COMPAIR

DELIVERABLE

D7.1 Participation risks and compliance

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Executive Summary

COMPAIR is an EU funded Citizen Science initiative designed to empower anyone, including those with no science background or technical skills, to use new technologies to collect data that measures local air quality, understand what it means for their community, and work with others to make local policy and social changes that will improve the quality of the air for all. The Citizen Science (CS) Labs are at the heart of the COMPAIR approach. Before starting these Citizen Science labs, this deliverable aims to offer strategies, recommendations and techniques to manage participation risks and correct use of the outcomes related to the different types of initiatives. This deliverable was compiled by asking all the partners involved about the literature they use or refer to when designing and implementing a CS project.

The deliverable starts with a general introduction to Citizen Science and the relevance of civic engagement within Citizen Science activities. A particular focus is put on what participation in Citizen Science means and what the different levels of participation might be. We learned that Citizen Science practice is very diverse. We also observed that there is not one overarching definition of Citizen Science. All Citizen Science projects have in common the participation of non-professional scientists in scientific research. This participation, or engagement, can take different forms and apply to all steps of the research process, from problem definition to data collection to dissemination.

Next, the deliverable builds on the lessons learned from previous CS projects (with a particular focus on citizen engagement). Given that the goals and approaches of each of these projects are different, we can take different lessons from each project about how to tackle participation in Citizen Science and what COMPAIR can learn. These are described in the third chapter.

In conclusion, several specific challenges, opportunities, and recommendations for Citizen Science projects and citizen engagement for the COMPAIR project are tackled. The challenges are approached from different angles: (1) Setting up a Citizen Science project with a strong focus on citizen engagement, (2) setting up a Citizen Science project from the point of view of resources, (3) setting up a behavioural change project, (4) lessons learned from general voluntary work and literature and (5) how to enable continuous participation and engagement in Citizen Science projects.

1. Introduction

COMPAIR is an EU funded Citizen Science initiative designed to empower anyone, including those with no science background or technical skills, to use new technologies to collect data that measures local air quality, understand what it means for their community, and work with others to make local policy and social changes that will improve the quality of the air for all. COMPAIR approaches behaviour change from a capacity-building standpoint, giving people the digital tools to model, understand, and analyse their existing behaviours and encourage them to choose their path forwards, making changes they know will benefit them, their family, neighbours, etc. and friends.

The Citizen Science (CS) Labs are at the heart of the COMPAIR approach.
Before starting these Citizen Science labs, this deliverable aims to offer strategies, recommendations and techniques to manage participation risks and correct use of the outcomes related to the different types of initiatives.
Therefore Chapter one starts with a general introduction to Citizen Science and the relevance of civic engagement within Citizen Science activities. A special focus is put on what participation in Citizen Science means and what the different levels of participation might be.

To not start from scratch in setting up a participatory Citizen Science approach within COMPAIR, chapter 2 first provides a general introduction to Citizen Science. Chapter 3 describes some lessons learned from previous Citizen Science projects (focusing on citizen engagement). Finally, chapter 4, addresses several specific challenges for Citizen Science projects.
We conclude the three chapters and what is essential to include in the COMPAIR Citizen Science Labs.

2. Citizen Science and civic engagement

2.1. What is Citizen Science

The European Citizen Science Association describes Citizen Science as "*an umbrella term that describes a variety of ways in which the public participate in science*" (ECSA, 2022). This definition points to different important aspects about what can be understood by Citizen Science. There are boundaries of what can be considered Citizen Science. At the most basic level, to be considered Citizen Science there has to be some contribution/participation by non-professionals (citizens) to scientific activity or research (Haklay, 2013; Haklay, et al., 2021). Depending on the project, citizens can volunteer in every step of a research project: data collection, analysis, problem definition or dissemination (Land-Zandstra, Agnello, & Gültekin, 2021). Important to note is that participation in Citizen Science differs from being a respondent in a survey eg. However, by calling it an 'umbrella term' the ECSA description also illustrates that it's difficult to construct one all-encompassing definition of 'Citizen Science'. A lot of different definitions and descriptions of what is understood by 'Citizen Science' can be found (see Haklay, et al., 2021, p. 15-18 for a limited list).

The fact that a lot of different definitions exist also points to certain specific aspects of Citizen Science. The practice of Citizen Science is not limited to a certain academic discipline. To a certain extent the roots of Citizen Science can be traced back to environmental research. A lot of Citizen Science projects can still be found in this field, but nowadays Citizen Science has been applied in virtually every scientific discipline, from humanities and social science to medicine to natural sciences (Haklay, 2013). The definition that someone uses in general tells something about the perspective or idea of the project. In that sense the lack of one single definition is an advantage. It makes it possible to include a variety of different approaches to Citizen Science. Every Citizen Science project needs to create its own identity within the basic boundaries of Citizen Science (Haklay, et al., 2021).

Since it is explicitly part of the scientific process, the goal of Citizen Science projects is to generate knowledge. However, in a sense Citizen Science challenges our preconceived ideas of the way knowledge is produced and who can produce it. As mentioned above, modern science is structured around disciplines and subdisciplines. These are generally highly specialised and have their own traditions and practises. Citizen Science cuts across these structures and in that sense challenges them. Within academia, very strict protocols that describe the 'correct way of doing science' are used to limit uncertainty in the scientific process. The practice of Citizen Science shows that uncertainty is an integral part of data collection and that you don't have to be a long trained scientist to contribute to scientific data collection (Haklay, 2013). This can be seen also in the fact that Citizen Science projects can be initiated by different actors, both from within and outside academia. Not only scientists themselves, but also government agencies, civil society, NGO's or individuals can take the initiative for a Citizen Science project.

Several rather recent trends made the growing popularity of Citizen Science possible (Haklay, 2013). Firstly, there are technical evolutions that contributed. The growth in internet connections makes it easier to register observations. Smartphones on the other hand are having more and more features that can be used to make observations without much effort (think about GPS, microphones,…). Secondly, thanks to the growing educational levels more people become familiar with scientific practises. Besides, we see a bigger interest in scientific research although it is not part of people's day to day job. Thirdly, an increase in leisure time outside of working hours makes it possible for people to act upon this interest and wish to contribute to scientific research. These trends opened up possibilities for participation of non-professionals to the scientific practice that are new. Citizens can now engage in research with more ease and in a higher number of ways than before.

The above shows that practitioners/people involved have to make clear from the beginning what is understood by Citizen Science in their project (Haklay, et al., 2021). In other words, it should be clear how and to what extent citizen science participants are involved and participate in the project. As we have seen, all Citizen Science projects have some form or level of participation or engagement. It's therefore important to think about how citizen participation can take form and what kinds of participation exist. These lead to different kinds of Citizen Science projects. The next paragraph delves deeper in the question of participation in Citizen Science.

2.2. Participation in Citizen Science

To have a clear picture of Citizen Science, it's important to look at the meaning of participation within a Citizen Science project since "*participation is the differentiating element between what is now called Citizen Science and public engagement with science*" (Haklay, 2018). In part, thinking about participation is thinking about the relationship between professional scientists and the wider public. This relationship is historically complex and a gap between both exists. Like already mentioned above, participation of citizens in scientific research challenges the idea that only full-time professional scientists can produce knowledge. However, this doesn't mean that the need for 'professional science' will disappear. In general, citizens still acknowledge the expertise of scientists, but they build their own expertise (Haklay, 2013). This stimulates scientists to think about how they relate to the wider public. Citizen Science is about citizens as scientists, but also about scientists as citizens. A first step in thinking about participation and engagement in Citizen Science is about who exactly it is that participates.

2.2.1. Who participates

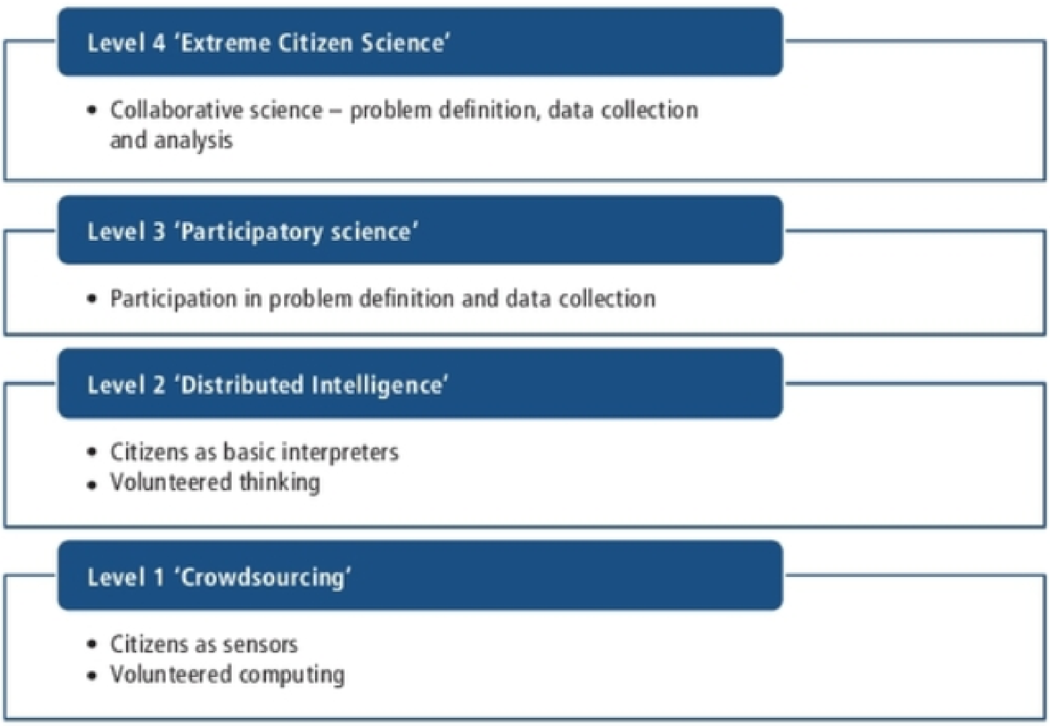
In theory, everyone can participate in a Citizen Science project. However, in practice we see that not everyone participates equally. The drivers of the growth in Citizen Science that we've mentioned also explain in part the Participants of Citizen Science projects are "*predominantly male, well educated and from higher brackets of the income scale*" (Haklay, 2013). It is well documented that educational level is a driving characteristic of who participates in Citizen Science, whereby higher educated participate more. This is especially true when the complexity of the expected tasks becomes higher.

Participants with a higher educational level can be an advantage for a Citizen Science project. By engaging with Citizen Science, it becomes possible to harness the research skills and knowledge of a higher (and longer) education for a socially beneficial outcome. On the other hand, it shows that Citizen Science doesn't reach the entire population sufficiently, which is important if the goal is to engage every group of society. It is clear that the question of who participates/about the characteristics of the participants is closely related to what is expected from them. Citizen Science projects differ in the kind of tasks they ask citizens to conduct. For example, volunteers can contribute actively (by consciously recording observations eg) or passively (by acting as an observation platform). This leads to different levels of participation or engagement (Haklay, 2013; Land-Zandstra, Agnello, & Gültekin, 2021).

2.2.2. Levels of participation/engagement

Haklay (2013) made the following typology of participation within Citizen Science, depending on the level of engagement of participants in the project:

Figure 1: *Levels of Participation in Citizen Science (Haklay, 2013)*



At the basic level, citizen science participants act as sensors, by carrying around sensors or sharing GPS data e.g. This means that at the cognitive level, their contribution is very limited. This is the difference with the second level, where the cognitive skills are being used by asking participants to do some interpretation of the data they observe. Participants often receive a basic training to enable them to do the required tasks. At these two levels, participants only engage in a data collection process developed by scientists. This changes on the third level, where citizens are engaged in the problem definition and, together with scientists, develop a data collection method. When participants are also involved in the data analysis and dissemination of results, we talk about ‘extreme Citizen Science, or collaborative science’. This fourth level involves citizens in all parts of scientific research. Scientists often act as facilitators rather than experts at this level (Haklay, 2013).

With this ladder of participation, it’s possible to describe the level of engagement of volunteers within a Citizen Science project. Practitioners should find the most appropriate level of engagement for their project. Not all projects should strive for the deepest level of participation or engagement. This also means that there is no value judgement attached to the different levels or the position of a project on the ladder (Haklay, 2013; Land-Zandstra, Agnello, & Gültekin, 2021).

Projects can differ on their level of participation, where they are at the ladder or can move from one level to another during the course of a project. Not only between projects or over time the level of participation can change, also within a project at a certain point it’s possible to find different levels of participation. This points to something called participation inequality. This means that not every participant contributes to the same extent to a Citizen Science project. Moreover, in practice often only a small number of the people subscribed make the most of the contributions. This has positive consequences, like some participants being very committed to the research and becoming experts in the subject matter. On the other hand, it also has possible negative consequences in the fact that the level of engagement of most participants is often rather limited (Haklay, 2018).

All the above points to the advice to look for the most appropriate level of engagement, both for the project as a whole as for different groups of participants. Projects should strive for the highest level of engagement suitable for the project. Furthermore, if appropriate projects should enable participants to be engaged on different levels with a project and to switch between levels during the course of a project. This can stimulate people with different interests to participate. Different participants require different approaches to engage and motivate them and the level of training necessary to participate (Haklay, 2013; Land-Zandstra, Agnello, & Gültekin, 2021; Senabre Hidalgo, et al., 2021). This leads us back to the fact that Citizen Science deals with uncertainty in a different way. Data collected through Citizen Science is heterogeneous, meaning that data quality might vary according to the number of participants, their characteristics, level of engagement or training required to contribute. This shows that from the start, initiators of a Citizen Science project should carefully consider how participation and citizen engagement, the core of Citizen Science, will look like in the project.

3. Lessons learned from Citizen Science projects and research

3.1. Approach

Within this section we describe strategies, recommendations and techniques to manage participation risks learned from previous projects, guidelines and papers. All partners involved in WP7 have to some extent experience in setting up Citizen Science projects, and have therefore already encountered the participation challenge. In order to make use of this knowledge and expertise, each partner was asked to list manuals and tools they use to set up a Citizen Science project and tips to deal with the participation challenge. In what follows, each of these projects, handbooks are briefly described, and what is useful for COMPAIR is extracted. In the conclusion of this section, we list the relevant tips and tricks.

3.2. Overview of inspiring projects, papers and guidelines

3.2.1. WeCount

WeCount (Citizens Observing Urban Transport; 2019-2021)[1] was a Horizon 2020 funded project, part of a Science with and for Society call (SwafS). Uniquely, this Citizen Science project empowered citizens to take a leading role in the production of data, evidence and knowledge about mobility in their own neighbourhoods. WeCount aimed at quantifying local road transport (cars, large vehicles, active travel modes and speed), produce scientific knowledge in the field of mobility and environmental pollution, and co-design informed solutions to tackle a variety of urban mobility challenges (from traffic to air pollution and safety issues). Participatory Citizen Science methodologies were used to co-create and use an innovative low cost, automated traffic counting sensor.

Citizen Scientists (citizens) in five case studies across Europe were trained on how to install the sensors in their own homes, enabling them to collect and analyse traffic data, as well as how to engage with key stakeholders throughout the process. Citizens took part in several workshops, from assembling the sensor to learning how to interpret and analyse the data. The five cases followed a similar execution pathway, Leuven and Madrid deploying first and serving as pilots for the remaining three case studies.

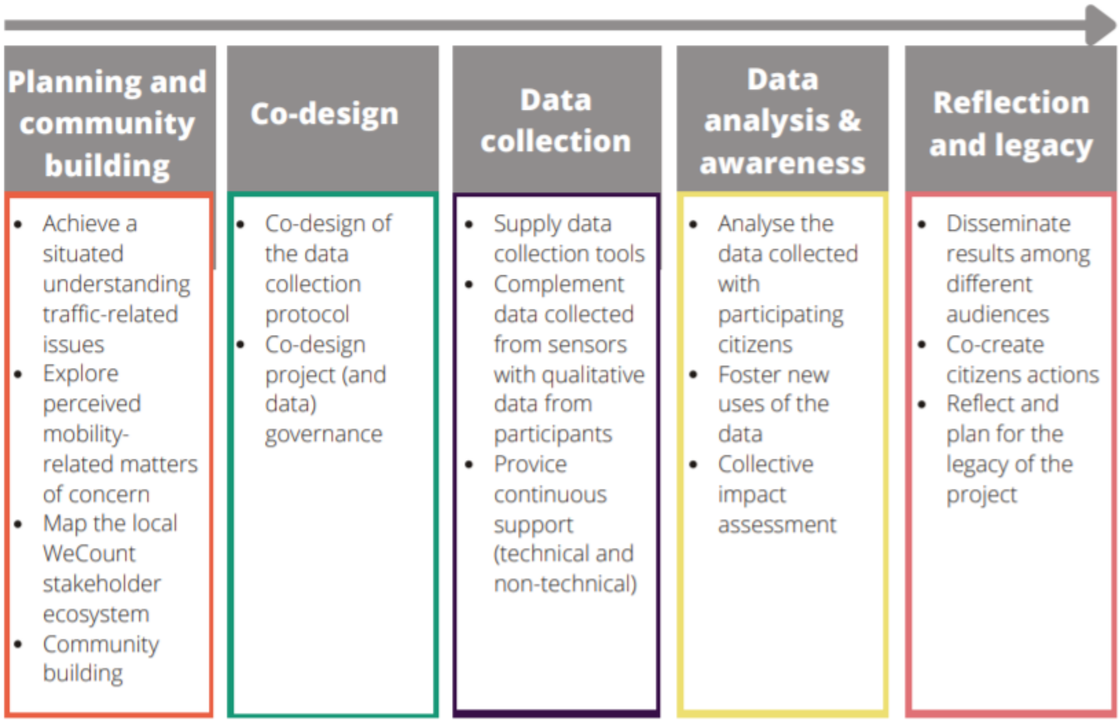
Citizens were recruited through traditional media and social media. The project put extra effort in working with community groups, specifically those from low socio-economic backgrounds, and schools. Citizens with a suitable window qualified to install a sensor. These counting citizens could then connect their data on an online platform (www.telraam.net/en). Not only did this allow other counters to access their neighbours' data; it provided cost-effective data for local authorities, at a far greater temporal and spatial scale than what would be possible through classic traffic counting campaigns. Professional stakeholders and decision makers saw huge added value in the data collected by citizens.

[1] https://cordis.europa.eu/project/id/872743

Several local authorities plan to continue working with citizens in the production of data to monitor planned traffic interventions.

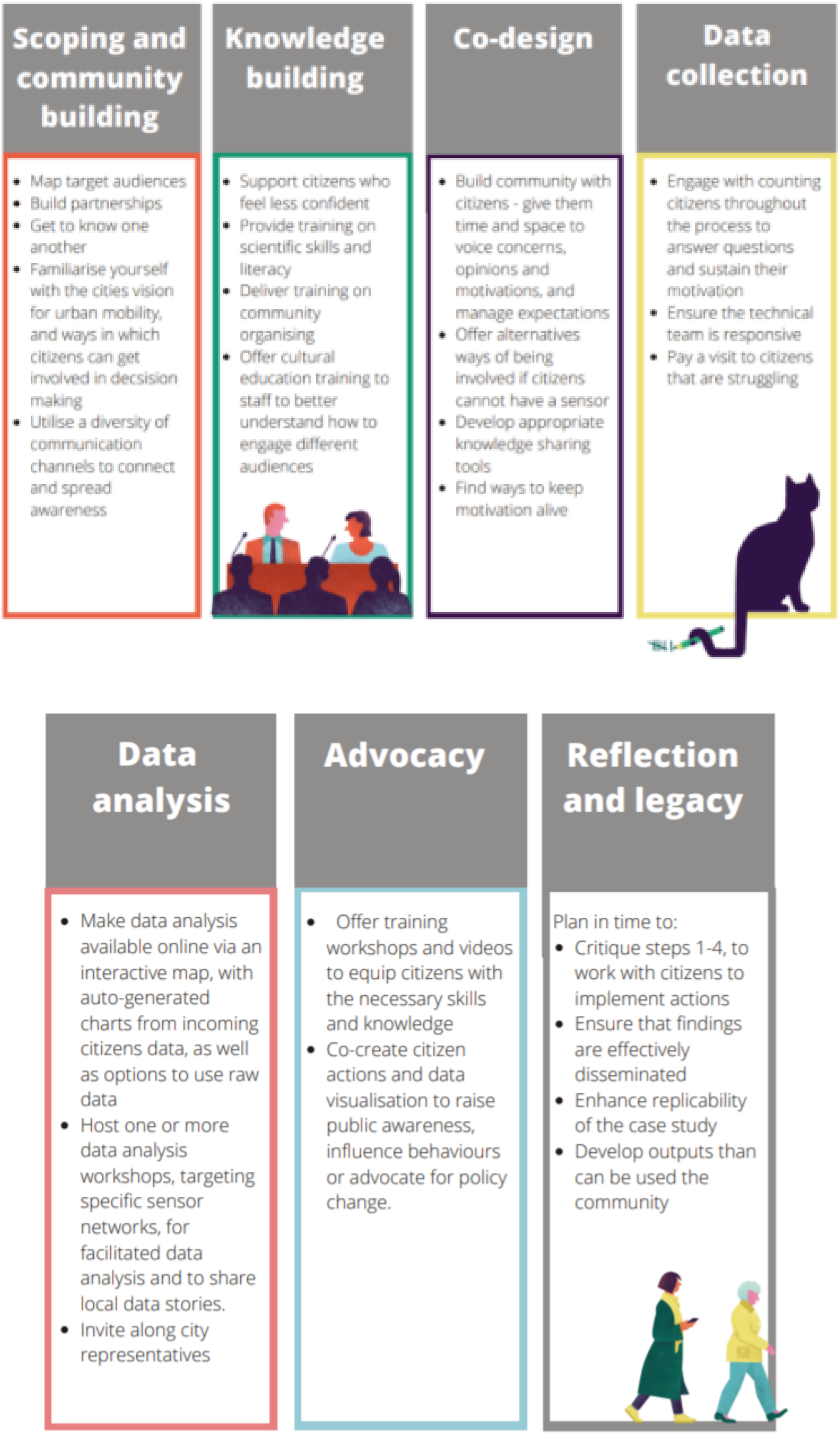
The WeCount engagement approach was a five-step framework, as can be seen in the next figure.

Figure 2: *The WeCount engagement approach*



Thanks to the monitoring and evaluation framework within the WeCount project, all steps of engagement were evaluated extensively. This resulted in a Practitioners guide for citizen science on urban mobility (Laggan e.a., 2021). Out of this guide, the following lessons learnt throughout the WeCount project on the engagement work are summarised in the next figure.

Figure 3: *Lessons learnt throughout the WeCount project*



3.2.2. TRACE

The mission of the H2020 EU project TRACE[2] was to trigger innovative behaviour change initiatives and urban planning practises by expanding the knowledge about cycling and walking and leveraging the potential of cycling and walking tracking in changing behaviour. TRACE assessed the potential of tracking to carry out new and improved initiatives to tackle urban road congestion by promoting cycling and walking in the scope of different contexts, stakeholders and target groups. This research addressed how to apply tracking for behaviour change initiatives, how to use tracking data to improve urban mobility planning, and how to tackle ICT challenges posed by the development of tracking services that meet the interests of stakeholders. The knowledge generated by TRACE was consolidated in three tracking tools and one planning tool. Each of the tools was tested at different pilot locations and evaluated in terms of impact, success factors and benefits (Bossuyt, E., e.a., 2016).

Within the TRACE project, a report 'Assessment of the potential and conditions for use in behaviour change initiatives' was delivered. This deliverable assessed the potential and conditions for the use of tracking in the context of behaviour change initiatives. The deliverable can be used by stakeholders to develop a strategy for using tracking tools to support behaviour change campaigns and other initiatives aimed at changing behaviour. This report provides (a) a description of stakeholder interests in tracking, (b) an analysis of the benefits of tracking data to different types of behaviour change initiatives, (c) the identification of new potential initiatives made viable by tracking, (d) a review and evaluation of past and ongoing cases, and (e) the identification of challenges for the implementation of tracking tools, including ICT aspects.

This deliverable explains the **psychological theories behind a set up of behavioural change campaigns** using tracking services. Therefore, it functions as a useful guidebook to set up a Citizen Science strategy making use of these tracking tools and behavioural change.

An important focus, are of course the users of these tracking tools, and what they expect, when looking at participation risks. What do users expect from a tracking tool?

- **Delivering data to improve the mobility policy** is a huge motivator for individuals to start using tracking apps.
- Leader boards tend to **motivate people to track more trips**. Group participation and group competitions additionally motivated people to install the application.
- **Individual feedback** after a trip (e.g., in terms of burned kcal, distance covered) is perceived as interesting and useful. In some cases this even motivates users to track and/or bike more.

The potential risk related to the use of tracking tools are as follows:

- People tend to **delete behaviour change apps** when the campaign has ended.
- An important issue within all apps is the **accuracy of data and the stability of the app**. By evaluating existing tools, this seems to be a crucial issue that will determine if users will keep on using the app or not.

[2] http://h2020-trace.eu/

3.2.3. Guidebook 'Citizen Science for local governments'

The Guidebook 'Citizen Science for local governments' is a Belgian guidebook. This Guidebook is an initiative of the Flemish government and has been made by the consortium imec-SMIT, Vrije Universiteit Brussels, Scivil and IDEA Consult. This roadmap outlines what Citizen Science can mean for local governments, how a local government can get started and what the success factors are (Veeckman, 2021).
The guidebook's roadmap consists of 22 steps within 6 following phases: Phase 0: Consider, Phase 1: Define, Phase 2: Develop, Phase 3: Launch, Phase 4: Analyse and Phase 5: Valorise.
The guidebook wraps up with some general points to consider in order to successfully participate in or support Citizen Science in a city or municipality. These elements emerged most strongly from the interviews and workshops that were held with local authorities and Citizen Science projects.
First element is the success factors for local governments:

1. **Scientific support**
   Collaboration often adds great value to the research in Citizen Science. The scientific partners bring expert knowledge of the researched domain and know the most reliable ways of collecting or interpreting certain data.
2. **Activating and engaging citizens**
   Keep in mind that with Citizen Science it is easy to reach a certain target group and that this can have consequences for the representativeness of the data that is collected. When air pollution is mapped, for example, it is not a good idea to only map this in the neighbourhoods and streets where older, highly educated people live.
3. **Expectation management**
   When a local government commits to a Citizen Science initiative, it sends a signal to citizen science participants that the administration is taking the research seriously. This will create expectations among citizen scientists that the local government will also take action if the results of the research shown that this is necessary or desirable. The residents of a city or municipality are not always fully informed about how their government works and therefore it is necessary that the government clearly communicates their commitment during and after the project.
4. **Sustainability**
   Most Citizen Science projects see a large peak in participation at the beginning of the project. Keeping large numbers of participants engaged during a long-term project is a challenge in itself, which requires its own communication and participation strategy.
5. **Control**
   A local authority can choose whether or not to support a Citizen Science project. In both cases, it is recommended that the government does not disregard Citizen Science and openly communicate why it may or may not commit itself to action.

The second element is the expectations that Citizen Science initiatives have towards local governments:

1. Gaining the **trust** of the local government. Recognising that what citizen scientists do is scientifically responsible and that this data can be valuable for administration and policy.
2. The research can have an **impact** in the city or municipality. Measures are taken by or with the support of the local government to meet the research results. Even though this sometimes takes a lot of time.
3. Use the extensive **network** of the city administration to find partners or participants for the Citizen Science project.
4. Citizen scientists want to be appreciated for the work they do. Citizen Science is usually set up to make the world a better place and it is nice when that is recognised.
5. News about the Citizen Science project **are communicated** through the channels of the city or the municipality. This can be a message in the newsletter at the launch of the project, or spreading the research results via an interactive screen in front of the town hall.
6. Citizen Science projects sometimes experience only temporary support t of the local government for their research. A policy strategy that can guarantee some **continuity** would certainly be welcome.
7. More resources are welcome. Small-scale and local Citizen Science projects indicate that limited **funding** from the city or municipality could help them a lot.
8. Local authorities can also help Citizen Science in help in kind, by offering **logistical and technical support**. This may include providing a room for activities, offering data infrastructure or technical support in building or maintaining sensors.

3.2.4. D-Noses | DIY Guidelines

D-NOSES[3] project stands for The Distributed Network for Odour Sensing, Empowerment and Sustainability) (Woods T., 2021).
Each Citizen Science project is different in terms of its scale, participants, location and focus. Likewise, the **resources** that each project can draw upon will vary. The trick for project organisers is to establish which resources are available, and decide how to make the best use of them. Resources you will need for your project are likely to include the following:

- Financial resources.
  The dedicated budget for the project will **determine many aspects**, such as the level of engagement of your stakeholders, tools and equipment you use for data collection, how you communicate the data and results, and even where you hold project meetings. You could see if there are small environmental grants available locally. Alternatively, there may be a nearby university that conducts research on environmental issues, which may be able to support a Citizen Science project.
- Time.
  Running an odour-pollution project is likely to require a lot of time for the project organisers and the participants. **Early discussions** with stakeholders should cover the amount of time they are willing or able to commit.
- People.
  A lot of people need to contribute to the project for it to be successful: policy-makers, industry players, professional scientists and local communities. It is important to

[3] https://cordis.europa.eu/project/id/789315

make **contact with them at an early stage**, and continue this at **regular intervals** to keep them engaged throughout. Moreover, community engagement requires a lot of time and human resources to be successful.

- Tools and equipment.
  One way to save money is to **borrow** the equipment and tools you need to measure odours. Try asking the odour-emitting industry (if they have engaged with the project) or local sources of scientific equipment (e.g. universities, companies, research institutes).
- Methodological resources.
  There is no need to start from scratch with your project. Instead, take stock of the **many existing resources** for running Citizen Science projects on odour pollution.

3.2.5. Volunteering Literature review

Despite the importance of understanding the factors that influence people's participation in Citizen Science and other environmental projects, relatively little research has been published about what influences people to start participating in a Citizen Science project. The paper (West, 2016) summarises the key literature on this topic using the general volunteering literature and the more limited literature relating to environmental volunteering and Citizen Science. It makes recommendations for those running Citizen Science projects about how to recruit and retain participants. Volunteering can be defined as **planned, unpaid, pro-social behaviour that benefits strangers** (Penner 2002). In Citizen Science, participants also contribute their time without financial reward. In addition, the conducted research often does not have direct impact on the participants and is led by scientists whom the participants will never meet (West, 2016).

Interesting to see, are the three main factors influencing people's decision to participate in for example biological recording schemes. These were 1) that the people need to be **aware the opportunity** exists, 2) the opportunity needs to be **appropriate** for them, and 3) they need to be **motivated**. (West, 2016).

The next figure summarises the recommendations that have been made throughout the paper (West, 2016). This figure contains a checklist of things that project organisers may want to consider to maximise the participant experience. It begins with identifying **roles** for volunteers and ends with providing an **opportunity for feedback** when the participant leaves the project. In between these stages, project staff need to advertise the **opportunity**, appeal to people's **motivations** to encourage them to become **interested** and start volunteering, and give people a **positive volunteer experience** in order to retain them.

Figure 4: *What Can Be Learned from the Volunteering Literature?*

Stage of participant journey	
	Project planning • Find out what people's motivations might be for participating in your project (see Box One) • Make sure your project is well-organised with clear expectations and meaningful tasks • Create tasks that appeal to different motivations • Consider the potential barriers to participation and how you could overcome them • Design your monitoring and evaluation plan
Awareness of opportunity and decision to participate	• Advertise to diverse groups, through diverse means, including through use of gatekeepers • Ensure a diverse range of people are represented in your advertising materials • Appeal to the breadth of motivations in advertising • Make it clear what the project is about, what the tasks are, and consider "taster sessions" for potential participants
Initial participation	• Make sure participants' expectations of the role, and the reality of the role match – match the right person to the right role from the beginning • Consider providing opportunities for learning and development • Find out what motivated your participants to join your project
Sustained participation	• Make sure your project is well organised with regular communication with volunteers • Provide volunteers with feedback to let them know their time is well spent • Try to understand how your participants' motivations change over time • Refine the project if possible to meet changing motivations, or provide alternative tasks for participants • Provide opportunities for participants to interact with each other • Consider rewarding participants • Talk to participants to find out if they want to change role, e.g., due to available time, skills
Finish participation	• Allow participants to give feedback, and learn from this

3.2.6 Understanding Motivations for Citizen Science

This study (Dyke, 2016) focused on the understanding of motivations for Citizen Science. Next to delivering environmental data at local and national scales, Citizen Science also plays an important role in connecting people with nature, and has been used to help organisations communicate the importance of their work in the area of nature conservation. However, without an understanding of why and how people (**non professional volunteers**) participate in Citizen Science, some initiatives could miss their mark and fail to provide the expected benefits to science and society. This study explores the motivations of environmental-based Citizen Science participants and stakeholders from 'science', 'policy' and 'practice' (Dyke, 2016).

The environmental volunteering literature frequently categorises motivations for participants as **intrinsic** (inherently valuable or satisfying) or **extrinsic** (leading to some other benefit, such as future career prospects). Citizen Science literature provides more detail on these **types of motivations**, with categories such as: egoism, where the motivation is personal growth or gain; altruism, where others benefit; collectivism, where a particular group benefits; or principalism, where individual principles are upheld. Digitally mediated Citizen Science projects frequently use motivations of competition or reputation to encourage (continued) participation. Of course, participants vary individually and will not necessarily conform to one type.

An earlier study (West et al. 2015) of motivations in data submission to environmental Citizen Science projects found that the most commonly held motivations of participants were **wanting to help nature** in general, followed by a desire to contribute to **scientific understanding** and the **purely intrinsic motivation (**'it's a valuable thing to do'). A **desire to please others** by participating and a category of 'other' motivations came next. The results of the survey done within this study are broadly in agreement with this list. Further definition of intrinsic values were illustrated through comments on **enjoyment of the activity**.

It is suggested in the volunteering literature that continued participation is motivated by the fulfilment of initial motivations to participate. Poor organisation often contributes to a decline in participation. Most participants, with the exception of those involved in science-led (hypothesis driven research, Dyke, 2016) projects, said that their motives had not changed over time. Participants in **science-led** projects said they were now **more motivated** by contributing to science, sharing knowledge and caring more about conservation.
The majority of respondents to the online survey were encouraged to continue participating because their initial motivation was satisfied. There were also respondents who were encouraged to continue participating in projects despite their dissatisfaction, indicating that other variables also play a role.
Two other potential incentives for continued participation that emerged from the online survey were skills development, and feedback and communication. In summary, **shared motivations** and the importance of **communication and feedback for meaningful participation** in environmental volunteer projects suggest that Citizen Science may be attractive to many environmental volunteers.

4. Tackling specific Citizen Science aspects

4.1. The motivations, expectations and consequences of CS participation and non participation

In the context of COMPAIR, it's important to recognize particular motivation aspects when involving citizen scientists in sensor data collection. 'Citizen Science can open up situations in which participants efforts are exploited or in which projects are conceived without allowing participants to develop deeper engagement even if they wish to do so' (Haklay, 2018)

This means, there should be sufficient opening for citizen scientists participating in COMPAIR to do much more than passive data collection. An example of "passive data collection" could be installing an automated sensor for data collection, requiring little more participation from the citizen scientist than the setup of the sensor to collect data. We propose COMPAIR should be much more and an open attitude from the project team should be maintained. A loose framework allowing experimentation and exploitation of the participants will enhance and facilitate deeper engagement during the activity, talking directly into intrinsic motivations of participants. Conversely, limiting the role of participants to mere passive data collectors, will likely increase drop-out rate and non-participation.

In this sense, specifically for COMPAIR, a common guideline for all pilots in the project is to engage citizen scientists early in the process and continue to engage, including in (sensor) data analysis in an open engagement framework (see WeCount example earlier). This process is already started with scoping workshops and should be continued throughout the project. Taking the hypothetical example of the Kiezblock-Network, which could be a part of the COMPAIR case in Berlin, using Telraam devices to monitor traffic-impact. There is an opportunity to not only involve citizens in the data collection (installation of sensors) but also interpreting the data post-intervention. This means the citizen engagement is to be extended over a long period of time and participants need to be made aware of the next steps when onboarded.

(Haklay, 2018) provides further in depth reading on addressing motivations and expectations of participating citizens.

4.2. Vested bias and other issues of ethics

Citizen science creates specific risks both in terms of validity of data collected and the ethical issues (e.g. data protection, intellectual property rights)

On the first part, there's the risk of participation bias which could result in a sample bias of the data collected, IF there is a correlation between the socio-economic properties of the citizen scientists and the specificity of the data collected. For example, as mentioned earlier, participation in citizen science projects is not equally distributed among the social strata of the population. In case of air quality, there could be a participation bias with people more conscious about poor air quality, although they are not per se adversely affected and the most adversely affected population groups are typically living in deprived areas (Barnes, 2018), who in turn are typically less engaged in citizen science activities. *(Coincidentally, this is a further argument to aim for a diverse and inclusive pool of participants in any citizen science project)*. This issue should be dealt with in the data analysis as sample bias is not unique to citizen science activities and data analysis techniques exist to correct for sample bias. In the spirit of the citizen science activity, this phenomenon creates an opportunity for the citizen science activity as such to create awareness on the concept of sample bias and increase knowledge on how to alleviate adverse effects using statistical techniques, together with participating citizens.

Secondly, and more challenging, is the intrinsic motivation of the participating citizen scientists, leading to the opportunity to, actively or passively, tamper with data and thus destroy the scientific value. For example, an activist participant is participating in a citizen science project with a speed sensor to demonstrate a specific issue of concern (i.e. speeding of passing traffic) and is willfully enabling/disabling sensors collecting this sensor at times the speeding issue is evident (or not). This clearly leads to a bias in the generated data set, moreover in a way that is hard to detect. The latter is an extreme example, but also more implicit behaviour can lead to a similar outcome, for example (re-)activating an air quality sensor at times of noticeable poor air quality or air quality warnings which triggered the participant to (re)activate the sensor.

There are several approaches to mitigate these risks:

1. First, a formal engagement clause, a “terms of use/participants” when participants are selected to contribute to the citizen science project. A statement to commit to the project as well as respect findings creates a moral barriere, likely sufficient in most cases to mitigate at least active tampering.
2. A sensor/project setup, designed to disable tampering e.g. real-time data collection or rigoreus deployment/installation protocols leaving no room to manoeuvre.
3. Active control by the citizen science project team, verifying if the sensor setup is still within specifications.

It’s important for the COMPAIR pilots to consider the above when designing the citizen science activities in each pilot.

With respect to ethical issues, key elements to pay particular attention to are privacy, data protection and intellectual property rights. In chapter 20 of The Science of Citizen Science: Ethical challenges and dynamic informed consent (Tauginienė, 2021), informed consent is referred to as the point of departure for the description of multiple ethical facets in Citizen Science.

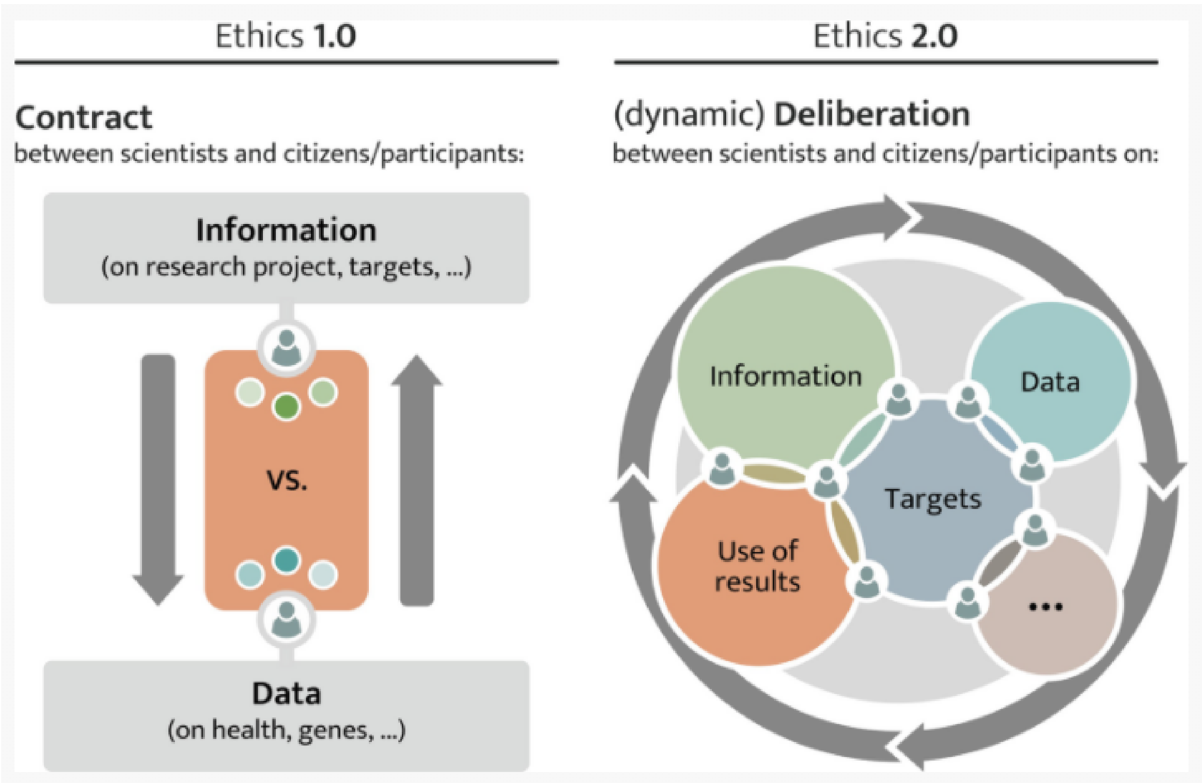
Participants need to be fully aware about what they sign up to when participating in a citizen science project. This includes, at least:

1. Rights on personal information, in compliance with the GDPR
2. Intellectual property of the data collected and analysis done

3. Terms of use of equipment (e.g. ownership or lending of sensors equipment), or service provided (e.g. licence of the data being generated)
4. Rewards for service: voluntary contribution and extend of reimbursement of own costs made

The chapter goes on to describe the different types of informed consent, particularly focusing on dynamic informed consent as the solution to the challenges described. Figure below describes the conceptual difference between a classic informed consent, which is more transactional in nature vs. a dynamic informed consent, evolving as the citizen science activity develops. Broadly summarised (see also figure below), what is referred to as “Ethics v1.0” is a project team led, “top down” of information sharing and clearly stated predefined goals of the project to which participants can change little about and have to consent to for participation. “Ethics v2.0” is more fluid with continued development and redefined (sub-)project goals (for example specific experiments, or joint/participatory data-analysis) that require specific ethical considerations and thus consent form participants. Ethics v2.0 is not static and evolves with the project.
For COMPAIR, at the minimum informed consent is required for participation in the data collection, and a transactional approach to informed consent can be sufficient, but a more immersive approach to the citizen science activities will at least require several updates, leaning more towards the v2.0.

Figure 5: *informed consent in research ethics 1.0 and 2.0 (Tauginienė, 2021)*



To conclude, any citizen science activity must address diversity and inclusion. In (Paleco, 2021), a full chapter is dedicated to good practises encouraging engagement from all members of society, whatever their social status, sociocultural origin, gender, religious affiliation, literacy level, or age.

Recommendations that can apply for COMPAIR activities include, directly quoting (Paleco, 2021) in *italic*:

1. *Offering multiple project entry points as well as multiple ways to participate at different levels of commitment are key to engaging new and diverse participants. This requires acknowledging that people have very different interests and motivations for engaging in citizen science*. In the case of COMPAIR, for example, interaction at different points can be pure data collection with a sensor, or data analysis.
2. *Framing research problems as local issues can help to engage individual citizens if they feel a sense of place attachment*. This should provide opportunities for the scope of COMPAIR as both traffic concerns and air quality issues are hot topics with a direct personal link to participants.
3. *The more project leaders or facilitators participate in actions and are present in the communities affected, the better and the wider community engagement is*. Engagement for inclusiveness is typically more labour intensive for the project team. Obviously, there is an important cost trade-off to be made.
4. *ethnographic fieldwork prior to engagement* i.e. choosing pilot sites in deprived areas for example. This is an opportunity for COMPAIR as poor air quality is mostly an issue of deprived neighbourhoods.

More examples of good practices are available in (Paleco, 2021).

4.5. Risks of using false or incorrect information

Although briefly touched upon in the previous sections, for COMPAIR particular attention is needed to address the quality of the data from the low cost sensors. While sensor quality is not specifically an issue of citizen science (all sensors have quality limitations), particular attention is needed when used in a citizen science project, because of the direct involvement of untrained citizen scientists and the risk of misinterpreting sensor data.

EPA Handbook Citizen Science (EPA 2019) in this respect states “ *With the advent of new technologies for environmental monitoring and tools for sharing information, citizens are more and more engaged in collecting environmental data, and many environmental agencies are using these data. A major challenge, however, is that data users, such as federal, state, tribal and local agencies, are sometimes sceptical about the quality of the data collected by Citizen Science organisations. One of the keys to breaking down this barrier is a Quality Assurance Project Plan (QAPP).*”

In (Balázs, 2021) on data quality in citizen science, authors *consider how we ensure the validity and reliability of data generated by citizen scientists and Citizen Science* *projects*. The authors further provide *a high-level overview of the main themes and issues in data quality in citizen science, mechanisms to ensure and improve quality, and some conclusions on best practice and ways forward. We encourage Citizen Science projects to share insights on their data practice failures. Finally, we show how data quality assurance gives credibility, reputation, and sustainability to Citizen Science projects*.

Following (Balázs, 2021), risks can be summarised as follows:

1. Data collection protocols are not followed by participants.
2. Data collection protocols do not match the goals of the project.
3. Data collection protocols are incorrectly implemented.
4. Data collection protocols are not comprehensive and are used by stakeholders with different data quality expectation levels.
5. Data used are not fit for purpose.

Several options are available to mitigate these risks, by validation/verification in various ways. **Peer verification** is an option where collaborating citizen scientists verify observations from colleague citizen scientists. In the case of COMPAIR, this could be manual verification of traffic counts of an automated Telraam sensor by manual counts by a participating citizen scientist. Secondly, **expert verification** is an option as well, allowing a scientist with subject matter expertise to affirm or correct findings (e.g. affirming a data analysis done by a participating citizen). Thirdly, **automated verification** using various machine learning techniques can help to identify anomalous data points collected by citizen scientists. Finally, an extreme case of the latter is **model-based verification**. Model-based verification requires a predefined set of algorithms that can [1] detect potentially faulty data (similar to automatic verification) and [2] automatically attribute a meaningful flag and/or correct errors in citizen science generated data. Setting up model-based verification requires thorough preparation yet can operate fully automatically once in place.
As a whole, again this is not unique for COMPAIR. Collaboration with other ongoing citizen science projects can provide mutual learning opportunities cross-projects on the issues of validating citizen science generated data.

Combinations are possible, for example the detection of anomalous data signals using machine learning, triggering a verification by a citizen scientist (peer) and/or an expert.

Given at least the air quality sensors considered in the COMPAIR project are known to demonstrate systematic deviations (correlating with humidity), COMPAIR pilots should pay particular attention to validation.

The literature shows citizen science participants can be involved in this verification step as well, not only adding depth to the citizen science activity, nurturing participation, but also capitalising on the “wisdom of the crowds” in yet another novel way.

5. Conclusions

This report started with the question ‘What is Citizen Science?’. From this literature review, we learned that Citizen Science practice is very diverse. Citizen Science now can be found in (almost) all possible academic disciplines. In that sense, and how it deals with uncertainty in research, Citizen Science cuts through traditional scientific practice. This also leads to the observation that there is no overarching definition of Citizen Science other than the general umbrella of “the public participating in science”. A lot of different meanings exist, often even at a project level. However, this doesn’t mean that there are no boundaries of what can be considered Citizen Science.

All Citizen Science projects have the participation of non-professional scientists in scientific research in common. This participation, or engagement, can take different forms and apply to all steps of the research process, from problem definition to data collection to dissemination. Furthermore, citizens can participate at different levels. Participation doesn’t always mean the same. Haklays typology of participation clearly describes these different possible levels of participation of citizens in research projects. The typology also clarifies that the level of participation of a specific project doesn’t have to be fixed and can be changed during the course of a project. A Citizen Science project should find the level of participation most suited for the project at hand. In other words, the participation strategy must be taken into consideration from the start. From the beginning, a Citizen Science project must find its identity between the boundaries of Citizen Science and make clear what is understood by citizen participation.

Some examples can also illustrate the diversity of Citizen Science projects and how participation takes form within. Given that the goals and approaches of each of these projects are different, we can take different lessons from each project about how to tackle participation in Citizen Science. We provide an overview of some important lessons learned from previous Citizen Science projects regarding the design of a citizen science project and the approach to citizen engagement and its relevance for this project, COMPAIR.

We argue COMPAIR should aim for deep citizen involvement beyond strict data collection. COMPAIR should engage a diverse audience of participants to avoid pitfalls of sample bias in participants and the data collected. Finally, given the nature of the COMPAIR project using low-cost sensors, the project needs proper data validation protocols. The latter should be perceived as an opportunity for the project as it’s quite specific to this citizen science project, allowing COMPAIR to differentiate and stand out as a good example of how to employ low-cost sensing technologies with citizen science in a scientifically robust way.

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