hydrography, vegetation, urban morphology, population, economic activities or equipment.



Different layers used for the characterization of the urban framework of Pamplona

The Action proceeded mostly as expected. However, a few of the initially envisaged layers were significantly late in delivery by the corresponding Administration services, or were not delivered at all. However, the largest temporary departure from the initial work plan derived from the difficulties encountered during the construction of the 3D model of the entire city. The best available tool to model the city was the Navarra Cadaster, indeed a very useful source but not without flaws such as e.g. building overlaps. Cadastral maps could not be used without prior manual corrections, which we undertook. Next the corrected model was simplified to fit within the specifications of the calculation capabilities of CIEMAT's resources.

This action remained active until the end of the project, which allowed us to update the basic information of the city as it was available through the public authorities responsible for the corresponding statistics. Thanks to this, new layers were included in the GIS platform that have allowed obtaining a more detailed digital terrain model (DTM) and a full vegetation layer of the municipality of Pamplona.

In the last months three activities were developed to complete this action:

- Upgrading of some context data, according to new information collected.
- Implementation of manual corrections of the cadastral base of streets. This task was necessary to properly analyse air pollution data and for designing the "healthy route planner" app.
- Development of a digital and online urban atlas of the city (Atlas urbano de Pamplona). It was thought that this new product would help to disseminate the material produced in Action A3, putting it at the service of society on a specific website (http://arcg.is/1n5vXL), as well as serving to raise awareness about the LIFE + RESPIRA project.

ACTION A4	Characterization of cycling mobility in the general context of urban mobility in Pamplona		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	6/14	Planned completion date	11/14
Start date	6/14	Completion date	12/17
Description of the task undertaken:			

The characterization of Pamplona urban mobility was performed through the combination of different sources of information:

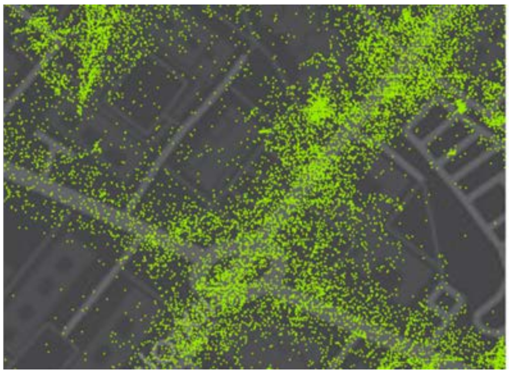
- City traffic data and cycling infrastructure provided by the City Council;
- Data from a household survey on mobility carried out by the Urban Transport Association of the Pamplona District ("Mancomunidad de la Comarca de Pamplona", hereinafter MCP), representing the most complete and up-to-date information available;
- Data from a series of direct cycling gaugings carried out by the City Council. These

gaugings rendered it unnecessary to re-gauge cycle traffic using the same methods. However, a more efficient gauging was proposed through the use of the city's traffic cameras. Despite the various meetings we had with the City Council of Pamplona in order to have these data, it was finally impossible to access the camera records, so this source of information could not be used in the project.

- An extensive and intensive (80-question) survey of urban cyclists in Pamplona, to characterize many aspects of bicycle mobility such as user profiles, habits, their views on infrastructure, their perceptions, etc. The survey was conducted both online through Google forms and on paper issued to demanding users. The forms were discussed with cyclist clubs to check for validity prior to fielding. The survey reached both project volunteers and general public, and elicited a highly significant response level (453 complete questionnaires). A special report on this survey is annexed to this Report.


Bicycle count points in the City Council of Pamplona (left) and the Pamplona District Mancomunidad Association (right)

- ICT tools: the sensors that were used by the projects' volunteer cyclists to record the air pollution values simultaneously showed their location in main streets of the city as they moved about the city. The millions of points recorded clearly illustrate the most important transport corridors, and, what is even more interesting, the location of the type of street in which the bicycles commute.

Cycling mobility corridors recorded by the volunteers

This Action was running in parallel to the action A3 and extended longer than planned due to two reasons:

- Delays accumulated in Action A3 pushed Action A4 to the background until Action A3 could be completed or at least be significantly advanced; and
- The data from the household survey by MCP, which were basic to understand the statistics about traffic choices in the City, and that were relied upon to draw the journey matrix (origin, destination, schedule, and other additional data), were not made available to us until well into the Action's schedule.

However, the delay allowed us to incorporate a traffic model based on the average traffic intensity (ATI), built as an important addition to the traffic survey. The model has been passed on to CIEMAT as a critical input for the 3-D Computer Fluid Dynamics (CFD) model of pollutant distribution that the group is developing in another Action.

All the tasks foreseen in this Action were completed at the end of the project, including Action A4, which remained open because the team preferred to periodically update the mobility data.

ACTION A5	Training and establishment of volunteer teams		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	6/14	Planned completion date	11/14
Start date	6/14	Completion date	9/16
Description of the task undertaken:			

A volunteer recruitment strategy was designed at the start of the project by the Communication and Geography teams of the University of Navarra. The strategy included specific communication actions and contacts with persons specialized in sustainable mobility and cycling known to the researchers. With the collaboration of the City Council, the project was advertised during the European mobility week 2014-2015.

The project appeared often in various media, positively impacting the registration of volunteers. Direct pick-up worked well too, and contribution of already-registered volunteers was significant to both disseminate the project and involve new volunteers. Meetings and electronic and telephone contacts with the Collaborating entities of the project also contributed to spread the campaign on their own environments, and they also provided volunteers among their partners, employees and representatives.

Volunteers

As result of this strategy, the initial group of 114 volunteers was constituted in February 2015. By March 2016 the group has grown to more than 150 people, reaching up to 200 volunteers at the end of the project. All volunteers received a form and filling instructions, and they returned it complete with personal data and daily and weekly cycling habits. The form included provisions about willingness to perform on-demand journeys as well as to complete a medical and respiratory examination.

Launch of the measurement campaign by the volunteers

As the number of interested people exceeded our expectations, and certainly the number of available devices, we established a week-long cap on device loans to ensure that all volunteers would rotate and have periodical chances to contribute data. Two tools were designed to manage the volunteer interaction: a reservation agenda based on the Sharetimetable service to reserve available devices, and an operations verifier based on Google Forms to keep track of loans, operations, exchanges, and change of status of the devices.

Device loans and measurements started in May 2015 with eight Device Exchange Centers (DECs, in Spanish CIACs) participating: Two on campus at the University of Navarra (UNAV), five Municipality sports and leisure buildings (CiviVox), and one Cultural Foundation (Fundación Caja Navarra: CiviCAN) building. In March 2016 two additional DECs were incorporated, one in each of the other two Universities with campus in Pamplona: Public University of Navarra (UPNA) and National Distance Education University (UNED). Volunteers could reserve, retrieve, and return devices at any of these ten centres scattered all over the city at their convenience, usually along or near their usual paths during their daily journeys.

As the uniformity of coverage increases with the variety of paths, throughout the development of the project the possibility of adding new people as volunteers was kept open. This also helped ensuring a more even turnover with the devices with less dead time, as the number of daily journeys the average volunteer travels is naturally low, their schedules may have voids, and their level of commitment is rather variable. Even so, very few volunteers dropped out.

Training and equipment

In April 2015, with more than 120 people already registered, we held two joint training sessions (on separate days to facilitate participation) with a total enrolment of 113. Training was considered essential to obtain uniform data collecting behaviour and to commit volunteers. People who could not attend the formal training sessions were offered alternatives. In June, 23 additional volunteers had their training through four joint and five individual training sessions. Thereafter, all newly recruited volunteers were trained individually.

Training included how to handle, mount, and operate the devices; the use of the booking agenda and handling of reserves with the DECs; the registry of events (borrowing, returning, exchange, etc.); and the attribution of path typology through a mapping application. Volunteers were also provided with some additional, LIFE+RESPIRA-branded gear to be used during journeys: carrying basket; helmet; reflective (day & night) high-visibility vest; raincoat; lights; etc.

Other volunteer functions

A selection of volunteers committed to carry on with the medical study. They were provided with heart rate meters and underwent a medical examination including pulmonary capacity in May 2016. From then on they started to use the heart rate meters during their journeys. Thanks to the commitment of this group of volunteers, more than 1.5 million records obtained during 5000 km of commuting were obtained.

ACTION B1	Calibration of the pollutant measuring electrochemical sensors		
Coordinator	UNAV	Participants	GAN
Action status	Finished		
Planned start date	2/15	Planned completion date	3/17
Start date	1/15	Completion date	12/17
Description of the task undertaken:			

Electrochemical sensors integrated within each sensor-recorder-transmitter suite (hereinafter “device”) supplied direct voltage readings that needed to be converted to actual gas concentration through appropriate functions and parameters. This task ensured that this conversion was accurate, reliable and repeatable, producing pollution readings that could be trusted as true.

Rationale

Each individual sensor was supplied with a factory-issued data sheet including conversion functions and parameters experimentally obtained for its batch. Gas sensors work by measuring the potential resulting from the electrochemical reaction between the gas to be analyzed and an electrolyte, within which a working electrode (WE) is embedded, respective to a reference zero electrode (AE) outside the electrolyte. A regression between potential and concentration is used to obtain the slope, or conversion factor.

However, AE is subject to its own potential w.r.t. the board electronics, resulting in an offset. Once mounted in the device offset and slopes can vary or drift, resulting in unrealistic readings (e.g. negative concentrations). Also, electrode readings are dependent on ambient temperature. Although factory supplied, this dependence factor is coarse and drifts over time.

In addition, other factors compromise readings. Sensors can show capacitive coupling with the GPRS system when transmitting data. This results in lingering, abnormal WE readings.

Therefore, conversion functions need to be optimized and the calibration parameters need to be experimentally obtained for each sensor in each device. This is accomplished by reproducing the factory test conditions, having devices read air that is synchronously analysed by certified methods. Correlating device readings with certified readings allows finding the correct, individual sensor-specific parameters to be used for extended periods.

Components in task

We identified six separate components for the calibration task:

1. Ensuring that abnormal readings from capacitive coupling are identified and discarded.
2. Ensuring that device's and reference readings are matched.
3. Finding the appropriate temperature-dependence factor.
4. Ensuring smoothness in the conversion algorithm.
5. Finding the correct offset for each sensor and the correct slope for each WE.

Methods and algorithms

We used a three-pronged calibration strategy to cover most sources of variations:

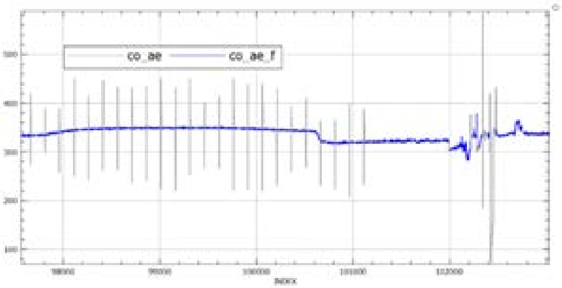
a) Statistical experiments over the entire dataset;
b) Co-location experiments alongside official reference monitors; and
c) Laboratory experiments with zero-air (no pollutants).

We performed six types of analyses:

1. Time series analysis on the AE readings. This allowed discovery of the capacitive coupling and resulted in an ad-hoc filtering algorithm for compromised data points through the use of an adjustable moving variance window and threshold values. These sets were done over the entire dataset.
2. Time correlation between sensor readings and reference readings obtained from certified analysers. This allowed discovery of exact time offsets and drifts between reference and experimental data by applying different time lags to maximize the correlation.
3. Autocorrelation analysis to intercalibrate sensors and obtain a relative offset for each sensor against the average of all sensors of the same type, and the correct post-integration AE offset.
4. Polynomic Regression analysis from the experimental data on temperature/voltage interdependency for each sensor, in order to obtain the regression parameters to be used in the temperature correction.
5. Linear Regression analysis between each sensor and a reference source to obtain the slopes for the voltage-concentration conversion functions.
6. Zero-air experiments under varying, controlled T and RH conditions to determine actual electronic offsets, to replace factory-supplied offsets and their dependencies.

Algorithms and filters were created as xBASE programs. Correlations and analyses were performed in a variety of environments (VFP, Excel, R, TableCurve, Lineplot.)

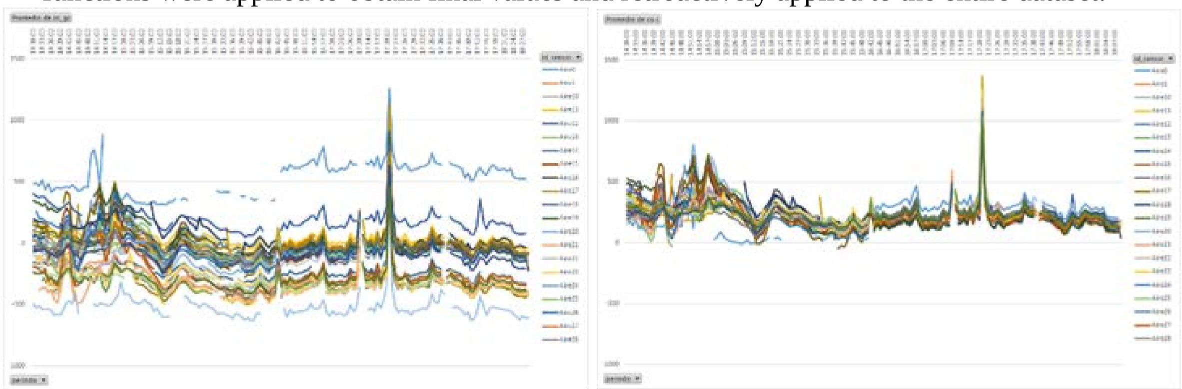
1. We collected calibration data from synchronous measurements of all devices and reference systems in seven separate locations and periods spanning the entire experiment.
2. We created a series of prototype spike filters and experimentally obtained appropriate filter parameters to consistently filter out capacitive coupling abnormalities.



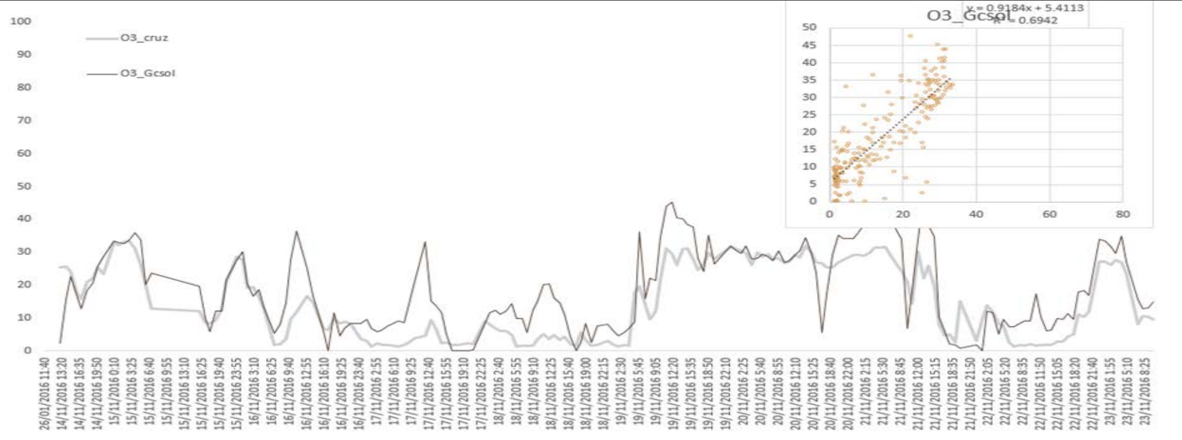
Raw data (grey) and after capacitive coupling has been filtered out (blue)

3. We correlated sensor data with five-minute official data from calibrated sources, and found a time lag between both datasets that, when corrected, maximized correlation.
4. We performed polynomial regressions on the temperature data and substituted the original, three-point temperature correction levels with the regression function, ensuring smoothness of data irrespectively of temperature.
5. We obtained electronic offsets for all gas sensors at zero-concentration and replaced all factory-supplied parameters with experimental parameters.
6. We used Generalized Linear Programming and regression to determine experimental sensitivity values by finding the minimal divergence between each sensor and the corresponding value of a reference sensor co-located with an official, calibrated and validated source.
7. Finally, we applied the experimentally-obtained calibration parameters, regression parameters, correction factors and polynomial functions on the electronic readings of each sensor to obtain the corrected gas concentration.

Since the previous report, two zero-level experiments were executed. The difference between these values and the initial ones were used to calculate the drift of the sensors. New sets of functions were applied to obtain final values and retroactively applied to the entire dataset.



Raw readings (left) and offset-corrected (right) for CO (all sensors)



Correlation between official data (gray) and sensor data (black) for ozone during a co-location run

ACTION B2	High resolution modeling of urban air quality		
Coordinator	CIEMAT	Coordinator	CIEMAT
Action status	Finished		
Planned start date	6/14	Planned start date	6/14
Start date	6/14	Start date	6/14
Description of the task undertaken:			

In Task B.2. CIEMAT worked in air quality simulations of two different scales: 1) A Pamplona district (domain: 2 km x 1.6 km) in order to evaluate the model with the measurements obtained in the experimental campaigns carried out in this zone and with the data from an air quality monitoring station and 2) the entire Pamplona city (5.4 km x 7.7 km). Additionally, very local scale simulations were done to study the effect of *vegetation* barriers. Particularly, *CIEMAT* has been involved in the following activities of this task. Some of them are related to other technical tasks as A3, B3, B4, B5, B7, C1 and C4 besides other tasks related with result dissemination or project management.

B2.1 Preparation of the input data, information processing and adaptation of CFD Street-canyon model requirements:

Urban digitized morphology: CIEMAT has developed different urban morphologies at district level (2 km x 1.6 km) and a city-level (5.4 km x 7.7 km). At district level, we have modelled the buildings both under a simplified arrangement (categorizing the buildings by an average height and smoothing their contours) and more realistically (taking into account the actual building heights and smoothing their contours). At city-scale, CIEMAT has worked on urban morphologies with different levels of detail based on the information provided by the University of Navarra (Task A.3), to generate their corresponding 3D CAD models by means of AutoCAD 2016, which could be imported by CFD Street-canyon models. Finally, the Pamplona morphology considered in the CFD model simplifies some details of buildings, such as internal courtyards, but takes into account the true height of buildings. More complex arrangements were discarded due to an expensive computational cost. Concerning topography data, a plain city was assumed due to some computational problems found when the real topography was taken into account.

Urban tree cartography: regarding the urban trees, satellite images from Google Earth have been used to locate the trees within the streets, determine the type of leaves (deciduous or evergreen, without regard to the type of species) and set their bases and their canopies. A 3D CAD model has been done by means of Autodesk Inventor professional 2016 in which only rows of trees within the streets and squares have been taken into account. This 3D model is compatible with CFD Street-canyon models. This has been implemented in the district simulations. No more accurate urban tree data were available on time.

Emissions: Traffic is the major source of pollutants in Pamplona (for example, 82% of NOx emission are from traffic). Data of daily average traffic intensity of a Pamplona's district domain and for the complete city provided by the University of Navarra has been used and processed with ARCGIS to create a 3D CAD model compatible with CFD Street-canyon model. The exact number of traffic lanes by street has been taken into account for the district domain while for the complete city domain, the emission data were computed with a resolution of 5x5 m^2.

Meteorology: Data from two meteorological stations of Pamplona (Pamplona (ETSIA) UPNA and Pamplona GN) have been analyzed, in order to set atmospheric boundary conditions on the CFD model (mainly, wind direction and reference velocity at 10 m height) for the simulations to city-scale. The data have been analyzed in terms of hourly averages.

Air quality data: NOx, NO and NO_2 data of three different air quality monitoring stations (*Iturrama*, *Rotxapea* and *Plaza de la Cruz*) in Pamplona have been processed with the purpose of using experimental data to test our CFD simulations. These data have been analyzed in terms of hourly averages in order to obtain time evolutions of an annual mean day and the four seasonal mean days.

B2.2 Calibration and validation of CFD model.

The CFD model has been evaluated from the numerical and experimental points-of-view. From the numerical point of view, at district level, different meshing models have been carried out in order to determine the optimal spatial resolution. At city level, different meshing models have been also carried out in order to determine the maximum CIEMAT's computing performance without losing quality of the results.

From the experimental point of view, comparisons between CFD results from district simulations and NOx data of Plaza de la Cruz air quality station for several periods of time have been conducted taking into account progressively aerodynamical and deposition effects of the urban trees. The results show a good agreement of CFD simulations against experimental concentration of Plaza de la Cruz air quality monitoring station, especially during winter time (Fig. 1).

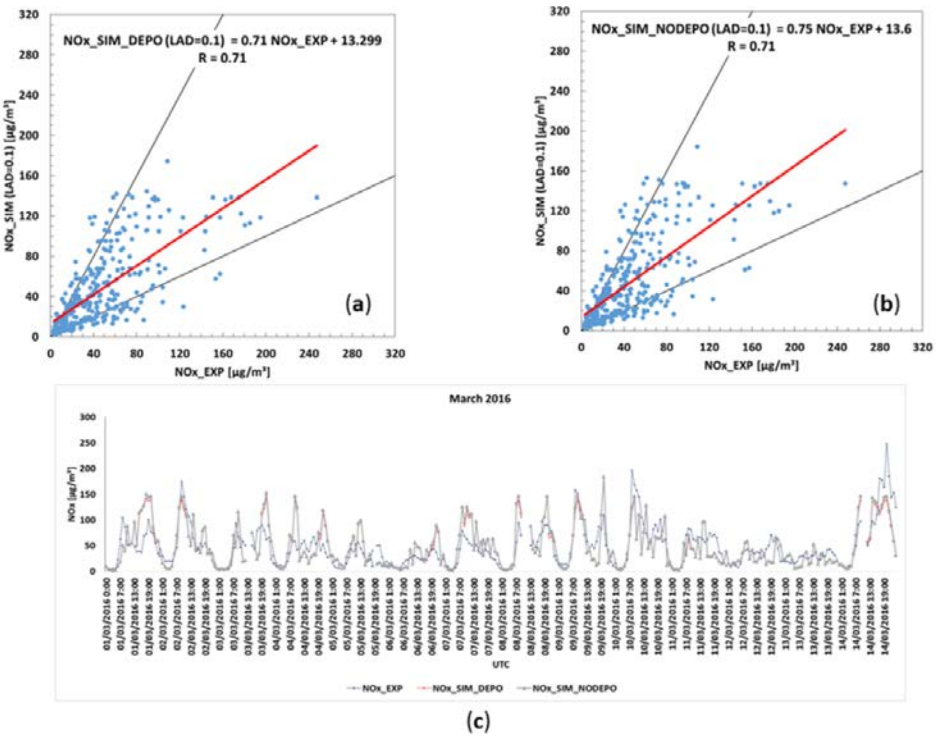


Fig. 1. (a) Scatter plots of modelling results considering pollutant deposition; (b) Scatter plots of modelling results when deposition is neglected. (c) Time series of concentrations at the monitoring station position from 1st March to 14th March. (Santiago et al., 2017).

Additionally, a more detailed evaluation was done with black carbon data obtained during the experimental campaigns carried out with fixed microsensors in this area (Task B.4) including measurements at different heights above ground level in different streets with and without tree in the sidewalks. Furthermore, experiments to study the effect of vegetation barriers were used to validate the vegetation parameterization implemented in CFD model (Task B4). Table 1 shows the concentration reduction between a red point (just before the barrier) and two points (green and blue points), one after the vegetation barrier and the other at the same distance as green but outside of the vegetation barriers. CFD average results for the three wind directions are 26.6% and 45.3% at the blue and green points, respectively, showing a good agreement with the experiments.

Table 1. Experimental (Exp.) and CFD relative concentration reduction of concentration respect to a point red point for the three wind directions investigated.

Measured./CFD	Height of points	Wind direction	Percentage of reduction	
			Blue point	Green point
Measured	0.3	~ 0°	20.0%	44.3%
CFD	0.3	0°	26.5%	44.6%
		45°	21.5%	46.1%
		-45°	31.9%	45.1%

At city scale, we have done the evaluation of the whole city simulations (see next section) by using air quality monitoring stations of the city measurements, and experimental data from cyclists carrying sensors while travelling in the city during the project.

B2.3 Simulations of Pamplona's air quality.

The pollutants maps (NOx maps, in µg/m^3) at district scale at pedestrian level (at 3 m height) have been simulated with a very high resolution (2 meters approx.) depending on the atmospheric conditions. The aerodynamical and pollutant deposition effects of trees have been analyzed for typical wind directions at Pamplona (NNW, NW, W) (Fig. 2.) and their impacts have been quantified depending on leaf area density of trees. These results related with effect of urban vegetation are discussed in next section B2.6.

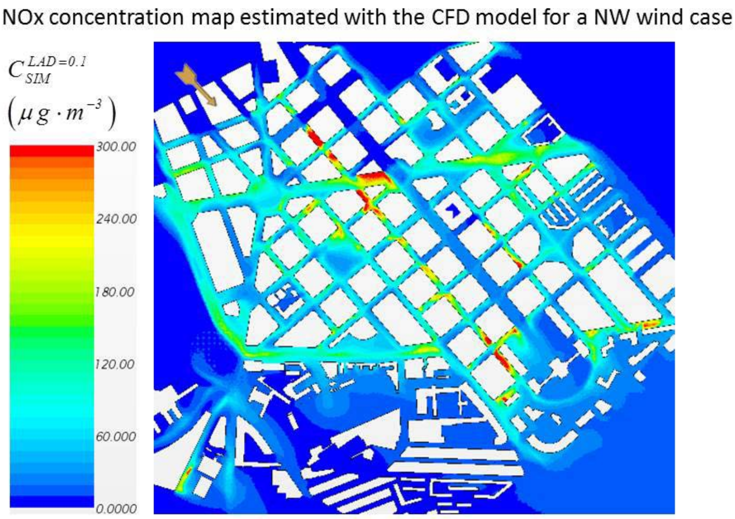


Fig. 2. CFD simulation of NOx in the Plaza de la Cruz district for a winter case with NW wind direction.

Concerning the simulation of the entire Pamplona city, the CFD simulations were done. They took long time due to the very important computational cost needed. The computational domain has 45 millions of grid cells covering an area higher than 35 km^2 with a spatial resolution of 5x5 m^2.

The pollutants maps (NOx, NO_2 and NO maps, in µg/m^3) at city scale at pedestrian level (at 3 m height AGL) have been simulated with a very high resolution (5 meters approx.) depending on the atmospheric conditions. 16 simulations were done, one for each of the wind direction sector. Then, high resolution maps of average concentration of pollutants at 3 m above the ground were computed using a procedure of weighted-average called WA-CFD-RANS, which takes into account the statistical frequency of wind direction and speed along selected time periods.

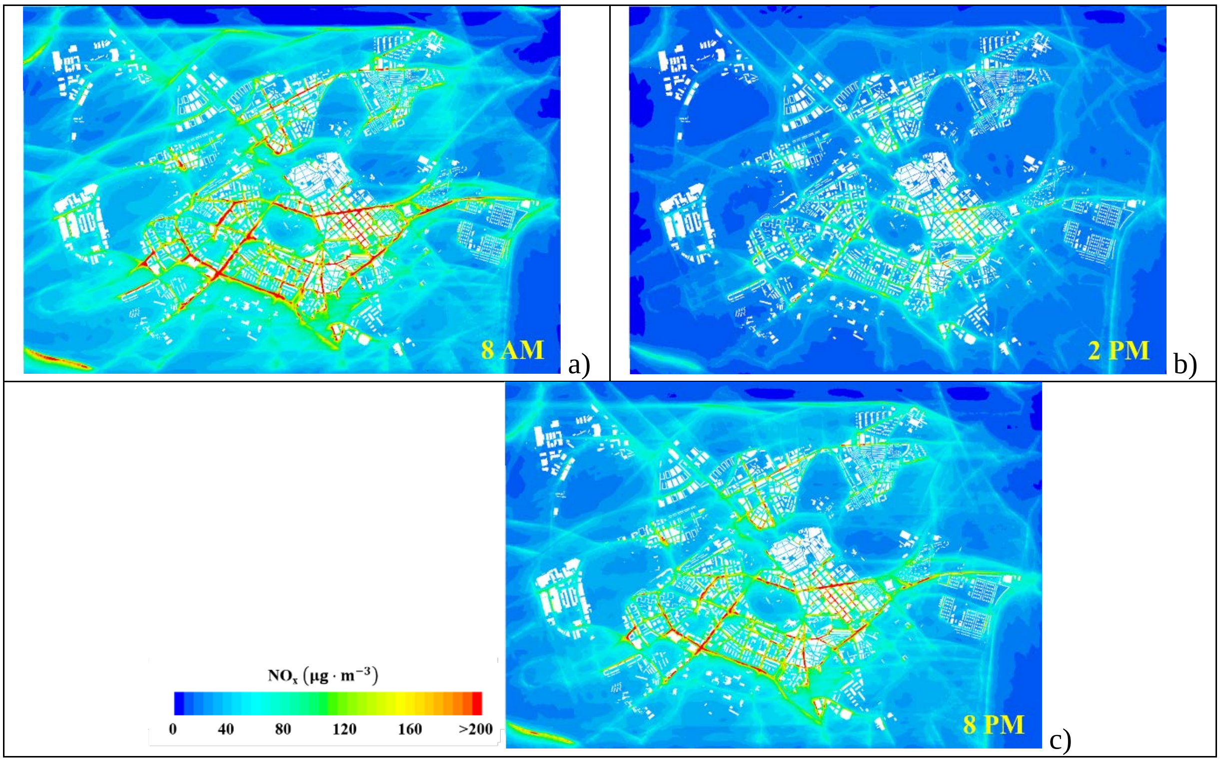
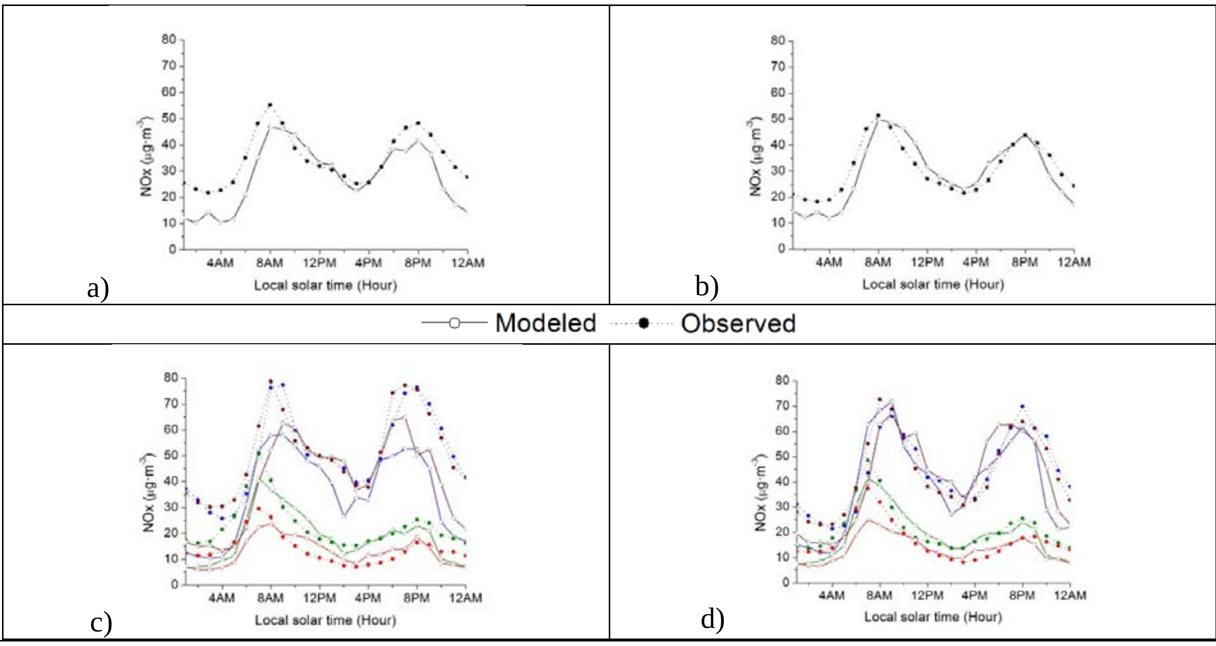


Fig. 3: High resolution 2016 annual hourly average maps of NOx concentration at: a) 8 AM, b) 2 PM, c) 8 PM, all of them local solar time. Red areas indicate NOx concentrations greater than 200 µg·m^{-3}.

In addition, maps corresponding to the hourly evolution of the NOx concentration in an annual mean day of 2016 were computed (Fig. 3). The results of the simulated annual mean day and the seasonal mean days were compared with data of two air quality monitoring stations of Pamplona showing a very good agreement (see Fig. 4).

These results have been used by other groups in task C4 and next for the healthy route planner to be developed in task B.5.



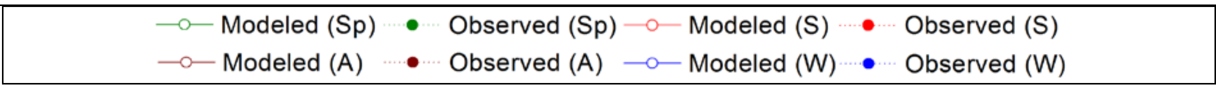


Fig. 4: Comparison between modelled and observed hourly NOX concentrations for 2016. Average annual day at station: a) Rotxapea, b) Iturrama. Seasonal average day at station: c) Rotxapea, d) Iturrama.

B2.4 Estimates of population exposure to air quality in streets.

During LIFE+RESPIRA project, different experimental campaigns of volunteer cyclists, carrying microsensors in their bikes which collect data every 10s of O_3, NO, NO_2, CO and PM_{10} concentrations, were carried out. One of the aims was to know what pollution exposure of cyclist in Pamplona is. Approximately 10 million data records from microsensors were treated in order to remove outliers, pooled by hour and spatially-averaged in cells of 50 × 50 m^2. This cell size is related with the sampling period (10 s) and the average speed of the cyclist, 5 $m \cdot s^{-1}$. The 2016 spatially-averaged hourly maps of annual averaged NO_2 concentration at pedestrian respiration level have been used for the CFD model evaluation. From these maps, the corresponding 2016 spatially-averaged annual concentration map of NO_2 has been obtained considering only the cyclist cells of the different annual hourly GPS position maps (cyclists' cells) with measurements at all hours, which has been also used for the CFD model evaluation. Some limitations are associated to these experimental data, namely: 1) All these spatially-averaged concentration maps cover only the roads, streets, and other areas accessible to cyclists; 2) Measurements from cyclists are accompanied by some spatial uncertainty due to the measuring errors and sampling period of the microsensors and the movement of cyclists (GPS uncertainties), and 3) the total number of cyclist measurements in some cells should not be enough to obtain a representative average concentration, especially at night. Therefore, to overcome these limitations in the CFD model evaluation with these experimental data, it is computed and compared hourly and annual average concentration spatially averaged district-by-district (Fig. 5).

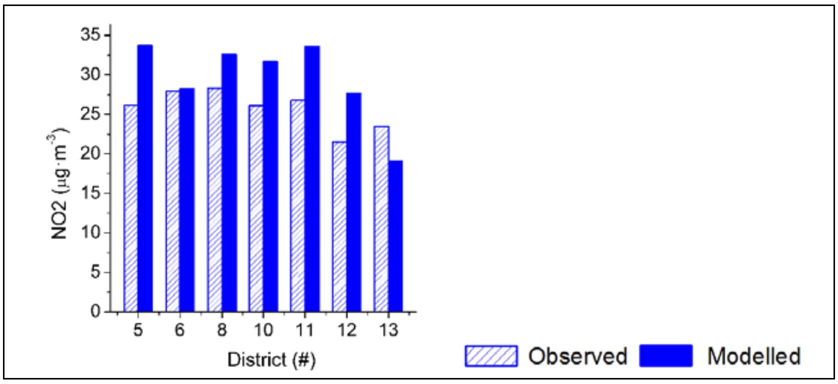


Fig. 5. Comparison between modelled and observed NO_2 average-concentrations. Average annual day at districts 5, 6, 8, 10, 11, 12, and 13.

Results indicate that, in average, the observed concentrations are slightly overestimated by model results, according to the previous results and the annual averaged daily cycle is quite well simulated. In summary, considering the positive results of the model evaluation both, with point as mobile measurements, the obtained average maps from models are reliable enough to represent suitably the air pollution in Pamplona and to estimate the population exposure in order to study the traffic related NO_2 health effects and their associated externalities (Task C4). Additionally, the spatial representativeness of the air quality monitoring stations in the city has been estimated. The results indicate the network of stations represents quite well the air quality of the city but some streets with higher NO_2 concentrations are not well represented by the stations.

From the CFD simulations at city-scale, average NO_2 maps have been obtained in cells of 100 m x 100 m (typical size of blocks in the simulated district) (Fig. 6). These maps have been used to estimate population exposure maps and to calculate health risks (Task C.4) (Fig. 6).

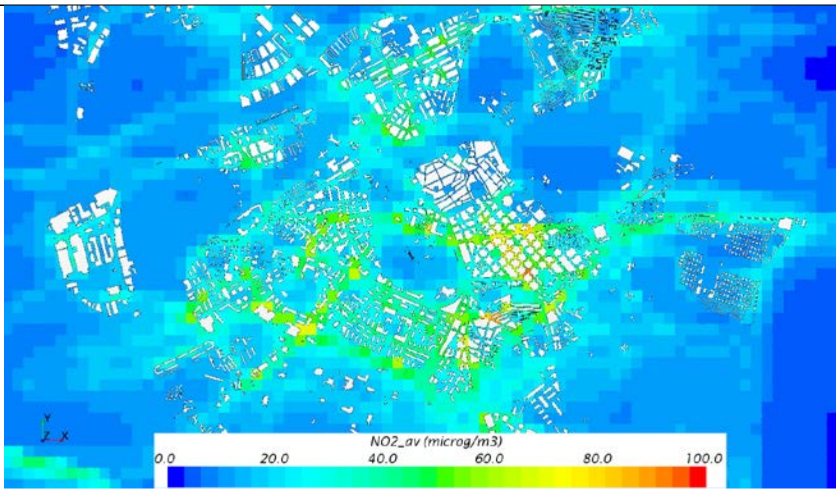


Fig 6. Annual averaged NO_2 map aggregated in grid cells of 100x100 m.

B2.5 Analysis of the simulation results and qualification of the streets.

High resolution maps of pollutant concentrations have been used to identify the highest polluted streets. The highest levels of concentration at Pamplona occur during peak traffic hours: at 8 AM and at 8 PM as shown in Fig. 4. In the corresponding maps to both peak hours, the red areas are located, on the one hand, close to interurban, arterial and distribution roads (Fig. 3 in Section B2.3), as expected, since here the observed traffic levels are intermediate and high. But, on the other hand, there are also red areas close to local roads in some central districts where the observed traffic levels are lower but the streets are narrow (street-canyons) with low ventilation and generally, this area is surrounded by streets and avenues with high traffic.

B2. 6 Simulation of scenarios of pollutant reduction.

We have worked in simulating the experimental campaigns in some streets of Pamplona in order to analyze the role of the vegetation respect to the air quality. We are mainly focused on finding out what effect is dominant: aerodynamical effect (trees disturbed the air flows reducing ventilation) or the pollutant deposition one (trees are sinks of pollution). Several cases with different Leaf Area Index (simulating trees with and without leaves) were studied. Our main finding is that the dominant effect is the reduction of ventilation increasing air pollution in a street with trees and traffic of motor vehicles. The effect of planting virtual trees in a street (which did not have trees) was also studied showing the trees in a traffic street can affect to the distribution of pollutants not only in this street but also in the other next streets (see Fig. 7).

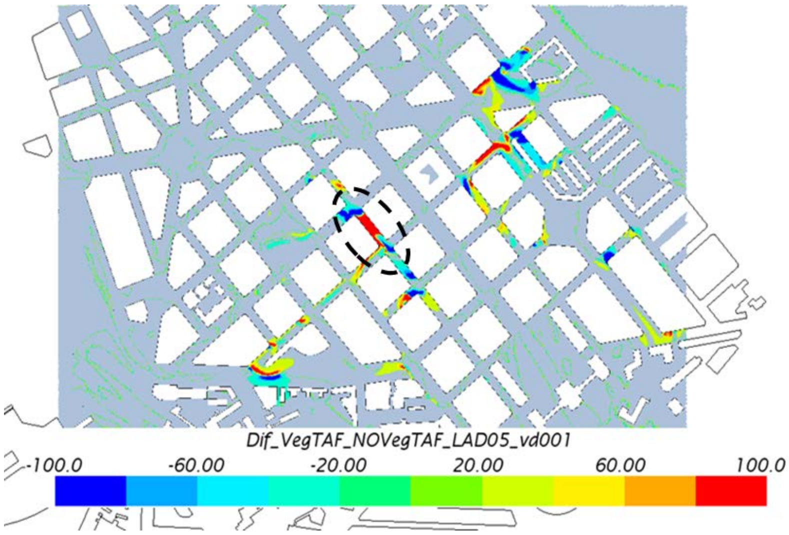


Fig. 7. Differences of concentration comparing a real case (street without trees) versus a virtual case (street with trees). Red indicates that the concentration increases in the new vegetation scenario and grey indicates the zone

where the differences are lower than 20 µg m^{-3}.

The mitigation effects of vegetation barriers on pollution corresponding to the effect of hedges and trees located on the sidewalks of large avenues with traffic were studied. By means of measuring experiments in real streets (see B4) and simulations with CFD models replicating the experiments in real streets and also simulating different configuration of barriers to evaluate their efficiency. Results showed that the concentration of pollutants behind the hedge at ground level is reduced significantly but at the level of the hedge height the estimated concentration exceeds that which would be at the point without hedge. The sheltering of barrier is much effective when trees are present (BASE and NEWTREES cases). Trees induce a slight reduction of wind speed above z = 2 m and an important increase of TKE reducing the concentration (Fig. 8). We must also consider what would happen in other configurations, for example, the effect of a building (driveway-hedge-sidewalk-building). It shows that there is still a fairly open field of research.

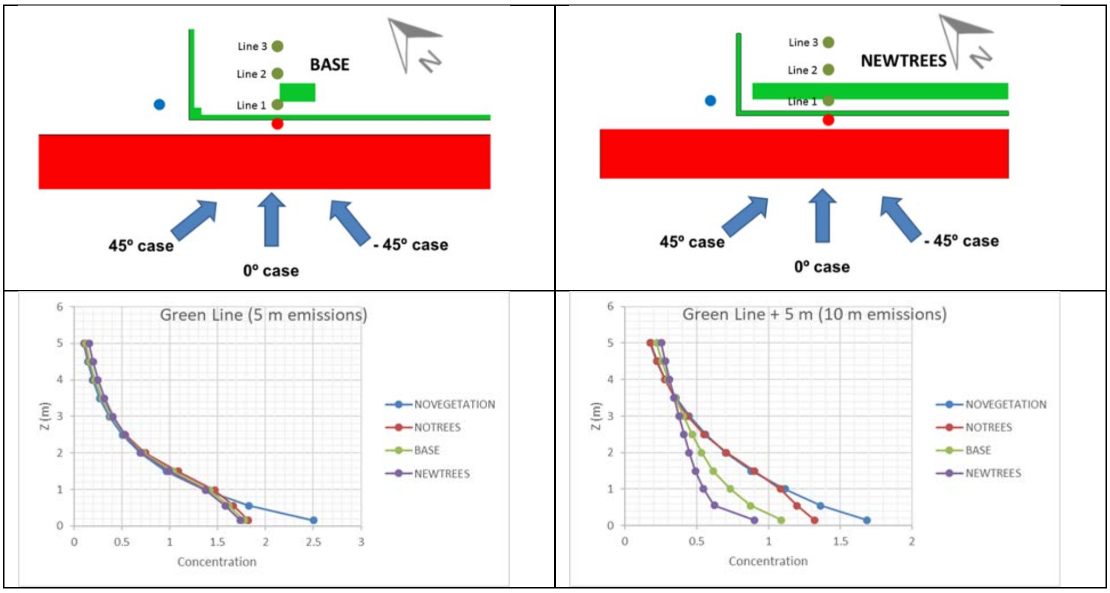


Fig. 8. Configurations of vegetation barriers (top figures) and vertical profiles of concentration at line 1 and 2.

The effect of banning traffic and pedestrianizing some non-main streets around Plaza de la Cruz, considering the redistribution of traffic has been also studied. A set of simulations focused on the district of Plaza de la Cruz have been carried out assuming different scenarios of reduction or total restriction of traffic applied to the secondary streets of that district. It has been considered that these measures are applied to a different number of streets, that is, the reductions or restrictions of traffic in a set of smaller streets (just those closest to Plaza de la Cruz) and another area much wider that encompasses this mentioned area (extending to the East). It has been considered the reduction of 100% (total traffic restriction), 80% (partial restriction) and also the redistribution or diversion of restricted traffic in the affected streets towards the main avenues that surround those areas (0% without redistribution, 30% and 60% redistribution). It was estimated that the reduction of pollutant average concentration in Plaza de la Cruz is range from 70 to 40%. However, the increase in pollution in the surrounding large avenues and nearby streets can be very significant (above 80 % in many sections) in the scenarios assuming the redistribution or diversion of banned traffic (Fig. 9).

Finally, simulations of analyzing the effect of photocatalytic pavements have been done.
CFD simulations of the NOx dispersion were carried out in the Plaza de la Cruz area considering that in an area of about 400 x 400 m^2, photocatalytic material was installed on the sidewalks (Fig. 10). Analysing the relative difference between the concentration around the breathing level of pedestrians and cyclists, obtained in the case of having photocatalytic material against the case of not having it, we can see that the reduction of the maximum concentration of pollutant in Plaza de la Cruz does not reach 6%, and on average it would be between 3 and 4%. In the whole of the area, the average reduction is around 2 %. Therefore, the photocatalytic material is not entirely effective in reducing pollution in an urban area and is clearly less effective than other measures such as traffic restriction

(Fig. 10).

It is important to point out that the modelling activities shown in this report are quite connected to the other projects such as LIFE MINOx STREET (for testing the impact of photocatalytic pavements investigating real cases in the Alcobendas town) or the TECNAIRE project (a Madrid Regional Government project, where high resolution CFD modelling is being carried out for some districts of the Madrid City.

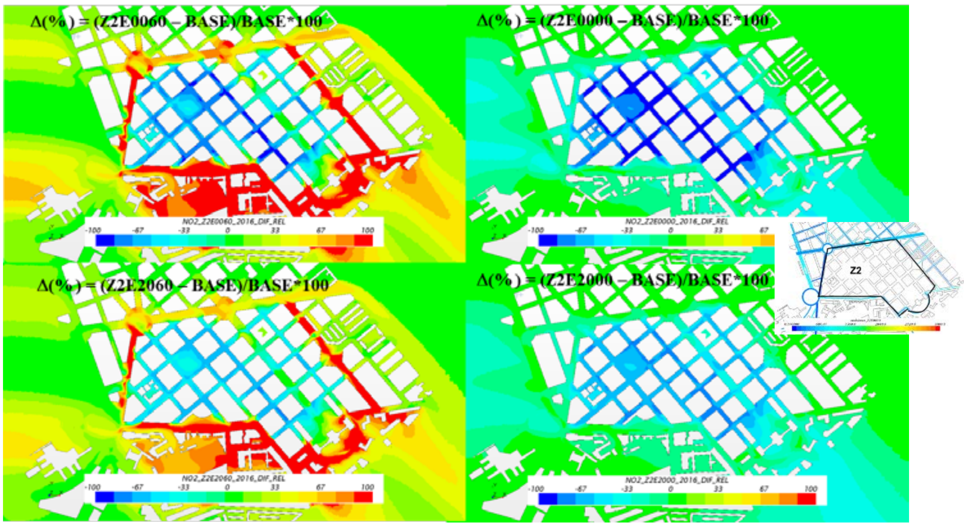


Fig. 9. Relative differences of NOx concentration in the District of Plaza de la Cruz estimated for the cases in which the zone indicated in the map above have been applied to different traffic restrictions: traffic reduction 100 % (above) and reduction of traffic by 80 % (below); and with different redistribution of traffic: with 60 % of the traffic diverted to the surrounding avenues (left) and without diverted traffic (right).

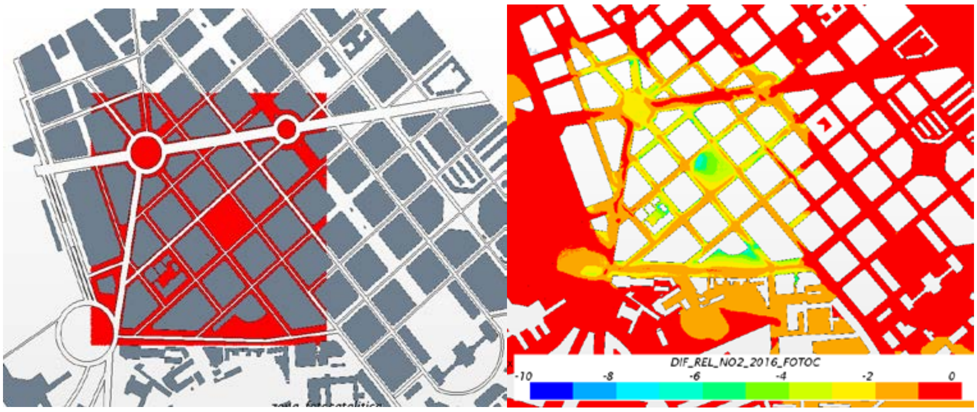


Fig. 10. Relative difference in NOx concentration (right) in the District of Plaza de la Cruz estimated for the case where photocatalytic material is installed on the footpath in the area indicated in red on the map on the left.

ACTION B3	Photocatalytic pavement installation and demonstration of their effects on air quality		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	5/15	Planned completion date	8/15
Start date	5/15	Completion date	5/17
Description of the task undertaken:			

The main objective of this action was to test the effectiveness of a photocatalytic pavement in the destruction of urban contaminants, mainly those related to road traffic. To perform this test, the ideal situation would be a street with heavy traffic and long enough to establish two differentiated areas: control, and paved with photocatalytic tiles. Given these requirements we conducted a detailed study of the urban framework of Pamplona, selecting an area that met these criteria. The chosen street was the Avenue of Navarra, which features a bike lane close to a road with high traffic density. Moreover, the length of this street allows differentiating two areas (with and without photocatalytic pavement) that share the same characteristics with respect to vegetation and building proximity, slope, orientation, etc. Consequently, the homogeneity of both areas avoids the influence of other variables than pavement on air pollutants, allowing a more accurate study of the influence of the pavement.

View of the bike lane paved with Ecogranic

Once selected the place, the next step was to pave a stretch of the bike lane. However, this action suffered a significant delay due to two circumstances:

1. We decided to postpone the installation of the photo-catalytic pavement until we had collected a large amount of data on pollution levels in the area;
2. As the baseline data collection was concluded, the newly-elected City Council paralyzed the agreements we had reached with the previous Council, including the installation of the pavement.

For several months we had to work with the new stakeholders, explaining the project from scratch and trying to overcome the public opposition we encountered with the councilman of mobility of Pamplona, who voiced his flat refusal to collaborate with the project. He gave no grounds for this. Given this standstill, we wrote a letter to the new Mayor of the city, explaining the main features of Life+Respira project and showing our surprise at the unexplained refusal of one of the members of the City Council to collaborate with the project, because we believe that the action derived therefrom may be a great benefit to the city.

Finally, the Mayor of Pamplona answered in April 2016 showing his support to our project and during the second week of May we received the approval to the installation of the pavement, which was executed in June. As a result, the experimental measurement of the potential effect of the photo-catalytic pavement was achieved from June to December 2016, period that was considered long enough to collect reliable data of traffic-related air pollutants by volunteers cycling over the control area and the paved surface.

Pollutant	**Control** (ppb)	**Ecogranic** (ppb)	**Total removed** (ppb)	**Removal** (%)
NO	147.6	81.1	66.5	45.1
NO_2	53.0	36.5	16.5	31.2
NOx	200.6	117.6	83.0	41.4

The results obtained during the NOx measurement campaigns carried out in the paved area and in the control area (unpaved) by the use of NOx monitors showed that the Ecogranic pavement was capable of degrading up to 41% (mean value) of nitrogen oxides at ground level. This percentage of degradation is very important and demonstrates the role that this type of photocatalytic pavements can play as a passive measure for the improvement of air quality. However, these results were not obtained when the NOx measurements were performed at 1.5 m from the ground (cyclist volunteers), which indicates that the photocatalytic degradation is a superficial phenomenon. Regarding other pollutants, like particulate matter, black carbon and volatile organic compounds, no significant reductions were observed in the paved area with respect to the control.

ACTION B4	Quantification and modeling of air quality improvement by action of urban vegetation		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	7/14	Planned finish date	5/17
Start date	7/14	Finished date	12/17

Description of the task undertaken:

Characteristics of the urban tree vegetation of Pamplona

The LIFE+RESPIRA project has evaluated the characteristics related to air quality of the urban trees in the city of Pamplona (Figure B4.1). The city has more than 87,000 trees of more than 300 species, which represents a significant diversity of urban trees. However, the 10 most abundant species represent 62% of the wooded area (Table B4.1), and more than a third of the species are only represented by less than 10 trees in the entire city. Interestingly, only 9% of Pamplona's trees are evergreen, which indicates that a very small percentage of urban trees can provide air quality-improvement services during the winter, the time of the year when air pollutant concentrations tend to be higher.

Table B4.1 shows the available information on the traits related to air quality of the most abundant species present in Pamplona. Most of the 10 most abundant species have a medium capacity to mitigate air pollution, both gaseous pollutants and particulate matter. But it should be noted that 6 of the 10 most abundant species produce pollen with a high allergenicity index. In addition, 9 of them present medium or high emission rates of BVOCs. These results indicate that air quality in Pamplona could be improved by incorporating a larger surface area of evergreen species and tree species that maximize air pollution uptake.

Species	Surface (%)	PFP	Air pollution mitigation	Stomatal conductance	Allergenicity	BVOCs emission
Platanus x hispanica	16,9	2,3	Medium	65	High	High
Populus nigra	11,6	-2		110	High	High
Populus x euramericana	9,4	-2			Low	High
Aesculus hippocastanum	4,6	2.7	Medium		Medium	Medium
Populus alba	4,2	-2	High	289	High	High
Celtis australis	3,5			159	Medium	Medium
Ulmus minor	3,3			94	High	Medium
Acer negundo	3,2	1.7	Medium	76	High	Medium
Acer pseudoplatanus	2,9	1,7	Medium		Medium	Medium
Fraxinus excelsior	2,3	2,1	Medium	97	High	Low

Table B4.1. Characteristics of the 10 most abundant tree species in Pamplona related to air quality: percentage of the total woodland area of Pamplona corresponding to a species; PFP is the "pollution flux potential" index, which represents the capability of the interaction with the atmosphere, providing the net effect between atmospheric pollutants released and/or deposited, higher values indicate more benefits for air quality; the ability to mitigate air pollution includes PM and gaseous compounds; stomatal conductance (mmol m^{-2} s^{-1}) measured under optimal physiological conditions during the Life+RESPIRA project, indicating the potential capacity of absorbing gaseous atmospheric pollutants; allergenicity index; emissions of BVOCs.

Figure B4.1 Measurement campaign of stomatal conductance in urban vegetation

<u>The role of urban and peri-urban vegetation on air quality in areas without emission sources</u>

In addition to the morphological and physiological features of the selected species, the location and configuration of the urban vegetation is an equally important factor in determining the ability to improve air quality. In those areas where there are no on-site atmospheric pollutant emissions, such as in peri-urban forests and gardens and parks, vegetation plays a fundamental part in filtering and reducing atmospheric pollutants.

The LIFE+RESPIRA project has made a significant contribution demonstrating experimentally that, in areas without emission sources, the concentrations of different atmospheric pollutants such as ozone, nitrogen oxides, ammonia and nitric acid are significantly lower below tree canopies than in open areas without trees (Fig B4.2). These results confirm the predictions made with different models and highlight the importance of the presence of trees in sensitive areas, such as playgrounds, school playgrounds, sports areas, hospital gardens or homes for the elderly, etc., in order to reduce the exposure of the population to air pollution, especially the most vulnerable (children, the elderly and people with a history of illnesses or chronic patients).

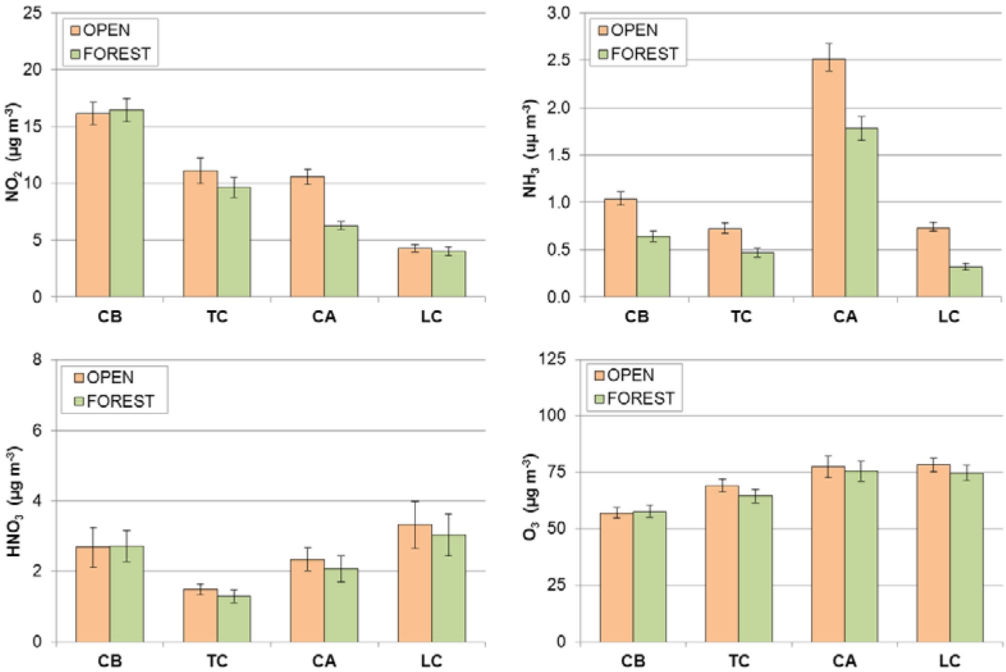


Figure B4.2. Concentrations of air pollutants in open, woodless areas (orange bars) and under the tree canopy in peri-urban forests (green bars). The values represent the mean value from two years of measurements. The decrease in concentration (Δ-) is only shown for cases that are statistically significant.

The effectiveness of vegetation barriers at reducing exposure to atmospheric pollution.

Urban vegetation can also be effective at stopping the dispersion of pollutants to areas that should be protected, for example to separate the bike lanes from the road, or to protect sensitive common areas intended for the population, such children's playgrounds, parks, sports and leisure areas etc. that are close to roads with heavy traffic. The benefits of vegetation barriers for air quality have been quantified in measurement campaigns analyzing two types of barriers: green hedges and tree lines. The Navarra avenue was selected for these field campaigns (Fig. B4.3). Air pollutants have been measured at both sides of the vegetation barrier and at another site at the same distance to the road but without the presence of the barrier. Air pollutants have been measured with the sensors designed in Activity A1 (Kunak sensors). Additionally, aethalometers, and in some campaigns also Grimm monitors, have been used to measure black carbon and particle concentrations respectively. Seasonal campaigns have been performed measuring during one day in each type of barrier.

LIFE+RESPIRA has demonstrated through experimental measurement campaigns that the distance between the bike lanes and the traffic lanes on the road is the main factor to decrease the concentrations of black carbon in the air (which is one of the main pollutants linked to traffic). When it is not viable for a cyclist to move away from the road, the use of separation vegetation barriers, (in particular hedgerows) helps to reduce the exposure to polluting particles emitted by traffic by up to 30% (Fig. B4.4). The efficiency of the vegetation barrier will depend not only on the dimensions, density and the selected species, but also on the prevailing winds that carry pollutants emitted by traffic, increasing efficiency in those conditions in which prevailing winds carry pollutants from the road towards the hedge (Fig. B4.5).

Figure B4.3. Experimental measurement campaign to sample the effect of hedges on air quality in Pamplona: LIFE+RESPIRA project.

The figure B4.4. shows the black carbon concentrations and the wind diagram on Avenida de Navarra (Pamplona). The red line represents the concentrations measured at the roadside next to traffic; the green line shows the concentrations on the other side of the hedge; the blue line shows the concentrations using the same distance as the sensor behind the hedge, but without the vegetation barrier between them.

Roadside tree barriers can also be effective, but with this type of vegetation it is important to take into account the height at which the emissions occur and the exposure to the population, and the height of the tree canopy. If the crown becomes leafy at a certain height (typically 3-4 metres) to facilitate the transit of vehicles or people underneath, this kind of vegetation barrier will be less effective at reducing air pollution at a pedestrian or cyclist height compared to shrub or hedgerow barriers, which have full leaf coverage from the ground. The combination of experimental measures with pollutant dispersion models (see activity B2), has shown that vegetation barriers that are made up of hedges, with a tree line behind, are particularly efficient to reduce the exposure to pollution at a pedestrian or cyclist level. These results also indicate that it is necessary to take into account the aerodynamic effects of the barrier depending on the prevailing winds, the size and density of the vegetation, and its position from the road, in order to maximize the beneficial effects of vegetation barriers on air quality.

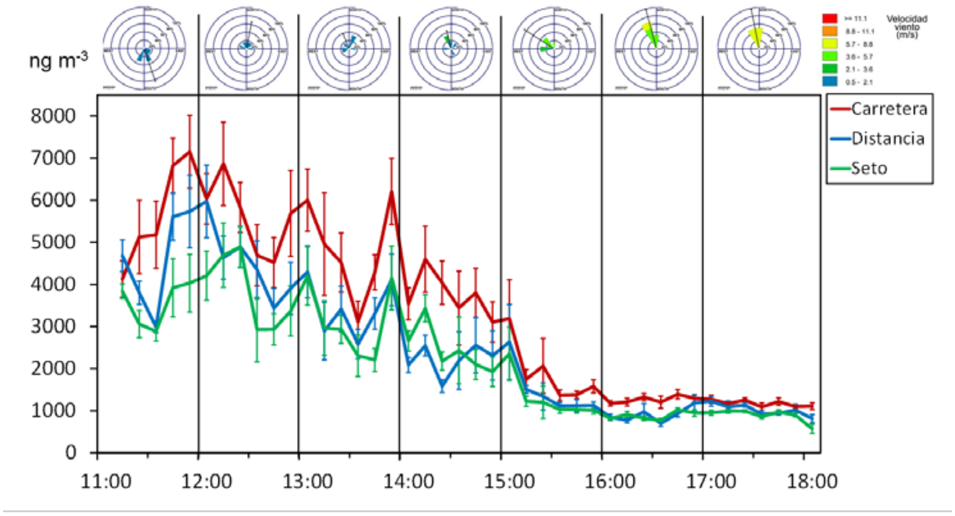


Figure B4.4. Analysis of the effectiveness of a hedge as a vegetation barrier at dispersing near-road air pollution.

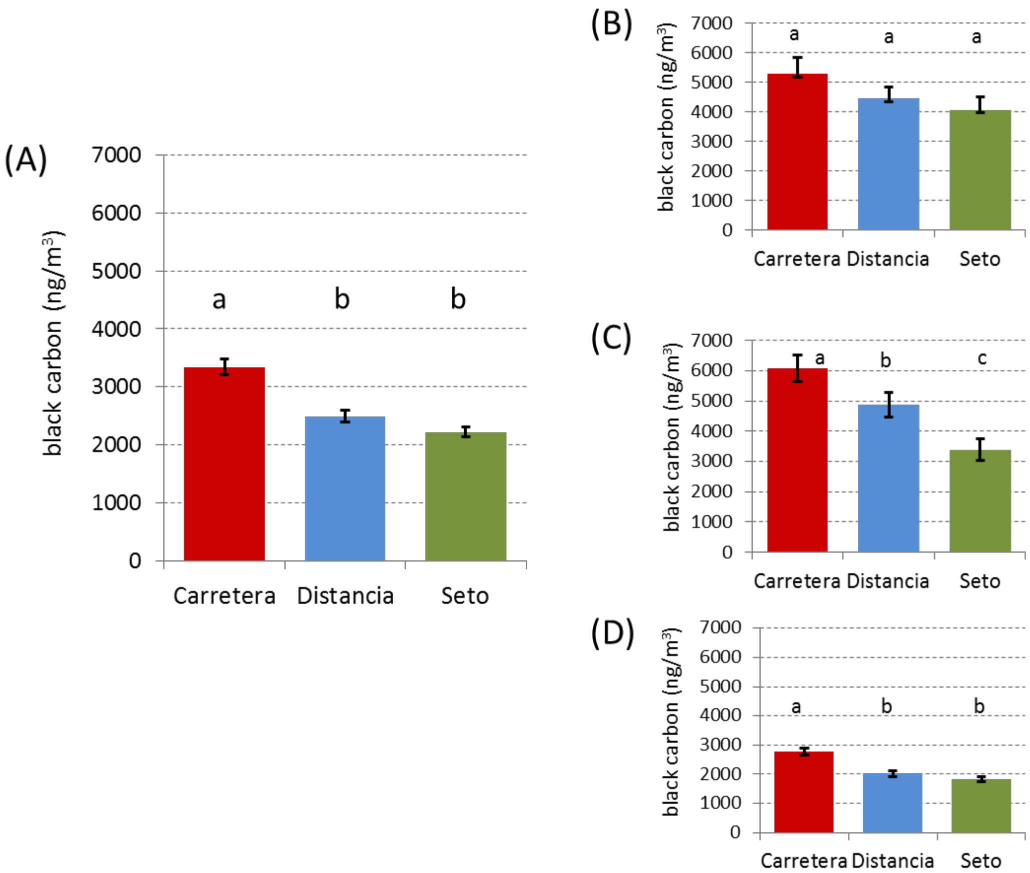


Figure B4.5. Analysis of the effectiveness of a hedge as a vegetation barrier for the dispersion of air pollution.

The figures show the average black carbon concentrations throughout the campaign (A); the average values in calm wind conditions (B); the average values in windy conditions coming from the road (C); and the average values with wind blowing in a parallel direction to the road. (D).

The effect of roadside trees on the air quality in street canyons.

The role urban trees play on the air quality in narrow streets with relatively heavy traffic is more controversial, since vegetation can be an obstacle to the street ventilation, preventing the dispersion of emitted pollutants, with this effect being more significant than its capacity to capture pollutants. The CFD-type (Computational Fluid Dynamics, see activity B2) atmospheric models, which simulate the concentration and distribution of pollutants at street level, have been used to estimate the effect of roadside trees. However, it has been acknowledged that the scarce experimental data have prevented wide model validations until now. Thanks to the collaboration and participation of the citizens, who allowed the installation of sensors on their buildings, the LIFE+RESPIRA project was able to perform several monitoring campaigns to measure meteorological parameters and the concentration of atmospheric pollutants at various heights on the facades of buildings within street canyon with and without roadside trees (Figure B4.6 and B4.7).

Two streets with similar orientation, size and traffic intensity, but differing in street tree presence were selected for the field measurement campaigns in order to analyze the distribution of air pollutants within a street canyon and the possible changes due to the presence of trees. The selected streets were: San Fermín with trees and Tafalla without trees. The streets are located in Zabalgunea neighborhood in Pamplona downtown. Both streets have schools that allowed the installation of the sensors out of the windows at 3 different floors. Additional measurement points were set up on the facade opposite to the schools using private flats of volunteers when possible. Air pollutants have been measured with the sensors designed in Activity A1 (Kunak sensors) combined with meteorological sensors. Additionally, is some campaigns, Grimm monitors and aethalometers were added to measure the distribution of particles and black carbon respectively in the street canyon.

Figure B4.6. Streets selected for the field campaigns to analyse the influence of urban vegetation in the air quality of street canyons.

Figure B4.7. Measurement of atmospheric pollutant concentration and meteorological parameters at different heights in a street canyon in Pamplona.

The results showed that when trees were not present, the concentrations of black carbon were 19% lower at a height of 10 metres when compared with concentrations at 3 metres. On the other hand, the presence of trees reduced that difference to 10% on average (Fig. B4.8). These results confirm that the presence of urban trees reduces the vertical dispersion of the particles emitted by traffic, which may sometimes worsen the air quality in streets with trees and intense traffic. The effect of roadside trees on the distribution of temperature in this type of streets has also been verified, validating the predictions obtained with atmospheric CFD models. The modelling, combined with the experimental measures, detected that roadside trees can also act as a horizontal barrier for the entry of pollutants emitted in nearby streets with heavy traffic. For this reason, neighbourhoods with narrow street canyons require detailed studies on the distribution of the emissions, the prevailing weather conditions and the geometry of the streets in order to help to decide on the design, positions and size of the roadside vegetation in a way that maximize the benefits for climatic comfort while avoiding the interruption of street ventilation that could aggravate air quality problems.

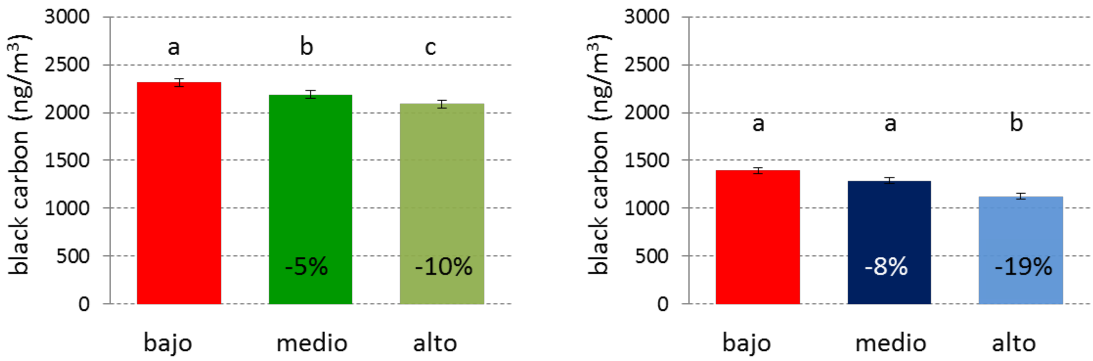


Figure B4.8. Concentrations of black carbon at different heights on the facades of a street with the presence of roadside trees (left) and in another similar street without trees (right) in Pamplona as part of the activities of the LIFE+RESPIRA project

Modeling the influence of urban vegetation in air quality

The quantification of pollutants removed by urban vegetation has been performed using the UFORE model. The Urban Forest Effects model (UFORE, currently included in i-Tree), developed by Novak et al. (2008), combines information from a city tree inventory with monitored data of air pollutants and meteorological variables to estimate different environmental services such as mitigation of air pollution, CO_2 absorption or emissions of BVOCs at city scale. The amount of pollutant removed by vegetation depended on the concentrations of the different pollutants with higher amounts of pollutants removed during spring and summer when the leaves of trees are present (Fig. B4.9).

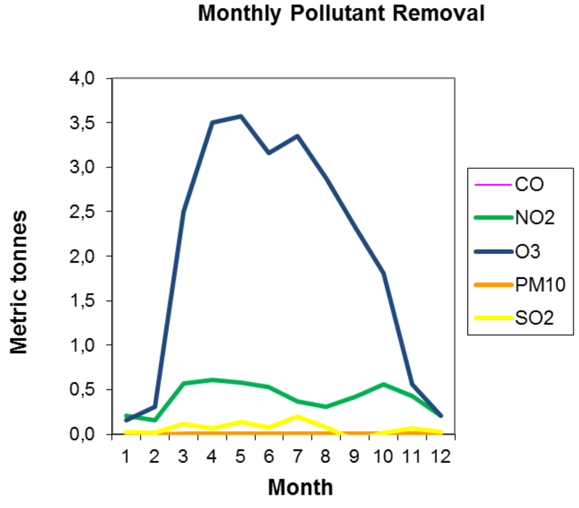


Figure B4.9. Monthly pollutant removal by urban vegetation in Pamplona estimated with the UFORE model.

ACTION B5	Development of a Healthy Routes planner		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	3/15	Planned completion date	2/17
Start date	10/14	Completion date	12/17

Description of the task undertaken:

In the final phase of the Life + Respira project, researchers have used a demo version of the application to detect possible failures and propose some changes. After verifying several functional aspects and proposing some improvements, the application can be considered finished.

The functionalities included in the backend are the following:

Authorization

Authorization to access the application has been defined according to the identified user typology. The desired functionalities for the applications and their authorizations (Edit/Visualization/No Access) are linked to the corresponding user profiles through an Authentication Master Table.

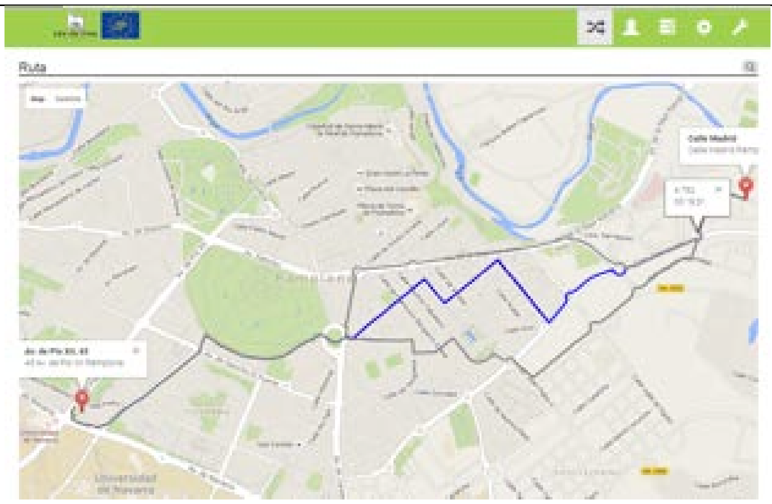
Authentication

Upon accessing the application, the login screen is shown. The user must log in using his or her user login code and access password.

Public Access

Healthy route selection

The way to trace possible routes between two points selected by the user has been defined. The route is displayed in Google Maps, taking advantage of Google's services and API.



<u>Research</u>

GIS Maps

The App has been connected to the IDENA engine to demonstrate the capacity for showing the maps that the defined GIS server could offer. The figure below displays a noise map imported to the App.

<u>Volunteers</u>

Ranking

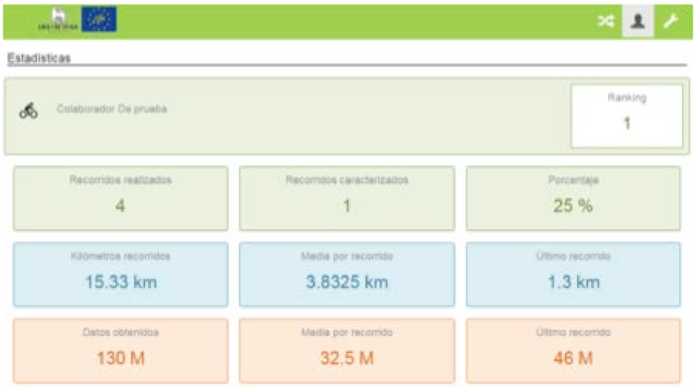
A ranking of volunteers sorted by the number of kilometres covered by each one has been prepared. Total collected data is shown along with the total travelled kilometres data.

Volunteer statistics

Statistics for each volunteer are shown, including the following data:

- Ranking position
- Routes
  - Nº of journeys travelled
  - Nº of characterized routes
  - Percentage of characterized routes
- Kilometres
  - Total travelled kilometres
  - Average travelled kilometres
  - Kilometres travelled in the last journey
- Data
  - Total collected data

- Average collected data per journey
- Data collected in the last journey



Administration console

The following procedures have been developed:

- Management of users and their authorizations by profile assignment
- Management of collaborating centres and their employees
- Management of volunteers.
- Management of prototypes.
- Visualization of the current prototype status in a matrix table.
- Visualization and characterization of the routes.
- Management of prototype reservations (calendar).

Although the route planner was finalized, it was not available to users. This was due to the fact that the company in charge of its execution went into bankruptcy due to not being able to face the breaches of several clients. As a result, Life + Respira researchers could not use the application until the company was liquidated, since we did not have the source code of the App. Once the company was liquidated we were able to obtain the source code and we had to hire another computer company to install the App on a supercomputer of the University of Cantabria (Altamira). This has been possible thanks to the agreement established between Life + Respira and the European infrastructure LifeWatch ERIC, which has included our project in one of its strategic lines.
The link to access the Healthy Route App is: http://193.146.75.196/life/

ACTION B6	Demonstration of the effectiveness of anti-pollution masks		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	6/14	Planned completion date	8/15
Start date	6/14	Completion date	9/17
Description of the task undertaken:			

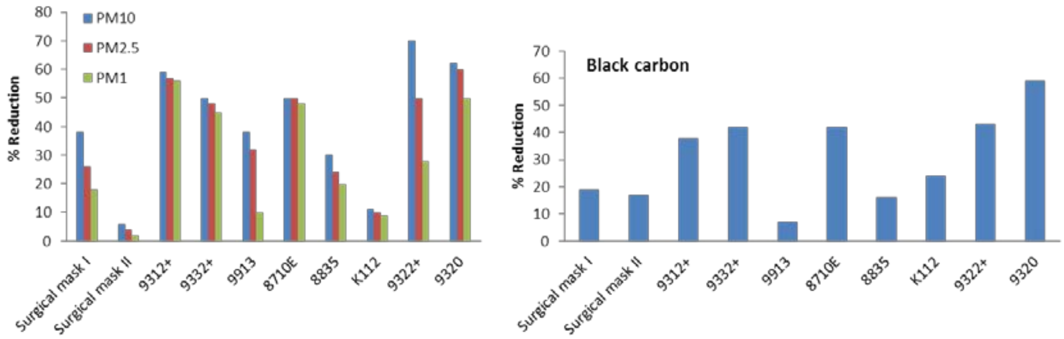
The first task of this action started with a comprehensive review of the different anti-pollution cycling masks available on the market. After studying their characteristics a group of 30 types was selected and bought. In order to verify the effectiveness of masks in filtering the main urban pollutants (volatile organic compounds, particulate matter and black carbon) a prototype that simulates a person's breathing was built. The prototype consisted of a styrofoam mannequin head to which holes were made in the area of the mouth. The sampling tubes for the measuring of the air pollutants above mentioned were introduced inside the mouth, measuring the effectiveness of the masks placed on it. The air was pumped through the mouth at a flow rate of 6 L/min.

Once the first prototype was built and tested, five more replicas were made. Three of them were used to study the ability of masks to reduce VOC levels and the other three to assess their effectiveness to absorb PM and BC. In each group one of the prototypes acted always as a control (without mask) and the other two were used to assess the effectiveness of each type of mask (in duplicate).

Since the purpose of the action was to simulate the response of masks under field conditions (urban cyclists facing road traffic pollution) we decided to carry out the experiment inside the University parking lot, a semi-underground facility with open walls ensuring swift dispersal of pollutants. This parking has a very strong influx of vehicles during the arrival and departure of workers and students to the University, and a very small activity during intermediate hours. This mimics what happens to a cyclist in the city, being exposed to very high levels of pollutants when cycling behind a vehicle and at very low levels when circulating far away from the road. Therefore, testing the effectiveness of the anti-pollution cycling masks under these conditions can be considered very realistic.

View of the prototypes used to perform the quality control of anti-pollution facemasks

A great variability was observed between the different models of studied facemasks. Not surprisingly, surgery masks (designed to *contain* user's *exhaled* particles) were the least effective (16% of air pollutants retention), while those provided with influx filters showed the highest filtering efficiency, reaching a reduction of pollutants up to 70%.



Percentage reduction of PM and BC depending on the different types of masks classes tested

In all cases the masks were less effective in filtering the smallest particles (black carbon and PM_1), which are the ones most dangerous to health. As the relation between free-air and filtered-air concentration is almost lineal, it indicates that an increase of BC in air produces an increase of BC inhalation. These results suggest that when cyclists are exposed to high BC or PM concentrations, the amount of inhaled pollutants increases linearly.

Concerning VOC, results were worse, since none of the tested masks proved to be very effective in reducing the levels of gaseous pollutants. The maximum rate of removal of VOC was 50%, but most of them showed very low removal efficiency (< 10%). According to the results obtained, it is evident that the most effective masks are those that contain absorbent elements (FFP2 class), such as activated carbon, capable of retaining gaseous pollutants, and also filtering elements to capture the particulate material present in the ambient air, thus reducing its inhalation by the cyclist. In view of the results, it is evident that cyclists should take additional measures to reduce their exposure to urban pollutants, such as increasing the distance from the emission sources, which means riding on the bike lanes instead of on the road.

ACTION B7	Cycling mobility plan in the general context of urban mobility, according to air quality criteria		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	3/15	Planned completion date	5/17
Start date	3/15	Completion date	12/17
Description of the task undertaken:			

This Action has included two main aspects: A diagnosis of urban cycling, and a context-specific mobility plan based on the diagnosis.

1. Diagnosis

The development of an urban cyclist mobility plan was initiated with a proper diagnosis on this topic. This phase of diagnosis consisted in the analysis of all cycling-related aspects about city mobility, including the study of existing infrastructures, cycling facilitators, cycle traffic conditionals (safety, comfort, facilities, mode exchange, etc.), as well as current bicycle use and potential, post-action use enhancement.

In this diagnostic context, the project introduced air quality as a new driver in the city design and in the cycling route planning. This was achieved through the innovative air quality measurement method and the resulting condition-specific pollutant maps.

The diagnosis was based on information collected through, and continuously updated in Action A4 (characterization of the cyclist mobility in the general context of urban mobility of Pamplona), as well as its map representation through a GIS in Action A3 (analysis of the urban framework) that in turn incorporates both cycling-specific infrastructures and general infrastructure for urban mobility.

2. Cycling mobility plan

Measures were proposed based on the above information, summarized as a detailed knowledge of the air pollution distribution and evolution throughout the city. The measures' aim is urban transformation towards a cleaner environment overall, by acting on transportation modes. A management tool has been developed that may be useful to the city and local authorities to create a sensible mobility plan.

We have therefore prioritized maintaining a direct contact with managers and municipal technicians, as well as other stakeholders and experts. The chosen framework is the Pamplona Mobility Observatory, where two team members have long been serving as University representatives. The Observatory is coordinated by the Department of Urban Ecology and Sustainable Mobility.

In addition, we have collaborated with the Pamplona District Urban Transportation Services (Mancomunidad de la Comarca de Pamplona, MCP) in the revision of the Plan of sustainable urban mobility (PMUS), which was launched in November 2016. Given the nature of this document, the PMUS is likely the most appropriate framework for the implementation of the recommendations derived from LIFE+RESPIRA. According with that, LIFE+RESPIRA was involved in the PMUS elaboration, including the public participation phase.

Because of this institutional collaboration and other LIFE+RESPIRA actions, a publication related to "The bicycle in Pamplona" has been prepared.

ACTION B8	Post-project sensor network		
Coordinator	UNAV	Participants	CIEMAT
Action status	Ongoing		
Planned start date	4/17	Planned completion date	5/17
Start date	4/17	Completion date	
Description of the task undertaken:			

After the completion of the project, it was considered essential that the methodology developed for the monitoring of air pollutants in Life + Respira could remain active. Therefore, it was planned to create a post-project network of sensors, based on the lessons learned during its implementation, which ensured the continuity of the data collection in areas not covered by the city's air quality stations.

Since at the end of the monitoring campaign achieved in Life+Respira it was observed that prototypes were reaching the end of its lifetime, it was decided to build new prototypes that incorporated updated versions of the sensors (much more precise) and with a set of improvements that reduced the different types of interferences detected throughout the project. The characteristics of the new prototypes, which are going to be used for the implementation of the monitoring network, have been described in Action 1 (A1).

1. Deployment of a monitoring network of fixed sensors in the city of Pamplona

Although we had already planned to install a pollutant monitoring network once the project was completed by deploying new prototypes in the city of Pamplona, the representatives of the mobility area of the City Council communicated us that they were very interested in supporting the deployment of a monitoring network, even expanding the number of prototypes to achieve a greater coverage of the city.

Precisely during these last weeks, at the request of the City Council, we have submitted an offer to deploy 30 monitoring prototypes in the city of Pamplona. We are currently working with them in the selection of the sites where to install the prototypes based on the pollution maps generated during the project. The objective is that this network covers the main areas of the city, so that citizens can know in real time the concentrations of pollutants in the streets where they usually move.

Therefore, the deployment of a monitoring network in the city of Pamplona will be a reality very soon, also having the institutional support of the City Council to maintain its operation over time.

2**. Impact of the reorganization of urban traffic on air quality**

In September 2017, the City Council of Pamplona launched the so-called "Plan for the Improvement of the City Center". This plan is a new city model that prioritizes the pedestrian, cyclist and urban transport. For this purpose, pedestrian streets, a new bike path and urban transport stops closer to the City Center have been created. Moreover, sidewalks have been enlarged and converted into parking areas (green zone), exclusively for resident parking.

The aforementioned plan has meant a restriction of traffic in the city center, and the City Council is interested in knowing the impact of such plan on the air quality of the affected area. For this, the City Council has commissioned us to apply the methodology used in the Life+Respira project to determine the levels of pollutants in the restricted traffic zone and in the buffer area (where traffic density is assumed to have increased), with object of knowing how air quality has changed since the implementation of this plan.

In order to carry out this study, we have contacted some of the volunteers who participated in the Life+Respira project, who have committed to begin recording data with their bicycles in the month of April. Although this activity was not initially planned, it can be considered as a post-project action, which will also serve to further extend the Life+Respira project among the citizens of Pamplona.

View of the restructured area to favor sustainable transport

ACTION C1	Large-scale exposure of cyclists to air pollutants		
Coordinator	UNAV	Participants	CIEMAT
Action status	Finished		
Planned start date	12/14	Planned completion date	3/17
Start date	12/14	Completion date	12/17
Description of the task undertaken:			

The actual measurement of air pollutant concentrations in Pamplona by means of prototypes was at the core of the project. Although much preliminary work was done using black carbon, particle analyzers, and the pre-production prototypes, the Action started officially on May 10th, 2015 once all sensor suites ("devices") became available and pre-calibrated.

Opening of the air pollution monitoring campaign

The main data collection lasted until June, 2017 although some additional data were still collected until December, 2017, to fill gaps and ensure correct calibrations. The main activities and results within C1 are the following:

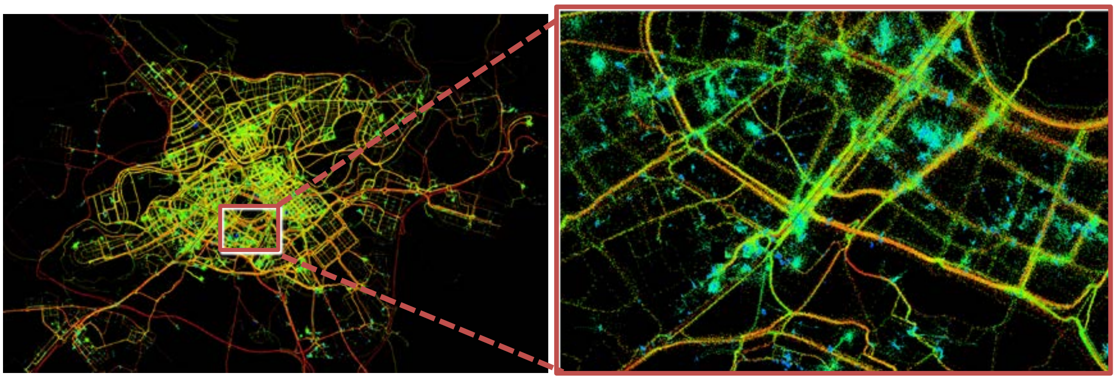
1. **Volunteer uptake**. More than 140 active volunteers borrowed devices during 8,108 person-days (average: 58 days/volunteer), while an additional 2,614 device-days were used up by the research team in various data gathering tasks such as reference and calibration data. The Device Management Program registered 2,031 distinct bookings and 2,690 operations.
2. **Mileage**. The team (researchers + volunteers) logged 61,541 km during 73,210 device-hours. Some journeys have been videotaped in sync with particle, black carbon, and gas readings to show how the air pollution changes with the type of area and traffic density. Also, more than

20 volunteers regularly provided biomedical data from heart-rate sensors during their journeys.

Images from a video recorded by a volunteer commuting to work

3. **Data collection.** Bike and vehicle journeys allowed recording about 3.55 million georeferenced, valid data points spread all over the city. In addition, 9.1 million records provided calibration, verification, and static reference data to validate the route measurement records. In total, 13.4 million records (including unused records) were built from 149.3 million measurements that integrated more than 2 billion individual readings by the sensors.

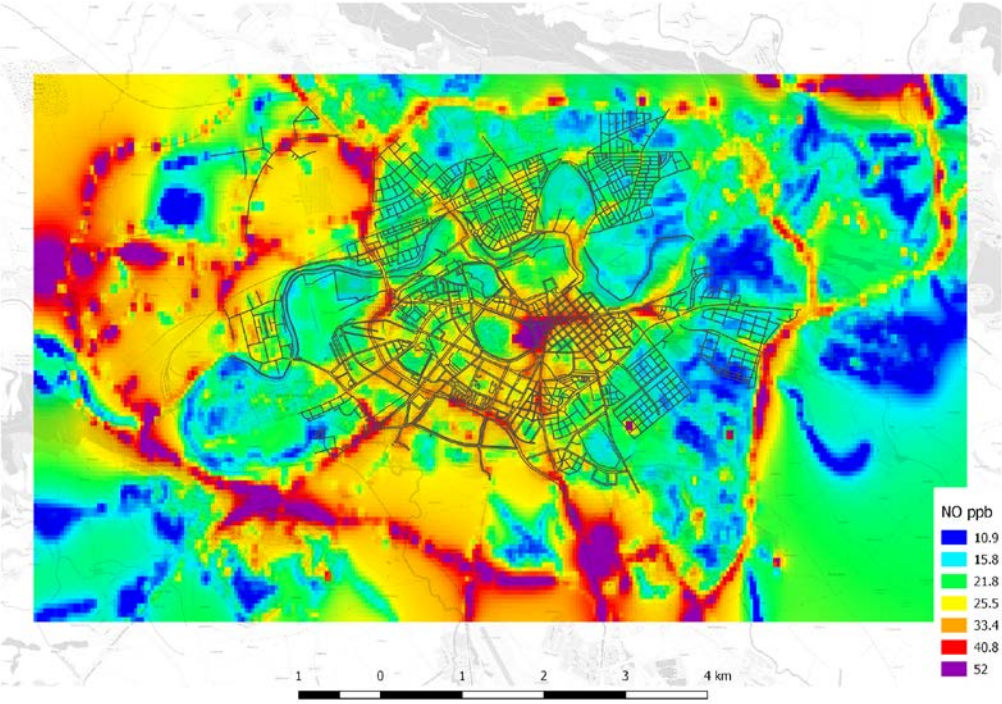
4. **Coverage.** Most of the city received coverage. The density of coverage was naturally determined by the volunteers' preferred routes; therefore, a coverage map using point density accurately represents the cycle traffic density of the city and also naturally allows more dense measurement data from the most frequent lanes, thus optimizing the reliability of the data by providing more precise data where they are most needed. Also, these maps can be useful for city managers planning for bike lanes or mobility optimization.



Map of the metropolitan area (left) and blowup (right). Each dot is a data point. Denser areas correspond to preferred routes. Colors indicate speed of movement (blue: slower, red: faster). Lane segregation is clearly visible.

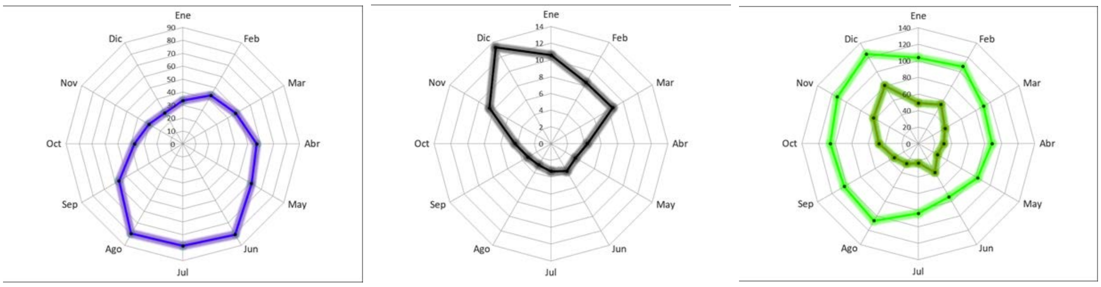
5. **Results.** Data from the measurements were used to plot the levels of pollutants across the city. While calibration proceeded, preliminary data were relativized over the whole series for each parameter, allowing us to depict the relative differences between city areas; with a complete calibration, actual levels could be represented. The maps were highly consistent with pollution point sources. For example, the highest NO concentration were found around industrial estates and in neighborhoods that are subject to a dense traffic, e.g. the northwest sector. At fine scale, we recorded significantly high levels on roads, very dependent on two traffic-related factors: slope and speed. The main trunk roads and approaches showed significantly high pollution levels, often more than five times that of the residential areas and twice as much as most streets. Hot spots were readily visible owing to the fine scale of the collected data. For example, a significant concentration of pollutants was detected around the central bus station, located next to an urban park that nonetheless showed the effect of the point source (see map below). Similar maps have been produced for the rest of air pollutants, segmented according

to various criteria: time of day, day of year, weather patterns, etc.



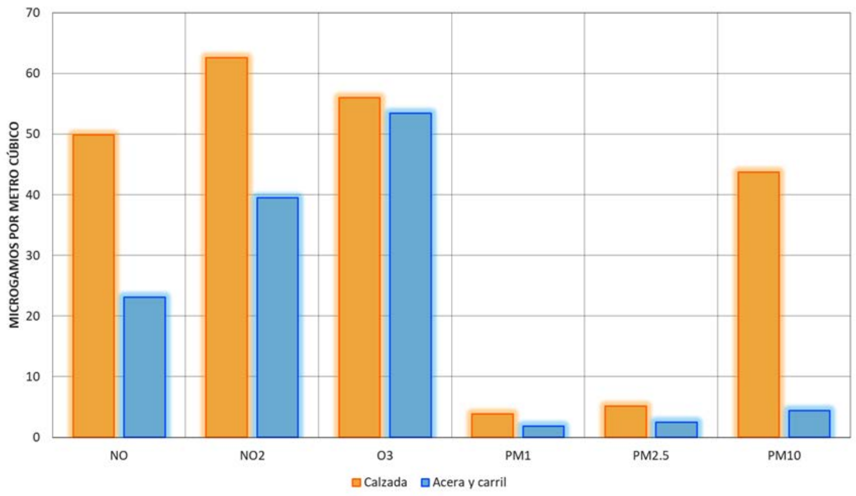
Map of NO concentration resulting from the data, averaged over a year. Concentrations match traffic patterns.

Summary results have also been produced, showing patterns of social and health interest. For example, seasonal patterns (O_3, particles) related to domestic primary energy use, or weekly/daily patterns related to traffic patterns and activity hours.



Seasonal patterns of ozone (left), PM2.5 (center) and nitrogen oxides (right) showing photochemical activity and winter's loads from domestic heating.

The fine-scale spatial analysis made possible by the project uncovered an emission pattern whereby the distance to the point source (traffic) was determinant for the levels of several pollutants faced by cyclists and pedestrians. Although our results here are still preliminary and require further statistical refinements, they suggest a strong decay in the space of a few meters, an extremely important observation (if confirmed) to help city planners draw routing and mobility ordination plans.



Average pollutant concentrations along the road axis (orange) and on sidewalks or segregated bike lanes (blue).

ACTION C2	Quantification of inhaling contaminants by cyclists		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	1/15	Planned completion date	4/15
Start date	11/15	Completion date	10/17
Description of the task undertaken:			

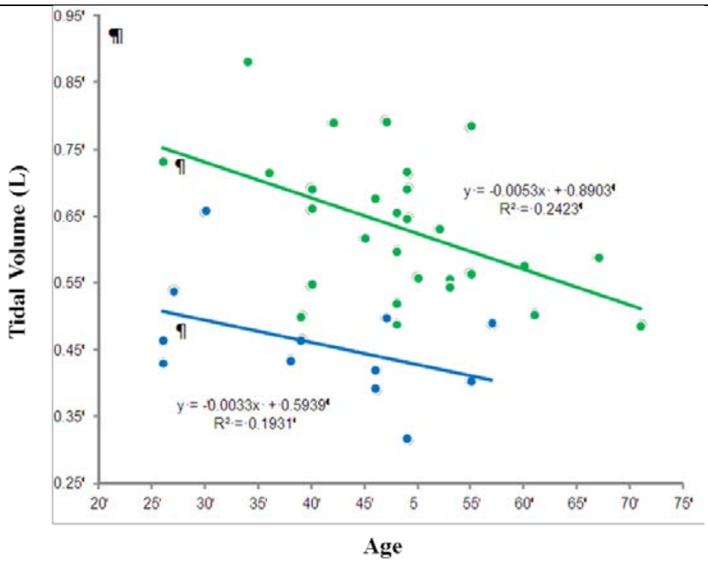
This action experienced a delay because it was dependent of Action B2, which due to technical reasons was postponed until May 2016. However, this delay had not any impact on the project.

To quantify the inhalation of pollutants by volunteers it is necessary to determine the volume of air they breathe during their commutes. This variable can be estimated from the measurement of the heart rate provided by sensors, which in turn is related to the ventilation rate. However, the heart rate – inhaled volume correlation is individual-specific and must be determined through a spirometry test.

The group of volunteers selected to wear the heart rate sensors underwent a spirometry test at the Navarre University Clinic (CUN) during the month of May. They also filled a questionnaire in order to obtain relevant information on possible respiratory diseases and other health parameters, which will be of great interest to properly interpret the results. These data were subsequently used to estimate the volume of respiratory intake of air during their trips by bicycle and the amount of pollutants they were therefore exposed to in the routes that they took.

The spirometry tests showed the typical relationship between respiratory volume expressed as Tidal Volume (the volume of air that is displaced when we breathe in a normal cycle of inhalation and exhalation), age and gender.

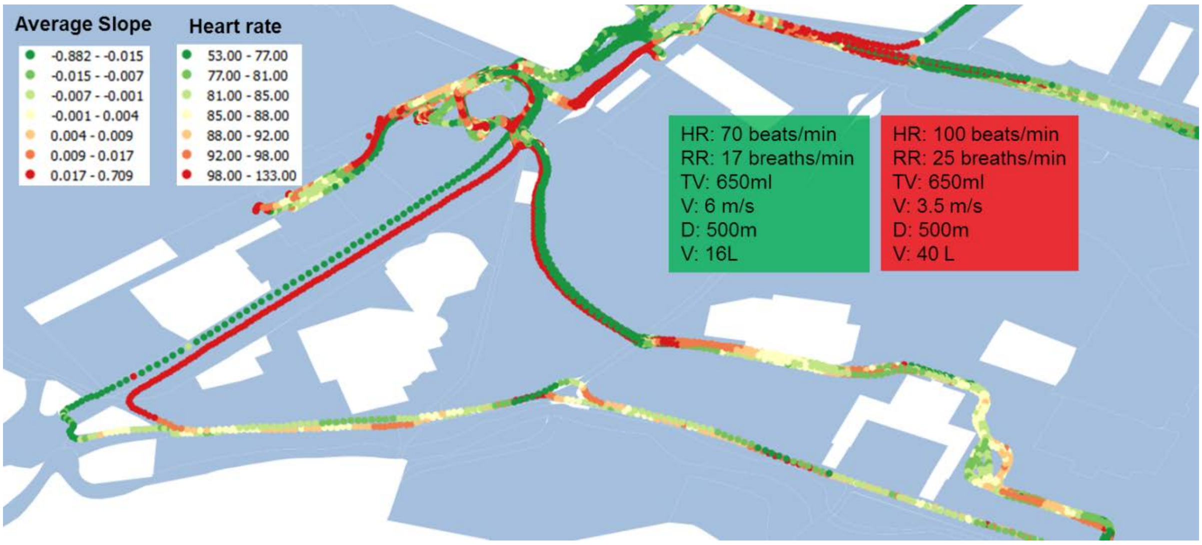
The selected group of volunteers used the heart rate sensors for one year, providing a huge amount of data. The position of each heart rate (HR) record was superposed on a Digital Elevation Model with a resolution of 5m (National Geographic Institute) to obtain the altitude of each point and, using spatial analyses, to calculate the speed values, road slopes and distance travelled by each volunteer. Before proceeding to analyse the data, the routes were divided into 30-second segments (the heart-rate monitors provided a HR reading every second), in which the statistics Average, Maximum, and Minimum were calculated for the variable speed, slope and HR.



Relationship between respiratory tidal volume and age of volunteers

In order to consider a segment valid, a series of conditions were introduced, which allowed for the assumption that the segment maintained certain uniform conditions of slope and orientation and in in which the volunteer was carrying out a stable physical effort. These limitations for permissible data meant that a considerable amount of available information was lost, but in exchange, the statistical noise in the analyses was greatly reduced, thus providing higher quality information. The analyses were finally performed on more than 20,000 segments, each of which corresponded to sets of a maximum of 30 points.

Several conclusions can be drawn from the statistical analyses of data, which corroborate the approach that led to the development of this action within the LIFE+RESPIRA project. Cycling requires a great effort, as supported by the value of the average heart rate of all the volunteers, which reached 113 beats per minute. This value differs significantly when studying each person individually, which points to both the heterogeneity in the representation of the group of volunteers, such as age, gender and also most likely to their different habits in regards to the use of the bicycle, such as the average speed of travel (global average being 4.3 metres per second, about 15 km/h) or the type of urban routes.



Example of the variation of heart and breath rates versus slope

The majority of the trips occurred in the areas with no or small slopes (<1%), as corresponds to the relief in the urban area where the routes were primarily located. However, segments with moderate (1-

2%) or strong (2-6%) slopes were often identified. Both positive and negative slopes had a significant effect on the on two fundamental parameters with respect to pollution: the level of physical effort of the cyclist and the amount of time spent on a certain route.

The average speed in the segments of small or null slopes was slightly above 4m/s, while in the sections of higher slopes the speed reduced to 2m/s in the case of the ascents, or reaching 6m/s in descents (this effect is more evident in male cyclists). These notable differences in speed, determine the time it takes for the cyclist to travel a certain segment, which is significant from a pollution point of view, since steep roads are usually associated with higher fuel consumption by motor vehicles and, therefore a greater production of polluting gases. The slope is also reflected in the cyclists' HR: the average values can fluctuate between 40%-80% with respect to the basal value, as the volunteers move to roads with steep or very steep ascending slopes.

These results show the impact that changes in the routes' slopes have on cyclists cannot be overlooked when estimating their exposure to pollution. An increase in heart rate can mean that breathing frequency is doubled, so the air intake into the lungs becomes increasingly higher than when at rest or while cycling on flat roads. Combined with the variation in speed, it is clear that the exposure to urban air of a road of a certain length can change significantly depending on the ascending or descending slope of the route. Therefore, just knowing the concentration of pollutants in a given road may not be enough; as demonstrated by this study, it is essential to consider the average gradient and the direction the cyclists travel to determine their real exposure to air pollutants.

ACTION C3	Determination of VOCs in air and in cyclists' exhaled breath		
Coordinator	UNAV	Participants	
Action status	Finished		
Planned start date	12/14	Planned completion date	3/17
Start date	12/14	Completion date	9/17
Description of the task undertaken:			

The initial task of this Action involved the development of all analytical methodology necessary to determine the levels of VOC in air and in the breath exhaled by cyclists after riding along the city.

Several tests were performed to confirm the suitability of the sampling and analytical procedures to be used. These tests included determination of appropriate sampling volumes and estimation of lower detection limits using field and blank samples. In order to test the performance of the method, samples of VOCs were collected by drawing air through a stainless steel tube containing 200 mg of Tenax TA resin using a personal air sampling pump (SKC Pocket Pump) during the journeys. Tubes were pre-conditioned by forcing through them pure nitrogen gas, ensuring that no target pollutants were present.

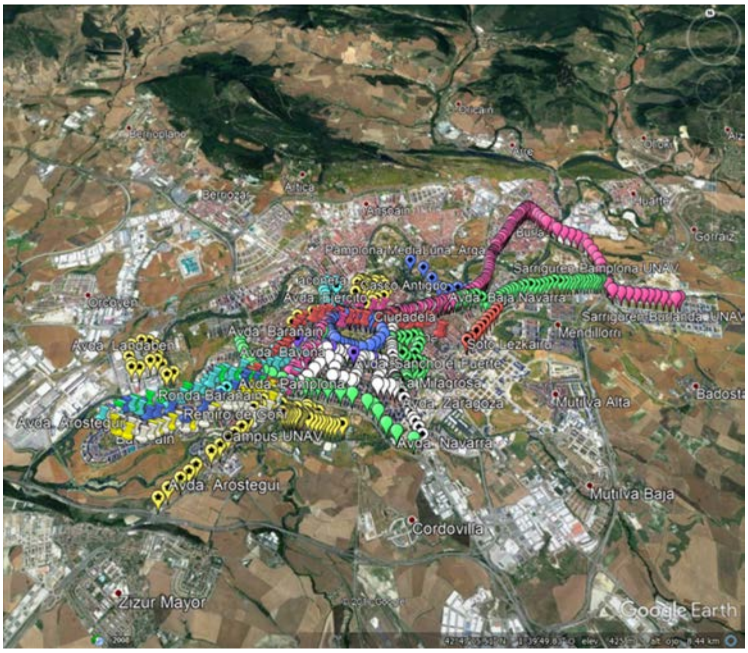
In addition, samples of exhaled air were taken from 3 volunteers before and after riding around the city using a BioVOC sampler. This device allows relating the concentrations of VOC in blood with the levels of VOC in air. An adult, exhaling deeply, typically breathes out over 4L of air. Only the last 100 ml of this, all from the alveolar portion of the lungs, is retained by the Bio-VOC Sampler. Once the exhaled air has been collected, a screw-in plunger is used to steadily discharge the sample into a concentrating (sorbent) trap. After collection in a sealed sorbent tube, the breath sample is ready for analysis.

After collecting both type of samples, analyses of VOCs were made using a Markes thermal desorption unit coupled to a gas chromatograph (Agilent 6890) fitted with an Agilent 5973 mass selective detector (TD-GC-MS).

The volunteers participating in this action (May 2016-May 2017) performed a series of preselected tours that covered the entire city of Pamplona. During their trips the volunteers collected VOC samples using the methodology discussed above and at the end of the trip they also provided a sample of exhaled air.

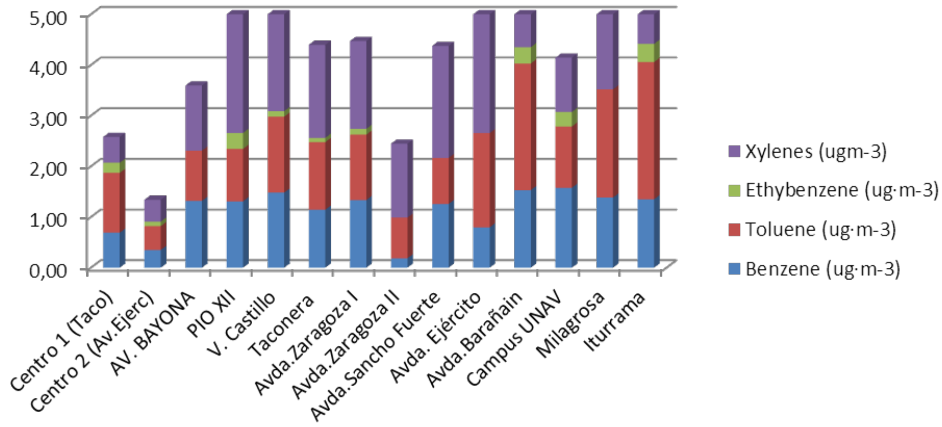
View of the BioVoc sampling device

The exposure results indicated that the limit concentration established by the legislation for benzene was not exceeded in any case and the concentrations of BTEX were lower than those registered in many other urban areas. However, significant differences were observed in BTEX concentrations when volunteers circulated, a) in front of a gas station in the presence and absence of a fuel tank recharge truck; b) by one of the access roads to Pamplona (Avda. Aróstegui) with the highest traffic density at peak or off-peak hours; and c) through the downtown streets of Pamplona (Avda. del Ejército, Avda. Zaragoza) on a working day or on a public holiday.



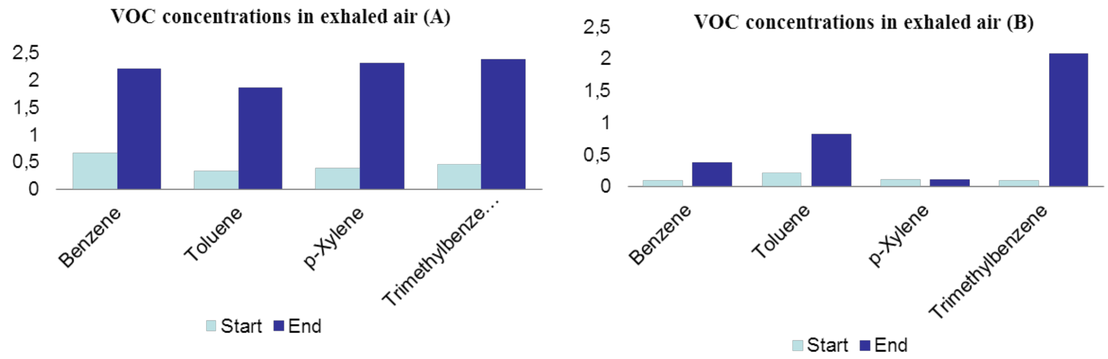
VOC monitoring campaign in Pamplona

On the other hand, certain access roads to Pamplona presented relatively high BTEX concentrations due to high traffic density at any time of the day (Avda. de Pamplona), even during the weekends (Avda. Baja Navarra). A similar situation was observed in the industrial zone of Landaben and in the Old Town, where traffic (and the relatively high concentration of BTEX) extends for longer periods of time than the defined peak hours for certain traffic routes.



VOC concentrations in different areas of Pamplona

Regarding the amount of pollutants inhaled by cyclists, the BioVoc sampling device proved to be effective detecting significant differences in exhaled air before and after cycling throughout the city. In general, the amount of pollutants inhaled by cyclists showed a significant association with traffic density. Thus, the BTEX values present in blood, which can be estimated from their concentration in the exhaled air, were higher in those cyclists who circulated on routes with higher traffic or close to the emission sources (A). However, when the cyclists rode on bike lanes or on more open streets and with a less traffic volume (B), the BTEX concentrations detected in the exhaled air were clearly lower.



Average BTEX concentrations in cyclists who commute on busy roads (A) and areas with little traffic (B)

These results corroborate the results obtained in actions C1 and C2, demonstrating the convenience of moving away from the center of the road to reduce the inhalation of pollutants originated by road traffic.

ACTIVITY C4	Economic valuation of the impacts caused by pollution and estimation of the benefits of the reduction measures.		
Coordinator	CIEMAT	Participants	UNAV
State of the action	Finished		
Expected start date	6/14	Expected completion date	12/17
Start date	6/14	Completion date	12/17
Description of the tasks			
Task C4.1 was completed and the selection of dose response functions and monetary values was done. It has been decided to use the recommendations made by WHO (2013). Regarding task C.4.2, the economic valuation of the impacts of NO_2 emissions in the city of Pamplona			

in the base case situation (without improvement measures) has been carried out.

Traffic related NO_2 concentration distributions throughout the city have been provided by activity B2. NO_2 annual averaged and hourly maps from annual averaged days were computed by activity B2 with a resolution of few meters at pedestrian level. In order to use these results for the quantification of health impacts, these concentrations were spatially-averaged in cells of 100 m x 100 m, which is the resolution of the population data.

Quantification of health impacts was done using the results from the WHO project "Health risks of air pollution in Europe- HRAPIE project" (WHO, 2013). Only those effect estimates that contribute to the total effect – additive effects- are considered and both Group A* (pollutant-outcome effects for which enough data are available for a reliable quantification) and Group B* (pollutant-outcome effects for which there is more uncertainty) effects are quantified.

Monetary valuation of the estimated health impacts is done using monetary values of the different health endpoints recommended by Holland (2014) for the Cost Benefit Analysis done for the EU Clean Air Package.

Overall externalities are quantified for the set of concentration-response functions A* and the extended set of concentration-response functions A*+ B*. An estimation of the uncertainty around the main value of both sets has also been done, using the uncertainty ranges proposed by WHO (WHO, 2013).

The exposure to air pollutions leads to the appearance of various health effects that have been quantified, for the conditions existing in 2016, to 16 years of life lost due to exposure to high levels of NO2 pollution in the city, 111 hospital admissions for respiratory diseases, 141 additional cases of bronchitis in asthmatic children and 50 years of life lost due to long-term exposure to these increased levels of contamination (Fig. 1). The results of the uncertainty analysis performed are shown in the graph as error bars. These effects translate into medical costs and loss of well-being that are called external costs or externalities. The results obtained, as can be seen in Fig. 1, amount to a total of M€1.37 (0.83-1.91) if we only take into account the effects considered as A * (green in the graphs), and a total of M€4.85 (2.78-6.99) if we consider all the effects. The most important external costs are due to the reduction in life expectancy followed by hospital admissions due to respiratory problems and cases of bronchitis in asthmatic children.

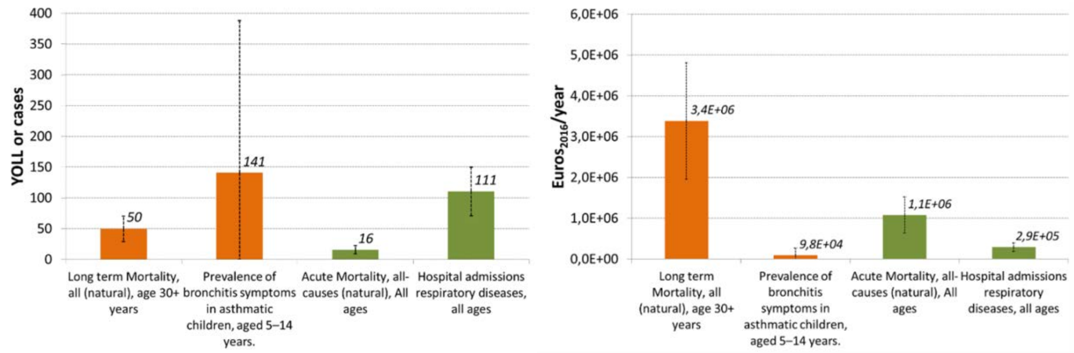


Figure 1. Health effects and externalities form NO_2 in the city of Pamplona

The distribution of externalities in the city is shown in Figure 2 and it is computed considering the distribution of both NO_2 concentrations and population. For each cell of 100m x 100m the effects are calculated taking into account the spatially-averaged concentration and the population data in this area. Externalities in the zone marked with a red circle in figure 2 are important because NO_2 and population density are high there. However, there are other areas where high concentration does not induce high externalities due to the low population density.

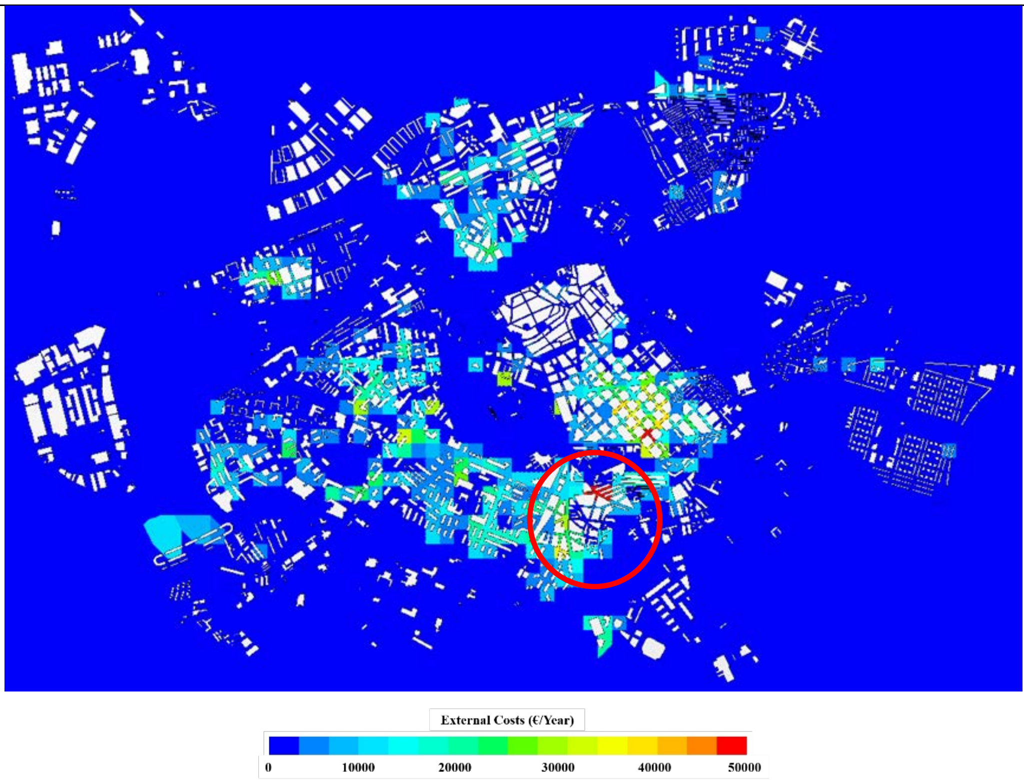


Figure 2. Map of NO_2 related external costs in the city of Pamplona during 2016

These results were presented in the 14th International Conference on Atmospheric Sciences and Application to Air Quality 29-31 May 2017, Strasbourg, France.

A tool based in excel has been developed to calculate the economic impacts of pollution in the city of Pamplona as well as the benefits of the reduction measures.

Regarding C4.3, in this area where external costs are higher, the effects of the measures explored in this project to reduce urban pollution have been quantified. These measures are the following:

- Introduction of urban trees in one of the streets.
- Installation of photo-catalytic pavements.
- Redistribution of traffic to avoid these more densely populated areas.

The introduction of urban trees in one of the streets in the area showed very similar external cost results. This is because in addition to reducing contamination by deposit, the trees affect the vertical and horizontal transport of the pollutant and that this aerodynamic effect can, under certain conditions, be more important than the deposit effect. The correct choice of the vegetation layout and the chosen species are crucial to achieve the desired mitigation effects.

The installation of photocatalytic pavements on the footpaths of this area of the city resulted in the reduction of the concentration of NO_2 in the area, with a corresponding reduction in the effects on health and the associated external costs of 2%.

The traffic redistribution scenarios analyzed consisted of cutting the total or partial traffic in this area of the city and its total or partial redistribution in the surrounding streets. The results showed a very important potential for reducing impacts of up to 58% when the traffic in a large area of this area of the city was totally eliminated and it was not redistributed in the surrounding areas. When this traffic is redistributed through other streets and these are densely populated, the results show greater impacts on health. Therefore, it is important to design with care these measures of redistribution of traffic to prevent it from accumulating in nearby streets, generating undesired effects.

The results obtained from the quantification of impacts of NO_2 emissions by road traffic carried out show that around 7 % of the citizens of Pamplona have been exposed in 2016 to levels of nitrogen oxides contamination above of the maximum levels of 40 µg·m^3 recommended both by the European Union and by the WHO. This is in line with the findings of EEA (EEA 2017). This caused important impacts on health, which in economic terms represent a loss of between M€1.37 and M€54.85. The results obtained from the analysis of the mitigation measures show that these measures, if they are well designed, improve the welfare of the population of Pamplona by reducing health conditions and associated external costs. These results can be used to inform the air quality policymaking process in the city of Pamplona.

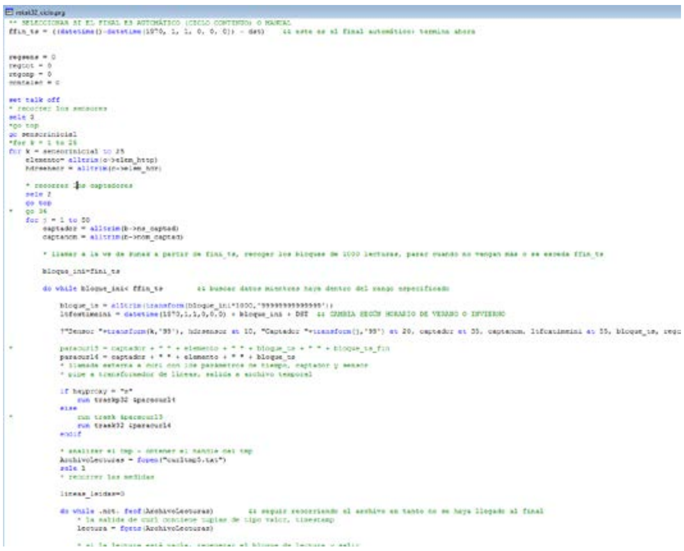
ACTION C5	Data Management Plan		
Coordinator	UNAV	Coordinator	UNAV
Action status	Finished		
Planned start date	6/14	Planned completion date	3/17
Start date	6/14	Completion date	12/17
Description of the task undertaken:			

This action carried on throughout the entire project lifetime. Its purpose was to ensure all collection, pre-processing and dataflow within data-generating Actions C1 through C4, and data-delivery to any requiring Action. Ongoing research uncovered several hurdles in the data sources. Much of the Action had to be reshaped to cope with problematic data. Several corrections were devised and set up to ensure a constant flow of quality data. These are listed below.

A major development of the DMP was to engage a European infrastructure, EUDAT, to ensure long-term public availability of the data. This was achieved through a parallel Data Pilot, PAIRQURS, designed to place LIFE+RESPIRA's results in a repository accessible by all interested parties.

The following activities have been already carried out during the ongoing Action:

1. Sensor data retrieval processor. Data are transmitted by the devices as timestamp/ID/parameter/value tuples and stored temporarily at the receiving cloud facility. A processor has been written that uses calls to web services and retrieves the tuples for ingestion into a database table collating all parameters from timestamp/deviceID pairs. The processor is in production and runs continuously, generating the production database of raw readings.



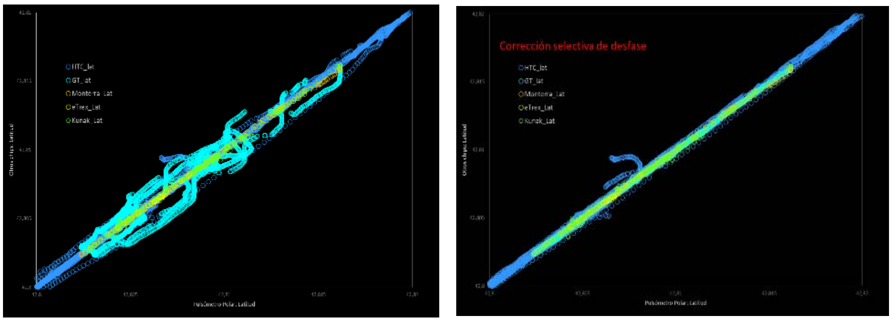
A few lines of the DRP's main routine code

50 ▾ entries per page			
Node	Parameter	Value	Date
Aire30	AIRQ NO WE (mV)	341.62	2016-03-09 22:48:19
Aire30	AIRQ NO AE (mV)	299.67	2016-03-09 22:48:19
Aire30	AIRQ NO GC (ppb)	37.11	2016-03-09 22:48:19
Aire30	AIRQ NO2 WE (mV)	230.70	2016-03-09 22:48:19
Aire30	AIRQ NO2 AE (mV)	226.73	2016-03-09 22:48:19
Aire30	AIRQ NO2 GC (ppb)	-2.91	2016-03-09 22:48:19
Aire30	AIRQ O3 GC (ppb)	164.30	2016-03-09 22:48:19
Aire30	AIRQ CO WE (mV)	492.22	2016-03-09 22:48:19

Id	Datetime	Lat	Lon	Ele	Id_sen	Hdop	Co_ae	Co_gc	Co_we	No2_ae	No2_gc	No2
airex_20150501_20150526.csv	2015-05-10 13:05:49.0	42.818066	-1.644134	467.2	Aire39	1	353.46	269.025	421.96	192.62	-7.527	21
airex_20150501_20150526.csv	2015-05-10 13:05:39.0	42.818092	-1.644110	472.8	Aire39	1	350.18	229.075	416.33	192.77	1.158	21
airex_20150501_20150526.csv	2015-05-10 13:05:29.0	42.818092	-1.644076	475.2	Aire39	1	349.91	214.200	410.60	192.46	-16.212	21
airex_20150501_20150526.csv	2015-05-10 13:05:19.0	42.818081	-1.644076	478.3	Aire39	1	347.73	198.050	411.72	192.53	-22.774	20
airex_20150501_20150526.csv	2015-05-10 13:05:09.0	42.818108	-1.644076	487.3	Aire39	1	349.04	215.900	414.78	192.31	-30.108	20
airex_20150501_20150526.csv	2015-05-10 13:04:59.0	42.818111	-1.644069	487.1	Aire39	1	349.05	227.375	419.84	193.04	-20.265	20
airex_20150501_20150526.csv	2015-05-10 13:04:49.0	42.818108	-1.644055	484.3	Aire39	1	349.62	239.700	423.18	194.67	-12.738	21
airex_20150501_20150526.csv	2015-05-10 13:04:39.0	42.818100	-1.644021	482.9	Aire39	1	350.16	252.450	426.78	193.88	-9.264	21
airex_20150501_20150526.csv	2015-05-10 13:04:29.0				Aire39		349.56	255.000	430.16	194.32	-12.159	21
airex_20150501_20150526.csv	2015-05-10 13:04:19.0	42.818043	-1.643997	481.9	Aire39	0	349.79	257.975	430.67	194.05	-18.142	21
airex_20150501_20150526.csv	2015-05-10 13:04:09.0	42.818047	-1.644004	481.1	Aire39	0	350.32	261.800	430.31	195.18	-13.124	21
airex_20150501_20150526.csv	2015-05-10 13:03:59.0	42.818077	-1.643975	487.9	Aire39	1	351.15	253.725	423.56	193.84	-16.212	21
airex_20150501_20150526.csv	2015-05-10 13:03:49.0	42.818058	-1.643969	490.2	Aire39	1	350.89	249.900	422.77	193.87	-11.966	21
airex_20150501_20150526.csv	2015-05-10 13:03:39.0	42.818058	-1.643955	497.3	Aire39	1	348.79	229.500	421.51	193.50	-13.703	21
airex_20150501_20150526.csv	2015-05-10 13:03:29.0	42.818123	-1.643884	508.0	Aire39	1	351.22	258.825	425.49	193.65	-18.528	21
airex_20150501_20150526.csv	2015-05-10 13:03:19.0	42.818130	-1.643883	508.3	Aire39	1	350.41	250.325	424.66	193.67	-18.914	21
airex_20150501_20150526.csv	2015-05-10 13:03:09.0	42.818096	-1.643923	501.0	Aire39	0	352.77	271.575	425.23	192.89	-17.563	21
airex_20150501_20150526.csv	2015-05-10 13:02:59.0	42.818092	-1.643952	497.0	Aire39	1	351.91	258.825	422.78	194.46	-18.528	21
airex_20150501_20150526.csv	2015-05-10 13:02:49.0	42.818092	-1.643965	498.1	Aire39	1	351.11	262.650	427.49	193.73	-13.703	21
airex_20150501_20150526.csv	2015-05-10 13:02:39.0	42.818096	-1.643977	498.6	Aire39	1	350.17	301.750	448.53	194.24	-10.808	21
airex_20150501_20150526.csv	2015-05-10 13:02:29.0	42.818096	-1.644002	499.7	Aire39	1	350.07	395.675	490.97	194.43	-21.616	20
airex_20150501_20150526.csv	2015-05-10 13:02:19.0	42.818089	-1.644032	500.2	Aire39	1	348.77	443.700	517.38	194.45	-25.476	20

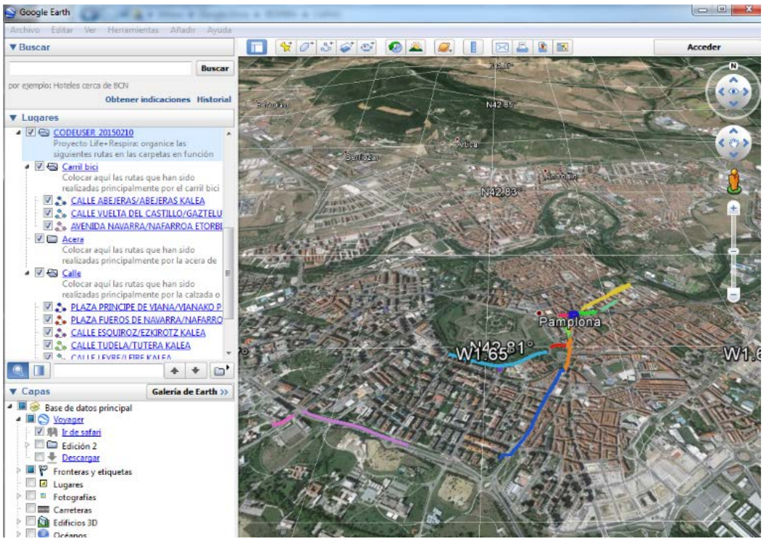
Transmitted tuples (left) and production database after pre-processing (right)

2. Track reconciliation. A GPS issue was discovered during the early test stages. GNSS units would use separate timestamp sources (satellite, GSM cells), that compounded with inherent GPS errors due to poor geometry or loss of SBAS correction in urban environment resulted in lower than desired precision. A phase-correction procedure was written to poll readings from separate GPS sensors when in use (e.g. GPS-enabled gear and smartphones) and obtain increased precision.



GNSS inter-sensor concordance tests before (left) and after (right) phase correction. Latitude reported by reference (horizontal) and other (vertical) GNSS units.

3. Track attribution. Precise locations were desired to separate different cycling surfaces (road, sidewalk, curbside cycle paths). To verify GNSS-derived data, a protocol was set up by which volunteers would attribute each track segment a typology. This task was a prototype for a more efficient app being awarded as a contract. Scripts working on Google Earth API and database processing algorithms were created to segment each user's tracks and allow attribution.



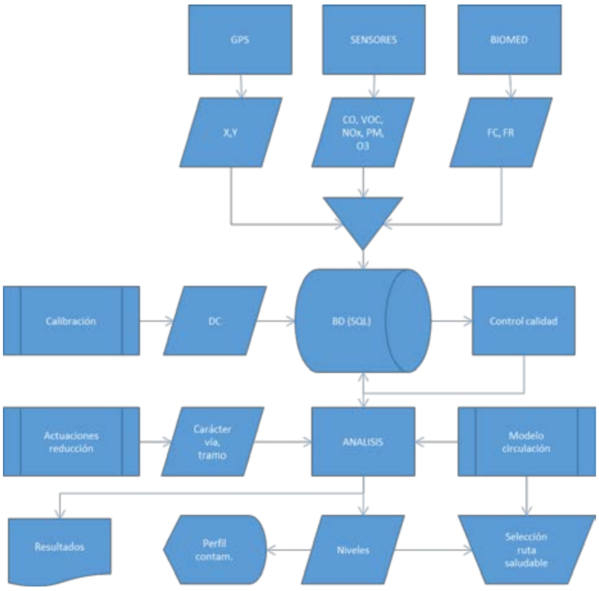
GE-based track attribution screen used by volunteers to categorize track segments.

4. Data fitness assessment algorithm. The data retrieval processor includes routines to decide whether individual data come from actual, measuring tracks or are unfit data (e.g. devices active while inside buildings, during function tests, or during calibration) based on several criteria such as time of interrogation, relative speed, GPS signal, etc. The routines tag the data with appropriate fitness values for analysis.

5. Data filtering routines. An algorithm was designed to find and tag transient readings affected by capacitive coupling at transmission time (see Action B1). The algorithm sits between the data retrieval processor and the concentration calculators in the analytical pipeline, filtering out unreliable data to avoid contaminating the model.

6. Pipeline and common repository. The data management revolves around a master database, built by the data retrieval processor, and a filtered, analytical database containing all tags. We teamed up with EUDAT to ensure that a copy of the master database, as well as the primary analytical database, are available through the B2SHARE service. The plan also called for additional EUDAT services to be progressively put in place to facilitate external access to all raw and processed data. A pilot EUDAT project (PAIRQURS) was approved to grant data management support to LIFE+RESPIRA throughout the duration of the project and beyond.

7. As a result of EUDAT involvement, several services (B2DROP, B2SHARE, B2ACCESS) were made available to LIFE+RESPIRA through PAIRQURS. This separate project created scripts and protocols to ensure that LIFE+RESPIRA data products were uploaded to EUDAT together with all metadata necessary to locate them. An XML schema was prepared with controlled-language terms that described each L+R product in terms or content, span, aggregation, file type, etc. More than 2,000 maps and datasets were uploaded to the B2SHARE and can be located and retrieved by querying the service supplying the desired aggregation parameters.



Dataflow around the master database. A filtered copy of the DB for analytical purposes is now being handled within EUDAT framework.

5.3 Dissemination actions

5.3.1 Objectives

The general objective of the Communication Plan was to ensure and enhance dissemination of the project's specific objectives, strategies and project results to all stakeholders, at the local, national and European levels.

Specific objectives of the Communication Plan included:

- To introduce the Project to potential stakeholders and main beneficiaries of the project's results.
- To report the project's results to public and private administrative and management bodies in other European regions, and the European and national Institutions that might be interested in the subject.
- To optimize the information flow across the project's partners and to organize an efficient communication within the project.

5.3.2 Dissemination: overview per activity

D1	Communication and outreach tools and plan		
Coordinator	UNAV	Coordinator	UNAV
State of the action	Finished		
Expected start date	6/14	Expected start date	5/17
Start date	6/14	Start date	12/17
Description of the tasks			
According to the Action plan, the following tasks have been carried out:			

1. **D 1.1. Communication plan.** The communication plan included some detailed information on all the actions planned within the project. We followed a transmedia strategy that includes over 100 actions, through traditional mass media, internet and face-to-face events. This plan includes a corporate image handbook and the logo. The project logo was selected from 50 proposals sent to a competition that we convened.
2. **D 1.2. Web site** (www.liferespira.eu). This is the main communication tool where all actions are conveyed. It has four profiles in Spanish, Basque, English and French, with different levels of information, according to the expected needs of potential users. Until December 31st, 2017, it had been visited by 17.150 users, for a total of 47.320 page views.
3. **D 1.3. Social networks.** At the very beginning, profiles of the project were set on Twitter, Facebook and YouTube. Results indicate that a growing participative community has been established. On December 31st, 2017, we had 1485 "likes" on Facebook, 901 followers on Twitter and 7420 views on YouTube.
4. **D 1.4. Production of audio-visual content.** We have produced 18 videos that are available from the YouTube channel and have been distributed through our social networks. The first one (https://www.youtube.com/watch?v=vV--l1135KA) was used as part of the campaign to recruit volunteers. The second video (https://www.youtube.com/watch?v=fu3S7QTdZX8) is a general introduction to the project that is being used in many meetings, conferences and events. We have produced version in English, Spanish and Basque. The English version was also distributed through the Life+ website. The other videos have focused on other events and tasks. We have also shot some images for the documentary that will be ready at the end of the project. We have also produced a 57 minutes documentary that was distributed through the project website and environmental film festival.
5. **D 1.5. Information boards.** We have produced five boards that were used as part of the recruiting campaign, as well as two other boards with general information on the project. They have been displayed in several cultural citizen centers of Pamplona.
6. **D 1.6. Booklets.** As scheduled, we produced three different booklets. The first one was a flyer for the recruiting campaign (2000 prints in Spanish and 1000 in Basque). For this campaign, we also printed 500 DIN A-3 posters and 500 labels that were placed in bicycles. The second one contains some general information on the project, and has been used in several events and presentations. The third booklet presented some tips for urban bikers and was distributed in several events. We also produced 500 files that are being used to deliver printed information on the project.
7. **D 1.7. Electronic newsletter.** Matching the information available, we have produced and distributed 10 newsletters. They are sent to a mailing list of 600 people.
   Although this was not planned, we have also produced 81 blog posts, in which the project researchers disseminate information for the general public.
8. **D 1.8. Merchandising.** As planned, we have produced several types of merchandising materials: t-shirts, raincoats, helmets, stickers, sports watches, and several bike accessories.
9. **D 1.**9. **Layman's report.** 500 copies of the Layman's report have been printed in English, Spanish and Basque.

D2	International seminar and training actions		
Coordinator	UNAV	Participants	GAN, CIEMAT
State of the action	Finished		
Expected start date	6/14	Expected completion date	
Start date	6/14	Completion date	12-17
Description of the tasks			
Several events were organized, according to the action plan: - Presentation of preliminary results, on May 30th, 2017. It took place in the venue of the			

Planetarium of Pamplona, with an attendance of over 100 people.
- Meeting on renewable energy and sustainable mobility. Public University of Navarra, Pamplona, May 4th, 2017, over 25 people.
- 2 Workshop on Urban Creativity. Museum of the University of Navarra, Pamplona. April 29th, 2017, over 25 people each.
- Workshop for school teachers. November 4th, 2016, 20 people.
- Presentation of Life+Respira project. Public University of Navarra, Pamplona, March 16th, 2016, over 25 people.
- Project launch to the city on February 19, 2015, with an attendance of over 200 people, including some of the volunteers.
- Seminar on climate change and air quality on December 12th, 2015, over 50 people.
- Seminar on Scientific research, citizen participation, air quality and urban mobility. It was held on March 16th, 2016, over 20 people.

<u>D 2.3. International seminar</u>
The final seminar took place in Pamplona on December 12th and 13th, with 26 speakers and over 100 participants.

<u>D 2.4. Publication of a technical document.</u>
A book entitled: “Reduction of exposure of cyclists to urban air pollution” was published in December 2017, in English and Spanish. The book is available on the project web site.

<u>D 2.5. The project has been presented in the following external conferences and scientific meetings:</u>
- HARMO17. 17th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes. Budapest (Hungary), May 9th-10th, 2016.
- EUDAT User Forum, Cracow (Poland), September 26th-28th, 2016.
- Greencities 2016. 7º Foro de Inteligencia y Sostenibilidad. Málaga, October 5th and 6th, 2016.
- European Week of Regions and Cities. Brussels. October 13th, 2016.
- 6th European Communication Conference (ECREA), Prague, November 9th-12th 2016.
- CONAMA. Salud, movilidad y calidad del aire. Madrid, November 29th, 2016.
- EUDAT Data Quality Workshop, Helsinki (Finland), January 25th-27th, 2017.
- EUDAT User Forum, Oslo (Norway), February 16th-17th, 2017.
- TFIAM/FAIRMODE Workshop on modelling of urban and regional measures for improve air quality. February 15th-16th, 2017, Utrecht, The Netherlands.
- Towards RDA Iberia Workshop. Barcelona, April 4th, 2017.
- Green Infrastructure: Nature based solutions for sustainable and resilient cities. Orvieto (Italy) 4-7 April 2017.
- Research Data Alliance (RDA) Plenary, Barcelona, April 5th-7th, 2017
- Atmospheric Sciences and Application to Air Quality. Strasbourg (France), May 29th-31st, 2017.
- International Conference on Urban Landscape. Barcelona, June 19th, 2017.
- Thinking of Mobility, thinking on the road. Asociación Española de la Carretera. Oral presentation by Jesús Miguel Santamaría: El rol de las nuevas infraestructuras de I+D+I en la adaptación al cambio climático, biodiversidad-gestión de ecosistemas e infraestructura vial. Iniciativa LifeWatch ERIC y Life+Respira. Madrid. September 20th, 2017.
- 6th European Communication Conference (ECREA), held in Prague, from November 9th to 11th, 2016. Oral presentation by Cristina Sánchez Blanco.
- Iberian Congress "The bicycle and the city", held in Malaga, from April 29 to May 3, 2015. A specific presentation on the project was carried out by one of the researchers of the Area of Geography of UNAV. Oral presentation by Maribel Gómez.
- Conference of the network of sustainable schools, held in Pamplona on November 13, 2015, organized by the Department of Education of the Government of Navarra. A presentation of Life+Respira was included in the schedule. Oral presentation by Maribel Gómez.
- E. Rivas, JL. Santiago, F. Martin, B. Sánchez, A. Martilli. (2016) CFD study of induced effects of trees on air quality in a neighbourhood of Pamplona. 10th International Conference on Air Quality

– Science and Application, 14-28 March 2016 Milan, Italy.
- E. Rivas, JL. Santiago, F. Martin, B. Sánchez, A. Martilli. (2016) Estimating the impact of urban vegetation on air quality in a neighbourhood: real case vs new vegetation scenarios. 17th International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes, 9-12 May 2016 Budapest, Hungary.
- M.N. Sánchez, B. Sánchez, S. Soutullo, J.L. Santiago. (2015) Modelling of urban greening effects on air quality in an undeveloped residential area. 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment. Toulouse, Francia. 2015.
- Rocío Alonso, V. Bermejo, H. Calvete, S. Elvira, H. García-Gómez, I. González-Fernández, I. Rábago, J. Sanz, F. Valiño. Improving urban air quality: Why urban vegetation matters. Presented in: Green Infrastructures and Urban forests for improving the environment and the quality of life . COST Action GreenInUrbs FP1204. Rome (Italy) nov 2014. Oral presentation.
- Rocío Alonso, V. Bermejo, H. Calvete, S. Elvira, H. García-Gómez, I. González-Fernández, I. Rábago, J. Sanz, F. Valiño. Why urban vegetation matters. Presented in: Mediterranean Urban Forests for improving the Environment and the Quality of Life in our Cities. Side event at the IV Mediterranean Forest Week. SANT PAU, Barcelona-Spain, March 2015. Oral presentation.
- Two researchers from the Geography and Environmental Biology Departments of UNAV have regularly participated in the meetings of the Pedestrian and Cyclist Mobility Observatory of Pamplona.
-Two researchers of the Geography Department of UNAV participated in "Sustainable Mobility 2015 Award", organized by the AMTS Association and the Government of Navarra.

<u>Some results of the project have been published in the following articles:</u>

- García-Gómez, H., Aguillaume, L., Izquieta-Rojano, S., Valiño, F., Àvila, A., Elustondo, D., Santamaría, J.M., Alastuey, A., Calvete-Sogo, H., González-Fernández, I., Alonso, R. (2016), "Atmospheric pollutants in peri-urban forests of Quercus ilex: evidence of pollution abatement and threats for vegetation", *Environmental Science and Pollution Research* 23: 6400–6413.
- García-Gomez, H., Izquieta-Rojano, S., Aguillaume, L., González-Fernández, I., Valino, F., Elustondo, D., ... & Alonso, R. (2016). Atmospheric deposition of inorganic nitrogen in Spanish forests of Quercus ilex measured with ion-exchange resins and conventional collectors. *Environmental pollution*, *216*, 653-661.
- Aguillaume, L., Izquieta-Rojano, S., García-Gómez, H., Elustondo, D., Santamaría, J. M., Alonso, R., & Avila, A. (2017). Dry deposition and canopy uptake in Mediterranean holm-oak forests estimated with a canopy budget model: A focus on N estimations. *Atmospheric Environment*, *152*, 191-200.
- Calvete-Sogo, H., González-Fernández, I., García-Gómez, H., Alonso, R., Elvira, S., Sanz, J., & Bermejo-Bermejo, V. (2017). Developing ozone critical levels for multi-species canopies of Mediterranean annual pastures. *Environmental Pollution*, *220*, 186-195.
- Avila, A., Aguillaume, L., Izquieta-Rojano, S., García-Gómez, H., Elustondo, D., Santamaría, J. M., & Alonso, R. (2017). Quantitative study on nitrogen deposition and canopy retention in Mediterranean evergreen forests. *Environmental Science and Pollution Research*, *24*(34), 26213-26226.
- Santiago, J. L., Rivas, E., Sanchez, B., Buccolieri, R., & Martin, F. (2017). The Impact of Planting Trees on NOx Concentrations: The Case of the Plaza de la Cruz Neighborhood in Pamplona (Spain). *Atmosphere*, *8*(7), 131.
- Buccolieri, R., Santiago, J. L., Rivas, E., & Sánchez, B. (2018). Review on urban tree modelling in CFD simulations: Aerodynamic, deposition and thermal effects. *Urban Forestry & Urban Greening*.
- Santiago, J. L., Martilli, A., & Martin, F. (2017). On dry deposition modelling of atmospheric pollutants on vegetation at the microscale: Application to the impact of street vegetation on air quality. *Boundary-Layer Meteorology*, *162*(3), 451-474.

D3	Outreach addressed to the general public		
Coordinator	GAN	Coordinator	UNAV, CIEMAT
State of the action	Finished		
Expected start date	12/14	Expected completion date	12/17
Start date	12/14	Completion date	12/17
Description of the tasks			

D 3.1. Actions in related events. The following activities have been carried out:

- European Mobility Week (September, 2014), organized by the Town Hall of Pamplona. We delivered 2000 flyers for the volunteer recruiting campaign at a Life + Respira booth situated in the city center and the Environmental Education Museum. During this week, we also displayed 200 posters of the project in several strategic places of the town.

- A cyclist parade was organized on May 10th 2015, to celebrate the beginning of air quality measurements. Over 100 volunteers and friends participated. It ended at the Town Hall square, where the silhouette of a gigantic bicycle was formed by the participants.

- Bicycle day (June 14, 2015), organized by the Pamplona Town Hall and other local institutions. It involved over 3000 participants, including many Life + Respira researchers and volunteers, who led the parade and helped in security tasks.

- European Mobility Week (September, 2015). In similar action to that of the previous year, we delivered information on the project to several thousands of participants. Two UNAV researchers (Dr. Santamaría and Dr. Pons) participated in the seminar on urban cycling that was organized by the Pamplona Town Hall. The very first results of pollution measurements were reported in this meeting. Many researchers and volunteers also participated in the cycling parade.

- Participation in the “Bicycle day”. Pamplona. June 6th, 2017.
- Participation in World Environment Day event. Pamplona, July 4th-5th, 2016
- Celebration of the Bicycle Day in Pamplona, July 12th, 2016
- European Mobility Week. Public University of Navarra. September 17th, 2016.
- Talk on air quality and mobility. City hall of Tudela (Navarra). September 22nd, 2016.
- Painting of the air quality station located in Rotxapea by students of the Escolapios School. Pamplona, March 2017.
- Planting of a tree at the Garden of Galaxies. Planetarium of Pamplona. April 5th, 2017.
- Talk on air quality and mobility. Civivox Iturrama, Pamplona. April 25th, 2017.
- Meeting for volunteers. Pamplona (Planetarium), May 30th, 2017.
- Celebration of the Bicycle Day in Pamplona, July 11th, 2017.
- School Board Day. Pamplona (Ezpeleta Palace), June 15th, 2017.

D 3.2. Didactic unit on air quality, mobility and health

The planned technical assistance has been hired, in order to develop this unit. In addition, we have created a cooperation network with the public educational institutions (Department of Education of the Government of Navarra, Department of Culture and Education of Pamplona). We have also started a cooperation project with MancoEduca, a prestigious environmental education program created 25 years ago by a local public institution (Mancomunidad de la Comarca de Pamplona). This cooperation seeks to integrate the educational activities of Life + Respira in the framework of this program, to ensure that the didactic unit will be used during the 2016-17 academic season and beyond. This will also help to strengthen institutional links with the transport authority of the metropolitan area of Pamplona that will be very helpful for the implementation of our educational program.

"LIFE Education" development program
• 290 educational centers of the Ministry of Education (Government of Navarre) have been invited. • 12 centers participated in the educational project • 19 teachers received training and have worked on the project • 800 students / researchers involved • 13 trained educators and technicians from MANCOEDUCA • 3 activities for students in collaboration with MANCOEDUCA • 2 activities for APYMAS (families) • 19 meetings held • 10 schools involved • 21 teachers and 400 schoolchildren sensitized • 26 workshops held (involving 520 students) • 32 participating teachers • 16 volunteer teachers and parents involved Students from ten schools in the Comarca of Pamplona participated in a meeting (School Board on June 15th, 2017) with the Mayor of Pamplona and other authorities to discuss the state of the air quality of Pamplona. This meeting, which took place at the School Council of Navarra, ended the educational project associated with LIFE + RESPIRA.

D4	Mass media		
Coordinator	GAN	Participants	GAN, CIEMAT
State of the action	Finished		
Expected start date	6/14	Expected completion date	12/17
Start date	6/14	Completion date	12/17
Description of the tasks			
D 4.1, D 4.2. A database of mass media contacts has been created and updated. At the moment it includes over 500 contact names of journalists and media, mainly specialized in environment, health and mobility, to whom we have sent press releases and other materials. D 4.3. We have produced and distributed 17 press releases. Other materials have also been distributed among the media, including the project logo, photographs and videos. We conducted 2 press conference to present the project to the media (February 16, 2015) and to present the final results (December 12th, 2017), with over 15 journalist attending each one and a very good impact among local and national media. D 4.5. The project press officer has received over 50 request of information from the media. D 4.6. 23 radio programs have been produced and broadcast on 98.3 local radio station, as well as on the web site and social networks. D 4.7. Press clipping. 130 impacts on national and local media have been collected (see annex), reaching a potential audience of over 12 million people.			

5.4. Evaluation of Project Implementation

In this section a summary of the methodology applied is briefly presented together with the results reached within each action. Concerning the cost-efficiency of actions, this information is described in detail in the financial section. Anyway, it is important to note that the expenditures for all actions are generally consistent with those reported in the original proposal.

Task	Foreseen in the revised proposal	Achieved	Evaluation
A1. Development of air quality monitoring prototypes and development of new improved sensors	Yes. The initial design of the prototype was changed to include newer and more accurate sensors.	Yes. A total of 50 prototypes were constructed. New improved sensors have been constructed.	There has been a side by side work between the company Kunak and the University of Navarra to design, construct and calibrate the prototypes. New sensors for the post-project network have been constructed with AICIA.
A2. Sensors Management Plan and acquisition of additional equipment	Yes. A management plan was designed for the using of sensor suites by volunteers.	Yes. This action ended belatedly due to the delay accumulated in A1, although this didn't affect the progress of the project.	This action was developed by UNAV and GAN. All manuals, apps and management protocols were prepared. Monitoring equipment was acquired.
A3. Analysis of the urban framework	Yes. Urban data about the city of Pamplona was collected and included in a GIS.	Yes. According to the schedule this action continued until the end of the project.	A report on the analysis of the urban framework has been produced. The action has been extended till the end of the project to include updated layers in the GIS platform. There has been a close collaboration between UNAV and CIEMAT to produce suitable layers to feed the models.
A4.Characterization of cycling mobility in the general context of urban mobility in Pamplona	Yes Although this action was delayed with respect to the planned schedule.	Yes. This action lasted until the end of the project	This action was led by UNAV. Despite being a preparatory action it was decided to extend it until the end of the project in order to keep periodically updated the data on mobility
A5. Training and establishment of volunteer teams	Yes The recruitment of volunteers was designed at the beginning of the project.	Yes. A total of 200 volunteers were recruited to participate in the project.	This action was developed by UNAV. Almost all volunteers received training courses to learn how to use the prototypes, the use of the booking agenda and handling of reserves, etc.
B1. Calibration of the pollutant measuring electrochemical sensors	Yes. Laboratory and field calibration tests were performed.	Yes. This action lasted until the end of the field campaigns.	This action was developed by UNAV in close collaboration with Kunak. Several mathematical analyses were performed to calibrate the readings given by sensors. A set of calibration functions were developed to correct sensor readings.
B2. High resolution modelling of urban air quality	Yes. This action used pollution data gathered by volunteers and meteorological data from two stations located in Pamplona	Yes. Due to different problems this action was delayed, but it did not affect the development of the project.	This action was led by CIEMAT in collaboration with UNAV, which provided the data needed to feed the model in the required format. Preparation of input data and calibration and validation of CFD model have been achieved. Also several simulation maps were produced.

B3. Photocatalytic pavement installation and demonstration of their effects on air quality	Yes A bike lane close to a road with high traffic density was paved. The objective was testing the ability of the pavement to reduce air pollutants.	Yes. This action lasted until the end of the field campaigns.	This action was delayed because of a change in the Government of Navarra. The pavement was installed in June, allowing the development of the action, which took place from June to December 2016.
B4. Quantification and modelling of air quality improvement by action of urban vegetation	Yes	Yes The action was delayed slightly but it didn't affect the project.	This action was coordinated by CIEMAT and was mainly performed by UNAV. Interesting conclusions about the role of urban vegetation and air pollutant distribution were obtained.
B5. Development of a Healthy Routes planner	Yes	Yes, although later than expected, since the company in charge of carrying out this action went bankrupt.	This action was developed by the company d2d closely with UNAV. Due to the mentioned problem, we had to hire another company (with funds from the University) to finish the App on time.
B6. Demonstration of the effectiveness of anti- pollution masks	Yes 6 prototypes were built to perform this action.	Yes. Due to the importance of this task two field-campaigns were performed.	This action was led by UNAV. A report on the effectiveness of anti-pollution masks was written.
B7. Cycling mobility plan in the general context of urban mobility, according to air quality criteria	Yes	Yes. This action lasted until the end of the project.	This action was led by UNAV. A management tool was developed to create a sensible mobility plan.
B8. Post-project sensor network	Yes	Not yet, because the city council is deciding where to install the sensors taking into account the changes in traffic that is taking place in the city	There is a great interest in the City Council to install this network. In the last weeks we have held several meetings to study different alternatives to place the monitoring network.
C1. A large-scale measurement of the pollutants exposed by cyclist	Yes This action is at the core of the project. Volunteers have logged 20,802 km in some 9,215 legs. This has produced 6.3 million records.	Yes. However, due to the large amount of data collected the production of scientific papers will last for at least two or three years.	UNAV was the coordinator of this action. The collaboration with volunteers is very fluid. To date, distribution maps of pollutants have been obtained that have aroused great interest in the Government of Navarre.
C2. Quantification of inhaling contaminants by cyclists	Yes	Yes This action lasted until the end of the project.	This action was led by UNAV. A committed group of volunteers was chosen to perform this action. A report has been written on the effects of physical exertion on the inhalation of air pollutants.
C3. Determination of VOCs levels to which cyclists are exposed and of	Yes	Yes. This action lasted until the end of the project.	This action was led by UNAV. A committed group of volunteers was chosen to perform this action. A report has been written on the

concentrations present in their exhaled breath			exposure of cyclists to VOC.
C4. Economic valuation of impacts caused by pollution, and estimation of benefits derived from reduction measures	Yes	Yes. This action lasted until the end of the project.	This action was led by CIEMAT. A report has been prepared that includes the main costs associated with pollution levels registered in Pamplona
C5. Management and processing data plan	Yes This action ensures all collection, pre-processing and dataflow within data-generating Actions C1 through C4, and data-delivery to any requiring.	Yes. This action carried on throughout the entire project.	Much of the Action had to be reshaped to cope with problematic data. Several corrections were devised and set up to ensure a constant flow of quality data. A Data Management Plan was implemented. An agreement was reached with EUDAT to ensure the availability of a copy of the master database through the B2SHARE service.
D1. Plan and tools for communication and dissemination	Yes	Yes. This action lasted until the end of the project.	Several deliverables were produced: Communication plan, web site, profiles on Facebook, Twitter and YouTube, merchandising materials, booklets, videos, electronic Newsletter, etc. The media impact of the project was larger than initially expected
D2. International meeting and training actions	Yes	Yes. This action lasted until the end of the project.	Several events were organized according to the initial plan. Likewise, the project was presented in a number of conferences.
D3. Dynamization targeted to the general public	Yes	Yes. This action lasted until the end of the project.	This action was led by GAN in collaboration with UNAV and CIEMAT. Thanks to the close cooperation between the three partners several join activities were organised. Moreover, the Life+Respira team participated, together with the volunteers, in a number of ephemeris. Finally, a didactic unit on air quality, mobility and health was prepared, having a huge positive impact on students.
D4. Communication Media	Yes	Yes. This action lasted until the end of the project.	This action was led by UNAV. All partners actively contributed to the appearance of Life+Respira in the different media: press, radio, television, web, etc. The potential audience reached by the project amounted to more than10 million people.
E1. Project Management	Yes	Yes This action lasted until the end of the	The project management system was structured by the coordinating beneficiary and supported by the

		project.	associated beneficiaries. The Partnership agreement was signed on January 2015. All partners were committed with the project manager, sending all information they are required.
E.2 External audit	Yes	Yes	The project has been audited and the corresponding report is attached.
E3. Networking	Yes	Yes. This action lasted until the end of the project.	Members of Life+Respira participated in a number of networking activities, creating new liaison between stakeholders through the sharing of competences within networking activities and the participation in national and international events.
E4. Communication plan after-LIFE	Yes	Yes	A document has been prepared that includes the dissemination strategies of the Life + Respira project. The objective is to ensure that the main outcomes of the project continue to spread information and promote engagement among citizens about the importance of air quality.

5.5 Analysis of long-term benefits

5.5.1. Environmental benefits

Life+Respira's foreseen outputs are expected to noticeably influence society by providing, if carried on to their logical consequences, environmental benefits for the city of Pamplona. These benefits will ultimately be dependent on the degree of implementation of the proposed actions once the project is completed. In this regard, we have provided strong empirical evidence to support measures to reduce air pollution through the promotion of sustainable transport and other management measures.

In fact, at the end of the project, the Municipality of Pamplona has conducted a pilot test to restrict traffic in the city center and has signed a contract with us to apply the methodology developed in Life Respira to quantify the benefits in terms of air quality for citizens as a result of traffic restriction.

Therefore, it seems clear that the methodology developed in Life+Respira is a very useful tool to improve the environmental quality of urban areas, and can be replicated in other European cities to improve the quality of life of citizens.

5.5.2. Long-term benefits and sustainability

The results of Life+Respira may have long term results on the following areas:

• Environment and health: when new policies on air pollution will be evaluated at EU level, the results from this project of long term health effect on cyclists and pedestrians may be taken into account. The impact of air pollution on population health can be estimated directly through the running of the model calibrated in this project.

• Social: this project has tried to raise public awareness on the problems of air pollution. The high social participation that has taken place in this project has shown that citizens play a key role to improve the quality of life in their cities.

• Economic: Life+Respira has allowed calculating the real cost of the impacts caused by air as well as the benefits arising from the implementation of management plans. These data are of great interest to municipal and environmental managers, who, thanks to this information, can adopt measures to reduce the expenses associated with pollution while promoting an improvement in the quality of life.

• Occupational: Life+Respira has facilitated the establishment of a research group that can be consolidated, particularly if this pilot study will be widened to other EU countries. In this sense, Life+Respira has been included as a success case in the European Research Infrastructure LifeWatch ERIC, thanks to which it will be possible to replicate the project in other European cities (Spain and Italy initially).

5.5.3. Replicability, demonstration, transferability, cooperation

The usefulness of Life+Respira outcomes does not stay local. In the long term it is expected that this project can be replicated in other European cities. In fact, based in the experience gained in Life+Respira, we are planning to replicate the project in other European cities thanks to the use of structural funds (ERDF). In these new projects we will develop activities to facilitate compliance with European Union air quality and to provide integrated approaches to the implementation of air quality legislation.

5.5.4. Best Practice lessons

The project has been designed, and has been carried out, to strict scientific standards and practice. As the project has worked near the limits of available technology, most of the project's specialist time has been devoted to ensuring reliability and replicability of data through exhaustive data checking and tests. We have ensured the data's fitness-for-purpose and through extensive modelling and experimentation. This is not a realization during the project, but rather a design constraint. We have thus set the accuracy requirements of the project to current scientific research practice (10% or better) rather than to managerial (25%) or exploratory (50%) approaches.

Thanks to this, we have achieved a very high reliability of the results, which has allowed us to be more ambitious when proposing improvement measures that can be used by the managers.

5.5.5. Innovation and demonstration value

The Life+Respira project can be considered a pilot study that is implementing a novelty methodology to determine the distribution of air pollutants in cities and to quantify the amount of pollutants that cyclists and pedestrians inhale under actual traffic conditions. The using of cutting-edge sensors constitutes an expanding market and will reach great importance in a near future. Therefore, the demonstration of the utility of these sensors throughout the project is an important milestone for companies developing these types of devices.

Moreover, this project is producing a high-resolution model that can be applied in other EU member countries as a valuable tool to improve air quality control strategies.

This project is affordable at a bigger scale thanks to the relative cheapness of this methodology in comparison to other studies requiring very expensive instrumentation to get the same information obtained in this project.

Finally, the project has a significant added value, the social involvement of volunteers, acting as drivers and main beneficiaries of the results.

5.4.6. Long term indicators of the project success

Quantitative long-term indicators of the expected project success are reported below:

Air quality status before and after the project.

- Number of countries which positively reply to the "join our project" survey.
- Number of publications achieved after the end of the project.
- Number of times the project representatives are invited at conferences, seminars, other events.
- Number of times the Life+Respira publications are cited.
- Number of visits to Life+Respira website.
- Number of requests for clarifications, update, dissemination and scientific material(publications, Layman's report, etc.)
- Future funding
- Continuation/replication after the Project period
- Entry into new sectors/projects/geographic areas
- Possible creation of a company or spin-off

6. Comments of the financial report