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Team 8 – The Feynmans

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CBI Challenge Based Innovation

Run 4IR

FINAL REPORT

ATTRACT · esade Ramon Llull University · UPC Universitat Politècnica de Catalunya BarcelonaTech · IED

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1. INTRODUCTION

This report delves into the multifaceted challenge of air pollution in the vibrant city of Barcelona, where we explore its profound impact on public health, scrutinize the limitations of current monitoring systems, and the evolution of our innovative initiative known as "Run for Air" or simply "Run4ir."

Our goal was to use Attract's cutting-edge technology to develop a practical and scalable solution that directly addresses major global environmental issues, like air pollution, sustainable cities, and water pollution. We started our investigation in Barcelona, a city we know well.

In the following sections, we will explain our research process. We started with in-depth research to gain a deep understanding of the air pollution problem. We unraveled the intricate web of the problem through interviews as we illustrate in the "People and Connections Map”.

The "Impact Gap Canvas" served as our compass, laying bare the disparities between the current state of air quality and our aspirations for a healthier environment.
To get a deeper understanding of the problem, we used something called the "Iceberg Model" to uncover hidden issues.

Our journey then led us to the conceptual development phase, where we revisited and refined our comprehension of the problem. We diligently crafted two robust solutions, subjecting them to rigorous validation to identify our primary path forward.
Guided by the "Impact Model Canvas," we assessed the scalability and feasibility of our chosen idea and determined the most promising solution.

In the final stretch, we delve into our "Final Idea and Solution," providing a comprehensive breakdown of our initiative's objectives and functionalities. This section offers a detailed glimpse into what our solution aspires to achieve.

2. RESEARCH REPORT

2.1. People and Connections Map and Interview Insights

Connecting with people has been our primary source of inspiration in developing and guiding our idea. The main reason we chose to focus on Barcelona was precisely the vast network of quality contacts we could access. From the first day, when Ian warned us it wouldn't be easy to convince people for interviews, we got to work. We discovered that the key was always to open the door because, through one interviewee, we could be recommended to other valuable contacts and eventually immerse ourselves more fully in the world of air quality in Barcelona.

Initially, we made more general contacts, and as we refined our ideas, we became more specialized. In total, we've spoken with around 18 individuals from institutions, companies, or consortia such as BSC, ESA, Hospital Universitari de Bellvitge, ISGlobal, Generalitat de Catalunya, Diputació de Barcelona, CSIC, Kunak, Bettair, Lobelia, Fiware, etc.

Following this, we have documented the most relevant insights we've gathered:

Kevin McMullan
Mission leader for the Copernicus programme, Sentinel 5P at ESA
“Sentinel-5P data is freely available. [...]High resolution (7 Km2 pixel) helps to pinpoint sources of methane emissions. [...]It can help policymakers to develop targeted interventions.”

Dr. Alicia Pérez
Head of Pneumology Service at Hospital Universitario de Canarias
“Respiratory disease varies significantly with the season (more cases in the fall and winter). [...]Higher air pollution means more emergency room visits for respiratory and cardiac problems. [...]Issue due to the economic and political interests of powerful lobbies.”

Dr. Yolanda Ruiz
Pneumologist specialist in Pulmonology at Hospital Universitari de Bellvitge
“Difficult to quantify the impact of air pollution on the quality of life. [...]Reducing exposure can help to prevent exacerbations. [...]Patients with exacerbate respiratory diseases are advised to move to less polluted areas.”

Marcos Blay

Business and Expansion Area at ZONAIR3DTM

“Little awareness of toxic pollution. [...]Breathing: 11,000 litres of air/day. [...]Biggest handicap: invisible and tasteless. [...]Difficult for people to understand the problem and take action.”

Jordi Sunyer

Research Professor at ISGlobal

“Suspected traffic-related particles in Barcelona may have increased neurotoxic effects, requiring in-depth analysis. [...]ISGlobal's extensive research, including collaborations with groups like Urbanom, explores pollution's complex interactions with factors such as noise, physical activity, and vegetation for a holistic understanding.”

Fulvio Amato

Air Quality Senior scientist at IDAEA-CSIC

“Relationship between exposure to air pollution and children's cognitive development is complex and not fully understood. [...] Research: exposure during pregnancy and early childhood can lead to lower IQ scores, poorer school performance, etc. [...] More affected: low-income families or children in polluted areas.”

Dr. Daniel Rodriguez Rey

Urban Air Quality post-doctoral researcher at BSC_CNS

“Traffic dominates more than half of air pollution at street level in BCN. [...] I think there is a need for information about the real impacts on health. Because whenever air quality is discussed, the environment is mentioned, but no, we need to focus on health. [...] There is a misunderstanding. Whenever air quality is discussed, the enviroment is mentioned, not our health. There is a communication problem. [...] Health interpolated forecasts are very inaccurate (they work with postal codes and relate their impact to the nearest base station). There could be synergies, but it's very complicated.”

Dr. Francisco Ramírez Javega
Lead Data Scientist en Bettair Cities
“An application is being developed to access personal information, such as individual exposure or the cleanest routes for travel. [...] Nowadays, the distribution of pollutants at street and urban level is not completely understood because the sources of the emissions of the gas concentrations may change fast at a given location and between nearby sites.”

Peio Ibañez
National Sales Manager at Kunak Technologies SL
“All air quality data collected by our equipment belongs to our clients, and we do not have the authority to share it with anyone. [...] Some air quality data is public and can be found on various platforms of different municipalities. For instance, the Albacete City Council has published data from our equipment on their website, and many others share data from reference stations."

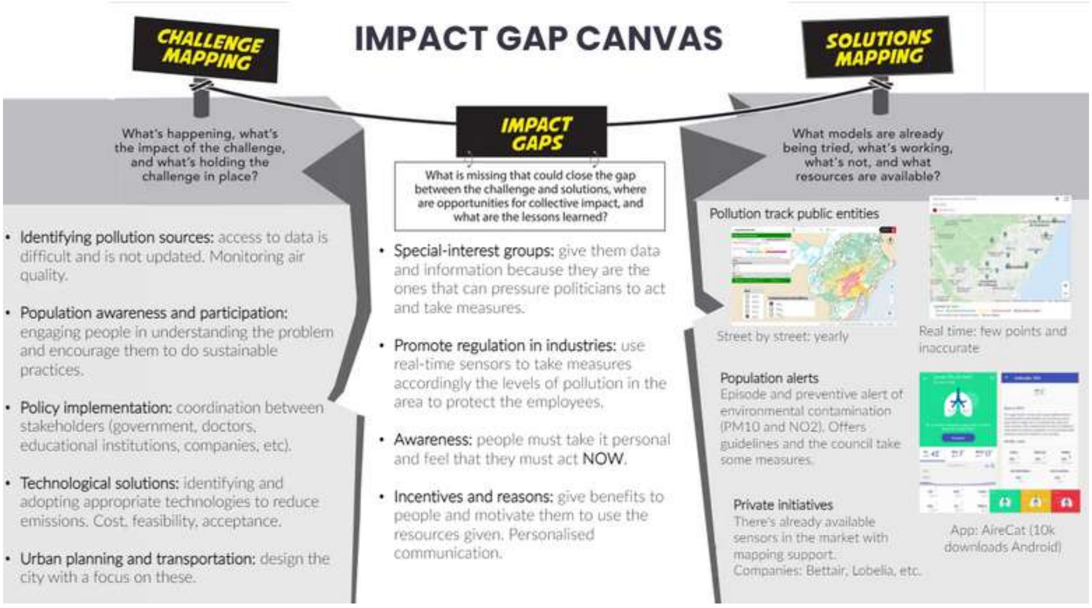
Yuzhen Li
Project Developer for FIWARE’s Smart World and Software demonstrator
“Introduced us to a collaborative project between Bettair and FIWARE that caught our interest.”

Oriol Martínez
Commercial Director at MCV, S.A. - Air Quality and Meteorology
“We focus on developing, designing, and manufacturing environmental equipment and systems. [...] We're working to make our data more accessible by developing an early warning system for air pollution.”

Mar Garcia Miró
Climate Action and Energy Transition Area
“Our office policy is not to believe in models. How do you verify a model? We receive responses like "with another model. [...] We are more about measuring. Models help us a lot, especially for prediction, but the most valuable thing is to measure, have data. If it were that simple, why do we measure? Models as a complementary method, fantastic. But it will never replace a measurement.”

2.2. Impact Gap Canvas

Graphic 1. Impact Gap Canvas



In the Impact Gap Canvas, we learned that obtaining real-time information on air pollution in Barcelona was quite challenging due to outdated information and inadequate sensor placement. We also recognized the need to monitor air quality and realized that this could only be achieved by identifying sources of pollution.

On the other hand, we also discovered that people need to raise awareness about air pollution to increase engagement and encourage greater citizen participation. We believe that by offering incentives and benefits, we can motivate them to use the resources provided.

2.3. Problem Definition

Air pollution, the foremost environmental health risk per the World Health Organization, incurs significant mortality, diminished quality of life, and economic burdens. This issue is particularly pressing in urban settings, where over half of the world's populace resides, and air quality often surpasses acceptable levels.

In Barcelona, a city acclaimed for its visionary urban design and sustainability commitments, air pollution poses a stark contradiction. Despite notable green spaces, broad pedestrian zones, and a robust public transport network, the city grapples with environmental challenges. Barcelona's innovative Superblocks initiative, which reconfigures neighborhoods into low-traffic areas, along with rigorous historic conservation efforts, underlines its strategic actions against pollution. However, the continued battle with air quality underscores an urgent need for cutting-edge solutions to improve the health of urban environments.

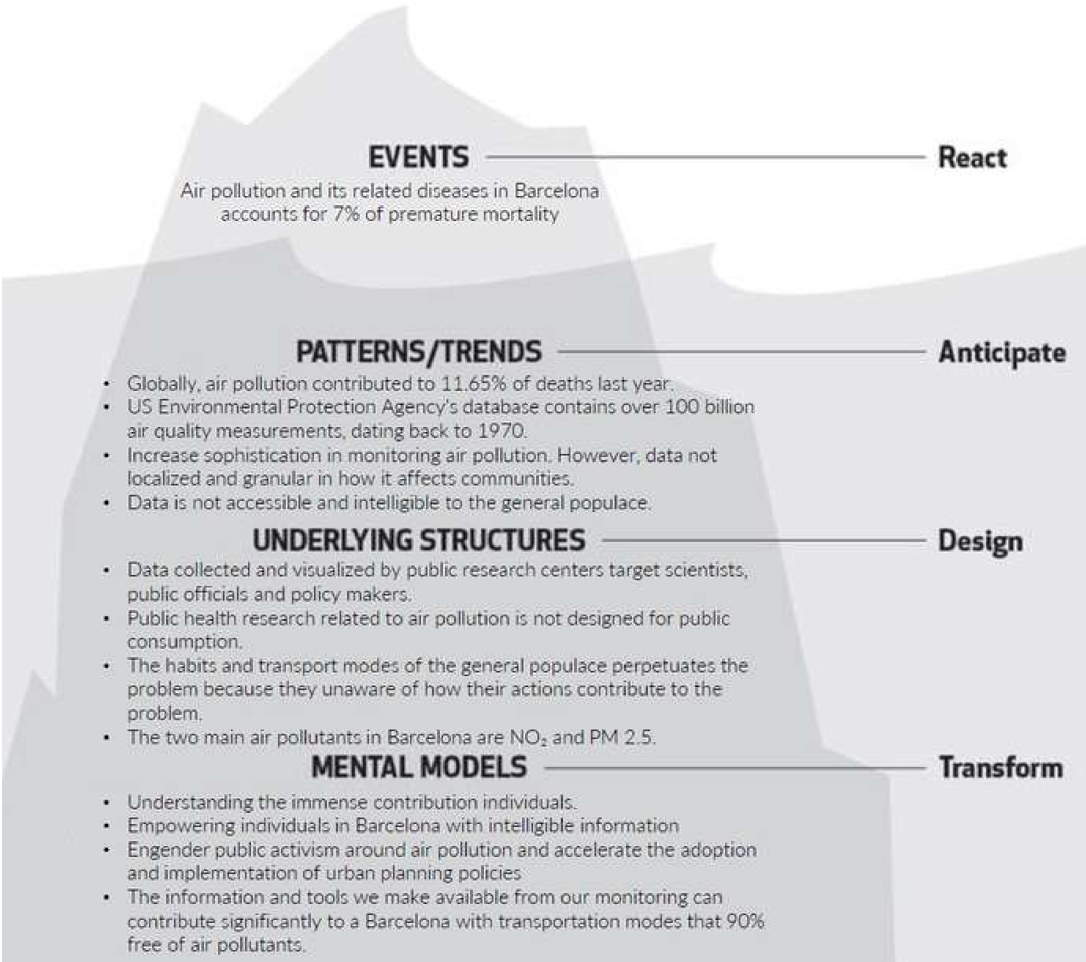
According to the 2022 health report for Barcelona, air pollution is linked to 1,500 deaths, 900 new childhood asthma cases, and 130 lung cancer cases annually.

Further studies conducted by the Public Health Agency of Barcelona, underscore the severity of the issue, air pollution causes more than 350 premature deaths each year and poses a particularly significant health problem for the most vulnerable population, such as the 200,000 children under 14 years old living in the city.

Barcelona is notably impacted by a chronic NO2 issue due to high vehicle density, so much so that *Ajuntament de Barcelona* released an annual report stating that around 60% of the NOx inmissions are due to terrestrial traffic (cars, trucks, motorbikes...), positioning it as the sixth European city in NO2-related mortality. *High-resolution tracking of NO2 and other pollutants like PM2.5, PM10, SO2, O3, and CO2 is vital for informed urban air quality management.*

2.4. Iceberg Model

Graphic 2. Iceberg Model



2.5. State of art: Monitoring in Barcelona

Barcelona's local government and other public and private institutions recognize the current state of Barcelona's air pollution. Attempts to remedy the city of this detrimental phenomenon goes from measuring the concentration of the air pollution in the city to leveraging these measurements to make informed decisions as to what interventions the city needs to implement.

In this regard, more and more regulation policies are being installed in the city overtime. However, the concern of gathering accurate data persists. There are no right policies without updated and precise data. Therefore, if we want to make bigger steps into healthier and optimised city organisation, we must collect the best data with the least cost possible, in order to prevent implementing inadequate regulations in the city that do not align with reality, which could result in ineffective or even counterproductive measures. Nevertheless, monitoring and measuring air pollution with the right accuracy can be a complex endeavour.

2.5.1. Air quality monitoring stations

Barcelona has established a network of nine substations, each equipped with advanced sensors, to monitor air quality in real time. These stations measure a range of pollutants, including gaseous pollutants (O_3, NO_2, SO_2, CO), particulate matter (PM10, PM2.5, PM1), and meteorological conditions. The data collected is analysed using chemiluminescence for gases and beta attenuation for particulate matter.

Graphic 3. The air pollution monitoring and forecasting network

Source: Ajuntament de Barcelona

Drawbacks

Air quality monitoring stations are often located in fixed places, and thus, **they do not capture the real spatial variability of pollution throughout the city**. This can lead to an inaccurate representation of air quality in specific areas.

2.5.2 Passive dosimeters

Dosimeters contain a material that is porous and allows air to pass through it. The pollutants in the air diffuse into the material, and the concentration of pollutants is determined by measuring the amount of pollutant that has accumulated in the material over time.

Drawbacks

These tools measure personal exposure to air pollution over time, but **they often do not offer the same temporal resolution as measurements taken by base stations**. This can result in a lack of detailed information about rapid changes in air quality.

2.6. State of art: Parametric models in Barcelona

An air quality model is a mathematical representation that brings together and synthesises all the factors involved in air quality: meteorological conditions (wind, rain, temperature, etc.), mobility, as well as the main sources of pollutants.

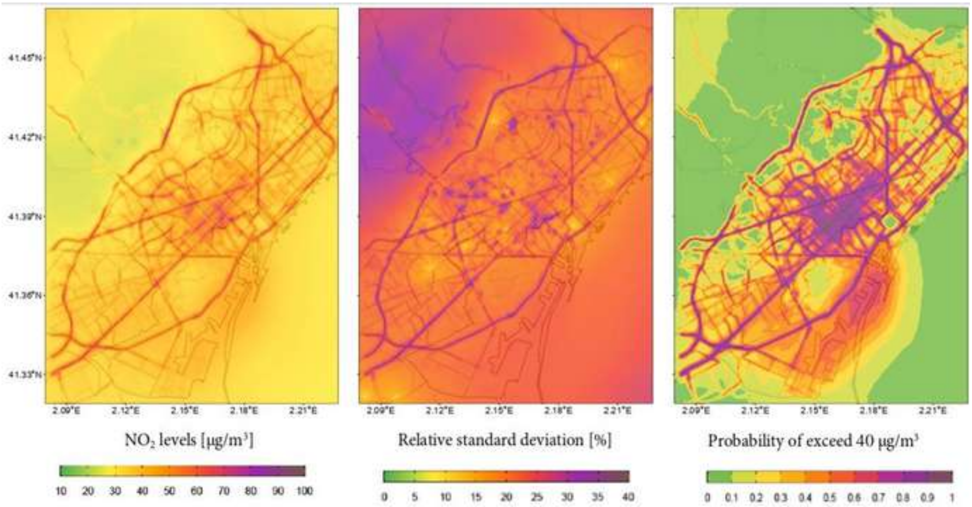
The combination of all these elements results in the spatial distribution and temporal evolution of pollutant concentration. In general, an air pollutant dispersion model consists of a meteorological module, an emission module and a photochemical or pollutant transport/dispersion module.

For this project, our group immediately considered focusing on the Caliope-Urban model, operated by the Barcelona Supercomputing Centre (BSC). The choice is straightforward for several reasons. Firstly, it leverages one of the most powerful supercomputers globally, facilitating operation on high-performance computing systems and enabling the production of rapid and up-to-date air quality forecasts. Secondly, it demonstrates proficiency in forecasting air quality in the city of Barcelona. Furthermore, the model stands out for its adaptability, easily accommodating updates with new data sources. Lastly, given their close relationship with UPC, contacting them would be a seamless process.

The Barcelona Supercomputing Centre (BSC) Model: Caliope-Urban

This modelling system provides high-resolution NO2 concentrations for Barcelona by coupling the regional-scale CALIOPE with the urban-scale R-LINE model. On the one hand, CALIOPE is a mesoscale air quality forecasting system and, on the other hand, R-LINE is a Gaussian dispersion model designed for near-road applications. The system adapts to street-specific conditions, considering meteorology, background concentrations, and traffic emissions.

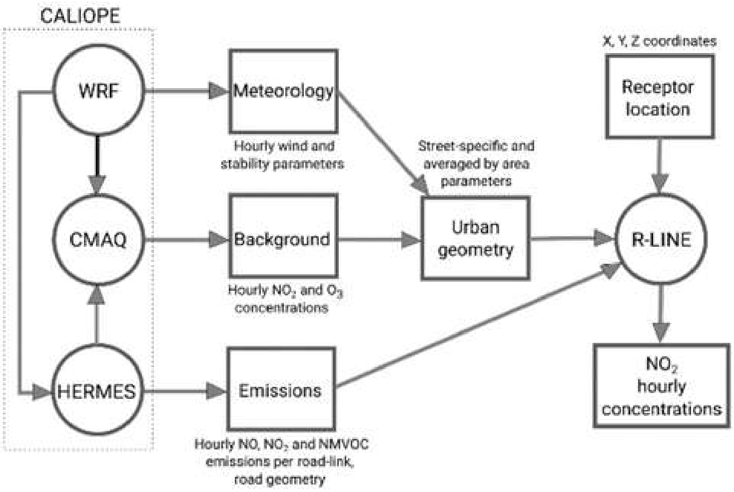
Graphic 4. Annual average of NO2 2019; uncertainty field associated with the methodological correction; probability of exceeding the legal limit of the annual average during 2019



Source: Barcelona Supercomputing Centre

The methodology dynamically adjusts to street conditions by incorporating street-specific surface roughness, channelled winds, and recalculated meteorological parameters for each street. The system estimates background concentrations using an upwind background scheme and applies a vertical mixing parameterization based on urban geometry and atmospheric stability.

Graphic 5. CALIOPE-Urban workflow.



Source: Barcelona Supercomputing Centre

Graphic 5 states that the meteorology and background from WRF and CMAQ are combined with urban geometry to create inputs for R-LINE. R-LINE dispersion is left untouched, after adjusting meteorology and surface roughness for local urban geometry.

Additionally, the public consortium uses three datasets of observations to evaluate the performance of CALIOPE-Urban to reproduce the temporal and spatial variation in NO2 concentrations within Barcelona city.

Graphic 6 shows the location of passive dosimeter and monitoring site locations used in the evaluation of CALIOPE-Urban. Red dots with a yellow border represent passive dosimeters (spatial performance) and white numbered dots depict monitoring site emplacements (temporal variability).

Graphic 6. Location of passive dosimeter and monitoring site locations

Source: Ajuntament de Barcelona

Drawbacks

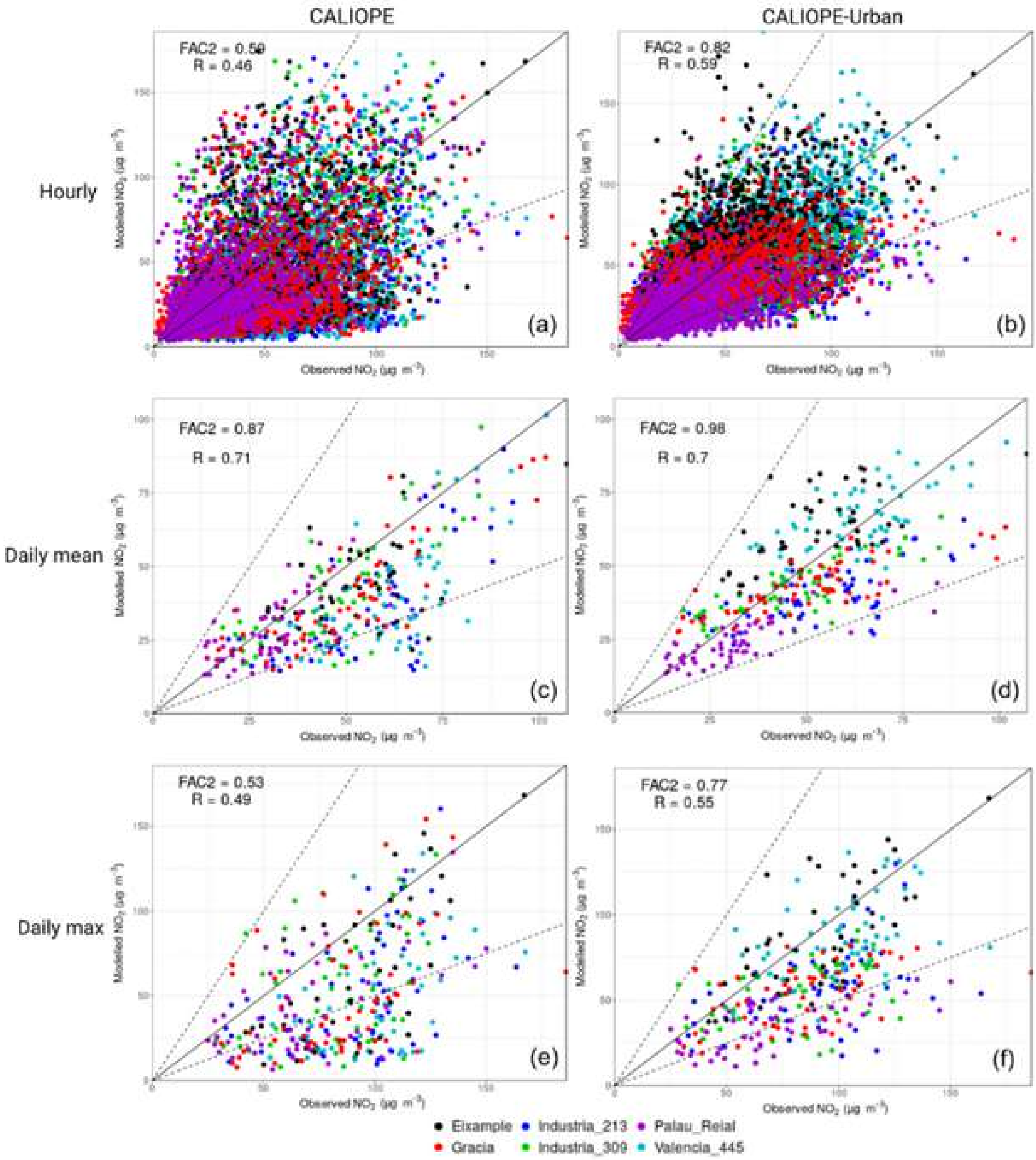
To begin, it's crucial to acknowledge that the observations obtained from *ground-level sources*, which are the most reliable and, consequently, carry the most weight in the model, are often *not representative either temporally or locally*, as discussed earlier.

Furthermore, it's essential to bear in mind that the *current BSC model strictly focuses on predicting NOx concentrations, excluding other pollutants*. This choice is attributed to the substantial cause-and-effect relationship of NOx and its relative ease of estimation. On the other hand, the exclusion of PM particles is due to their considerably higher computational cost, as they involve regional influx—meaning they originate from external sources rather than being directly emitted by the city itself.

Despite these considerations, it's noteworthy that the Caliope-Urban model remains *vulnerable to the high spatial and temporal variability* of air pollution in cities, even for NOx, which it ostensibly specialises in.

Graphic 7 shows the temporal variation in NO2 concentrations within urban streets Scatter plot of hourly (a, b), daily mean (c, d) and daily maximum (e, f) modelled concentrations against observed concentrations with colours representing monitoring sites for CALIOPE (a, c, e) and CALIOPE-Urban (b, d, f). Purple represents Palau Reial, the urban background site. The other colours represent traffic sites as described in Sect. 3.1.

Graphic 7. Temporal variation in NO2 concentrations within urban streets Scatter plot



Source: Barcelona Supercomputing Centre

3. CONCEPTUAL DEVELOPMENT: FINDING A SOLUTION

3.1. Problem Statement

The Problem as we saw it was is in two folds:

Challenge 1: Limited Granularity in Real-time Data Collection
The current method for monitoring air quality in Barcelona, centralized around six air quality monitoring stations and the analytical prowess of the Barcelona Supercomputing Centre (BSC), while technologically advanced, is not without its drawbacks. The operational costs are substantial, given the need for high-powered computing resources to process and analyse the vast influx of environmental data. These supercomputers, alongside the maintenance of the sensor network, require significant financial investment. Furthermore, the precision of the data provided is not yet at the level where it can fully empower citizens and local authorities to make informed decisions in real-time. For interventions and strategies to be truly effective, a more cost-effective and expansive monitoring framework would be necessary, one that could deliver detailed, localized air quality information to facilitate immediate and impactful actions.

Challenge 2: Air Pollution's Impact on Health
Air pollution poses a significant threat to public health in Barcelona, contributing to respiratory and cardiovascular diseases. Shockingly, an estimated 350 individuals succumb to air pollution-related ailments each year in the city.

Of the vulnerable groups most affected by air pollution, runners have emerged as quite interesting due to their unique exposure levels. Engaged in outdoor activities, they experience direct and prolonged contact with ambient air quality conditions. Unlike static populations, runners traverse various environments, which subjects them to fluctuating concentrations of pollutants. A runner breathes in 15x more air compared to a person at rest.

Furthermore, in Barcelona depending on the time and place chosen for running, it can reduce running can reduce exposure to pollution by 6 to 10 times exposure to pollution. From our experience as residents of Barcelona, we recognized that a fundamental aspect of the issue was the need for greater awareness and public education about air pollution in the city. Despite the availability of data and the presence of monitoring stations, there is a gap in effectively communicating the risks and realities of air pollution to the public. It's crucial to inform and empower the community with knowledge about air quality levels the health risks associated with exposure to pollutants, and the actions they can take to mitigate these risks. Strengthening public awareness is not just about disseminating information; it's about fostering a culture of environmental responsibility that can drive collective action and support for policies aimed at reducing air pollution.

3.2. Idea Selection, Alignment and Validation

In tackling the air pollution challenge in Barcelona, two innovative ideas emerged for consideration:

Interactive Air Quality System at Bus Stops:
The first concept involves installing interactive signboards at bus stops, integrated with the chemical sensors from the Sniffirdrone. These signboards would collect and display real-time air quality data, offering commuters instant insights into the pollutants present at their location. This interactive element aims to educate the public on the impact of air pollution on their health, fostering a deeper understanding and engagement with environmental issues. Additionally, the data harvested from these bus stops would be funneled to the government's Barcelona Supercomputing Centre models, with the potential to refine and enhance their predictive accuracy.

Runners as Mobile Air Quality Monitors:
Drawing inspiration from the principles of citizen science, the second solution proposes equipping runners with the means to measure air pollution during their routes across the city. As runners move through different neighborhoods, they would collect highly localized and detailed air quality data. This point-to-point data would not only benefit the runners by informing them of the least polluted paths but could also be invaluable to the BSC's efforts to improve their modelling system. By harnessing the mobility of runners, the city could achieve a dynamic and expansive data collection network, filling in the gaps left by stationary monitoring stations.

Both ideas center on the concept of integrating everyday activities with environmental monitoring to foster community involvement and generate valuable data to combat air pollution more effectively.

We chose to move forward with the second idea and tagged it "Run for Air" (Run4ir), because it empowers citizens and encourages active participation in improving air quality. While initially targeting runners, we firmly believe that the concept extends to everyone, regardless of their fitness level or mobility. The essence of Run4ir lies in the idea that anyone can put on their running shoes and take to the streets to make the invisible threat of air pollution visible.

With Run4ir, we envision a community-driven movement where individuals from all walks of life can contribute to monitoring air quality. It's a testament to the power of collective action and the belief that small steps, quite literally, can lead to significant changes in our environment. By engaging the public and involving them in the process of data collection, we aim to foster a sense of shared responsibility for the air we breathe and ultimately work towards a healthier and more sustainable Barcelona.

3.3. Impact Model Canvas

Graphic 8. Impact Model Canvas

This impact model canvas outlines an approach to utilizing the Sniffirdrone technology for promoting health and environmental awareness. The key partners range from technology owners and environmental research institutions to government organizations and health companies. The activities include app development, collaboration with research institutions, and marketing strategies to attract users. The crucial resources involve app developers, Sniffirdrone devices, and data storage servers.

The value propositions centre around providing optimal running routes with minimal air pollution, reward programs, real-time measurement, and personalized health statistics. Customer relationships are fostered through loyalty programs, frequent app updates, and enhancing user experience. Channels for outreach include sports event sponsorships, content marketing, and social media influencers.

The impacted segments are diverse, including amateur and professional athletes, individuals concerned about air quality, companies with wellness programs, urban communities, public health, and city planning. Costs and outgoings encompass app development, Sniffirdrone acquisition and maintenance, as well as marketing and advertising expenses.

To sustain the initiative, funding sources include social impact investors, corporate sponsorships, and government grant programs.

4. FINAL IDEA AND SOLUTION

4.1. Technology

Our initiative is focused on leveraging Sniffirdrone technology to enhance the running experience by incorporating pollution monitoring capabilities into a wearable device. The device will integrate sensors aligned with the Air Quality Index (AQI) standards, focusing on critical pollutants such as Suspended Particulate Matter (PM10 and PM2.5), Tropospheric Ozone (O3), Nitrogen Dioxide (NO2), and Sulfur Dioxide (SO2).

Graphic 9. Sniffirdrone Multi-Sensing Electronic Nose

Source: Depuración de Aguas del Mediterráneo

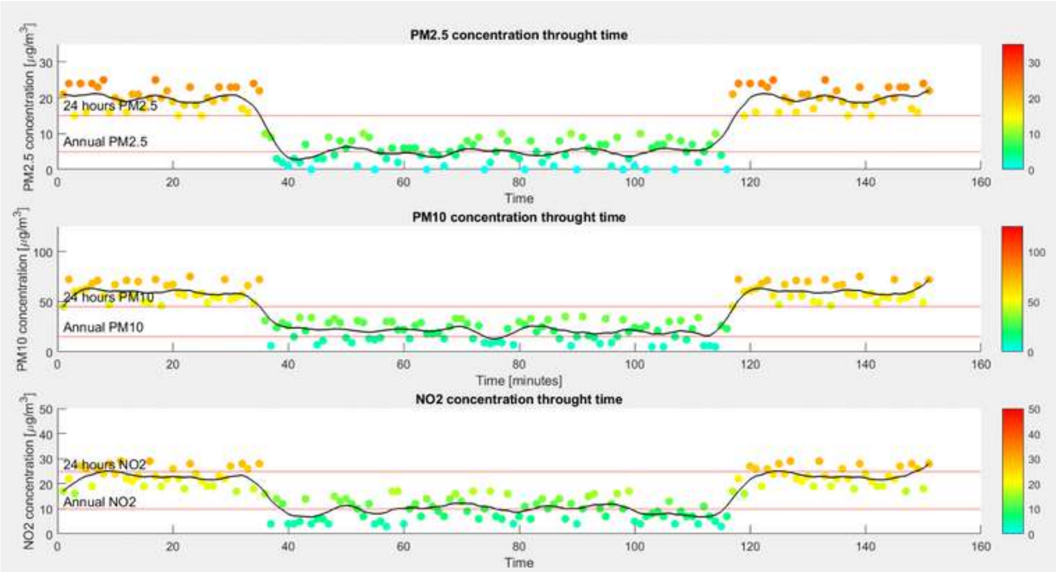
Our proposal simplifies the presentation of air quality data on maps using the AQI system. This system categorizes air quality based on the most concerning pollutant, providing users with a straightforward assessment:

Graphic 10. AQI Table of Colours and Levels of Concern

COLOUR	LEVEL OF CONCERN
Blue	Good
Green	Reasonably good
Yellow	Regular
Orange	Unfavourable
Red	Very unfavourable
Purple	Extremely unfavourable

As runners traverse the city, our system collects real-time data on various pollutants represented as dots on the map. Due to the sensitivity of these measurements, a regression analysis is employed to ensure accurate readings.

Graphic 11. Pollution rates tracked on a route



Upon completing their route, runners can review their actual exposure throughout the journey, as quantified by the AQI.

Graphic 12. Interface of a completed route

As one of our goals has been to improve Barcelona's current parametric models while helping them save costs, we have used Quantum GIS (QGIS), an open-source Geographic Information System (GIS) software, to create our own maps. The advantages of QGIS include its open-source and free nature, an intuitive interface, extensibility, and compatibility with various data sources.

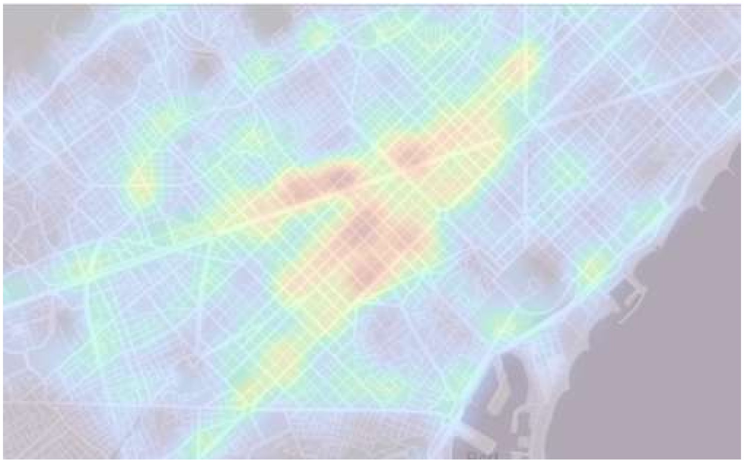
In the initial phase, we incorporated layers of air pollution provided by the Barcelona City Council to establish a solid information base. This layer has been used to display particle and NO2 pollution on the streets, providing a detailed view of the urban environment, where our users will ultimately move.

Graphic 13. Barcelona NO2 layer

Source: Ajuntament de Barcelona

Subsequently, we proceeded to incorporate another layer to spatially represent pollutant concentrations in Barcelona. For this purpose, we chose to import a dataset from the internet to generate a heat map that informs us of the concentrations of particles or other gases harmful to health.

Graphic 14. Barcelona pollution layer



Source: kaggle

Additionally, we intended to create a map showing the territory where our users have accumulated more samples. To achieve this, we integrated data from popular running routes in the city, obtained from the Komoot platform, generating a weighted heat map highlighting the most frequented areas. This heat map gives more weight to the most recent samples, thus helping visualize areas where we can ensure high precision in the results due to redundancy. In areas where red is predominant, the results are more reliable, and these can be used to feed the Caliope model of the Barcelona Supercomputing Center (BSC).

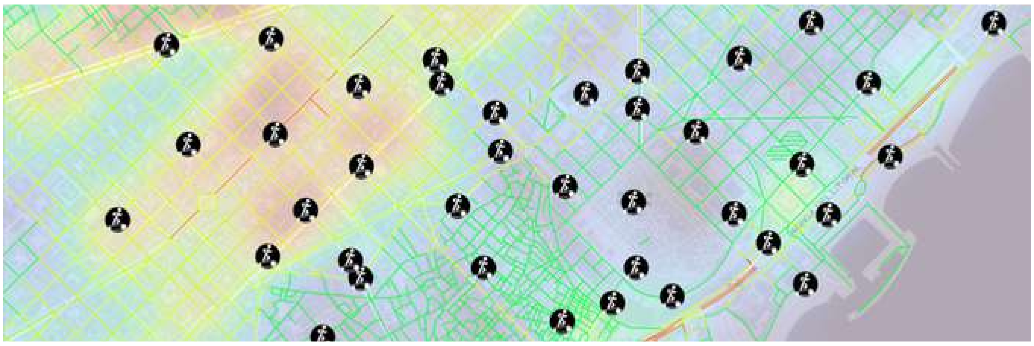
Graphic 15 & 16. Heat map of our users and configuration in QGIS

Finally, we added a layer illustrating our community. We achieved this by randomly plotting points on the map of Barcelona, conveying that these were users currently using our devices.

Graphic 17. Runner distribution along Barcelona

The result would be the following maps:

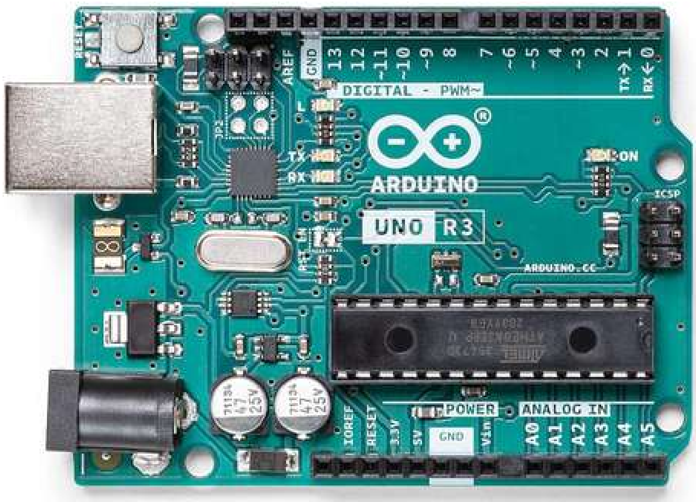
Graphic 18 & 19. Run4ir maps



4.2. Our prototype

In our initial prototype, we opted for the Arduino Uno R3 as the microcontroller, acknowledging that our final version will incorporate a more compact microcontroller.

Graphic 20. Arduino UNO R3



Source: Amazon

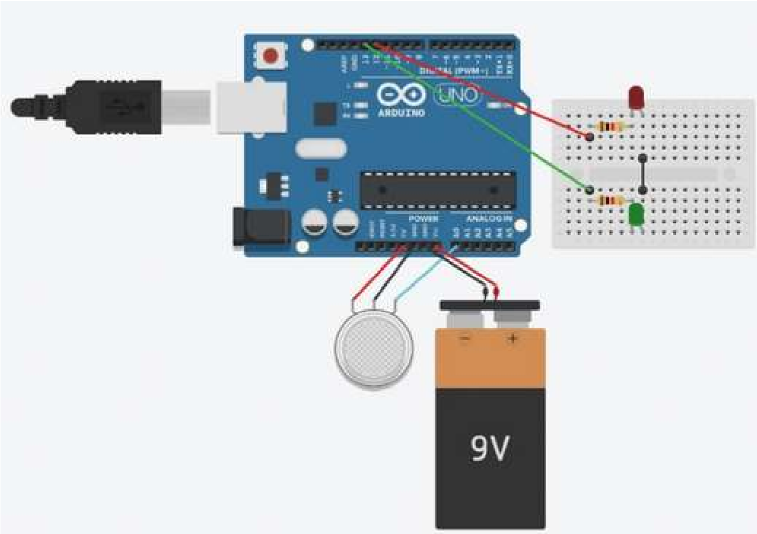
For pollutant detection, we utilized the Gas Sensor V2 DFROBOT SEN0132, which is particularly sensitive to CO concentrations ranging from 20 to 20,000 ppm. Although CO is not part of the AQI metrics, its inclusion in our prototype aims to demonstrate how gas and pollutant concentrations fluctuate during exhalation. The module is connected to the microcontroller via 5V, GND, and the analog pin A0, facilitating the transmission of data.

Graphic 21. DFROBOT SEN0132

Source: Farnell

To enhance user feedback, we integrated two LEDs, each equipped with protective resistors. These LEDs serve to indicate whether the gas concentration surpasses a predefined threshold (red LED activated) or falls below it (green LED activated). To optimize portability, we powered the prototype with a 9V battery.

Graphic 22. Electrical connections of all the components

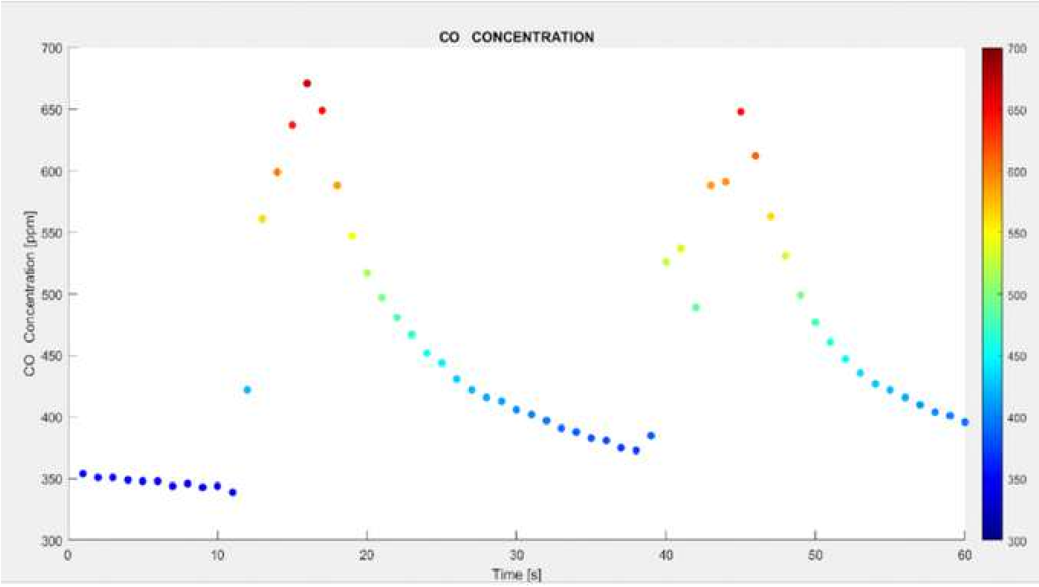


After all components were prepared, we assembled them within a 3D printed protective case, integrated with a standard quick release chest mount system, ensuring usability.

Graphic 23 & 24. Our prototype

Once everything is ready, the following figure is showed according to the values read from the Serial Port:

Graphic 25. CO concentration graph



By adopting this configuration, we demonstrate the capabilities of our pollution monitoring system in a tangible and accessible manner. This serves as a foundation for refining the prototype further in future iterations.

4.3. Our product

The wearable device is designed to be lightweight and compact. Crafted with a sleek and aerodynamic dot pattern, constant and symmetrical air flow is ensured, allowing maximum accuracy in the reading of its inside sensor unit. The vents on the cylindrical face, allow air to escape smoothly by being aligned with the radius of the front pattern.

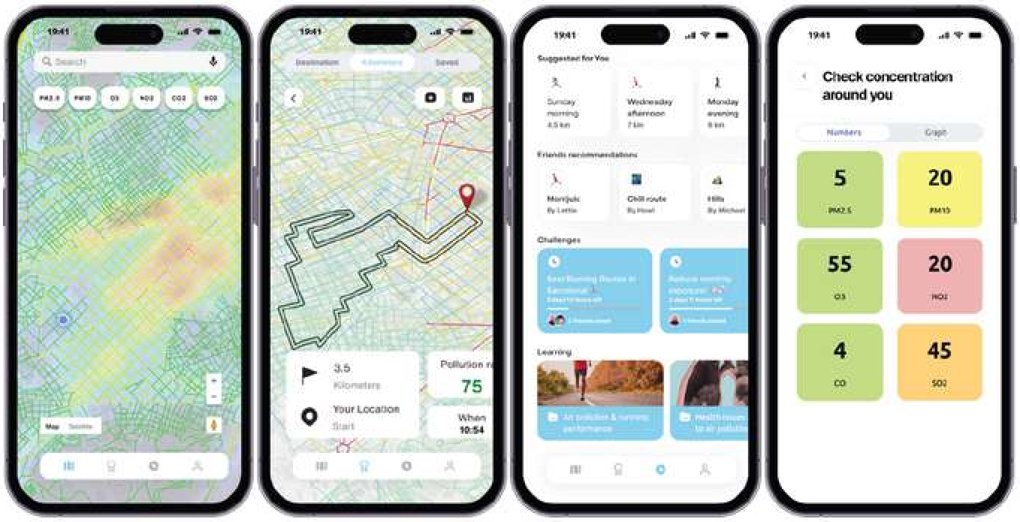
Graphic 26. Protective Case Renders

The top part is meant to be translucent, diffusing the LED lights and revealing a glimpse of the internal components, providing the product with a modern high-tech aesthetic.

Graphic 27. Protective Case Renders

To facilitate user interaction, we have developed a dedicated app. Its primary function is to assist runners in planning routes that minimize exposure to pollutants. The app offers additional features, allowing users to explore Barcelona's pollution map, inspect sensor values, share their running experiences with the community, track the evolution of exposure over time, and more. This comprehensive approach empowers runners to make informed decisions about their routes, contributing to a healthier and more aware running community.

Graphic 28. Different screens of our app: Barcelona pollution map; proposed route; community; real-time concentration



5. CONCLUSIONS

Our journey from unravelling the complexities of Barcelona's air pollution to crafting the final solution, Run4ir, has been marked by a dedicated exploration of challenges and the infusion of innovative ideas. Collaborating with experts in various fields provided valuable insights into the intricate nature of air quality issues. The Impact Gap Canvas highlighted the need for real-time data and increased public awareness, leading to the identification of two main challenges: limited granularity in real-time data collection and the health impact of air pollution. The Impact Model Canvas outlined our strategy, involving partnerships, development, and marketing to create a community-driven initiative leveraging cutting-edge technology. The prototype of the wearable device design showcased the tangible aspects of our product, combining functionality with a modern aesthetic. The app enhances the user experience, offering a set of tools to plan healthier routes, explore pollution maps, and contribute to a more informed and environmentally conscious runner community.

In conclusion, Run4ir stands as a testament to our commitment to addressing the urgent issue of air pollution in Barcelona. Beyond providing a technical solution, it embodies a holistic approach, empowering individuals to make informed decisions about their daily activities while fostering a sense of shared responsibility for the environment. The adopted solution not only enriches the health and overall experience of runners, but also creates a healthier and more sustainable urban environment for all. By bridging the gap between real-time data and public awareness, Run4ir not only provides a practical solution but also fosters a collective sense of responsibility. As we move forward, our vision is clear—to create a cleaner and more aware city, where every step contributes to a positive change in the quality of our air and the well-being of our community.

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7. APPENDIX

7.1. Prototype code for Arduino

```
#include<SoftwareSerial.h>
#defineLED_RED12 //Red LED
#defineLED_GREEN13 //Green LED
constint gas_sensor = A0;

voidsetup(){
 Serial.begin(9600);
 pinMode(LED_RED, OUTPUT);
 pinMode(LED_GREEN, OUTPUT);
}

voidloop(){
 int gas_sensorValue = analogRead(gas_sensor); //We check the value of the gas sensor
 Serial.println(gas_sensorValue);
 if(gas_sensorValue<300){ //Below threshold
 digitalWrite(LED_RED, LOW); //Red LED off
 digitalWrite(LED_GREEN, HIGH); //Green LED off
 }else //Above threshold
 {digitalWrite(LED_RED, HIGH); //Red LED on
 digitalWrite(LED_GREEN, LOW); //Green LED on
}
 delay(1000); // 1 second between samples
}
```

7.2. Prototype code for Matlab

```
% Time between samples
time=1;

% Configuring the serial port object
puertoSerial = serialport('COM6', 9600);

% Create a figure for the scatter plot and configure it
figure;
hold on
title('CO CONCENTRATION');
xlabel('Time [s]');
ylabel('CO Concentration [ppm]');
ylim([200 500]); % Callibration needed to see minimum and maximum
colormap ('jet');
colorbar();
ax=gca;
ax.CLim=[200 500]; % Colormap limits according to calibration

DataMatrix = [];

% Read data from serial port and update chart
while true
 % Read data separated by an enter
 splitData = readline(puertoSerial);
 value = str2double(splitData);

 % We save the data in a matrix
 DataMatrix = [DataMatrix; value];

 % Update the scatter plot every second according to the colormap
scatter(1:time:length(DataMatrix)*time,DataMatrix,[],DataMatrix,'filled')
 colormap('jet');
end
```

7.3. Prototype code for displaying sensor readings

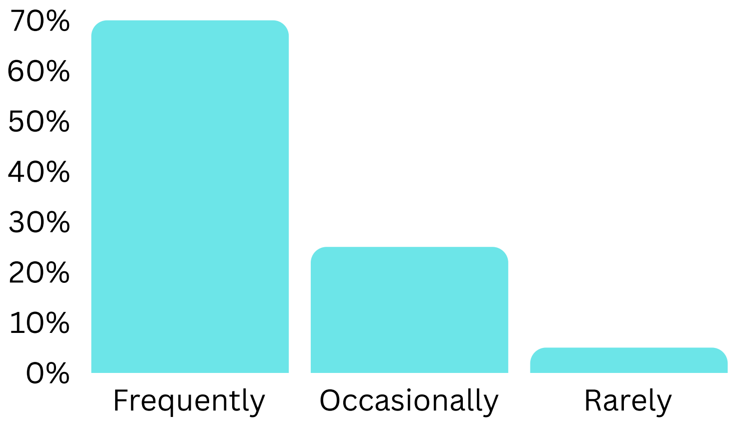
```
% Text file name
TextFile = 'text.txt';

%Colormaps
ColormapPM25_mat = 'ColormapPM25.mat';
load(ColormapPM25_mat);
ColormapPM10_mat = 'ColormapPM10.mat';
load(ColormapPM10_mat);
ColormapNO2_mat = 'ColormapNO2.mat';
load(ColormapNO2_mat);

% Create the figure with three subgraphs
figure;

%Time to update
time=1;

% Infinite loop to update graphs
while true
 % Read value from text file
 try
 data = readmatrix(TextFile);
 % Check if there are at least three columns in the data
 if size(data, 2) < 3
 error('The text file must have at least three columns separated by spaces.');
 end
 catch
 %Handle exception if file cannot be read
 disp('Error reading text file. Make sure the data is numbers and separated by spaces.');
 break;
 end

% Separate the data for each type of particle
 pm25 = data(:, 1);
 pm10 = data(:, 2);
 no2 = data(:, 3);

 % UPDATE PM2.5 GRAPHS
 subplot(3, 1, 1);
scatter(1:time:length(pm25)*time,pm25,[],pm25,'filled') % PM2.5 sensor reading
 colormap(ColormapPM25);
```

```
hold on;
xlabel('Time');
ylabel('PM2.5 concentration [\mug/m^{3}]');
title('PM2.5 concentration throught time');
txtannual25 = 'Annual PM2.5';
text(1,8,txtannual25)
txthour2425 = '24 hours PM2.5';
text(1,18,txthour2425);
annualPM25 = yline(5);
annualPM25.Color = 'r';
hour24PM25 = yline(15);
hour24PM25.Color = 'r';

% Colorbar PM2.5
colormap (ColormapPM25);
colorbar();
ax=gca;
ax.CLim=[0 35];
set(gca, 'colormap', ColormapPM25);
ylim([0 35]);
pm25filter=filtfilt(ones(5,1),5,pm25); % PM2.5 average moving
plot(1:time:length(pm25)*time, pm25filter, 'k-', 'LineWidth', 1);
hold off;

% UPDATE PM10 GRAPHS
subplot(3, 1, 2);
scatter(1:time:length(pm10)*time,pm10,[],pm10,'filled') % PM10 sensor reading
colormap(ColormapPM10);
hold on;
xlabel('Time [minutes]');
ylabel('PM10 concentration [\mug/m^{3}]');
title('PM10 concentration throught time');
txtannual10 = 'Annual PM10';
text(1,25,txtannual10)
txthour2410 = '24 hours PM10';
text(1,55,txthour2410);
annualPM10 = yline(15);
annualPM10.Color = 'r';
hour24PM10 = yline(45);
hour24PM10.Color = 'r';
%Colorbar PM10
colormap (ColormapPM10);
colorbar();
```

```
 ax=gca;
 ax.CLim=[0 125];
 ylim([0 125]);
 pm10filter=filtfilt(ones(5,1),5,pm10); % PM10 average moving
 plot(1:time:length(pm10)*time, pm10filter, 'k-', 'LineWidth', 1);
 hold off;

 % UPDATE NO2 GRAPHS
 subplot(3, 1, 3);
scatter(1:time:length(no2)*time,no2,[],no2,'filled') % NO2 sensor reading
 colormap(ColormapNO2);
 hold on;
 xlabel('Time');
 ylabel('NO2 concentration [\mug/m^{3}]');
 title('NO2 concentration throught time');
 txtannual25 = 'Annual NO2';
 text(1,13,txtannual25)
 txthour2425 = '24 hours NO2';
 text(1,28,txthour2425);
 annualNO2 = yline(10);
 annualNO2.Color = 'r';
 hour24NO2 = yline(25);
 hour24NO2.Color = 'r';

%Colorbar NO2
 colormap (ColormapNO2);
 colorbar();
 ax=gca;
 ax.CLim=[0 50];
 ylim([0 50]);
 no2filter=filtfilt(ones(5,1),5,no2); % NO2 average moving
 plot(1:time:length(no2)*time, no2filter, 'k-', 'LineWidth', 1);
 hold off;

 %Data sample each 10 seconds
 pause(10);
 end
```

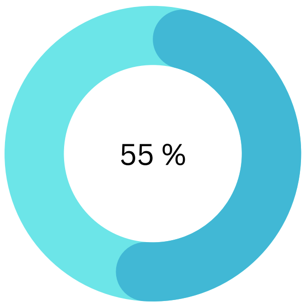
7.4. Poll about running and air

Graphic 29.
How often do you run?

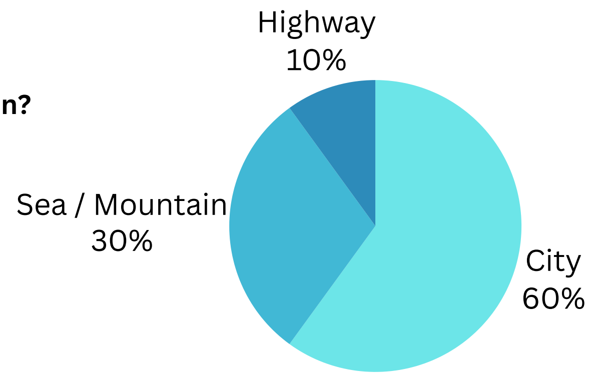


Graphic 30.
Would you be interested in a personalised running air sensor?

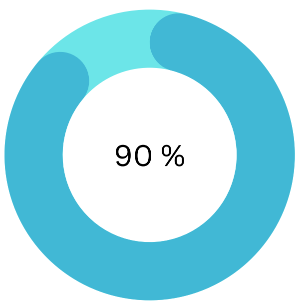
Graphic 31.
Do you consider air quality as a factor when planning their running routes or schedule?



Graphic 32.
Where do you run?



Graphic 33.
Do you believe that having real-time air quality data will influence their choice of running locations and times?



Team 8
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CBI fall 2023