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Designing Citizen Science tools towards increased awareness and participatory policy making for air quality: The Case of COMPAIR

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Abstract: Despite the concept of citizen science being around for a few decades, it is still considered a non-traditional data source, especially in policy circles. Further efforts are needed to build its acceptability by decision makers at various levels of governance. Determined to make this happen, the COMPAIR project sets out to deploy advanced quality assurance measures in the form of distant calibration to make citizen science data policy-ready. Additionally, the project will engage the entire urban value chain in pollution monitoring and analysis, with a special focus on people from lower socioeconomic backgrounds. Local stakeholders will get access to comprehensive, accurate and easily accessible information on air pollution via three purpose-built digital tools: the Policy Monitoring Dashboard, the Dynamic Exposure Visualisation App, and the CO2 Calculator and Simulator. By leveraging data-driven insights from these tools, members of the quadruple helix community will be able to co-create appropriate measures and strategies to set smart cities on a more carbon-neutral footing and reduce air pollution to levels that are considered safe for all.

Keywords: Citizen science, air quality monitoring, traffic monitoring, data visualisation, participatory policy making

1. Introduction

Having reliable data on air quality is necessary to understand how air pollution affects people and the environment and to inform reduction strategies at different levels e.g. individual, policy. Back in 1996 the Council Directive 96/62/EC provided a framework for ambient air quality assessment and management. A set of common methods and criteria were introduced to help EU member states obtain and assess adequate information on air quality (Marco & Bo, 2013). The Directive also articulated the need to ensure access to this information by the public.

We have come a long way since then both in terms of how we measure and share data on ambient air quality. As mandated by legislation, key pollutants (e.g. PM2.5, PM10, NO2) are being monitored on an hourly basis through a network of reference-grade measurement stations deployed by environmental agencies. This data is available in a visual format (e.g. interactive maps), allowing users to get insights on air quality in individual countries, regions and cities. While this progress is laudable, a few shortcomings remain.

When dealing with local and regional scales, the granularity of data is not always sufficient to allow meaningful policy analysis. In part, this is due to the limited overview of ambient air pollution in urban micro-environments. Official monitoring stations tend to be few and far between, making it difficult to obtain good representative coverage of an entire city to identify areas where pollution reduction policies could be most beneficial to the public i.e. pollution hotspots. Citizen science has the potential to fill this gap by providing high-resolution spatial and temporal data at a neighbourhood level. But despite its decades-long history, citizen science is still viewed with some scepticism in policy circles.

Another issue concerns the depth of insight provided by citizen science platforms. Many initiatives that collect data on air quality do share it publicly, with simple maps and dashboards being the most common visualisation tools. While access to air quality information is no longer an issue as both government related and citizen science sources provide this data with sufficient frequency and granularity, the limited analytical capacity of existing tools means that the true value of air quality data remains unlocked.

The EU-funded project COMPAIR tackles this problem by designing advanced monitoring and simulation tools that aggregate data from multiple sources to provide a well-rounded view of air pollution and related challenges e.g. traffic, waste management, energy use. Built-in analytics allow users to examine the impact of individual lifestyle choices and government policies on a range of indicators, and see more clearly what the result of a particular action or measure might be before implementing/advocating for it. One of the COMPAIR tools leverage Augmented Reality to provide personalised insight into air pollution in one's immediate vicinity.

More on this and other tools after a brief discussion on how we intend to make citizen science a trusted data source for decision making. After all, insights from digital tools are as good as the data that feeds them. There is little point in producing state-of-the-art visualisations if the underlying data elicits little trust from intended end users.

In COMPAIR, we produce citizen science data with a purpose that extends far beyond eye-catching visuals. The goal is to generate data which commands a high degree of trust and is endorsed by stakeholders as policy-ready. To this end, COMPAIR is using a hybrid mix of social and technical approaches. The former focus on co-creation with stakeholders representing different social groups. This ensures that an entire urban value chain is mobilised to tackle air pollution, a problem that needs everyone's input if it is to be adequately addressed.

The technical approach is employed to address one of the most common criticisms of citizen science - that it produces data of questionable quality which limits its use in policy making. COMPAIR's contribution comes in the form of cloud-based calibration algorithms that help provide accurate and reliable data.

2. Stakeholder engagement

When it comes to air pollution, it is easy to point the finger at governments and businesses for not doing enough to address the problem, or to think of them as only actors with ultimate responsibility to do something about the problem. This simplistic view, however, ignores the role of other stakeholders, notably research and civil society, in the fight against air pollution and climate change. COMPAIR believes that all four have something to bring to the table. If the ambition of zero air pollution is to be achieved, the entire urban value chain must be mobilised for a common cause.

COMPAIR stakeholder panels are organised around the quadruple helix model to ensure good sectoral representation in citizen science. The social pillar includes local communities that are engaged in air quality and traffic monitoring, as well as pre- and post-data collection stages. Represented in local communities are schools, minorities, people from lower-socioeconomic backgrounds and deprived areas that suffer disproportionately from air pollution. They are all included to ensure that benefits of citizen science do not benefit few but are spread more equally among different social strata.

Represented in other pillars are researchers which provide the scientific rigour, industry which provides low-cost devices for measurement campaigns, and policy makers which articulate policy needs that can be addressed with citizen science. The same quadruple helix approach is followed by all demonstrator locations that pilot the COMPAIR approach: Athens, Berlin, Flanders, Plovdiv and Sofia.

3. Improving data quality

Low-cost sensors that are typically used in citizen science can offer measurements with high spatiotemporal resolution which could be used to supplement existing datasets from official monitoring stations (Okafor et al., 2020). These low-cost sensors, however, require frequent calibration in order to provide accurate and reliable data as they are often affected by environmental conditions when deployed in the field.

COMPAIR uses a novel sensor calibration method called distant calibration (Hofman et al., 2022). Firstly, a few low-cost sensors co-located with reference grade measurement stations and several low-cost sensors in the region of interest are deployed simultaneously. This ensures that they go through a similar process of ageing in the field. Pollutants like particulate matter (PM) and nitrogen dioxide (NO2) that are caused mostly by anthropogenic factors have lower and relatively stable concentrations during night times due to limited human activity, and are fairly homogeneously distributed in an area compared to the daytime.

The distant calibration algorithm will be used to filter out out-of-range sensor data and combine data from low-cost sensors with data from reference stations to train a multilinear model. Then, the parameters extracted from the training model are applied to calibrate citizen science data of the next day in real-time in the cloud environment. This ensures that dynamic changes in the microenvironment around the sensors have a minimum effect on the calibration performance, as the calibration takes place in real-time. Performance of the calibration is evaluated during the deployment using the reference co-located sensors, which takes corrections for drift and ageing (loss of sensitivity) into account.

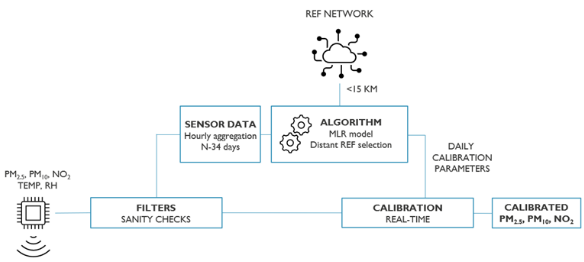

Figure 1. Calibration workflow used in COMPAIR

4. Tools

4.1 Policy Monitoring Dashboard

The Policy Monitoring Dashboard (PMD) is a visualisation and analytics platform for air quality and traffic data. The main purpose of the PMD is to show the impact of policy changes on traffic and air pollution. The platform displays data from multiple sources (COMPAIR, Discomap, sensor.community) and allows users to drill deeper into data to gain new insights. The PMD allows monitoring a target area as well as the surroundings to make sure the policy change does not simply move the problem to the surroundings. The PMD lets you first compare values or changes of traffic and air quality in an easy to understand overview. The advanced graphs let users dive into the details and investigate correlation between air and traffic values and between the target and surrounding area.

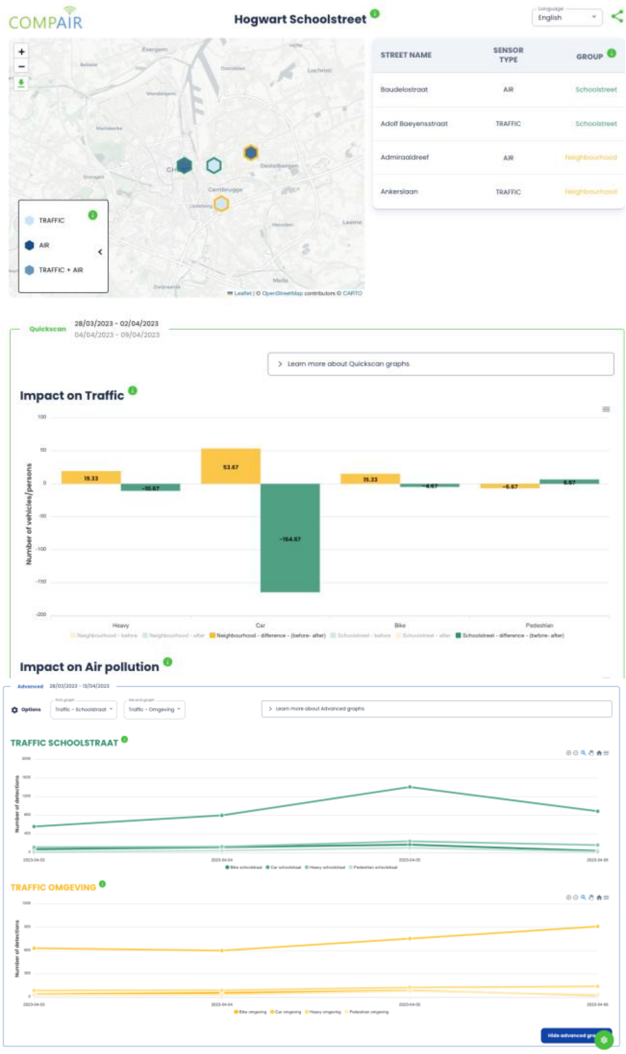

Figure 2. The Policy Monitoring Dashboard

4.2 Dynamic Exposure Visualisation App

The Dynamic Exposure Visualisation App (DEVA) uses Augmented Reality (AR) to show people air pollution in their local surroundings. By using AR capable mobile devices, such as smartphones or tablets, the app visualises air pollution as floating particles such as spheres, stars, pins or cubes. Pollution intensity can be visualised as clouds in gradients of different colours. The visualised data is received in real-time from a data server collecting pollution measurements from various sources, e.g. citizen science sensors, web platforms. Furthermore, DEVA will show other environmental information such as temperature and humidity, and will include gamification features to reward users for providing correct answers about air pollution, or for taking clean, less polluted routes to/from work, school, or home.

Figure 3. The Dynamic Exposure Visualisation App

4.3 CO2 Calculator and Simulator

The CO2 calculator and simulator helps people to measure their carbon footprint by answering questions on flights, recycling, travel, energy use and so on. Individual results are then calculated and presented in relation to a country's or EU average. Where there is room for improvement, the calculator provides recommendations on how to offset CO2 emissions in the area concerned. The simulator, for its part, will show which actions are needed from individuals and the government to meet Green Deal targets.

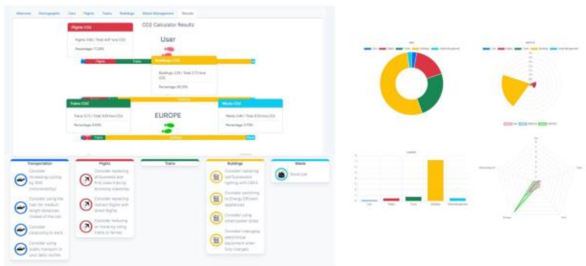

Figure 4. The CO2 Calculator and Simulator

5. Conclusion

Citizen science initiatives are popping up all over Europe to address some of the most persistent and pressing problems that cities are facing, among them air pollution. The widespread use of low-cost sensors has generated a lot of granular data on traffic and air quality in urban microenvironments, complementing official measurement efforts carried out using reference-grade equipment.

However, the deluge of new data has not been matched by great enthusiasm on the part of public authorities to use citizen science generated information for policy making due to concerns about data quality. Concerns also abound about the limited use of this information by the wider public to inform sustainable lifestyle choices. While reasons for that vary, the way in which information is presented has a direct bearing on the quality of insight, and thus on the extent to which data is reused. Despite the plethora of visualisation tools available, there is a noticeable lack of digital solutions that allow users to explore citizen science data in more intuitive, immersive ways.

COMPAIR addresses this problem by creating new digital tools - some web-based, some mobile - that leverage advanced analytics, simulation and AR to make citizen science data more insightful and impactful for urban stakeholders. The project applies a cloud-based distant calibration approach to improve the quality of underlying data and ensure that data visualisations are not only nice but also accurate. Participation of quadruple helix stakeholders in different project stages, from experiment design to location selection to data collection to policy recommendations, is expected to improve the validity of final results and their ultimate uptake by intended target audiences.

Collectively, these efforts paint a more reliable picture of local reality as regards air quality and allied areas on which it depends e.g. mobility, energy consumption, waste management. It is an image that provides a basis for dialogue and participatory policy making, a key instrument in the transition to a more sustainable future that is green, digital and just.

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