European Commission

Scaling up Citizen Science What are the factors associated with increased reach and how to lever them to achieve impact

Giovanni Maccani

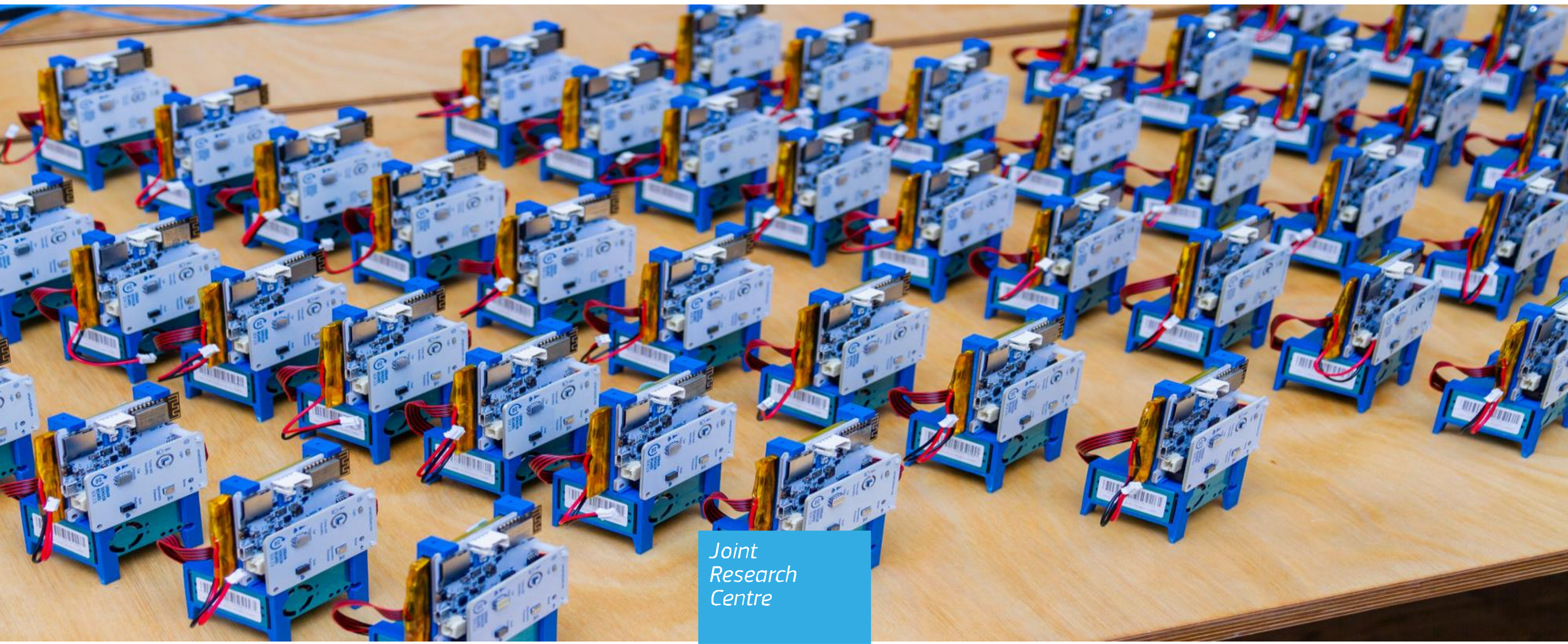
Margriet Goossensen

Valeria Righi

Javier Creus

Mara Balestrini

2020



Joint Research Centre

Contact information
Name: Sven Schade
Address: Via E. Fermi 2749, 21027 Ispra (VA), Italy
Email: s.schade@ec.europa.eu

EU Science Hub
https://ec.europa.eu/jrc

JRC122219

PDF	ISBN 978-92-76-25157-6	doi:10.2760/00926
Print	ISBN 978-92-76-25158-3	doi:10.2760/354206

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Maccani G., Goossensen M., Righi V., Creus J. and Balestrini M., *Scaling up Citizen Science - What are the factors associated with increased reach and how to lever them to achieve impact*, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25157-6, doi:10.2760/00926, JRC122219.

Contents

Foreword 4
Acknowledgements 5
Abstract 6
1 Introduction 7
2 Approach and Methodology 9
2.1 Theoretical Development and Overall Reasoning 9
2.2 Multiple Case Study 10
2.2.1 Case Study Selection 10
2.2.2 Data Collection and Analysis 10
2.2.2.1 The Semi-Structured Interview Protocol 11
2.2.2.2 Data Analysis 11
3 Building the Theoretical Lens 13
3.1 Scaling and Spreading Phenomena 13
3.2 Theoretical Background: Adoption, Diffusion and Infrastructuring 13
3.2.1 Diffusion of Innovations 13
3.2.2 Adoption Theories: The Unified Theory of Acceptance and Use of Technologies (UTAUT) 14
3.2.3 Infrastructuring Approaches in Participatory Design 16
3.2.3.1 Matters of concern 17
3.2.3.2 Community 17
3.2.3.3 Openness 17
3.2.3.4 Orchestration 18
3.2.3.5 Narrative and Communication Outreach 18
4 An Integrated Theoretical Framework for Unpacking Scaling in Citizen Science 19
4.1 Elements intrinsic to the initial intervention to be scaled or spread 19
4.1.1 Proof of Value 19
4.1.2 Ease of Use and Understand 20
4.1.3 Openness 21
4.1.3.1 Open Source Software 21
4.1.3.2 Open Data 22
4.2 Elements supporting the scaling process 23
4.2.1 Development and Dissemination of Narratives and consistent Communication Material 23
4.2.2 Community and Champions 24
4.2.3 Knowledge Sharing and Transfer Resources 26
4.3 Elements of the Target Socio-Technical Context 27
4.3.1 Alignment of Matter of Concern 27
4.3.2 Legal Alignment 27

4.3.3 Alignment of Social Values 28
4.4 Reflecting on the Role of Technologies 28
4.5 Summary....29
Empirical Findings: Four Scaling Scenarios 30
5 Making Sense Barcelona and the Smart Citizen Kit: Scaling Communities through Narratives....31
5.1 Scaling Communities through Narratives....33
5.2 Narratives Triggering Communication and Dissemination 34
5.3 Local Impact as Proof of Value 34
5.4 Knowledge Sharing and Transfer Resources and Ease of Use: The Onboarding Kit and the Making Sense Toolkit 35
5.5 Openness in MS/SCK....35
5.6 Target Context 35
5.7 Conclusions and Looking Forward 35
6 FreshWaterWatch: Infrastructuring through the Train the Trainer Approach 37
6.1 Proof of Value: A Scientifically Robust Toolkit 39
6.2 Ease of Use and Understanding: The Train the Trainer Approach 39
6.3 Local Communities for Local Impact....40
6.4 Communication and Dissemination Delegated Locally....40
6.5 The Role of Openness in FWW....41
6.6 Target context....41
6.7 Conclusions and Looking Forward 41
7 Luftdaten and Sensor.Community: Scaling through Platform-enabled virtuous cycles 43
7.1 Core Platform and Team 45
7.2 From Proof of Value to Virtuous Cycles 45
7.3 Little Centralised Communication 46
7.4 Local Contexts Fuelling Global Scaling....46
7.4.1 Local Narrative 47
7.4.2 Citizens Communities 47
7.4.3 Community of Developers....48
7.5 Openness....49
7.6 Target Context 49
7.7 Conclusions and Looking Forward 49
8 OpenStreetMap: Scaling through Platform-enabled Network Effects 51
8.1 Initial Proof of Value....53
8.2 Platform-Based Governance Structure 54
8.3 Ease of Use and Knowledge Sharing and Transfer Resources in OSM....54
8.4 Communication....55
8.5 The Multifaceted Community of OSM 55

8.5.1 Individual contributors 55
8.5.2 Local Chapters 55
8.5.3 Other Local Communities 56
8.5.4 Emergent Communities in response to Emergency Situations 56
8.6 From Proof of Value to Network Effects 57
8.7 Openness in OSM 58
8.8 Target Context 58
8.9 Conclusions and Looking Forward 59
9 Reflections and Recommendations 60
9.1 Reflecting on the Framework 60
9.1.1 Elements intrinsic to the initial project to be scaled or spread 60
9.1.2 Elements supporting the spreading and up-scaling processes 61
9.1.3 Elements of the Target Context 63
9.1.4 Citizen Science, Openness, and Scaling 64
9.2 Looking Forward: IT trends 65
9.2.1 Blockchain and Distributed Ledger Technologies 65
9.2.2 Artificial intelligence 65
10 Conclusions, Limitations, and Future Avenues 67
References 69
List of abbreviations and definitions 77
List of figures 78
List of tables 79
Annexes 80
Annex 1. Summary of Clusters and root constructs 80
Annex 2. The Framework and the Role of Technologies 81

Foreword

We live in both exciting and demanding times, in which the European Commission requests a stronger role of Europeans in decision-making processes and in the setting of political priorities. This new push for European democracy and increased citizen engagement is situated in already existing processes of evidence-based policy making and implementation, that is to say along the entire policy cycle. The requested change can benefit from - but also has to address the challenges of - the continuous digital transformation, where new technologies impact people's lives more than ever before and unprecedented amounts of data are collected by a heterogeneous mix of actors. This transformation increases the need of data and scientific literacy so that we can cope with issues, such as, infringements of privacy and the spread of disinformation. Accordingly, in its recent call to make Europe fit for the digital age, the European Commission underlines the need to improve the governance of data ecosystems, and calls for investigations about the role of Artificial Intelligence (AI).

Within this wider landscape citizen science - being people-centric by definition - has a particular role to play. And this is for two important reasons. First, the citizen science community has a strong sense of inclusivity and transparency. By their very principles, citizen science initiatives are cautious about the values, interests, motivations and learning pathways of their participants. Furthermore, they pay close attention to make resources, as well, as results openly available and provided in an understandable and clear form. Second, the different practitioners and supporters of citizen science got well organised over the past years. Many national and international associations could be established and they became interconnected. The improved governance of these parties led to an impressive growth and recognition of citizen science. It also established a baseline infrastructure that can now be used - within Europe and globally.

Complementing large questions (such as, the role of citizen science for governance, its contributions to human-centred and explainable AI, and relationships with data altruism) and building on leading examples (such as, participatory mapping, bird watching or water quality monitoring) there is an eminent need to develop a better and more structured understanding of the context dependency and growing potential of citizen science approaches. This is both, in terms of scaling and spreading. Here, (up-)scaling can be considered as expanding a successful citizen science initiative in terms of both, the number of participants and the geographic extent. Spreading refers to portability and replication of existing solutions, without a change of the actual scale of the activity in itself.

Once we understand the context dependency and pathways for expansion of single initiatives, we will be able to thrive for a systemic integration of citizen science approaches into larger governance structures. This will not only allow us to support digital transitions, but also to offer opportunities for engagements in policy making and implementation. In this way, citizen science will become one important piece of the larger puzzle that will help us all to get fit for the new digital age and to contribute to a vibrant democracy.

The work presented in this report provides us with an important step stone in the right direction. It lays the grounds for a theory about the spreading and scaling of citizen science, based on an exploratory and solid research approach. Being challenged with a task to explore new horizons, the team at Ideas for Change dived deeply into existing scientific concepts, and identified and transferred ideas from related fields. They ultimately propose a novel framework that helps not only structuring the complex topic, but can also serve as the basis for practical applications. A set of case studies is presented to illustrate and validate the proposal. The case studies also provide a starting point and possible inspirations for new activities that intend to engage large amounts of participants in citizen science. We are highly satisfied with the results of this work, and hope that it opens pathways for research and for policy advice – not only for ourselves, but also for others.

Sven Schade
Digital Economy Unit
European Commission, Joint Research Centre (JRC)

Acknowledgements

The authors would like to express their gratitude to Dr Sven Schade and Dr Chrysi Tsinaraki for their constant support and extremely ongoing and constructive feedback provided during this analysis. Sincere thanks to all to all interviewees for their time and invaluable input, the participants of the final event who gave important feedback to our work and, last but not least, to all those citizens who contribute time, creativity and efforts to make citizen science possible and a thriving discipline.

Authors

Dr Giovanni Maccani
Margriet Goossensen
Dr Valeria Righi
Javier Creus
Dr Mara Balestrini

Abstract

The rapid pace of technology advancements, the open innovation paradigm, and the ubiquity of high-speed connectivity, greatly facilitate access to information to individuals, increasing their opportunities to achieve greater emancipation and empowerment. This provides new opportunities for widening participation in scientific research and policy, thus opening a myriad of avenues driving a paradigm shift across fields and disciplines, including the strengthening of Citizen Science.

Nowadays, the application of Citizen Science principles spans across several scientific disciplines, covering different geographical scales. While the interdisciplinary approach taken so far has shown significant results and findings, the current situation depicts a wide range of projects that are heavily context-dependent and where the learning outcomes of pilots are very much situated within the specific areas in which these projects are implemented. There is little evidence on how to foster the spread and scalability in Citizen Science. Furthermore, the Citizen Science community currently lacks a general agreement on what these terms mean, entail and how these can be approached.

To address these issues, we developed a theoretically grounded framework to unbundle the meaning of scaling and spreading in Citizen Science. In this framework, we defined nine constructs that represent the enablers of these complex phenomena. We then validated, enriched, and instantiated this framework through four qualitative case studies of, diverse, successful examples of scaling and spreading in Citizen Science. The framework and the rich experiences allow formulating four theoretically and empirically grounded scaling scenarios. We propose the framework and the in-depth case studies as the main contribution from this report. We hope to stimulate future research to further refine our understanding of the important, complex and multifaceted phenomena of scaling and spreading in Citizen Science. The framework also proposes a structured mindset for practitioners that either want to ideate and start a new Citizen Science intervention that is scalable-by-design, or for those that are interested in assessing the scalability potential of an existing initiative.

1 Introduction

Over the last two decades, the engagement of citizens within scientific projects has grown significantly. Citizens are increasingly empowered to contribute to innovative policy making and participate in socio-technical innovation (Hecker et al., 2018). This is partly due to the rapid adoption of open innovation paradigms and the advancement and pervasiveness of today's digital technologies (Haklay, 2015; Balestrini et al., 2017). This involvement can take many shapes and forms, and generally comes together under the umbrella of Citizen Science. The essence of Citizen Science is in that citizens are involved in one or many stages of a scientific investigation, including the assembling of research questions, conducting observations, analysing data, and using the resulting knowledge (Craglia and Granell, 2014). Researchers or (scientific) institutions can play a leading or mediating role within Citizen Science projects, or no role at all such as in the case of Extreme Citizen Science (Haklay, 2015).

Nowadays, application of Citizen Science principles spans across several scientific disciplines, covering different geographical scales. While a large proportion of these projects focus on tackling environmental related issues (e.g. noise pollution, air pollution, odour pollution, or environmental monitoring in general), others have focused on diverse topics such as urban planning, green infrastructure in cities, wildlife monitoring and issues related to public health, among many others.

On the one hand, the interdisciplinary approach taken so far has shown significant results and findings. On the other hand, however, the current situation depicts a wide range of projects that are heavily context-dependent and where the learning outcomes are very much situated within the specific areas in which these projects are implemented. There is therefore little evidence on how to foster spread and scalability in Citizen Science (Craglia and Granell, 2014; Manzoni et al., 2019). Furthermore, the European Citizen Science community currently lacks a general agreement on what these terms mean, entail and how these can be approached. This analysis aims at addressing these challenges. To generally guide its scope the following general definitions have been established as an input to this study:

- Scaling refers to the extension of existing approaches from a smaller geographical area to a larger one - for example from a neighbourhood to an entire city, and then to a region.
- Spreading, instead, is understood as the ability to successfully replicate and carry over Citizen Science approaches from one location to another at the same geographic scale - for example from one neighbourhood, city or region to another.

In the existing literature within Citizen Science and its neighbouring disciplines, the terms scaling and spreading have been underexplored, or used inconsistently. For example, Manning (2013) talks about scaling in Citizen Science in the context of dung decomposition as a "replicated experimental design", where an initial pilot in a local area of Finland has been scaled ("replicated") to the overall country (Kaartinen et al., 2013). In the broader context of Social Innovation, scaling has been described as the "Holy Grail" for practitioners (Davies and Simon, 2013). However, the same authors use the terms "scaling" and "spreading" interchangeably to generally describe geographical growth and replication of social innovation actions.

In a similar vein, the Centre for the Advancement of Social Entrepreneurship (CASE) defined scaling as "the process of increasing the impact a social purpose organisation produces to better match the magnitude of the social need or problem it seeks to address" (CASE, 2008). In parallel, in the Business and Management literature, scaling is often associated with organizational growth in a market (DeSantola and Gulati, 2017). However, already in 2012, Clark et al. (2012) acknowledge how there is an increasing cross-disciplinary trend of shifting "away from the concept of scaling as organisational growth and towards the concept of scaling impact, or the outcomes the organisation has generated beyond just the organisation itself" (p.5). While this might appear as a mere terminology issue, we argue that a substantial gap exists with respect to a commonly understood theoretical and pragmatic framework to first understand and subsequently guide scaling and spreading of practices and outcomes (also) in the Citizen Science field.

To address these issues, we propose in this work a theoretically grounded framework encompassing nine constructs that represent enablers of the complex phenomena of scaling and spreading in Citizen Science. This is developed from an extensive review and systematic combination of three established cross-disciplinary academic theories. This framework is then instantiated through a multiple case study of four Citizen Science projects that successfully scaled and spread. The framework and the rich experiences allow formulating four theoretically and empirically grounded, rich, and thick scaling scenarios, which, together with the framework, represent the main contributions of this study.

This document is organised in ten chapters, as follows. After this introductory section, we describe the methodology designed and implemented for this study. Section 3 presents the theoretical background upon which this analysis is based. This is followed by the core chapters which present the theoretical framework developed and the rich empirical findings from the four case studies carried out respectively. Section 9 discusses the findings and the framework and provides reflections on the potential role of emerging technologies in the scaling and spreading of Citizen Science looking forward. Section 10 proposes some concluding remarks, future avenues of research as well as the limitations of this analysis.

2 Approach and Methodology

When tackling the concepts of scaling and spreading, we first searched for available evidence on what factors influence these two critical processes in Citizen Science. To do so, we looked at publicly available material from two main sources: (1) actual projects' material; and (2) the existing literature on the topic. While this way of approaching the topic resonates with the scope of this study, taking this road has proven to be challenging for two key reasons. First, Citizen Science literature on the topic is scarce and limited in the insights that can be extrapolated with respect to these two phenomena. In particular, these contributions either focus on "scaling" (meant as increasing) participation within one project, or simply call for more research in this direction, thus justifying the problem tackled in this study. Second, evidence from existing (both ongoing and completed) projects is scattered and often not fully accessible leaving room only for speculations and ill-informed interpretations. To overcome this scarcity of information, we have initially selected projects that clearly scaled and/or spread. Subsequently, for each, we tried to retrospectively search for evidence of the actual process that was implemented over time for enabling scaling and/or spreading. However, the amount of qualitative and quantitative information found did not constitute enough supporting evidence to provide statements with an acceptable level of confidence. Therefore, considering the two challenges outlined above, this lack of evidence forced us to reflect more in-depth on the concepts of scaling and spreading, and to get inspiration from several neighbouring disciplines.

2.1 Theoretical Development and Overall Reasoning

When reflecting on the initial definitions, we identified a common pattern for both scaling and spreading that is: both phenomena entail an initial project or intervention in a context and its replication (in its entirety or of some of its parts) in another context where, for reasons that we aim to highlight, some or all parts of the original project are adopted. This allows us to have a common theoretical and conceptual approach to both scaling and spreading (from now on referred to as scaling to aid readability).

Inspired by the concepts from the ongoing academic debates on Technology Adoption (Venkatesh et al., 2012), Diffusion of Innovations (Rogers, 2010), and the conversation around Infrastructuring in Participatory Design, we developed an integrated theoretically-grounded framework to be used as the lens to analyse the current advancements in the Citizen Science discipline towards scaling. Such lens includes the assemblage of several constructs from across these theories. Based on their extensive application within several disciplines, we argue that these are likely to be drivers for scaling in Citizen Science and represent the first core preliminary outcome of this study.

Once this theoretical framework has been outlined, we integrated this first conceptual and literature-based analysis with rich information across existing projects based on thick descriptions of their lived experiences. The next step of this analysis was therefore about leveraging the framework to accomplish four main purposes:

1. Contextualise those constructs that are found to be relevant to unpack scaling within the discipline of Citizen Science.

2. Populate the identified constructs and their role in fostering scaling with supporting evidence from existing projects.

3. Establish a final framework of constructs that play a role in enabling scaling in Citizen Science.

4. Propose scenarios for successful scaling of Citizen Science projects, practices, and outcomes.

To accomplish these objectives, we relied on the framework as the foundational basis to guide an empirical qualitative analysis of the concept of scaling. This analysis involved carrying out a multiple case study, of four different yet successful (i.e. that scaled and/or spread), cases. In summary, leveraging multiple case analysis and interviews allowed us to understand and collectively construct knowledge about scaling from the lived experiences of individuals and projects that successfully undertook these journeys. The outcomes of the multiple case study are: (1) an enriched version of the original theoretical framework; and (2) four rich scaling scenarios emerging from the different cases studied. These constitute the essence of the contribution of this study.

2.2 Multiple Case Study

Case study research aims at understanding an issue, problem, or phenomenon using the case as a specific illustration (Stake, 2013). The choice of multiple case study research methodology was motivated by several aspects. These are seen as both strengths of the methodology itself and aspects consistent with the purposes of this study. First, with its diversity across cases, multiple case studies ensure richness and depth in order to understand a shared phenomenon of interest (Anaf et al. 2007; Flyvbjerg, 2006; Stake, 2013) - i.e. scaling in Citizen Science. Second, this method enables the exploration of complex situations allowing for the gathering of multiple perspectives, from a range of sources, including contextual information (Lauckner et al. 2012). Third, it is particularly useful when the unit of analysis is a process, which is compatible with the focus of this report (Stake, 2013; Walsham, 1995; Lauckner et al. 2012).

2.2.1 Case Study Selection

When conducting multiple case study analysis, the choice of number of cases to consider is fundamental. Stake (2013) proposes to consider between four and ten cases. However, important considerations must be given to the target level of depth. In other words, one of the risks related to an increasing number of cases in multiple case study research is to reduce complex cases to a few comparable variables, resulting in the loss of the idiosyncrasies of individual cases (Lauckner et al. 2012). In order to mitigate this risk, Creswell (2007) suggests that no more than four cases should be examined to allow individual cases to be adequately explored. Accordingly, we chose to select four case studies.

The case selection process adhered to Stake (2013)'s criteria. Starting from a list of over 30 candidates, case studies were shortlisted and finally chosen based on:

1. Relevance of the phenomenon of interest: cases need to be clear examples of Citizen Science practices or overall interventions that scaled or spread.

2. Accessibility of information: cases selected are the result of a pre-selection process whereby potential interviewees were asked to dedicate time to contribute to this analysis. Only those cases where people agreed to be interviewed and to share relevant documents and experiences, were considered.

3. Diversity across cases: of those we initially shortlisted, we selected cases that cover significant diversity across contexts. In this way diversity was considered in terms of the field or discipline in which the project is situated as well as of the extent to which these initiatives have scaled.

This process resulted in the selection of the following case studies: Making Sense Barcelona[1] and the Smart Citizen Kit[2], FreshWaterWatch[3], Luftdaten and Sensor.Community[4], and OpenStreetMap[5].

2.2.2 Data Collection and Analysis

In case studies, Walsham (1995) argues that interviews are the primary source of data, "since it is through this method that the researcher can best access the interpretations that participants have regarding the actions and events which have or are taking place, and the views and aspirations of themselves and other participants" (Walsham, 1995, p.78). In addition, "interviews are highly efficient ways to gather rich, empirical data" (Eisenhardt and Graebner, 2007, p.28), consistent with the objectives of this phase of the study. Interviews were chosen because these distinguish themselves from other information gathering approaches by engaging participants directly in a conversation in order to generate deeply contextual, nuanced and authentic accounts of participants' outer and inner worlds, that is, their experiences and how they interpret them (Schultze and Avital, 2011). Among the different types we could select from (Fontana and Frey, 2000), semi-structured interviews were chosen as the most appropriate. As scaling and spreading experiences are usually not observable, the interview needed to help us reach beyond the superficial layers of their experience in order to generate informative and novel accounts of the phenomena of interest. Semi-structured interviews are argued to be useful as they activate and stimulate the interviewee's interpretive capabilities (Holstein and Gubrium, 1995). As a result, the objective became to ground the interview in the participants' own experiences.

1 http://making-sense.eu/

2 https://fablabbcn.org/0000/01/06/smart-citizen.html

3 https://freshwaterwatch.thewaterhub.org/

4 https://maps.sensor.community/#2/0.0/0.0

5 https://openstreetmap.org/

Acknowledging and valuing participants' narrative (re)construction of their experience implies that the data that is generated in an interview needs to be seen as narratives that are produced in the moment rather than facts or established stable meanings. To do this, an explicit framework for guiding the participants to articulate and interpret their experiences was developed to structure the conversation in such a way that guides the interview through his or her introspective journey while honouring his or her freedom of thought and expression. Thus, a protocol was developed prior to the beginning of the data collection.

2.2.2.1 The Semi-Structured Interview Protocol

As a first step in defining the protocol, the main areas of information needed had to be outlined. The targets were conceptualized as the elements that influence scaling in Citizen Science as well as the potential role of technologies in facilitating this process. Prior to these case studies, we have outlined an overarching framework based on the extant theoretical understanding of the elements that influence these critical processes. However, consistent with the exploratory nature of this analysis, we acknowledge that different cases might have been affected by elements that we did not consider thus far. Therefore, as part of the interview process, prior to the investigation of the elements of the framework, an open conversation about the interviewee's lived experience was undertaken. This is in accordance with inductive case study research, where studies should begin "as close as possible to the ideal of no theory under consideration and no hypothesis to test (…) because preordained theoretical perspectives or propositions may bias or limit the findings" (Eisenhardt, 1989, p.536). Subsequently, the interview was aimed at deductively exploring the relevance of the elements defined in our framework. Thus, the core objectives of each interview were about exploring:

1. Individual perception and understanding of scaling in Citizen Science.

2. Elements that facilitated or inhibited scaling of the case study technologies, practices and outcomes.

3. How these elements are likely to play a role in facilitating / inhibiting scaling over time.

4. Based on the interviewee's lived experience explore: (a) what intrinsic elements of the subject (e.g. an entire pilot, a technology, a specific practice) facilitated or inhibited its scaling; (b) what elements of the process played a (positive or negative) role in scaling; (c) what elements of the target context were relevant for the subject to scale to this new location.

After the lived experiences of the interviewee have been inquired, a further step was defined to leverage the opportunity of engaging with individuals with expertise in the field of analysis. In other words, in this stage we aim at building on the subject's generative capacity in an "appreciative" form of inquiry (Cooperrider and Srivastva, 2005). As stated in Schultze and Avital (2011), "the appreciative interviewing process is designed as a retrospective inquiry that catalyses a prospective act". In this way the interviewee is taken through a journey in which she or he has the opportunity to relate their most outstanding personal experiences (previous steps) to generate hopeful aspirations and desired futures about scaling (or not) in Citizen Science within the broader ecosystem.

In total, eight interviews were conducted across the four cases. Each interview lasted approximately between 60 and 90 minutes. All interviewees agreed to be recorded and signed a consent form to allow their contributions and extracts from the interviews to be included in this report.

2.2.2.2 Data Analysis

This analysis aimed at identifying factors that influence scaling within each of the four case studies. This implies that from a wide range of data collected from each case, the analysis process had the goal of clustering it within meaningful categories, i.e. the enabling factors. This was achieved through two cycles of coding: an open coding step to reveal elements that influenced scaling in the specific case; and selective coding to contextualize the framework to the specific case study.

Once all interviews had been transcribed, drawing on existing literature (Miles and Huberman, 1994; Walsham, 1995; Darke et al. 1998; Berg, 2001), the following steps have been undertaken:

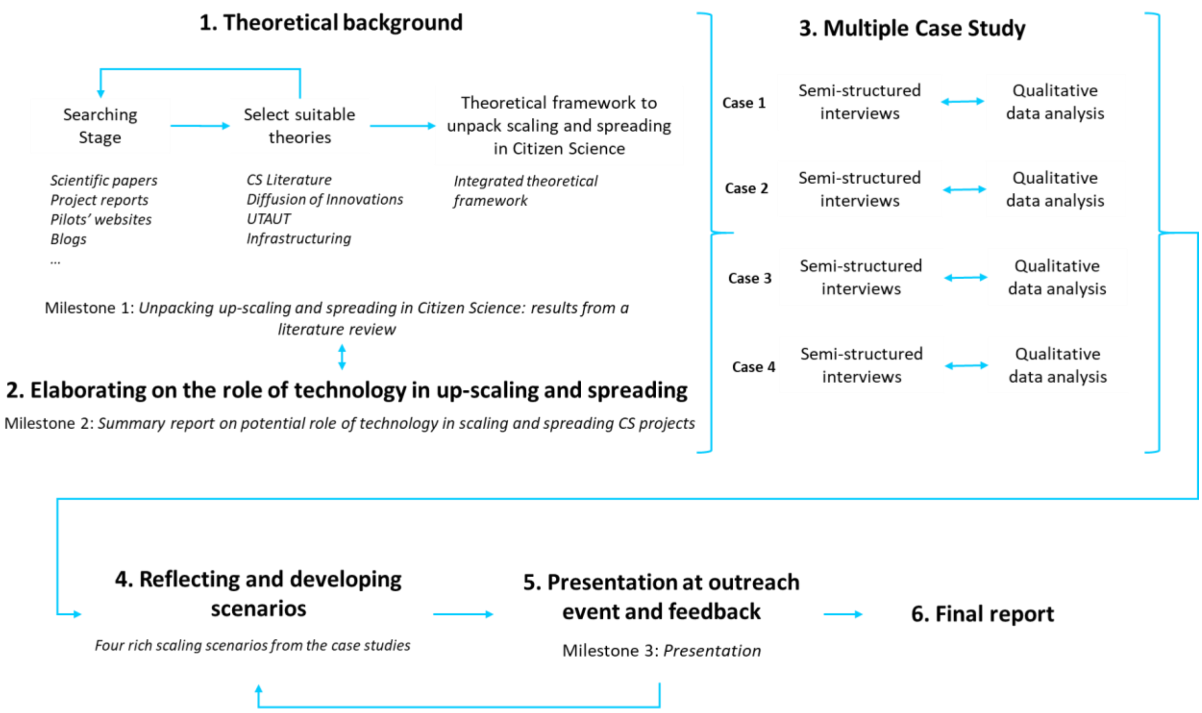
- Manually review the transcripts (and other publicly available documents), line-by-line and sentence-by-sentence, to uncover key patterns/themes and produce key words/phrases (inductive process) about elements enabling scaling in the specific case.

- Produce labels/categories of these keywords/phrases, under each macro category of codes (i.e. intrinsic elements of an intervention, those related to the scaling process, and those referring to target contexts).
- Develop raw tables of factors for each case.
- Validation phase undertaken by sharing the preliminary case study reports (i.e. the findings) with the interviewees to ensure correct interpretation of the data collected has been achieved.
- Develop the final case-related scaling scenario.

A further validation phase happened beyond the cases studied. The team presented the preliminary findings to a group of domain experts in a dedicated event and gathered significant feedback from the participants. This has been integrated thus augmenting validity, understandability, and relevancy of the final outcomes.

Concluding, the figure below proposes a summary of the overall methodology designed and implemented to address the objectives of this study.

Figure 1. Summary of Methodology



3 Building the Theoretical Lens

According to the methodology described above, the first step in this study was about reflecting upon the concepts of scaling and spreading (section 3.1). Given the scarcity of information currently available in the literature, we then reviewed three different related theories from different disciplines (section 3.2). This section is therefore dedicated to the theoretical underpinnings of our analysis.

3.1 Scaling and Spreading Phenomena

Overall, the Citizen Science discipline currently lacks a coherent understanding of what the terms scaling and spreading mean and how these can be approached. As exemplified by the brief and general definitions guiding this study (see section 1), these phenomena entail "extension" and "replicating and carrying over" in the case of scaling and spreading respectively. Therefore, the foundational cores of both concepts are elements of growth and replicability.

Two dominant concepts for scaling and spreading an innovation (of whatever type) are those of adoption and diffusion. We therefore leverage existing theories in these fields as a frame to guide the analysis of scaling in Citizen Science. However, we argue that solely focusing on these concepts entails some critical limitations. In fact, adoption and diffusion theories are typically used to investigate what factors influence the individual decision of adopting or rejecting a given innovation, without emphasising the importance of the social context. In other words, what these theories do not cover are socio-technical aspects of appropriation of certain innovations beyond individual perceptions. To address this gap, we found the concept of Infrastructuring from the Participatory Design discipline as a relevant source of insights.

In summary, from both a semantic and a pragmatic perspective, we argue that relying on the concepts of adoption, diffusion, and infrastructuring allows for accomplishing the objectives of this study, i.e. to unpack the meaning of scaling and spreading by focusing on the factors that influence diffusion, adoption, adaptation, and appropriation of Citizen Science practices and outcomes at an extended geographical scale (with respect to scaling) and in other contexts (with respect to spreading).

3.2 Theoretical Background: Adoption, Diffusion and Infrastructuring

This section is dedicated to an overview of the three theoretical conversations leveraged to unpack the meaning of scaling in Citizen Science. These are: diffusion and adoption of innovations (subsections 3.2.1 and 3.2.2 respectively) and infrastructuring (subsection 3.2.3). Each of the following subsections includes a general definition of the concept, an overview of its relevant constructs, and some reflection on the theory's previous application within the field of Citizen Science.

3.2.1 Diffusion of Innovations

Academic research on diffusion of innovations is mainly concerned with two fundamental questions: why and how some innovations spread more quickly than others? The most prominent and influential thinker and theorist in this space is widely acknowledged to be Everett Rogers (2010 - first edition published in 1962). Rogers' Diffusion of Innovation theory, initially developed in the discipline of Rural Sociology, is drawn upon the principle that differences in the rate of adoption of an innovation depend on the nature of the innovation itself, the adopter, and the social system. Given the scope of this study, we rely on the theoretical constructs in relation to the innovation and the social system in which its diffusion is investigated to better understand the phenomena of scaling and spreading in Citizen Science. The discussion about adopters goes beyond the scope of this report, as this moves from the actual design of scalable and spreadable Citizen Science pilots to a socio-psychological analysis of the type of individuals that are likely to adopt a specific innovation over time.

Regarding aspects of the innovation, the theory postulates that five of its intrinsic characteristics influence its diffusion: relative advantage, complexity, compatibility, observability, and trialability (Rogers, 2010). For the purpose of this report, we note that Trialability underpins considerations of the role played by the understanding of the innovation's ability to solve a given problem (i.e. the goal of experimentation). These are here ingrained in both the Observability and Relative Advantage constructs. Thus, the four constructs are presented below coupled with reflections on their potential relevance for achieving a better understanding of scaling in Citizen Science:

Relative Advantage is defined as the degree to which innovation is perceived better than its precursor, or better than doing nothing. To put it simple, this means acknowledging that a Citizen Science practice or intervention is more likely to scale and spread if its outcomes have produced a positive impact.

Complexity considers the way the innovation is perceived difficult to understand and use and correlates negatively with the rate of adoption. As explained in more details throughout the sections below, our review shows that Citizen Science projects which core concepts are easy to understand (e.g. observing butterflies, bird counting, mapping of quiet places) are more likely to scale and spread than those tackling more complex concepts (e.g. a project investigating the relationship between air quality and stress levels in humans).

Compatibility is defined as the way the innovation is perceived to be consistent with social values and needs, and past experience of potential adopters. This factor is positively correlated with the rate of adoption. In the context of Citizen Science, it is reasonable to think that practices and outcomes are more likely to spread to those locations that are subject to similar social values and needs.

Observability is defined as the way the results of the innovation are visible to others. It includes results' demonstrability and visibility. The former is referred to the ability to demonstrate that positive results have occurred, while the latter is linked to the ability to share those demonstrations with others.

Each of these characteristics on its own is insufficient to predict either the extent or the rate of diffusion, but previous studies have demonstrated that innovations affording advantages, compatibility with existing practices and beliefs, low complexity, and observability, will be more extensively and rapidly diffused than an innovation with the cluster of opposite characteristics (Dillon et al., 1996). According to Rogers (2010), from 49 to 87% of the variance of the rate of adoption is explained by these five attributes.

In addition to the characteristics of the innovation, diffusion theories assert that two further constructs influence these processes:

Communication channels: following the original formulation of Rogers' theory, an innovation can be communicated through mass media or through interpersonal communication. The two channels play different but complementary roles. Mass communication channels are usually the initial means for communicating the innovation, but interpersonal communication is more likely to influence the adoption process and decisions.

Champions: a further aspect that is dominant in diffusion research is the one related to opinion leaders and to the importance of interpersonal relationships and contacts. These roles, commonly known as champions, add a key social perspective on diffusion processes. Existing research extensively demonstrates the key role of champions as change agents and innovators and the importance of their ability to influence other individuals' attitudes and behaviours (Rogers, 2010). While in management literature scholars argue about the need to formally institutionalise these roles in the governance of an organization subject to change (Jones et al., 2003), informal champions might also emerge from the community of adopters in broader social contexts (Markham, 2001).

Despite its popularity among academic disciplines, surprisingly only few studies applied the Diffusion of Innovations theory within the field of Citizen Science. However, these focused on processes of adoption of specific innovations (technologies), rather than taking a broader cross-projects and cross-subjects perspective. Within these, we distinguish two types of contributions: those studies that leveraged the theory to explore adoption of technologies by participants of a given Citizen Science project (e.g. Beza et al., 2018), and those that focus on the role of Citizen Science interventions to foster adoption of specific innovations (e.g. Love et al., 2018).

3.2.2 Adoption Theories: The Unified Theory of Acceptance and Use of Technologies (UTAUT)

Similar to Diffusion of Innovations, the literature on the related concept of adoption is plentiful (Nakicenovic and Grubler, 2013) with a huge variety of studies that have focused on identifying and subsequently testing factors that influence adoption of particular innovations. These studies stem out of different focused disciplines such as Human-Computer Interaction and Information Systems. These research streams mostly rely on theories proposed by Ajzen and Fishbein (1980) - i.e. the Theory of Reasoned Action - and Davis (1989) - i.e. the

Technology Acceptance Model, better known as TAM. During the last three decades the academic debate on the most appropriate theories for investigating adoption has evolved substantially. Today, one of the most accepted theories in this space is the Unified Theory of Acceptance and Use of Technology" (UTAUT) proposed in its first version in (Venkatesh et al., 2003) and augmented in (Venkatesh et al., 2012). The UTAUT model is drawn upon the integration of eight widely used theories in the context of acceptance, use and adoption of technologies. These are: (1) Theory of Reasoned Action (Fishbein and Ajzen, 1975), (2) Technology Acceptance Model (TAM) (Davis, 1989) and its extension (Venkatesh and Davis, 2000), (3) Motivational Model (Davis et al. 1992), (4) Theory of Planned Behaviour (TPB) (Ajzen, 1991), (5) Combined TAM and TPB model (Taylor and Todd, 1995), (6) Model of PC Utilization (Thompson et al. 1991), (7) Diffusion of Innovations Theory (Rogers, 2010), and (8) Social Cognitive Theory (Compeau and Higgins, 1995).

For the purpose of this report we find UTAUT as a relevant inspiring theory as it addresses relevant limitations of other previous theoretical models in this space. First, previous theories are argued to be centred on individual-oriented technologies (e.g. adoption of a mobile phone); the UTAUT, instead, is argued to be suitable to investigate more complex and sophisticated processes of adoption, likewise the context of scaling in Citizen Science. Second, previous theories were mainly focused on acceptance and use in contexts of mandatory adoption of technologies (often in the realm of organizational settings where managers mandate the usage of certain technologies to their employees). The UTAUT is also applicable to voluntary adoption settings, i.e. aligned with scaling in Citizen Science. Thus, we argue that UTAUT is a valuable source of insights to frame how scaling in Citizen Science can be unbundled.

The UTAUT model postulates that four constructs represent a collectively exhaustive description of the causal antecedents of adoption of particular innovations. These are: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions (Venkatesh et al., 2012). The theory also proposes a number of moderating variables, such as gender and age, that offer a more accurate explanation of the weight of each construct. However, considering these is beyond the scope of this report. In fact, moderating variables are typically explored and tested through large samples - based quantitative studies (Hartwick and Barki, 1994; Venkatesh and Morris, 2000).

Performance Expectancy: along the same line as Relative Advantage in Diffusion of Innovations, Performance Expectancy is defined as the degree to which potential adopters believe that using the innovation will help them attain gains in performance (Venkatesh et al., 2012). Performance is here broken down into the following elements (Venkatesh et al., 2003): usefulness to accomplish a task, undertake actions more quickly, make it easier to perform a task, and increase productivity.

Effort Expectancy: in the same vein as Complexity in Rogers's theory (2010), it is defined as the degree of ease associated with the use of the innovation (Venkatesh et al., 2003). The core elements of Effort Expectancy are: ease of use, understandability, and aspects about the learning curve required to gain the sufficient experience for effectively using the innovation.

Social Influence: drawn upon Subjective and Social Norms (Davis, 1989; Venkatesh and Davis, 2000; Fishbein and Ajzen, 1975) and Social Factors (Thompson et al. 1991), this construct includes aspects related to compliance to: social and normative pressures. Social pressures are defined as the degree to which adopters perceive that important others believe they should adopt and use the innovation. Normative pressures emphasise the role that legislative and regulatory environments play in adoption phenomena.

Facilitating Conditions are defined as objective factors in the environment that observers agree make an act easy to do (Venkatesh et al., 2012; Thompson et al. 1991). The common denominator across these concepts is about aspects of the technological and/or social environment that are in place to lower the barriers for adopting and using an innovation. Originally, in the context in which this construct was defined, i.e. in organizational adoption and diffusion of information systems, Facilitating Conditions referred principally to the availability of resource materials and "helpdesks" to facilitate uptake of the new innovation.

In the context of Citizen Science, a few studies leveraged the UTAUT model for different purposes (Nov et al., 2011; Gharesifard and Wehn, 2015; Greenhill et al., 2016; Asingizwe et al., 2018). For example, Nov et al. (2011) developed an extensive motivational model describing the antecedents that are likely to predict public participation in Citizen Science interventions where the participation is mediated by technology. In the case of this study, the unit of analysis was motivational factors driving online citizen participation coupled with reflections on task granularity. This is also the case of (Gharesifard and Wehn, 2015)'s study, however in the specific context of investigating barriers and enablers for citizens to share personally collected weather data on web platforms. In a similar fashion, but from a different angle, Greenhill et al. (2016) use UTAUT to investigate the role played by game activities to drive motivations for citizens to participate in a given intervention. However, the main contribution of the latter study lies in the outline of how gaming-based solutions should be designed to increase participation in Citizen Science. From another angle, Asingizwe et al. (2018) use the theory to develop a conceptual framework describing how Citizen Science could contribute to participatory prevention and control of malaria. The purpose of the application of the theory in this case was twofold: (1) likewise the previous examples, as an attempt to predict the likelihood that citizen will participate in a related intervention in Rwanda; and (2) to investigate how Citizen Science can foster the adoption of two specific remedies to this disease: Long-Lasting Insecticide-Treated Nets and Indoor Residual Spraying. Like in the case of Diffusion of Innovations, these studies clearly show that, while the theory has been found suitable to understand specific aspects of Citizen Science (mainly related to participation), these remain investigations at the project level. Therefore, a cross-project and cross-disciplines perspectives are lacking to date.

In conclusion, we argue that adoption theories and specifically the UTAUT model, offer a valuable perspective for better understanding aspects of scaling in Citizen Science. However, a limitation in solely considering adoption and diffusion theories is in that these are typically suitable to investigate constructs that influence the decision on whether to adopt or reject an innovation, without specifically tackling the need for the adopter to then infuse, routinize, and implement the innovation itself (Saga and Zmund, 1993; Agarwal and Prasad, 1997). While Roger (2010)'s definition of Diffusion ingrains aspects of Sustained Adoption, additional insights can be gained from considering the literature on appropriation and infrastructuring from the Participatory Design discipline.

3.2.3 Infrastructuring Approaches in Participatory Design

The discipline of Participatory Design has recently challenged the way of looking at the appropriation of socio-technical artefacts. The field has gone beyond looking at the elements of the artefact per se (e.g. functionality, usability and intended uses) to explain why a product is adopted by shedding light on design activities and practices as important influencing factors (Björgvisson et al. 2012). The shift in focus moves from designing useful products / services to designing a supportive environment (infrastructure) that foster appropriation and future uses unforeseen at project time (Björgvisson et al. 2012). This perspective clearly complements those provided by Diffusion of Innovations theory and the UTAUT.

Infrastructuring has been defined as the process of building fertile ground to sustain participation of publics over long periods of time, allowing new opportunities to emerge and reveal dilemmas and controversies (e.g. Karasti and Syrjänen, 2004; Ehn, 2008; Bjögvinsson et al., 2012; Le Dantec and DiSalvo, 2013). In other words, through an artful work of infrastructuring, designers put in place the conditions for facilitating the appropriation of socio-technical innovations, thus their scaling.

Infrastructures (e.g., railroad tracks, cables, or the Internet) are embedded in social structures and, subsequently, get shaped by the conventions of social practices (Star and Ruhleder, 1996). This process of shaping and reshaping is aligned with strands of design-in-use, design-after-design, and meta-design (Henderson and Kyng, 1991; Dittrich et al., 2002; Fischer, 2003; Redström, 2008). Common to these design approaches is that they regard design as an open, everlasting process. This means acknowledging that the object of design - and consequently the object of scaling - does not denote only static tangible artefacts, but also relational qualities, social practices, agreements, that are shaped when people appropriate them since different publics can ascribe different and evolving meaning to an artefact (Righi et al., 2017). This reasoning implies that we must be open to acknowledge that different components of the innovation may have been appropriated and reshaped by new publics (Dewey, 1954). The work on infrastructuring has been dealt with mainly in the context of participatory design with communities (Karasti, 2014). It is therefore particularly relevant to Citizen Science projects that are structured around community interventions.

Within the scope of this study, the theoretical lens on infrastructuring triggers two important reflections. On the one hand, it challenges the traditional way of looking at scaling processes as mere extension and full-replication of an innovation, because it acknowledges that a socio-technical innovation can be appropriated in different ways and therefore different elements could be the object of scaling/spreading. On the other hand, it provides insights on the driving forces that contribute to the creation of publics and sustain their engagement.

Unlike the theories presented above, current works on infrastructuring have mainly been driven by practice rather than theory. There is still not a consolidated theoretical framework that presents clear constructs of infrastructuring. From a careful review of recent literature in this space, we have identified the following themes that scholars discuss as factors facilitating infrastructuring processes: Matter of Concern, Communities, Openness, Orchestration, and Narratives and Communication.

3.2.3.1 Matters of concern

The formation of publics is key when aiming at scaling or spreading an innovation. Contrary to the notion of community, which comprises sharing of an identity and a sense of membership or attachment, publics are emergent social arrangements that form when issues require their involvement (Le Dantec, 2016). In the case of Citizen Science interventions, such a public is constituted by groups of people who are willing to engage in scientific activities. Previous studies have shown that citizen interventions that are designed to address a matter of concern (i.e. an issue that citizens care about and/or are affected by) are more likely to promote the formation of publics because they galvanise (i.e. excite someone into taking actions) around the problem at stake. As a result, individuals are willing to take their time and energy to address the issue (Le Dantec & DiSalvo, 2013; DiSalvo et al., 2014; Teli et al., 2015; Balestrini et al., 2017). This contributes to promoting a shared sense of purpose over the project's aim and foster the development of attachments, both of which are considered key elements in preparing the base for future appropriations (Teli et al., 2015).

Too often a perceived lack of a clear goal among participants has led to user disengagement in these participatory projects (Liu and Kobernus, 2017; Balestrini et al., 2015). As Latour (2007) points out, participatory processes should be issue-oriented if they aim to trigger engagement, because the public is above all interested in a particular issue rather than in the participatory process itself.

It should also be noted that projects that have addressed known and acknowledged matters of concern tended to be more successful in reaching media coverage (Balestrini et al., 2014), which in turn can contribute to increase the participants base, foster uptake from other stakeholders and build a shared narrative. It is finally reasonable to expect that the articulation of matters of concern allows projects to spread to those locations or communities that experience similar issues.

3.2.3.2 Community

Once a public has formed by galvanising around a shared matter of concern, it is crucial to nurture such public by building a sense of community, a key and well-known motivator for participation in Citizen Science (Rotman, 2012). It comes with no surprise that many citizen science projects leverage on the sense of community to sustain and widen engagement. Leveraging existing local networks who are knowledgeable about local issues, has proven to be instrumental to widening the participant base and engage the broader population. Such local networks could either be community advocacy groups or emergent groups of people that gather around a shared interest. Among these, champions emerge as individuals who embrace a cause and become an advocate of it, mobilising others to join in (Taylor et al., 2011). Local champions can take leadership of the intervention after a project comes to an end and the researchers have left the field, thus helping sustaining contributions and engagement over a longer period of time (Balestrini, 2017).

3.2.3.3 Openness

In the literature on Infrastructuring the concept of openness has been discussed in relation to three aspects: (1) artefacts, (2) design methods, and (3) governance. Overall, applying an open approach to these three dimensions of a Citizen Science project catalyses the formation of a common (Balestrini et al., 2017; Marttila et al., 2014). We discuss the concept of common throughout the three dimensions below.

The most predominant strand of the open approach focuses on the designed artefact (material or digital ones) where the emphasis is on opening up its blueprint when making it publicly available. This allows for full replication, re-use, extension and adaptation. This trend most commonly relates to the concepts of open source as well as open data which have increasingly become a key characteristic of many citizen sensing initiatives.

With the proliferation of open source technology, the creation of makerspaces, and the growing popularity of crowdfunding platforms, new urban sensing technologies have been designed and released to citizens, way beyond those developed as part of citizen science projects or related research agendas. Their goal is often to empower citizens with more open systems that they can appropriate for their own purposes (Diez and Posada, 2013). The release of these technologies in open repositories, such as GitHub, allows for their uptake, replicability and appropriation by other communities beyond the one that initially created them. The fact that even before the technologies are developed, a community of users becomes involved with the project (Abe, 2014) reveals a new dimension of citizen empowerment that introduces investing in and using open-ended technologies as a type of collective and political action (Kera et al., 2013). A citizen science project that uses open source technologies is more likely to foster the formation of new publics willing to appropriate it. This is well known among the academic community who embraced the concept of open science.

While it has been argued that open-access is the main attribute for an asset to become a commons (Lessig, 2004), scholars suggested that a governance design that facilitates community control over the collaborative process of building the common-pool (Fuster Morell, 2010) and promotes citizen involvement in its improvement and management (Foster and Iaione, 2016), is equally fundamental. This dimension comprises the degree to which participants can have a voice in decision making processes. Participation in governance allows for new forms of appropriation that might have not been considered beforehand by the project promoters (Balestrini, 2017). However, the more open the governance of a project is, more rules, boundaries and mechanisms for self-governance and monitoring should be put in place (Ostrom, 1990).

The third strand of an open approach relates to opening the overall method used to deploy the intervention. The existing literature shows that community-based projects that delivered documentation about the steps carried out and the tools used during the intervention have increased engagement with the project (Teli et al., 2015), fostered its scalability (Marttila and Botero, 2013), shareability (Lessig, 2004) and forkability (Balka, 2011). In fact, documentation enables others to understand how the process was undertaken and what resources are needed to replicate or adapt it. This also includes publishing all material and information in open formats.

3.2.3.4 Orchestration

It has been widely acknowledged among Participatory Design scholars that simply handing over a new technology in a community, even when affordable and open source, would not necessarily imply its adoption (Taylor et al., 2013; Balestrini et al., 2015; Righi et al., 2017). This is particularly relevant when considering Citizen Science interventions that rely on technological tools to collect data. While many community projects are publicised as grassroots and self-organising, orchestration actions are often needed to sustain and upscale engagement over time (Taylor et al., 2013). Orchestration actions tend to develop around the organization of public events and workshops (e.g. meetup, hackathon) to help strengthening social interactions among participants and impart a sense of usefulness of the co-created resources (e.g. data, technology), showing how these could be used and appropriated by external actors as well, thus contributing to widen the participant base (Merkel et al., 2004; Crabtree et al., 2013; Balestrini et al., 2017).

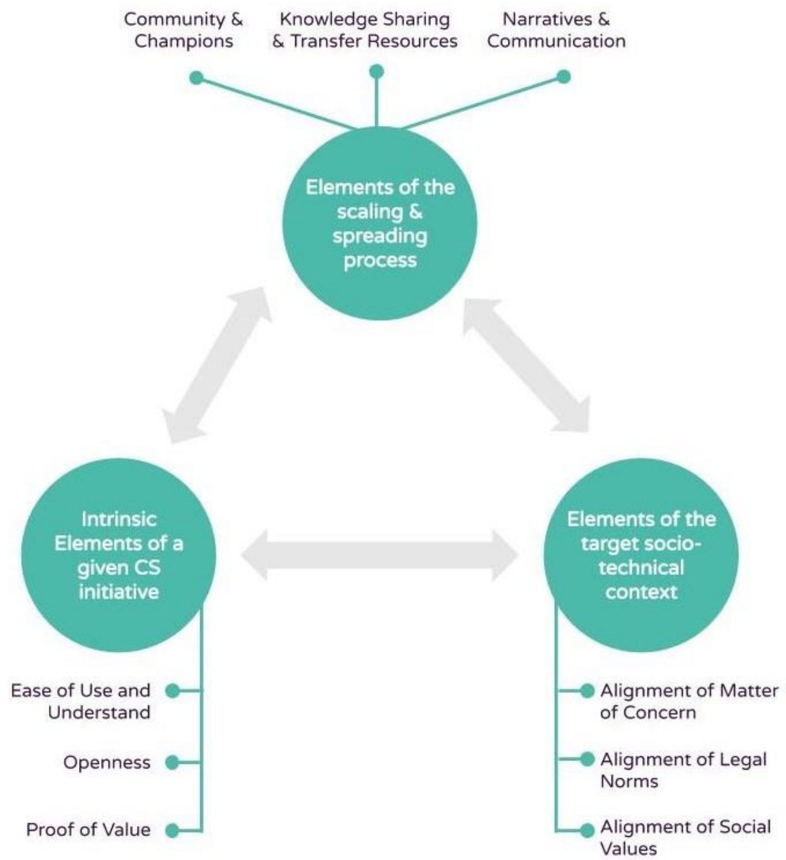
3.2.3.5 Narrative and Communication Outreach

Narratives, visions and imaginaries have long been recognised as powerful drivers for engagement, galvanising people around a shared vision (Ruddick, 2010). Narratives have been used to encourage individuals to think and behave in ways that will contribute to the collective good and to motivate individuals in challenging situations (Redman, 2005). Even when members of a public do not share an identity or history, narratives can be instrumental to frame matters of concern and nurture collective action (Balestrini, 2017). Having a clear narrative around the project scope also helps to attract media. Media coverage of pilot stories helps to raise the profile of the interventions and be known by external stakeholders, opening opportunities for partnership, funding and external adoption or appropriation. Media coverage also helps to develop a sense of pride and ownership among participants who see that their stories attract media attention (Balestrini et al., 2014). As also supported by the diffusion of innovation theory described in the previous sections (Rogers, 2010), media communication influences the adoption process. Therefore, it is reasonable to expect that external appropriations of a citizen intervention are more likely to occur when the project achieves communication outreach.

4 An Integrated Theoretical Framework for Unpacking Scaling in Citizen Science

According to the approach designed for this study (see Section 2), the next step was about reflecting on the three theoretical conversations with the objective of deriving an embedded framework to be used as the lens to unpack the meaning of scaling in Citizen Science. To do so, we have conducted a clustering exercise, whereby we grouped together similar constructs among the theories considered. This analysis led to the identification of nine unique elements. These are seen as conditions and characteristics that, according to the theories considered, are likely to influence scaling in Citizen Science. A further clustering exercise conducted upon these nine theoretical elements allowed us to identify three overarching categories. These are: (1) elements about the initial intervention to be scaled or spread (and the items within it); (2) elements supporting the spreading and up-scaling process; and (3) elements of the target context. As a summary, Annex 1 provides a list of each newly defined construct and the associated root constructs clustered for its definition. Figure 2 offers a graphical representation of these elements, which are presented separately below.

Figure 2. A Framework of Enabling Factors for Scaling in Citizen Science



4.1 Elements intrinsic to the initial intervention to be scaled or spread

Our review suggests that among the factors that enable scaling, three intrinsic characteristics of the subject to be scaled and spread play an important enabling role: Proof of value, Ease of Use and Understanding, and Openness.

4.1.1 Proof of Value

This newly derived construct emphasises the need for the subject of scaling or spreading to be valuable and for its impact to be measurable, understandable, and observable. The reasoning behind it is somewhat obvious, i.e. the theories predict that valuable elements for which impact can be demonstrated are more likely to scale and spread than those with opposite characteristics. In other words, this first driver acknowledges that for a Citizen Science intervention to scale, the value of its outcome must be present, clear, demonstrated, and understood. However, while this is easy to state, demonstrating impact from Citizen Science interventions is a widely acknowledged challenge. Existing literature in the discipline advocates for a homogeneous and simplified evaluation framework to measure the impact of citizen science projects. The European Commission strongly calls for the development of a common framework and emphasizes the need to, besides the economic impacts (cost & benefits), to also consider ways to measure the social impacts of a project (Manzoni et al., 2019). An example of a European project addressing this issue is Measuring Impact of Citizen Science (MICS)[6].

Further reflections can be drawn with respect to those situations whereby the subject of scaling is an actual technology (e.g. where scaling entails the adoption of a specific sensing technology or application in another context). Following existing adoption and diffusion theories, in a given task or practice in Citizen Science projects the impact of using a technology as opposed to either use another digital technology or a more traditional (e.g. manual) process, can be categorised across four elements. In other words, the potential scalability of a given technology increases if:

1. The technology plays a role in accomplishing tasks more quickly and efficiently (Davis, 1989; Davis et al., 1992; Rogers, 2010). This means that the use of technologies allows minimising the effort, time, or the raw materials needed to complete a task. The widespread use of mobile apps for data collection in Citizen Science is a clear example of this. Indeed, we argue that gathering data through a mobile app as opposed to traditional methods (e.g. through pen and paper) enables considerable saving of effort, time, and resources.
2. The technology increases the users' productivity compared to a situation where it is not used (Thompson et al., 1991; Compeau and Higgins, 1995; Venkatesh et al., 2003; 2012). Although apparently similar to the previous statement, the emphasis here is placed in the amount of work done in a given timeframe. Following the example of mobile apps for data collection, we argue that such technologies allow an increasing number of inputs in a certain period of time.
3. The use of the technology leads to an overall better quality of the outcome of the intervention (Compeau and Higgins, 1995; Rogers, 2010). This is the case, for instance, of Citizen Science projects that focus on mapping a range of issues such as mosquitos, air quality, quiet places, or radioactive radiation. In such cases, the use of modular platforms and appropriate visualization software is believed to substantially increase the quality of the output by, for example, increasing: retrievability of data, ease of understanding of the incidence tackled, and a clear presentation of project outcomes to both participants and (governmental) stakeholders involved.
4. Lastly, in relation to the need of this value to be measurable and observable, our theoretical framework postulates that the likelihood of a given technology to be adopted depends on the extent to which the general classes of benefits described above (i.e. in relation to time saving, productivity, and overall quality of the outcome) are measurable and observable. In the Information Systems discipline, this aspect is well acknowledged and has been referred to in different ways such as tangibility of the results of using a technology (Moore and Benbasat, 1991) or result demonstrability (Zaltman et al., 1973).

4.1.2 Ease of Use and Understand

This second cluster stresses the idea that the more the subject of spreading and scaling is easy to use (e.g. in the case of technology or specific practices) and understand (e.g. in the case of the core subject of an existing project), the more likely it is to scale. For a Citizen Science project to be effective in engaging a large group of people in collecting data, thus to be more likely to scale, it should provide easy ways for novices to get started in the process. When the data collection process implies the use of technologies, these must be easy to use, minimizing the need for help. In this regard, using off-the-shelf technologies, widely available and well-known among the population, can increase the uptake (Balestrini et al., 2014). Whereas, when a new technology is used - e.g. an app designed specifically for the project - this should be designed according to the most forefront principles of User Centred Design and should be tested and iterated with users before its large deployment, so as to prevent participants' disengagement and withdraw.

In the context of Citizen Science, most activities conducted across all stages of an intervention are mediated by some form of technology. As some examples, technology often mediates participation (Nov et al., 2011), data

6 https://mics.tools/

collection (e.g. through smartphone applications, sensors), data analysis (e.g. through advanced analytics, GIS tools), and communication (e.g. websites, social media). In all these cases, it can be argued that technology is introduced to make these tasks (e.g. participation, data collection, data analysis etc.) easier to perform and understand and therefore, according to existing theories, more likely to scale. A useful concept to discuss this is that of "task granularity", originally defined as the smallest individual investment necessary in order to make a contribution (Benkler, 2006). Our review indicates that Citizen Science projects differ significantly in the task granularity that is required for volunteers. The literature reviewed consistently states that today's technologies contribute to streamlining data collection, improving the management and governance of the collected data, automating control of quality and integrity of data and expediting communication (Newman et al., 2012), thus suggesting a decreasing trend of tasks' granularity (i.e. a proxy for a decreased effort expected by participants).

However, while the basic tasks might seem easier to perform, this is not necessarily true across the board. Despite their broader reach, technologies might act as important barriers to participation for those citizens that are not familiar with a specific technology or have overall low digital skills. In other words, given the usually (and strongly advocated) wide diversity among participants, one would expect that such diversity is also present in relation to people's ability to use and understand technologies of all kinds. While a study on what cohorts of participants have more or less abilities to understand and use technologies goes beyond of the scope of this analysis, it is worth to note that a strong interlink exists between Ease of Use and Understand and the need for Knowledge Sharing and Transfer Resources, and the importance of champions (both discussed in the relevant sections below). The former could include tutorials, onboarding kits, training and education sessions (among other resources) which are mainly oriented towards addressing this trade-off.

In summary, characteristics concerning complexity and ease of use, can influence the way a project is approached and designed, the type of participation and, unavoidably, its outcomes. By proposing some of the emerging challenges deriving from existing trends, we do not argue that projects that make use of more complex technologies are less likely to scale up or spread. However, these require a different approach, and it has to be kept in mind that different types of technologies leveraged in a project might attract different types of citizens.

4.1.3 Openness

The Citizen Science discipline strongly promotes the usage of open access and open technologies (Hecker et al., 2018). Following this trend, many citizen science applications incorporate open-source software, open hardware and apps, and open-access data and publications (Mazumdar et. al., 2018). As widely introduced before (see Section 3.2.3), this construct includes aspects about: open artefacts, design methods, and governance. As argued above the most dominant view in the discipline is currently around open artefacts and specifically technologies. In order to further articulate these concepts, in this section we reflect on the role of Open Source Software, and Open Data.

4.1.3.1 Open Source Software

Driven by the LAMP archetypal model of web services stacks (i.e. an acronym for Linux, Apache Web server software, MySQL database, and Perl/Python/PHP), Open Source Software is more and more popular and powers most of the websites we visit every day. In stark contrast with the conventional software industry, where proprietary software code is safeguarded for commercial purposes, the Open Source movement is based on Software's source code being made available and reusable by anyone. Open Source technologies are argued to afford several benefits. The most prominent are: (1) Cost, i.e. it is free of charge (King, 2008; Castelluccio, 2008); (2) Reliability and security, following the principle that "given enough eyeballs, all bugs are shallow" (McMillan, 2008); and (3) scalability (King, 2008), understood in this context as a scalable software, i.e. enabling the ability to either handle increasing workloads or to be easily expanded to manage workload increases. In brief, the key statement relevant to this analysis is straightforward: if technologies used in a given Citizen Science pilot are open source, the scalability of such technologies (and of the pilot itself) is facilitated. Nowadays, from our review, almost all IT-enabled Citizen Science projects use and/or develop Open Source technologies.

A useful example that combines both open source software and this construct is GitHub, a git-based repository management platform often used to share open source software codes. The platform has a section specifically dedicated to Citizen Science, described as follows: "a curated list of awesome software and other resources to enable those who want to use scientific tools to empower communities and/or practice various forms of non-institutional science. It is largely inspired by this repository listing digital tools for activists. Feel free to share suggestions. If you add software to the list, free and open-source software is strongly encouraged over proprietary software". To-date, HackAir[7], SafeCast[8], and NoiseTube[9] are just some examples of Citizen Science projects that published the source code of the technology leveraged on this platform.

Notwithstanding this, Open Source Software does not come without risks and challenges. First, the Open Source community cite certain open source products as being difficult to install and maintain, therefore suggesting a potentially higher Total Cost of Ownership (Gallaugher, 2019). Adopters often lament having to rely on undefined communities of volunteers for general support and software upgrades. Following this avenue, important considerations must be given to the levels of skills required by citizen scientists to be able to understand, extract, adapt, and re-use software code among different application domains (i.e. aligned with scaling across Citizen Science interventions). A second important challenge refers to potential risks of legal exposure (Lacy, 2006). Many times, developers distribute Open Source code while unaware of its licensing implications. For instance, in 2007, Microsoft claimed that Linux and other open source solutions were violating about 250 of its patents (Ricadela, 2007). To further complicate the legal scenario of Open Source Software, there are a plethora of open source license agreements (e.g. GPL, Apache License) and all these vary in their legal provision and dynamically evolve over time. The result, as argued by Gallaugher (2019) is that "keeping legal requires effort and attention, even in an environment where products are allegedly free".

In summary, according to the risks outlined here, in the context of scaling in Citizen Science, the role of Open Source for fostering scaling appears to be mediated by a set of required legal and technical knowledge.

4.1.3.2 Open Data

The definition of open data was firstly developed by the Open Knowledge Foundation in 2005 as "data that can be freely used, shared and built on by anyone, anywhere, for any purpose". There are three principles behind this definition: (1) availability and access; (2) re-use and redistribution; and (3) universal participation.

In their Digital Agenda (European Commission, 2011), EU commissioners listed four reasons for promoting open data initiatives (mainly at the government level):

1. Open data has significant potential for reuse in new products and services. Overall economic gains from opening up this resource could amount to € 40 billion a year in the EU;

2. Addressing societal changes. Having more data openly available will help discovering new and innovative solutions.

3. Achieving efficiency gains through sharing data inside and between public administrations.

4. Fostering participation of citizens in political and social life and increasing transparency of government.

In Citizen Science, open data is mainly discussed in relation to the data being collected and analysed as part of an intervention. Its contribution to the scaling of particular projects appears to be obvious, i.e. the scalability potential of a given intervention increases if the data collected (i.e. the raw data), its analysis (i.e. the transformation process from data to information to knowledge) and the data outcomes (i.e. the aggregated results) are made publicly available (preferably online). A considerable amount of literature advocates the need to make data available through portals acting as a single access point (Stephenson et al. 2012; Rittenbruch et al. 2012; Lakomaa and Kallberg, 2013; Lindman et al. 2013; Zuiderwijk et al. 2015). Moreover, this data should be free to use and re-use with little to no requirement of authentication or approval (Oh, 2013).

However, existing research also demonstrates that simply publishing data online is not enough. Further efforts should be put in place to increase reusability of the data, and specifically to ensure: (1) timeliness and overall quality of the data; and (2) effective accessibility. Among these two elements, the former is more straightforward - i.e. open data should be provided "as quickly as necessary to preserve the value of the data" (Matheus et al. 2012, p.23), and the quality and integrity of the data should be ensured for it to be reused. In this way, there is considerable research in Citizen Science tackling the importance and the challenge of obtaining good (enough) quality of citizen generated data (Crall et al., 2011; Kosmala et al., 2016). With respect to accessibility, the debate is still ongoing. Among the topics covered in the literature, we identify one critical

7 https://www.hackair.eu/

8 https://safecast.org/

9 http://www.noisetube.net/

aspect in the context of how open data should be provided to foster reuse (i.e. a proxy of scaling and spreading), i.e. the format. First, we argue that different options should be in place to accommodate different types of users and their wills. For example, data about a citizen science intervention should be made available to those that want to access it for consultation – e.g. to access a project results and the chain of evidence supporting these. Clearly, in this case the right format should be human-readable (e.g. pdf) to diminish the skills and effort required to interpret it, thus ensuring general principles of transparency and equal access to this data for the overall population, not only developers and IT skilled people. However, human-readable formats can substantially limit re-use of this data.

To address this challenge, data should be provided (also) in a machine-readable format (Aoyama and Kojima, 2013; Wilde, 2010). Appropriate Application Programming Interfaces (APIs) should be in place to facilitate access (Herschel and Manolescu, 2012; Stephenson et al. 2012; Palka et al. 2013; Frosterus et al. 2012; Guo and Kraines, 2010; Hannemann and Kett, 2010; Jurisch et al. 2015). The usage of APIs is also believed to help monitoring actual reuse of the data, which is otherwise argued to be a great challenge in the Open Data discourse (Foulonneau et al. 2014). Hence, we argue that to ensure that both these key objectives are met, both solutions should be in place to foster scalability and spreading through open data. This seems to be acknowledged by the Citizen Science community. For instance, Volten et al., (2018) emphasizes the importance of transparency and flexibility in presenting data in various ways. Some citizens might be satisfied with infographics and pictures, but others might prefer the data behind these visuals.

While positioned within the constructs about the original context, Openness emerged as a cross-cutting principle that is likely to be relevant for several of the constructs established. For example, we argue that as part of dissemination actions to foster scaling, such material should be published as open access. This is also valid, for instance, in the case of knowledge sharing resources. Furthermore, as highlighted in the theoretical section above (see section 3.2.3) open communities and opening the orchestration and governance to the public are all likely to play a role.

4.2 Elements supporting the scaling process

According to the theories considered, once the intrinsic characteristics of the subject to be scaled are in place, a critical role is played by several aspects supporting the actual scaling process. From the clustering exercise conducted, three interrelated dimensions were derived: (1) Development and Dissemination of Narratives and consistent Communication Material; (2) Community and Champions; and (3) Knowledge Sharing and Transfer Resources.

4.2.1 Development and Dissemination of Narratives and consistent Communication Material

This element includes aspects of communication, dissemination, and the importance of developing narratives to stimulate uptake of innovations. These encompass actions to disseminate information about projects and their elements, as well as the strategies for doing so. The rationale is that communication, dissemination and the development of narratives will not be limited to raising awareness but will play an important enabling role to foster appropriation of the subject to be scaled.

In Citizen Science, too often a given project cannot be replicated simply because the information about it is not (publicly) available beyond the end of the funding period. Typically, successful communication initiatives should include multiple means reaching all types of audiences. These might include scientific journal publications (aiming at the academic audience), publication in the local and global media, consistent update of the social media accounts etc. According to the existing literature, communication should occur at two levels (Zolait and Sulaiman, 2008): "mass communication" (through e.g. academic papers, reports of different kinds, blogs, websites, social media etc.); and "word of mouth" communication (i.e. interpersonal communication). In general, theories agree on the fact that the former should be leveraged to create general knowledge about the subject, whereas the latter is more effective in forming and changing attitudes towards an adoption behaviour.

Furthermore, this construct postulates that those Citizen Science interventions (or technologies) that underpin a narrative are more likely to scale. The reasoning behind this element is that sometimes technologies offer the opportunities to legitimise an effort to tackle a widely acknowledged challenge such as environmental sustainability, unemployment, gender equality, open innovation etc. Existing research demonstrates that there are cases where narratives can assume a dominant role in the adoption of a specific technology, e.g. (Balestrini, 2017). As an extreme hypothetical example, it might be the case that an entity decides to adopt an IoT-based solution (or blockchain, or AI, or alike) even though there is perfect consciousness that it has no proof of value associated with it, it is not easy to use or understand, and may result in no impact whatsoever. However, following the reasoning of narratives, this creates a "catchy story" to be used mainly for marketing purposes.

4.2.2 Community and Champions

To form this element, three root constructs (see Annex 1) were grouped together as they all support the concept that scaling is not simply about dropping a technology and a methodology into a new (or an extended) context. Rather, according to the theories considered, these must be supported by an artful work of aligning actors around the shared concern and fostering continuous engagement.

With respect to communities, when reflecting on how communities can help scaling in Citizen Science, it becomes useful to discuss the actual meaning of the term in our context. Inspired by the Bristol Approach to Citizen Sensing Programme (2016), to describe communities in Citizen Science we avail of the concept of "ecosystem of agents". As argued in their original report reinforcing the concepts originally provided in (Benkler, 2002), "communities around digital commons are more open to participation [than other communities types], which makes it difficult to establish their boundaries". The challenge is highlighted in terms of scoping the community element as one unique unit of focus, because of the different levels and degrees of contribution of all the actors playing a role in the sustainability and effectiveness of an intervention. Then, the report proposes a taxonomy of roles that are "crucial to the sustainability and scalability of an ecosystem of common and shared resources". These, overlapping, roles are summarised in Table 1.

Table 1. Taxonomy of Community Roles[10]

Name	The role in Citizen Science
The Contributor	Most contributors are ordinary citizens that proactively participate in all phases of a research project
The User	Users are the recipient of the resources contributed by a Citizen Science project (e.g. data). Uses vary depending on the type of resources, but usually this cohort plays a key role in demonstrating the usefulness of the outcomes.
The Seeder	"an agent that financially supports the development of a commons". While in the case of crowdfunding these might be also collaborators and/or users, this is not a rule for Citizen Science. Indeed, the vast majority of projects are funded by public money (local or EU-level) or, in a smaller amount, by public-private partnerships.
The Manager / Orchestrator	Those responsible for daily operations, assuming an overall project management role.
The Champion	"Someone who draws others to participate". Champions can assume a key role in enacting appropriation of citizen Science practices and technologies. Also referred to in the literature as "super users" (Ashurst, 2015), these are typically individuals with interest, aptitude, and experience and that thus have developed higher levels of knowledge to provide support and advice to potential adopters.

10 Source: Bristol Citizen Sensing Programme, 2016. A Future in Common: Understanding and Framing Commoning Strategies for Bristol.

When planning and setting the stage for scaling, this taxonomy can help in tailoring the requirements and the appropriate strategies for each community member type to meet the motivations required for these to play a proactive role. In other words, communities must be built upon the different motivations driving the participation of each actor, making the "one strategy fits all" impracticable in this way. For example, much literature investigated motivations for contributors. These typically include extrinsic motivations such as improvement of skills and enhancement of status (Lakhani et al., 2005), and intrinsic motivations such as altruism, fun, reciprocity, intellectual stimulation and a sense of obligation to contribute. Users are instead likely to be motivated by the sense of purpose they develop for the future usage of the outcomes.

This discussion can be further articulated for the role of champions. In this way, we believe that champions can be of two fundamental types (Balestrini et al., 2014): formal and emergent champions. The former can be individuals that become champions in an "organic way", i.e. participants within a given intervention, that demonstrate interest, positive and proactive attitude, and knowledge about a project or a specific technology; under certain conditions, these can naturally evolve into being opinion leaders and the "go to people" for the other participants within and, in some cases, across projects. The second type refers to individuals that have such a role formally established in the governance of the Citizen Science projects. Both types act as gateways and boundary spanners for building an extended community within a given project. We further distinguish among these roles being conducted at the local and international/global levels.

Leveraging existing local networks who are knowledgeable about local issues, has proven to be instrumental to widening the participant base and engage the broader population. Such local networks could either be community advocacy groups, such as environmental NGOs in the Smell Pittsburgh (Hsu et al., 2019), existing communities that galvanise around a shared concern, such as the neighbourhood community of Plaza del Sol in Making Sense project (Coulson et al., 2018), or emergent groups of people that gather around a shared interest, such as the community champions in Making Sense (Coulson et al., 2018). The latter group is also key in upscaling participation through training, as they generally have a level of understanding and skills which they could transfer to future participants (Corburn, 2005; Taylor et al., 2015). Champions are individuals who embrace a cause and become an advocate of it, mobilising others to join (Taylor et al., 2011). Local champions can take leadership of the intervention after the project came to an end and the researchers have left the field, thus helping sustaining contributions and engagement over a long time (Balestrini, 2017).

Unlike local networks, which mainly contribute to scale an initiative from neighbourhood to city-wise scale, leveraging on international networks can catalyse its spreading and scaling globally. Receiving the endorsement of an international entity can increase the prestige of the initiative, as well as amplify its outreach to potential interested stakeholders.

These arguments are strongly supported by existing research which advocates for more formal networks of champions and supporting entities to be built across different layers to balance the need to address specific local aspects with the need of promoting a common global agenda for the discipline. Critiques to the fragmented landscape of Citizen Science projects started to emerge in the previous decade. Newman et al. (2012) argued about the need for the overall Citizen Science discipline for a more embedded and synergetic ecosystem of projects.

In 2012, Citizen Science was seen as a scattered discipline, within which projects existed almost in isolation with little to no interaction with one another. To address these challenges, the authors envision a potential future scenario whereby five critical building blocks would have enabled what they have called a "formalised Citizen Science Enterprise", understood as an integrated infrastructure of projects that collectively advance an embedded agenda that "span multiple spatial, temporal and social scales, and that focus on diverse subjects" (p.302). The building blocks envisioned in this study were: (1) a network of local, regional and global organizations and (2) professional associations; (3) communication and dissemination through open access, peer-reviewed journals; (4) resources for best practices; and (5) expanded cyberinfrastructure support systems. Eight years after this study was published, such a scenario has not yet become the norm. Within their proposed scenario, points (1) and (2) clearly relate to aspects relevant to this driver. To date, we see the emergence of a network of local "offices" (e.g. the Oficina de Ciencia Ciudadana in Barcelona[11], the Citizen Science Centre in Zurich[12]), as well as a more extended scale (e.g. The European Commission, The European Citizen Science

11 https://www.barcelona.cat/barcelonaciencia/es/ciencia-ciudadana

12 https://citizenscience.ch/en/

Association[13], and Citizenscience.gov in the US[14], the Australian Citizen Science Association[15]). With the scope of bringing together these international networks, an attempt is being made through the establishment Global Citizen Science Partnership to function as a worldwide network to promote and advance citizen science. It must be noted however that the extent to which the existing network foster scaling is yet to be proven.

4.2.3 Knowledge Sharing and Transfer Resources

Inspired by the general concept of Facilitating Conditions in UTAUT (Venkatesh et al., 2012; Thompson et al. 1991), this dimension acknowledges the role that resources play in sharing and transferring of knowledge from one context to another. In the context of Citizen Science, our review suggests that three types of Knowledge Sharing and Transfer Resources exist at different levels of detail: (1) Inventories and Catalogues; (2) Best Practices, Education, and Training; and (3) Tools, Guidelines, and Tutorials.

The first level refers to knowledge resources made available as organised textual explanations of projects. These resources typically give access to some level of information which is meant to raise awareness of existing Citizen Science practices and approaches. Examples include the Citizen Science Inventory and Explorer by the European Commission's Joint Research Centre (JRC)[16], and the "Federal Crowdsourcing and Citizen Science Catalog" developed by the U.S. General Service Administration[17]. However, while valuable, these are probably not sufficient on their own to enable full replication. Also, the availability of a plethora of these catalogues results in an information landscape that is often fragmented, rather than integrated and easily accessible.

The second level of knowledge sharing initiatives specifically designed for enabling and facilitating scaling in Citizen Science identified refers to a more elaborated set of content such as best practices frameworks and actions in the space of education and training.

Finally, the most articulated examples of Knowledge Sharing and Transfer Resources refer to what is commonly known as toolkits. During the past decade, projects - including dedicated EU funded initiatives - have been increasingly looking at ways to document methods and learning in an attempt to aid project replicability or scalability by equipping others to perform Citizen Science activities. A plethora of toolkits have emerged such as Citizen Sensing (Making Sense, 2018), the Citizenscience.gov toolkit, or the toolkit developed as part of CitiSense and reported in (Fishbain et al., 2017). These resources typically provide access to tools and methods on how to: involve citizens in Citizen Science processes; collectively plan and design research studies; and even assemble environmental sensors and interpret complex data.

Similar considerations can be drawn with respect to technologies. The assumption is that the likelihood of a given technology to scale and/or spread among Citizen Science interventions increases if Knowledge Sharing and Transfer Resources become available. This substantiates the importance of: inventories and catalogues of technologies used as part of Citizen Science activities; the availability of best practices and other educational and training content to enable participants to undertake technology-related tasks in an informed way; and user guide as a more complete, actionable, and elaborated ensemble of guidelines. A very successful example refers to "Citizen Sensing: A Toolkit" (Making Sense, 2018). The book is described as "a compilation of our collective knowledge, successes and failures, offering you the tools, methods, and inspirations to start your own campaigning" (p.7). This resource represents a one-stop-spot for accessing the required knowledge to scale (through adaptation, replication, or a combination of these) technologies and related relevant practices in the context of participatory sensing.

The concept of toolkit acknowledges that although Citizen Scientists work is heavily influenced by local experiences and cultural traits, there are methods and strategies deriving from best practices that can be transferred across settings, making it easier for practitioners to enact or know how to run certain processes. In this regard, citizen scientists are conceptualised as motivated craftsmen, as opposed to followers of rigid methods. Toolkits are then understood as collections of resources that can be used during a project and when tackling common challenges associated with previous or existing Citizen Science initiatives.

13 https://ecsa.citizen-science.net/

14 https://www.citizenscience.gov/#

15 https://citizenscience.org.au/

16 https://ec-jrc.github.io/citsci-explorer/

17 https://www.citizenscience.gov/about/catalog/#

4.3 Elements of the Target Socio-Technical Context

The last overarching element is represented by characteristics of the socio-technical context where scaling could potentially take place. Among these, the theories considered suggest that projects (and items within them) are more likely to scale to contexts that are aligned in terms of: (1) Matters of Concerns; (2) Social Values; and (3) Legal landscapes.

4.3.1 Alignment of Matter of Concern

This element stresses the importance for the new context to be facing and experiencing similar issues as those tackled in the original intervention (i.e. the one to be scaled and/or spread), and for its individuals to perceive these as actual matters of concerns relevant to them. According to the extant literature, scaling the problem tackled is a key enabler for a new community to appropriate some or all elements of a project.

It is important to notice that for some citizen science projects, the discussion on spreading is simply not applicable. Some citizen science projects tackle problems and/or opportunities that are very context specific. As a basic example, a project that leverages Citizen Science to provide detailed and accurate information about the expected activity level of ticks in a pre-defined area (Tick Radar[18]), is simply not replicable by nature in those areas where ticks do not exist. This example shows an important overarching principle of replicability: a given Citizen Science initiative can be (fully) replicated in another location if (and only if) the problem is relevant in such a geographical area. It is noted that this statement is valid only for fully replicating a project. Similarly, it is reasonable to expect that technologies that have been proven successful in addressing a pressing issue in one context are more likely to scale to those areas experiencing a similar problem.

In these regards, we argue that Citizen Science projects that are designed to scale, should undertake extensive reflections during the problem formulation stage. This is to achieve a situation where the specific problem tackled in the pilot is defined as an instance of a class of problems that is relevant beyond the geographic location where the pilot is implemented (and in those areas targeted for scaling). One way to do this could be to anchor the specific issue under investigation to a reference framework of issues / opportunities affecting the area of target (e.g. the UN Sustainable Development Goals), which in turn will also contribute to the development of Narratives (see Section 4.2.1). Also, we highlight the dependency of this construct from Proof of Value (4.1.1). It is noted that the relationships among constructs will be elaborated when presenting the scaling scenarios below.

4.3.2 Legal Alignment

This element acknowledges the role played by the regulatory and legislative environment and the need for these to be aligned between the initial context and the one within which scaling will take place. An example comes from the ongoing WeCount H2020 project[19], in which the authors of this report are actively involved. The project promotes the usage of a camera-based sensor technology to enable citizen-driven traffic counting. The project is implemented in five pilots conducted across different European countries. Currently, the partners are facing a legal challenge for the different CCTV-related legislations in place among the contexts in which the pilots are being developed. This brief example shows how a lack of legal alignment might prevent scalability of an intervention.

With respect to Citizen Generated Data in Citizen Science, it is challenging to define one approach that complies with all data protection regulations worldwide. For example, the EU General Data Protection Regulation (GDPR), effective from 25 May 2018, requires protection of personal data and addresses the transfer of data outside of the EU. This has been argued to have implications for scaling global initiatives to the European context (Fritz et al., 2019).

Also, technologies, their features, and their potential uses must comply with the target context's regulatory environment and specifically to its data privacy regulations. Legal requirements to preserve individual privacy vary worldwide which could potentially limit the scaling of technologies that record personal data. Participants in citizen science frequently reveal personal details, often unwittingly. Sharing digital data leaves a digital footprint that embeds details of their everyday lives. In this way there is an inherent conflict between data sharing – which is often a requirement for generating valuable outcomes from Citizen Science projects – and

18 https://www.wur.nl/en/show/Tekenradar.nl-Tick-radar.htm

19 https://we-count.net/

privacy (Kim et al., 2013). Location data is often a fundamental part of the data being collected by Citizen Science projects and applications, which can also raise privacy concerns when, for instance, coupled with the date and time of the specific input (Kim et al., 2013). One approach to embed privacy protection from the start of the project is known as the privacy by design principle. A key component of this is about restricting the amount of personal information that is collected and shared. Due to this data minimization, only adequate, relevant and limited information is collected (Bowser et. al., 2017). By implementing this in the design of the technology, legal risks concerning spreading and scaling to different law contexts can be mitigated. Besides this, some projects provide the opportunity for citizens to decide on the data sharing rules. For example, participating citizens can hide certain data or location information from public view or have certain data information publicly published in an anonymous way. Today there are technologies that can facilitate this, such as fuzzing certain locations (e.g. close to a participants' home, work or school), or to anonymize identities (Bowser et. al, 2017; Kim et.al., 2013).

4.3.3 Alignment of Social Values

In a similar vein, the theories considered stress the importance for alignment of social values across contexts for scaling to happen. Typical misalignment of social aspects might include cultural and language barriers.

To clearly show the relevance of this driver, an extreme example is given by the usage of Citizen Generated Data for the development of the so-called Social Credit System in China[20]. As part of this national program, the central government is currently collecting data generated by citizens (more or less consciously depending on the source) to develop individual "credit scores" to be coupled with people's ID. Such credit score is derived from a multitude of data about individuals' behaviours in society, including for instance social media behaviour, measures of financial credibility. Clearly, such initiative is not replicable, for example in Europe, as this would be inconsistent with the shared social values being promoted of, for example, equality and inclusion.

Some reflections can also be made about scaling technologies from one Citizen Science intervention to another. First, the technology needs to be compatible with the participants' habits and lifestyle. As a simple example, it would be difficult to scale a mobile app for collecting a certain type of data in a place where smartphone diffusion and penetration is very low. Second, the technology needs to be compatible with the more general ethical values of the target context. In a hypothetical situation where a pilot avails of monitoring citizens' social media activities and behaviours to accomplish a research objective, clearly, we can expect that such systems would not be accepted across all social contexts. Also, in less democratic societies, it might be less common to engage citizens in science and policy making processes. Thus, those technologies for engagement in the so-called Extreme Citizen Science (English et al., 2018) will hardly spread to those contexts. As another example, the sharing of personal information can be experienced positively or negatively depending not only on the subjective preferences of citizens, but also on social norms and values in different cultural contexts.

4.4 Reflecting on the Role of Technologies

As a further step conducted in this analysis, an additional effort was undertaken to reflect on how the framework could be contextualised to explore the role of technologies in these processes. When doing so, we identified two similar but conceptually distinct areas of interest:

1. Conditions upon which the usage of existing technologies scales across pilots and interventions (e.g. technology used in pilot A is reused in, and/or adapted to, pilot B). In this case, the unit of analysis becomes the technology to be scaled and the main question to be addressed is: What are the factors that influence adoption of technologies used in a given project by another project either at an extended geographical scale (i.e. in the case of up-scaling) or in another context (i.e. in the case of spreading)? Accordingly, we named this phenomenon scaling *of* technologies.

2. Conditions through which an existing or new technology contributes to the scaling of Citizen Science practices and outcomes. In this case, the cornerstone becomes to understand how existing or new technology can improve, augment, or enable those elements that were found to positively influence scaling in Citizen Science. The main question to be addressed is: How can technologies contribute to

20 国务院关于印发社会信用体系建设规划纲要（2014—2020年）的通知. Central Government of China (in Chinese).

the scaling of Citizen Science practices and outcomes? Consistently, we name this second phenomenon of interest as scaling *by* technology.

The following example should be useful to explain the two different focuses of this phase of the analysis. Taking for example the Ease of Use and Understand construct, assuming a scaling *of* technology view means reflecting on what makes a technology easy to use and how this can foster its adoption across projects. In a scaling *by* technology scenario, this is tackled by reflecting on what existing or new technology can make a specific practice easy to undertake and understand, which in turn is expected to augment its scalability potential.

The table proposed in Annex 2 summarises for each construct: what key assumptions have been formulated from contextualising the framework to digital technologies (i.e. addressing scaling *of* technology) and what guiding questions were established to investigate the potential role of technology in facilitating spreading and scaling of Citizen Science practices and outcomes (i.e. addressing scaling *by* technology). In other words, in the first scenario, technologies are the subjects of scaling and therefore the framework can be leveraged as a deductive-based investigation of their role. The second scenario, instead, is by definition inductive as the role of technologies with respect to increasing scalability potential of Citizen Science interventions is explored rather than tested.

4.5 Summary

While it can often be inferred whether the scope of a given intervention has grown geographically and/or has been replicated elsewhere, the "how and why" remain unknown. To address this lack of information and the scarcity of existing literature reflecting on scaling in Citizen Science, our approach has been the following: we first reviewed some of the most cited theories in the broader cross-disciplinary contexts of adoption and diffusion of innovations, and the socio-technical perspective from Infrastructuring in Participatory Design. Through combining the insights from these theories, we developed a theoretical lens to analyse and unpack scaling. The elements within it have been extensively explained and preliminarily positioned within the discipline of Citizen Science.

It is worth reminding that we do not argue about the mutual exclusivity of each element derived in this embedded theoretical lens. Also, these elements are not standalone. Rather, we argue that some of these appear to be interrelated. For example, the importance of scaling Communities is clearly linked with the need of an aligned Matter of Concern and must be supported by appropriate Communication and Dissemination actions. The subsequent sections on the multiple case study findings highlights how different elements can be more or less relevant depending on the context, the timing, and the specific scaling processes.

Empirical Findings: Four Scaling Scenarios

The following chapters are entirely dedicated to the rich findings of the multiple case study. To effectively report the experiences with respect to scaling across the four cases, the same structure is adopted. Each case is tackled in a dedicated section below. Each of these starts with a general overview of the case and the elements that enabled scaling in that specific context. Then each case study report describes each of these elements in detail using the same terminology established in the previously introduced framework. Finally, for each case, a discussion on the target contexts and reflections looking forward are provided before conclusions are drawn. It is noted that extracts from the interviews are proposed in italic under quotation marks throughout the case study reports.

5 Making Sense Barcelona and the Smart Citizen Kit: Scaling Communities through Narratives

Making Sense[21] was a H2020-funded international project under the Collective Awareness Platforms for Sustainability and Social Innovation program, undertaken across three European cities between 2015 and 2018. Described as a participatory sensing (Making Sense, 2018; p. 11) initiative, Making Sense leveraged an open source, bottom-up, sensing platform to empower citizens to measure and address pressing environmental issues concerning air, water, soil, and noise pollution in Barcelona, Amsterdam, and Prishtina. Within Making Sense, this analysis focuses on the Barcelona pilot, where, leveraging the Smart Citizen Kit (SCK), communities of citizens were empowered to take actions and achieve impact with respect to noise pollution issues in the city. The focus of this analysis is therefore on elements that enabled scaling of the SCK within the specific intervention of Making Sense in Barcelona. The case study is referred to in this document as MS/SCK.

The SCK was initially designed in 2012 by FabLab Barcelona at the Institute for Advanced Architecture of Catalonia (IAAC)[22] to address the challenge of transforming existing smart city technologies being mainly "*top-down, expensive, and not involving citizens at all*". Early experimentation and design were supported by crowdfunding campaigns. However, initial applications of the SCK were far from successful. The reasons can be also traced to the fact that "*in 2013 IoT was in its infancy and you had to develop every single component from scratch*" coupled with low levels of resources beyond the crowdfunding outcomes. From there, a variety of projects (e.g. Organicity[23], Making Sense, iScape[24]) contributed to the improvement of the SCK technology and the release of different versions that ultimately led to the one available today. Each project resulted also in an improved set of resources to aid the usability and the inclusiveness of the technology (e.g. "*Organicity allowed us to do the front end and back end platform; in Making Sense we were able to improve usability through the onboarding and technical IoT stuff*").

Among these projects Making Sense was chosen as the unit of analysis to learn about scaling as it "*set a landmark*". At the beginning of the project, "*the SCK was not very versatile. Air quality monitoring was very basic. However, after Making Sense the sensor was way more robust with more features and less failures*". Today, also favoured by low-cost technological innovation in the context of sensing ("*mainly pushed from the Chinese engineering*") the SCK represents a more solid and reliable approach to environmental sensing. This enabled a commercial strategy "*incorporating the learning and progress achieved across Making Sense, iScape, and other projects*".

The MS/SCK case study has been selected as substantial evidence of scaling could be identified. However, while we could confidently assert that several of its elements spread and scaled over time, no evidence was found about scaling or spreading in terms of replication of the entire intervention. Still, the MS/SCK is a rich case to inform our findings as it represents a good example of scaling of both the community of participants within the project and the technology, i.e. the SCK.

The MS/SCK case study was found to be unique (compared to the other three cases) in one fundamental element: in this case, scaling started before actual Proof of Value or Ease to Use were achieved. The scenario emerging from this case study demonstrates that, while most elements of the previously derived framework influence scaling in some ways, the development, evolution, and distribution of Narratives appear to assume a dominant enabling role, especially during the first phases of scaling processes. Therefore, the MS/SCK experience becomes useful to shed light on the importance of Narratives and Communities and on how these can play a great influential role in enabling scaling in Citizen Science, especially during early phases of the scaling phenomenon.

Scaling in MS/SCK appears therefore to be the result of an overall approach focusing on "*matter of concerns and success stories to inspire people*". Unavoidably, impact from the usage of the SCK (i.e. Proof of Value) occurred later in the process, once improved the reliability and validity of the data collected by the sensor itself. Similarly, Ease of Use was also developed over time leveraging Onboarding and Toolkit resources (i.e. Knowledge Sharing and Transfer Resources) co-developed with the communities being established through the

21 http://making-sense.eu/

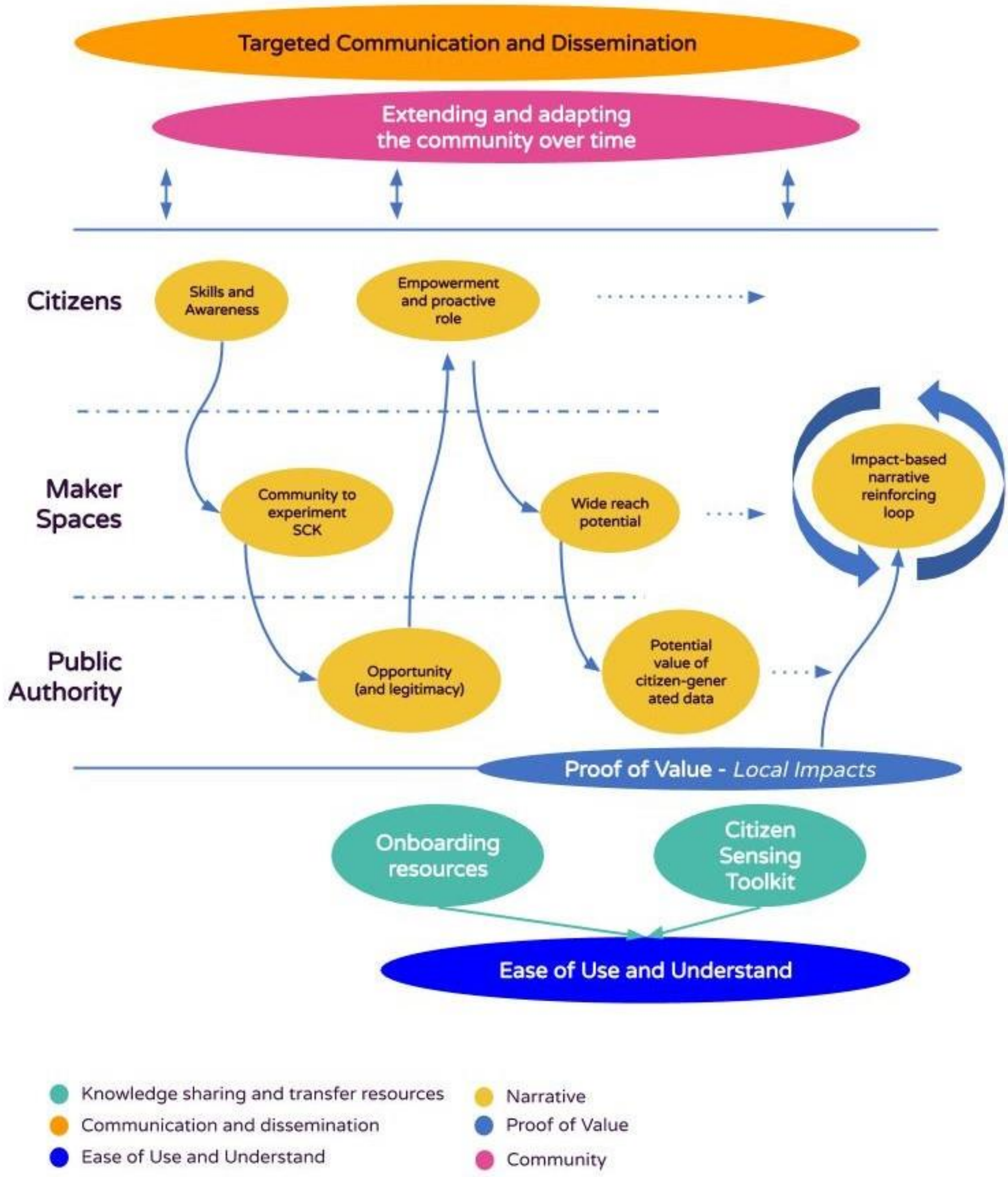
22 https://iaac.net/

23 https://organicity.eu/

24 https://www.iscapeproject.eu/

dissemination and evolution of the narratives. An overview of the MS/SCK scaling scenario is proposed in Figure 3 (next page). This is extensively described throughout the following subsections.

Figure 3. MS/SCK: Scaling Communities through Narratives



Thus, MS/SCK constitutes a valuable case to understand scaling triggered before actual Proof of Value and Ease of Use have been achieved. In this scenario, we first tackle the key role of Narratives and Communities. The means through which these narratives are communicated and disseminated are then reflected upon. This is followed by reflections on the role of Proof of Value as well as of Ease of Use enabled by Knowledge Sharing and Transfer Resources respectively. We then discuss the role of Openness before providing reflections about Target Contexts and some insights looking forward to what may be coming next.

5.1 Scaling Communities through Narratives

In MS/SCK, the development of a project narrative appears to be strongly interrelated with the concept of communities. Given the level of development of the SCK at that time, the beginning of the Making Sense project in Barcelona saw a strong focus on two iterative processes: mapping communities and developing an appropriate narrative for these communities. Once developed, the narrative becomes the key enabler for establishing connections with the communities, thus starting a "*ripple effect*". Interestingly, this entailed a phased approach whereby narratives developed for one type of community have strengthened further narratives targeting other community types.

All in all, Making Sense has been designed as a "*very horizontal project*", in which different types of communities become empowered and involved. In terms of sequence, the project first targeted communities of citizens as this "*is where the project comes from*". Communities started to galvanise around an issue-based narrative, i.e. about the need to react to the well-established air quality and noise pollution problems: "*the message was: if we keep doing like we have done so far, the issue will not be resolved. We have the chance to do something different. And the message was we can solve it, and during the process you are going to learn about IoT, digital technologies, meet new people etc*." Given the limits of the technology at that time, the narrative was stressing a call for action while not holding overpromises of impact. Rather, it was initially leveraging the opportunity for citizens to become involved with changing the "*dominant top-down Smart City concept*" by developing new skills and co-creating new IoT technologies. In turn, this narrative fed into engaging a second community, that of "*the makers spaces, the Civic Hacking and Open Source communities interested in Open Source empowerment and technical infrastructuring*", by proposing (through another narrative) a community of potential participants for the set of applications being developed by those groups.

However, while the narrative had allowed an increasing establishment of an extended community, this was not enough. "We had a concern. In the Open Source and civic tech community we were not being effective; we had to make what we were doing more actionable and pave the way for impact". In response to this challenge and pushed by realising impact (i.e. Proof of Value), the target for engagement became the public authority, as to conceptually close the loop between the problem and new policies (i.e. impact in this case). Thus, the communities of citizens and makers (and their related narratives) were leveraged to create a further narrative targeting the public sector. The message for the public sector is described by one of the interviewees as follows: "we are a genuine movement of participation through technology, and you have been talking about smart cities for so long, but this is how it should look like: inclusive and empowering people". At this point in time, the successful involvement of both the maker spaces and the public sector informed a new and enriched version of the narrative for citizens, which was now adding the potential proactive and empowered role to solve the issue at hand. This in turn created further narratives to motivate maker spaces and to foster the acknowledgment of the potential from the public sector.

In summary, the initial project and technology narratives were unbundled into multiple narratives for multiple audiences (i.e. citizens, maker spaces, and public authorities) whose engagement was considered crucial to achieve impact. In terms of sequence, "*the narrative for the citizens informed and helped developing the narrative for the maker spaces which, in turn, helped developing the narrative for the public authorities*", thus enabling a new cycle. Each of these cycles carried important outcomes, which can be seen as the gradual development of the building blocks for scaling.

First, at each cycle the community was extended as a result with new participants being attracted by the new narrative. Second, as these communities grew, community champions emerged, have been established and "*divided into groups based on their skills and interests*". These champions not only helped develop "*social ties that over time reinforce the community itself*", but also contributed to the development of the next narrative through conversations among themselves and with the project's partners and "*helped creating their communication channels with their own narrative to their audiences*". Third, after several cycles, narratives got more and more contextual and specific (e.g. from developing digital skills to enable new policies to solve a particular problem) and the project evolved to a point when actual impact occurred. This, obviously, creates a further narrative calling to expand and scale that impact. Clearly, in terms of enabling scaling, the narrative supported by Proof of Value (i.e. ingraining demonstration of impact) has been more effective as it was based on actual evidence: "*we showed it is relevant for affected communities. It is a very tangible case*". In other words, those narratives generated and informed by impact were more influential towards scaling and started new reinforcing loops where each new cycle had a greater contribution to scaling. As an example, with respect to the narrative towards local authority, one interviewee stated: "*today* [i.e. 2020] *data is becoming more* *meaningful and impactful also because local authorities are starting to learn how to deal with this data. Now when citizens approach them with this sensed data, they realise that they should complement the data they have with this new source. Now I see there is a conversation*".

In order to establish such generative role of Narratives to enable scaling even before Proof of Value is in place, two important considerations must be made:

1. Narratives must evolve supported by progress: "you can't survive with just a narrative. You need to deliver outcomes that demonstrate that you act on that narrative, that you fill that narrative. If you don't achieve those elements, over time you are killing off people. You need to produce outcomes to keep that narrative alive". In MS/SCK, "it has been mutating, changing. From a grassroots movement the project has become more professional. At the beginning it was about empowerment, but now it is about impact". It is noted, however, that after the end of Making Sense funded period – or of any funded Citizen Science project leveraging the SCK - it becomes challenging to sustain the community: "first we are not sure what happens, second people move on to other things because the momentum is not there anymore", i.e. the narrative is not kept alive.

2. Narratives must evolve consistently with the rapid changes in the underlying technological and knowledge ecosystem. In the context of MS/SCK, in 2013 the narrative was "*people using open source technology and developing the skills to do it. At the time, whether the technology was good or not was not very important. Now in 2020, there is not that story anymore. Open source technologies have evolved and are now all around us. The story now became that people using those technologies can solve problems that haven't been solved in 20 years*". One interviewee also argues that the narratives are much stronger today (not only because of the reinforcing loops over time) as the potential of new technologies "*like IoT and AI is much higher*".

5.2 Narratives Triggering Communication and Dissemination

The findings show that, even before actual impact is achieved, Narratives play a great role in fostering positive communication about the project. The story about "*using IoT devices to empower people to address a well-established matter of concern*" was successful in the media from the beginning and helped substantially in raising awareness among people. From there, "*snowballing effect followed, and the project was all over the Spanish media*". In terms of communication and dissemination effort from the project partners, the cornerstone was to "*show how it can be done and that everyone can do it*".

The different target audiences dictated a diverse approach in terms of channels for disseminating the narratives at various stages. Conferences (e.g. Smart City Expo) and "*confrontational dialogues*" were the main means to reach the public authorities. For citizens, a more varied and creative set of tools was employed. For example, a Tumblr page[25] updated on a weekly basis, a WhatsApp channel with the community "*for support and to keep momentum*". Finally, Making Sense in Barcelona created a movie which was broadcasted in a local cinema: "*people went to see themselves on the screen!*". In terms of who runs communication efforts, while acknowledging its importance, maker spaces often lack the resources for effective communication campaigns and rather concentrate their efforts on the development side.

5.3 Local Impact as Proof of Value

As described above, the peculiarity of the MS/SCK case is that scaling started to happen even before a well-established Proof of Value of the technology and the approach was achieved. Notwithstanding this, there is an acknowledgment that for scaling to be sustained, impact must occur at some stage. In this case, Proof of Value, once achieved, was found to: affect scaling by leveraging the media and other dissemination channels reporting such outcomes; and to reinforce the power of narrative towards scaling by enabling those reinforcing loops elaborated above. In the case of Making Sense Barcelona, although the "*impact was very local*", the results of the intervention were tangible: "*actions deployed to negotiate the tensions that have been developing in that area affected by noise pollution*".

25 https://makingsenseeu.tumblr.com/

5.4 Knowledge Sharing and Transfer Resources and Ease of Use: The Onboarding Kit and the Making Sense Toolkit

Early in the process, "*we realised the importance of thinking how to onboard the users. How could we make it easier for users to participate?*" At that point the first narrative cycles had been carried out, and initial experimentation activities had been conducted. Then, scaling was further fostered through improving Ease of Use through the development (and continuous improvement) of various Knowledge Sharing and Transfer Resources. Among these, two were identified as critical: the SCK Onboarding Kit and the Making Sense Toolkit. The Onboarding Kit represents the set of resources required to successfully install and run the SCK sensor. One priority was about making it accessible to everyone. "*It allowed moving beyond the community of open source and makers which, in general, remain rather technical. To make it for everyone, we used a user-centred design approach, and this all contributed to the ease of use*". In MS/SCK this was complemented by the development of a "*peer-to-peer learning system, a process of mapping community participants to community champions for meaningful local support*". The Making Sense Toolkit, instead, is a book (Making Sense, 2018) where the methods and tools for replicating Making Sense in other contexts are introduced and clearly explained. "*It really fascinated people. The toolkit does not only carry the tools but also the narrative*".

5.5 Openness in MS/SCK

Openness emerged as a relevant aspect supporting all activities, technologies, and engagement approaches undertaken with respect to the SCK and within Making Sense. All supporting resources are open access. The community was left open for everyone to participate. Last, but not least, the technology is fully Open Source, hardware and software. These choices have important implications towards enabling and fostering scaling. First, "*it is not a black box, meaning it can be easily replicated and maintained even if we are not there*". Second, "*open source ensures bringing a community of highly skilled people. It is a sort of ethical issue of developers*". Third, "*adoption is higher in our targets. Research institutions favour the SCK software because it is open source and it is free*"; users also are argued to care more and more about the ethics of the technology they use. Fourth, "*the developers also tend to be more engaged because the work they do will remain for the community, as opposed to me running away with it at the end of a pilot*".

5.6 Target Context

One of the learning from this case study is that narratives alone might not be sufficient to enable scaling. Rather, as argued above, these need to evolve over time in response to progress and to changes in the context. As these evolve, they get more and more specific and contextual (e.g. empowering citizens to address noise pollution issues in a specific square in Barcelona). These reflections support the fact that narratives are sensitive to different socio-cultural places and, instead of being prescriptive, must be adapted to the local Matter of Concern. "*Narratives are culturally embedded. You need to be very careful to scale a narrative. For example, the narrative in Kosovo* [where another pilot of Making Sense took place] *was much more belligerent, because the government was not supporting it. It was a lot more aggressive*". The (required) communication from local media is triggered if "*the matter of concern is newsworthy*". In Making Sense, the first narrative was developed at the consortium level and it was gradually adapted to the context of the different pilots.

Social values and local culture are also important. In this sense, in addition to those places where a problem and therefore room to promote and develop a narrative exist, scaling becomes more effective in places where there is a citizen engagement culture and thus it is more likely for community champions to exist and/or emerge.

Finally, an interesting reflection emerged in relation to the potential legal-related barrier to scaling: "10 years ago I would have said yes. But now, IoT devices are getting so widespread and today it is more of an ethical issue than a legal one. For example, I understand that our sensors could potentially collect noise from neighbours that have not agreed for their generated data to be collected. But at the same time, this happens everywhere with tons of other devices". This suggests that, while important, this is currently not inhibiting scaling of the SCK and the Making Sense outcomes more generally.

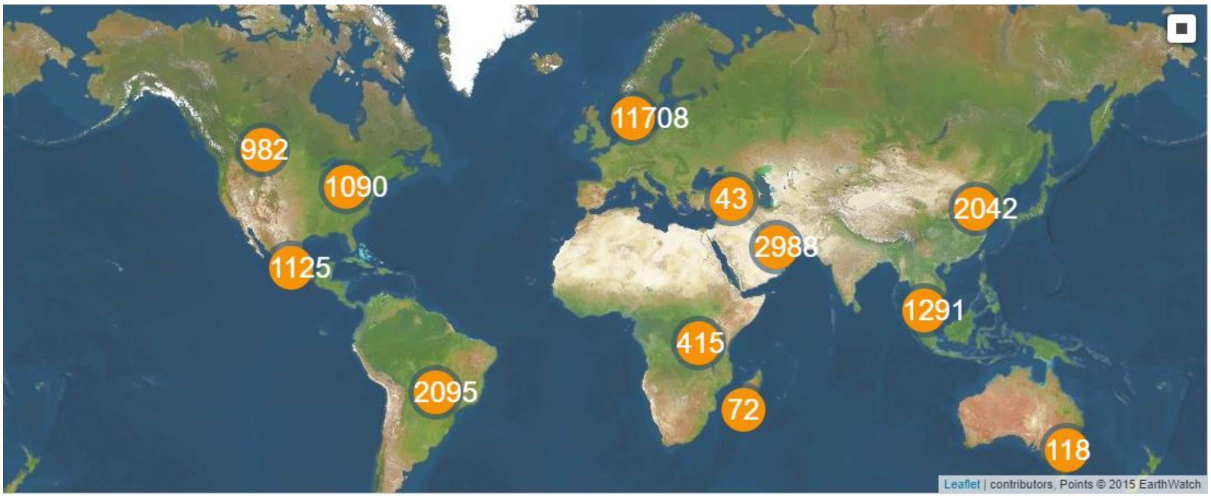
5.7 Conclusions and Looking Forward

MS/SCK represents a very valuable case study to understand early phases in the scaling process and specifically the important roles that Narratives and Communication and Dissemination can play to enable scaling through Communities even before Proof of Value and Ease of Use are achieved. As a final reflection, this scaling scenario underlines an approach defined in the interviews as "*design for appropriation*". This was described as an effort-intensive process of narrative development and community building where citizens are proactive in the co-design of the technology and the intervention. Clearly, this is not scalable, as it takes significant time and resources to culturally and socially embed the technology and the narrative. To address this challenge looking forward, and thus to further sustain scaling of the SCK, the team is currently targeting an approach whereby community actors would be responsible to run distributed locally relevant Citizen Science interventions using the SCK and the tools available. This strategy entails targeting more research institutions or NGOs that could act as champions and lead projects in their contexts in an autonomous fashion. In this transition, to address the challenge of providing substantial remote support to each group with very little resources ("*this is not scalable*"), the team is "*thinking to turn the onboarding kit into a MOOC. We believe the MOOC can help in getting self-sustainable*".

6 FreshWaterWatch: Infrastructuring through the Train the Trainer Approach

Started in 2012 as a corporate employee engagement program with the oversight of EarthWatch[26] (a well-established actor in the citizen science discipline), today FreshWater Watch[27] (FWW) represents an ongoing effort to achieve the overarching mission of investigating and preserving freshwater ecosystems worldwide. "*The corporate funding at the start was crucial*" to develop reliable, low cost, and scientifically robust methodology and tools to empower anyone to measure water quality level and to upload this data onto the centralised database. With more than 24,000 datasets generated to-date by more than 10,000 citizen scientists (April 2020), FWW today acts as a centralised data platform and set of resources and tools[28] enabling a distributed set of projects across the world. These are empowered to adapt water quality monitoring to tackle a wide variety of topics which include but are not limited to: testing and monitoring local water sources, promoting awareness, and addressing nutrient pollution from agriculture, industry and waste facilities.

Figure 4. Overview of FWW Projects[29]



FWW is "scalable on a geographic sense, as the measurements are designed to be useful for every type of freshwater ecosystem. It could be in Delhi or Jakarta [where water quality is generally low], or in the Rocky Mountains or the Alps where the water is cleaner". The methodology is then common across contexts and flexible enough to be adapted to the different local issues and priorities: "it is scalable because it can be, and it has been, used everywhere".

FWW is therefore scalable by design from both a technical and implementation point of view. Regarding the former, the "*same measurements, same methodologies and same training*" are used regardless of the context or the specific issue. Concerning the implementation perspective, as mentioned above, the project started as an engagement program from HSBC bank that has offices all around the world. The corporate's employees acted also as a "*pre-set up network of volunteers, and so a captive audience right from the start. This meant that in the initial couple of years we were able to get momentum*". Thus, FWW went global from the beginning.

In addition to local projects, FWW also integrates data contributions from the so called "*Blitzes*" whereby a mass engagement process is put in place to collect water quality data in a given geographical area for a short period of time. The value of this data complements the value provided by the more traditional longer-term established FWW local projects. Whereas the latter contribute with more longitudinal data over time, Blitzes add thick and massive data contributions. Combined, these result in both spatial and temporal dimensions of the water quality knowledge generated.

26 https://earthwatch.org/

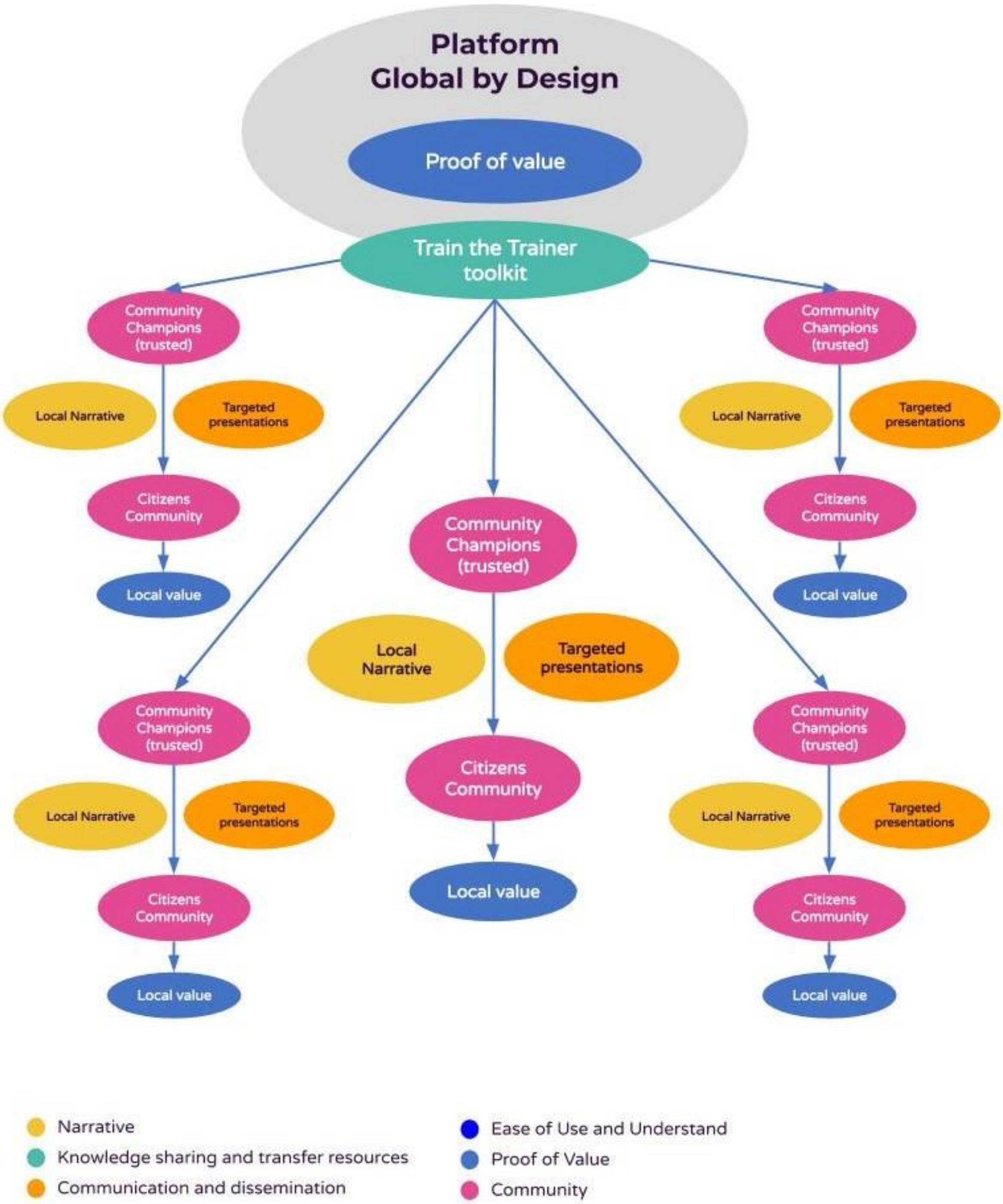
27 https://freshwaterwatch.thewaterhub.org/

28 Specifically, the FWW water quality measuring tool costs around 25 UK pounds and allows for 5 months of sampling. It includes the following off-the-shelf components: a pack of 5 nitrate water quality testing tubes; a pack of 5 phosphate water quality testing tubes; Colour charts for nitrate and phosphate test; Sample cup for use with testing tubes; Secchi tube.

29 Source: https://freshwaterwatch.thewaterhub.org/content/data-map

In summary, scaling of FWW is the result of the combination of a project that is global by design and of the infrastructuring approach undertaken whereby local projects are established underpinned by a common methodology and kits provided by FWW. The two core enablers behind FWW's scaling are identified as: the solid, robust, scalable, low cost, and valuable approach to water quality data measuring (i.e. Proof of Value) and the so-called "*Train the Trainer toolkit*" (i.e. a set of Knowledge Sharing and Transfer Resources). An overview of the FWW scaling scenario is proposed in Figure 5. Its key elements are extensively described throughout the following subsections.

Figure 5. FWW: Infrastructuring through the Train the Trainer approach



Consistently, this case study report is structured as follows: first, the role of Proof of Value is discussed; second, we reflect on how the Train the Trainer approach contribute to scaling by providing Easy to Use and Understand methodology and toolkit to local projects; third, we focus on the local communities before discussing the role of Openness and of Communication and Dissemination. Finally, as in the other case study reports, we discuss general characteristics of the Target Context before some reflections looking forward are proposed.

6.1 Proof of Value: A Scientifically Robust Toolkit

"FWW has hit a really sweet spot: it is scientifically robust, it has got good data quality, it is meaningful, and it is useful. It allows people to collect data that they could not collect otherwise"

Beyond its global focus by design, the main pillar upon which scaling within FWW is triggered resides in the value of its approach and tools to water quality measuring. The first phase was successful, but interestingly, its uniqueness was not in what it was designed for (i.e. a corporate engagement education), but rather "*the ability to go and record data about water quality in a way that can be applied everywhere with low cost equipment understandable by people who are not experts*".

The core focus of FWW is to keep the quality of the data to a level that is scientifically valuable. A "*quality control*" process is in place in order for the data to be "*globally valid*". One challenge is that, given the limited resources available, it is hard to "*check the quality of all the data*". The system itself has some internal logic (i.e. non-AI or Machine Learning based) quality control check algorithms. "*There are two algorithms: one checks the internal consistency of the dataset*"; the second enacts a feedback by comparing the entry with other data "*from a 25 km radio: if you upload a data, your measurement would be put within quartiles with respect to other measurements taken in the same area*". If the data, as a result, is seen as an outlier, the system sends an alert to the citizen scientist to double check her or his entry.

Overall, the key element that is in place to ultimately foster data quality is the "*Train the Trainer*" approach and toolkit. Such toolkit is central in the scaling process of FWW also because it is scalable in itself and contributes to enhance Ease of Use and Understanding of the overall FWW methodology. This makes it possible for anyone to participate, regardless of their level of expertise.

6.2 Ease of Use and Understanding: The Train the Trainer Approach

"Other water-related citizen science projects involve complex scientific analyses or collecting samples and bring these to labs. One aspect that makes FWW successful is the Train the Trainer toolkit and the simplicity of it"

Train the Trainer is referred to in the interviews as both an approach and a toolkit. In terms of approach, it means that "*we train other people* [i.e. community champions] *to train volunteers all around the world creating a sort of franchising*". The training is targeted for researchers, for the "*data utiliser*", as research institutions are typically responsible for the local projects (see Section 6.3 on local communities below). While the approach is the same for all communities, and is therefore highly scalable, the method of delivering the Train the Trainer might be different depending on the context. Sometimes, "*preferably*", it is done face-to-face, and sometimes it can be delivered through a training online. The latter forms are particularly suitable for "*Blitzes*" (see above) which are delivered to a larger audience of citizen scientists. Regardless of its delivery mode, undertaking the Train the Trainer process is mandatory for all those that want to set up a project or contribute during a *Blitz*. At the end of the training, people need to pass a quiz to be able join: "*it is not difficult, but at least it makes sure that you know what you are doing*". In other words, in addition to being a toolkit to aid understandability of the methodology, it acts as an additional (preventive) means to ensure that communities will implement the methodology correctly, thus ensuring the quality level of the data generated in FWW remains high.

The Train the Trainer Toolkit instead refers to the training materials and resources, as well the tools to measure water quality and to upload the data onto the platform. Training resources cover learning modules (about freshwater ecosystem at different levels), the actual FWW specific training program ("*also including case studies to enhance people's understanding of how the methodology is applied*"), material to support data collection (e.g. support videos linked to the FWW app), and even ready to use presentation's slides to be used locally to train volunteers.

Overall, in the case of FWW it can be argued that scaling through infrastructuring is the result of the combination of Proof of Value and Ease of Use and Understanding (drawn upon the Train the Trainer approach and toolkit). The following extract from one interview summarises this concept very well:

"I don't think either of those things alone would do it, it is much a case of: you approach a researcher who sees the value of the data; but why would people like to get involved in this? And then you show them the method. And they get it. It is simple and they can explain it to everybody. Then you talk to the volunteers that ask, 'why am I doing it?', and you hook them up with the researchers that are able to show the [scientific] relevance of what they do".

6.3 Local Communities for Local Impact

One element that makes it possible to maintain the quality of the data and the outcomes (thus contributing to sustain scaling) is, as mentioned above, a "*strict quality control*" process. This process is also enacted when involving local projects and communities. In other words, to be part of FWW, local communities need to go through the same training program, which, as described above, ends with a quiz to make sure "*you know what you are doing*". "*There are people coming to us expecting to be able to buy a product*, [and say] *'can't you just sell me the kit and I monitor my fish tank?'*". "*We are looking for a very specific set of circumstances*", that are: credible people that can ensure commitment and a base of volunteers, and people that have a good idea on what to investigate. If it is not suitable "*we would say no*". Therefore, in order to maintain its status as a reliable, robust, and viable initiative to tackle freshwater ecosystems, FWW needs to be based on these standard steps and quality control processes that are somewhat fixed. Therefore, FWW is different from other more Extreme Citizen Science projects whereby communities of citizens are more heavily involved in the co-design of the experiments too.

One further important consideration must be underlined to properly understand the FWW approach to communities. In the context of local projects, data collection about water quality, for example in a river, needs to happen over a period of time. In this domain, one data entry at one point in time carries less value. The consequence is that typically (this is not the case for a Blitz), communities need to be involved over a relatively longer period, if compared to other Citizen Science projects. A subscription fee paid by the local project and the Train the Trainer process contribute to increase the average level of commitment.

In terms of local projects, the preferred approach is to work with research institutions (or at a higher level with corporates that, as part of their CSR agenda join FWW, and then typically rely on local institutions) that then act as community champions and start local Citizen Science projects. Clearly, it is convenient for them to join FWW as they can leverage a robust measurement tool, an already available training program and resources, thus reducing the effort of starting a local intervention. Also, research institutions are seen, on average, as more reliable in taking longer commitment. These entities (or the local communities in those cases not mediated by institutions) play the role of linking water quality monitoring to a matter of concern experienced locally, e.g. poor water quality due to a specific industry. From there, community champions recruit citizen scientists that run the experiments to address the local problem, independently from what other FWW local communities around the world are doing. "*All projects have a local goal, e.g. reducing farming practices like in Mauritius*". In this sense, the various local communities within FWW can be seen more as a "*mushrooming of groups*" rather than one unified community. As a result, impact is usually at the local level. Outcomes are typically scientific knowledge (fostered by research institutions) and, in some cases, local impact on various water-related stakeholders. An example of the latter from the UK sees the contribution of FWW to understand that, despite local water authorities' efforts concentrate mainly on large rivers and lakes, small streams are those that host most biodiversity and thus deserve attention too. Building on these evidences, "*local authorities added these smaller streams to their priority list*".

Overall, impact from the projects is managed locally: "in order for local people to feel ownership we are totally reliant on the local connection to be able to follow up with that data. If, e.g. someone measured a sewage pollution event, we don't have the capacity to do anything with that data". In case this "follow-up" does not happen, this can have a negative impact on scaling as it would become "very easy then for volunteers to get demotivated". Once again, this underlines the importance for FWW "to be very careful of working with the right people locally".

6.4 Communication and Dissemination Delegated Locally

Due to the resources available through the initial corporate engagement program, at the very start of FWW there was a strong effort placed on communication, including employing a dedicated person. The current limited resources do not allow such an approach. Currently, FWW relies mainly on the local communities (mainly the institutions) to conduct communication activities towards different audiences, including communication to recruit local citizen scientists. The Train the Trainer kit supports the locals in this direction as it also provides guidance on "*how to write a press release*".

As a more formal communication plan, the FWW team releases quarterly project updates and it is sometimes supported by EarthWatch in this way, e.g. "*we are occasionally able to collaborate with them for press releases*". Other communications targeting future new local projects are currently limited. Local institutions, "*or local agencies or NGOs*", usually get to know FWW from an interest they have rather than from communication campaigns: "*if you don't come to us, we are very unlikely coming to you*". This further strengthens the idea of Proof of Value playing a key role in scaling, as those actors involved and interested in measuring water quality would be aware of FWW being a valuable option for an experiment or local project.

Finally, in FWW, "*Blitzes*" can act as "*mass marketing campaigns*". In these cases where thousands of citizen scientists go out and collect data for a weekend, all these people still need to go through the same Train the Trainer process. In this way, the trainer kit becomes in itself a means to communicate and disseminate the project.

6.5 The Role of Openness in FWW

The FWW data platform is open source but, as of now, not completely open access. The software is open source, the data license is creative commons, but in order to download the raw data, somebody either must be a registered member or needs to send a query to the FWW team with the data request (which is then executed). Interestingly, there are various reasons why the data is not currently completely open access. First, given that usually research institutions drive data collection, these want to publish the data they collect before making it publicly available. Second, the data goes through an internal "*manual*" quality review by the team ("*once a week or every day in a week after a Blitz*"), which, with limited resources available, can't be done in near real time. Third, in order to be made open access "*the data has to be cleaned so there is no personal information in there*". Members can download the data of their own local projects, "*but participants agree to share it only with the rest of their local group*".

6.6 Target context

One of the main elements enabling scaling of FWW is indeed its global-by-design nature. "*The measurements and methodology are identical all across the world*". At the local level, the various projects adapt water quality measuring interventions to more detailed and culturally-socially-economically embedded projects. "*In Nigeria we have people measuring bacteria. In other places algae. From the basic understanding, the locals can tailor it to something that is much more relevant to them. This attracts the community as they address problems that are relevant to them*".

Unlike other cases, interestingly, the common issue across all locations is not necessarily the severity of the water quality problem, but rather the lack of water quality data: "*Brazil is an example, where there are reservoirs for drinking water that must be monitored, and FWW fills that monitoring need. In Africa also, they have no monitoring. In the UK where we have got a huge professional monitoring network, the places where it has been more successful are small streams where there is no data*".

In terms of contexts, one local aspect that might vary across countries and inhibit local impact (which might have some effect on scaling of FWW down the road) is the attitude of the public sector. Sometimes these are very collaborative, whereas other times "*they just don't want problems because this would give them more work to do*". Other, few, experiences showcased a more political issue in this way, for example in those contexts where it is an important and well-established local industry causing water quality-related damages.

With respect to alignment of social values, at the global level, FWW experienced cultural differences on the way different communities and local projects approach the role of volunteering. As an example, in some developing countries, "*we suspected that the local leaders have been paying volunteers to collect the data, which is not really Citizen Science*".

6.7 Conclusions and Looking Forward

FWW offers a valuable scenario on scaling through infrastructuring. We highlighted the key roles of Proof of Value and the Train the Trainer approach and toolkit. One of the key priorities for FWW today is to make the data "*available live on the platform*". This is currently under development as part of an EU-funded project. The team is now in the process of writing scripts to be able to upload data on the website without personal information. At that point, the FWW datasets will be completely open access. This is acknowledged as a key priority because "*we are morally obliged to make it open access for the volunteers, because it is their data*". In addition, the role of technologies like AI and Machine Learning could substantially improve the quality check processes required to sustain FWW value while decreasing the effort of the team that currently undertakes these processes. Lack of funding, however, is the main barrier towards achieving this vision: "*that is down the road*".

Looking forward, once this set of data will be available online for anybody to access and re-use it, the potential for further scale FWW is clear: "*there is a lot of data and information there. More than any of us can think of ways to utilise or develop new models*" that enable new services on top of the platform.

As more and diverse communities become involved in FWW the Train the Trainer needs to be tailored for accommodating the needs of each community leader. For example, some might have more experience working with volunteers, and no expertise on sampling and collecting data, and some might have the opposite experiences. This is seen as potentially limiting scalability because of this additional, customised, effort that needs to be undertaken. To address this potential issue, the FWW team is now working on "*modular webinar forms for training the trainers*". This modular design will allow having ready content-specific modules that can be combined and readily delivered based on the specific local needs.

Concluding, FWW, as a charity organization, represents a great example of achieving a global scale with a limited amount of resources. These mainly come from "*little*" subscription fees that local projects pay to access the platform and the training toolkit. When asked about experiences in which scaling was not successful, the answer was clear: "*the limiting factor is always funding, from both sides*", i.e. the FWW core team side, and the local actors. From the FWW side, the subscription fees seem to cover part of the expenditures, but not all of it. This situation might create long term issues to both sides (i.e. FWW team and the local actors interested in starting citizen-driven water quality monitoring interventions) because of the risk of moving from being collaborators towards the same mission, to being competitors for what is often the same funding schemes that are targeted to achieve that mission. The aspiration looking forward is in the creation of clear and transparent collaborations which are expected to result in much more effective applications that can potentially produce sustainable benefits over time for the overall emerging FWW ecosystem, as opposed to short-terms achievements among several, not connected, actors.

7 Luftdaten and Sensor.Community: Scaling through Platform-enabled virtuous cycles

Born in Stuttgart from an open data and civic tech initiative named Code for Germany, Luftdaten[30] is today amongst the most acknowledged and clear examples of scaling and spreading in Citizen Science. The project comprises a particulate matter sensor and a platform technology to enable geo-localized visualisation of air quality data. Today, Sensor.Community[31] drives the scaling process of Luftdaten globally and is therefore taken as the unit of analysis for this report (the case study is referred to as LD/SC in this document).

From the initial mission of deploying 300 air quality sensors to citizens in Stuttgart in 2015, the project today counts "*almost 7 billion data points from about 11,500 sensors across 75 countries*" (see Figure 6). Furthermore, LD/SC is today experiencing several "*redeployments*" of its concepts, technologies, and principles through the establishment of emerging sub-set of projects such as InfluenceAir[32] in Belgium and AirBg[33] in Bulgaria. Evidence was found from a variety of other projects that are leveraging the LD/SC technology. For example, as documented by Tagle et al. (2020), Chile has recently launched an air quality citizen science project in Santiago using the LD/SC firmware to configure the IoT board as well as their cloud-based storage and visualisation platform.

Figure 6. Maps.Sensor.Community World Map[34]

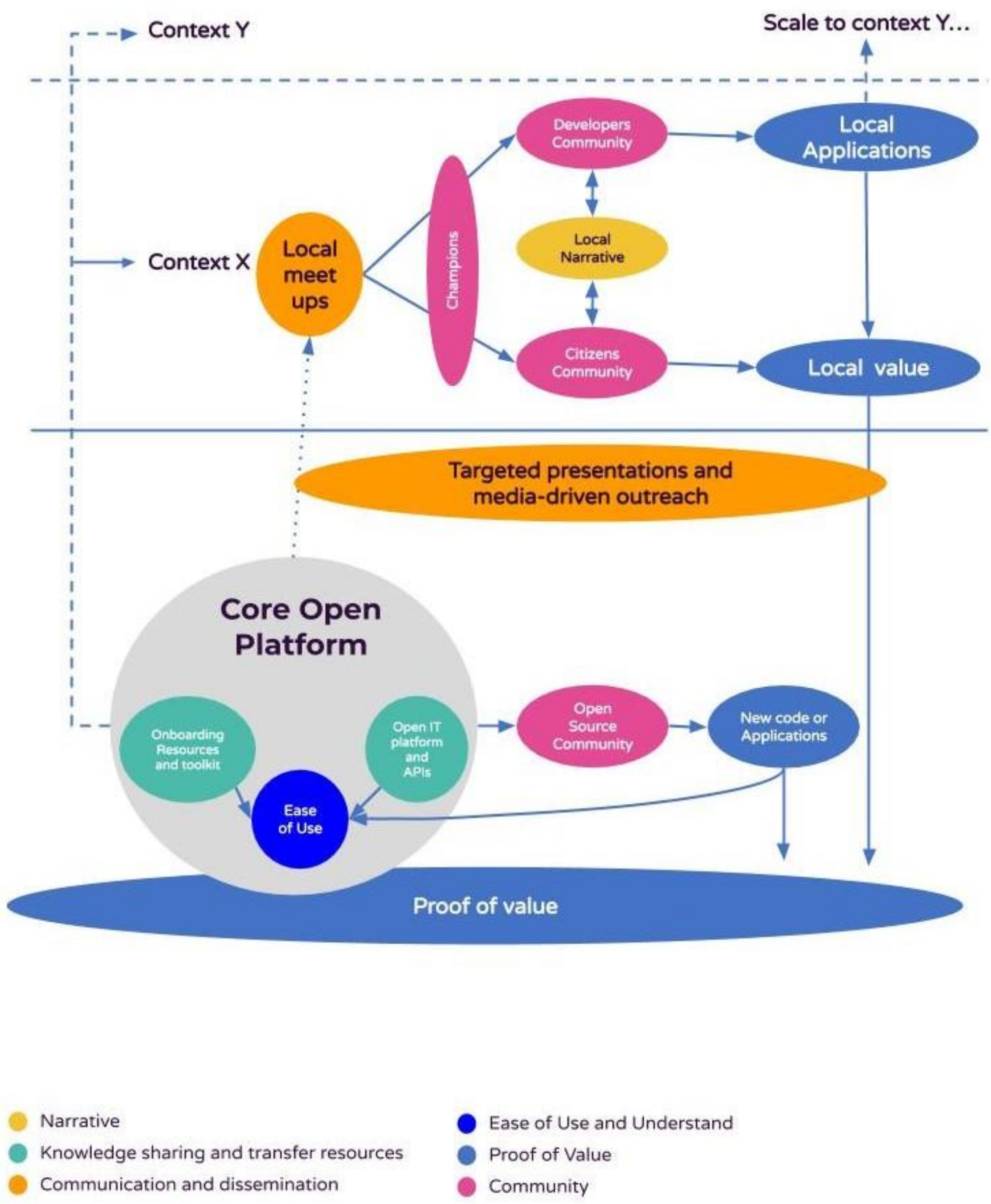
With respect to scaling, the initial Proof of Value achieved in Stuttgart triggered a wider, global scaling vision. To achieve this vision, the case study identifies a platform dominant approach, whereby a central open platform is leveraged across different contexts through a process facilitated by resources and methods provided within the platform itself. The fact that, at least initially, each context follows the same method and approach, allows identifying the following pattern: people are guided and instrumented to implement local events to start new citizen science interventions; after these, community champions emerge and start an effort to join together and establish two fundamental, interrelated and not mutually exclusive, communities: of local citizens; and of developers. Together, these communities establish the local Narrative of the project, i.e. an adaptation of the overall narrative to the local culture and issues. Subsequently, while the community of citizens creates local value by installing the sensors and collecting data, the developers focus on the locally generated data and, enabled by the open APIs in the central open platform, develop local applications. These are often adapted and

30 https://luftdaten.info/
31 https://maps.sensor.community/#2/0.0/0.0
32 https://influencair.be/
33 https://airsofia.info/
34 Source: https://maps.sensor.community/#2/20.6/5.8

adopted by other contexts, thus scaling themselves. Together, these two communities also contribute to provide value back to the core platform, thus increasing its trust and value, therefore further fostering its diffusion.

In summary, the platform-driven approach enables local communities to adopt the technology and design locally relevant interventions. These local communities become part of LD/SC as they perceive it as valuable and trustable. As more local communities get on board, more value is generated (through data and applications) thus attracting more local communities to join. Over time, these are effectively virtuous cycles driving scaling of LD/SC. Figure 7 summarises this scaling scenario and its key elements which are then extensively tackled below.

Figure 7. LD/SC: Platform-Enabled Virtuous Cycles



Consistently, this case study report is structured as follows: first, we provide some considerations on the core platform-based approach and the team behind this massive initiative. Second, we underline the fundamental role of Proof of Value followed by reflections on Communication activities conducted; then, we focus on the local contexts and specifically we leverage the experience of Save Dnipro[35], a local community in Ukraine, to elucidate the process of developing a local Narrative to engage with Communities of both citizens and developers as well as their role; we then discuss the role of Openness and how it is perceived to be a cornerstone for enabling scaling of LD/SC; finally, as in the other case study reports, we discuss general characteristics of the Target Context before some reflections looking forward are drawn.

7.1 Core Platform and Team

Before diving into the specific elements enabling scaling, and in order to better interpret this process in LD/SC, some considerations must be given to the technical and human infrastructure that is driving it. Surprisingly, behind the platform that acts as the engine for mapping and visualising data from around 11,500 sensors worldwide, there is a small team of three people. With very limited resources and financial support, this team is able to maintain an increasingly growing infrastructure. Critical success factors for achieving such a situation were identified as:

1. Relying on a clever open platform design made of two fundamental components: (1) live automated feed from the sensors into the map; and (2) APIs to allow developers to access, export and re-use the data for designing additional applications. All technical components are open source, also "*the firmware is open source and available on GitHub*".

2. The provision of a wide range of methods and resources to allow local communities to be part of the platform without the need of support from the core team. The resources provided make it overall easy for both communities of citizens and of developers to be on board. These resources are openly available online and include guides on how to use the API (for developers) and clear step-by-step guides for making it easy for citizens to install and activate the sensors. Resources also include guides and methods for setting up local communities through the deployment of "*local meet-ups*", including how and when to organise these.

3. A thoughtful data management scheme to aid understandability and discoverability of the data. For instance, "we facilitated filters and metadata, so, for example, you can select and download only data from sensors placed in third floors".

4. The passion, positive attitude, and openness of the core team to collaborate with anybody from anywhere regardless of whether they are citizens, companies, developers, universities, or other actors. While proactive engagement with some of these bodies has not always been a success, the will to further develop the ecosystem involving more stakeholders is there. The fact that the team does not have a business plan in place ("*we never sell devices, you can buy all the parts from multiple parties*") has two important implications: first, the core team, despite the very limited resource available "*is never a bottleneck*"; second, the overall vision is designed around a community and social innovation plan.

7.2 From Proof of Value to Virtuous Cycles

In 2015, at the start, "*Stuttgart had the highest air pollution index in all Germany*". At that time, data was coming from official measurement stations. Obtaining this data in a timely manner was a challenge, as the best situation saw data provided from "*6 months before in .spdf format*" (i.e. not machine readable). Therefore, "*there was no value in attaching an API to create this website and the map*". This phase created in the community a strong "*motivation out of frustration*" for action. So, "*we transformed into buying all possible sensors available and created a new network of measurement stations that had to be adoptable, accessible, and cheap*".

From the initial deployment of 300 sensors in Stuttgart, the local community was able to demonstrate the value of their approach by effectively visualising air quality data on a map. "*We thought we are serving 300 people*

35 https://www.savednipro.org/en/

and then it took off". Driven by the initial success, a team of developers started developing a scalable platform to allow communities around the world to be part of the initiative.

Over time, communities from different countries and backgrounds joined the project by procuring the sensors, adapting the narrative to the local contexts, and, in some cases, developing additional applications on top of the data generated (for more details see below the section on local contexts). As more local communities participate in (and contribute to) the platform, its value increases. In other words, as more data was being visualised and as more applications were being developed, the perception of LD/SC being a trustable and valuable platform is enhanced as a result. Clearly, these create virtuous cycles over time whereby Proof of Value drives scaling (and the other way around).

Another reinforcing element for scaling is linked with Ease of Use and Understand: "*this is not rocket science. The message is clear, and the air quality problem is well understood*". The previous section gave an overview of the resources provided to make it easy for both developers and citizens to participate, contribute, and actively appropriate the technology and the methodology by contextualising it to their local situations, cultures, and challenges.

7.3 Little Centralised Communication

Surprisingly, the platform scaled to this point despite the team having "*spent no money into advertisement. It was only through people power*". Early success and the novelty of the approach led to the presence on big media channels (e.g. "*BBC, the Guardian, German TV*"), but this was not the result of mass communication campaigns from the project team. Initially, Communication and Dissemination efforts were undertaken by the core team, mainly through interviews and presentations at relevant events. However, this approach had proven not to be effective. After each event the core team started receiving "*too many emails*" without having the resources to sustain that communication effort: "*we then became the bottleneck*".

To address these challenges, the core team changed its communication strategy, by empowering local communities to perform their local communications. In particular, the core team (through the platform) provides resources and methods to assist local communication. Resources include "*clear content differentiated for the press, for tech, for partnerships, and for the general public*". In terms of methods, the core team fosters the implementation of local meetups, which are "*now globally spread, like in Chile, Pakistan, South Africa*". As a result of implementing and making available these resources, the team "*realised that the locals have everything they need to do it by themselves*". Now for example, "*people in France write to their communities directly. We don't know what they do*".

The last communication building block is created to enable communities to contact each other directly: "*we developed channels that are country related and others that are topic related*". The latter appear to be mainly technical, but also include channels dedicated to specific approaches, e.g. supporting the implementations of campaigns tailored to schools, libraries etc.

7.4 Local Contexts Fuelling Global Scaling

Overall, the core platform appears to be self-sustainable. Local context avail of a variety of Knowledge Sharing and Transfer Resources for making it easy to both communities of citizens and developers to be part of the LD/SC community, without the need of centralised support: "*for example in Bulgaria and in the Netherlands, we are very successful. But we didn't know why. We did not have the direct contacts, and no one has ever called us. They found it, translated it, and we only realised when they had registered in the map*". In this way, scaling is achieved through providing the infrastructure "*to community champions that truly bring the potential to their local communities, and, together with them, shape a local narrative and project*".

The case of Save Dnipro (Ukraine) is useful to understand how existing initiatives join the platform as an additional element for them to tackle their context-related issues. In Dnipro, there has been a relatively long history of environmental problems. These, among other causes, were primarily attributed to a "*not efficient, coal-based thermal power plant*" in the area. Emissions were very impactful on the local water, soil, and air quality. New regulations fostering cleaner environments and a specific new law requiring dedication of resources to achieve that mission were established in the country. Interestingly, as part of this new law, "*citizens can play an active role together with enterprises and governments*" to address local environmental issues and provide related assessment measures. So, a legitimate channel was established for citizens to raise concerns. These then started a public advocacy campaign to raise awareness on the need to comply with these new laws. As part of this process, debates with companies (including the one owning the thermal power plant mentioned above) and governments (the "*minister of ecology gave great support*" to the campaign) started to take place. However, while conversations were positive and productive, investing the required money and resources "*takes a long way to go*". The problem at that stage was to have official data as objective evidence supporting the relevance of the problem, which was anyway clearly observable ("*you just need to look at the chimneys to realise it; you don't need measurements*"). "*During that period, we found that public information is not easily accessible. Often it is not understandable nor machine readable*". This lack of information prompted the community to take actions: "*we thought we need to know what the situation is where we live, on our balconies and neighbourhoods*". To tackle this need, the local community started looking for a solution. Initially, through a crowdfunding campaign, they were able to buy a limited number of "*professional devices*". However, lack of funding and resources impeded further progress in this direction. At this point, the community turned into the LD/SC sensor. The option to consider it came about more by accident than planned: "*when we got the first money, a person commented on one of our posts and suggested to look at Luftdaten. We saw this as an open source and low-cost sensor which was already widely used across Europe, while Ukraine was a white spot on the map*". According to the interviewee, LD/SC was chosen for several reasons: (1) positive outcomes from an initial trial of a limited amount of sensors; (2) it is low cost; (3) the presence of existing resources for making the sensor easy to assemble; and (4) the fact that the solution is "*open source and open hardware*". These elements, together with the fact that "*it is already working in Europe and, so it is trustable*", allowed the platform to be scaled to this new location. It is important to underline that the local community had little to no support in the first steps: "*we found the instructions, we analysed the slides proposed and the images from the workshops, and we just did it*".

In terms of process, like in the case of Dnipro, local actors get a first interest in the platform, usually to solve an existing problem of that area. Following the methods (e.g. meetups) and using the tools (e.g. step-by-step guides, contents) provided in the central platforms, local champions emerge and typically engage with communities of developers and of citizens. Together, these communities collectively shape a local Narrative, which in turn shapes and enables local projects and interventions. Therefore, three main elements of the local context appear to play a great role in fostering scaling of the overall platform: (1) the collective effort in shaping a local narrative; (2) the community of citizens that install the sensor and provide data to the platform; and (3) the community of developers that develop applications that both add value to the platform and improve its usability and user experience. These are tackled separately below. The experience of Save Dnipro is again proposed as an exemplar case of local context driving effectively these three elements to aid understandability of these processes.

7.4.1 Local Narrative

Clearly, to promote effective and meaningful local engagement, the global air quality issue must be enriched in a way that is embedded with the cultural situation and priorities. Depending on the context, local groups might be already involved in tackling environmental sensing issues or could start a new project from scratch. The case of Save Dnipro is a clear example of the former and of how LD/SC scaled to this context through a local effort of adapting the narrative to the local situation. More generally, the narrative makes sure that participants develop the right motivations to join the project in a meaningful way. Beyond these reasons, motivation for participation in the project is described as a "*hard topic: my experience says the motivation changes over time. The key is to always explore what's next to stimulate communities*". Other reasons are identified as developing social ties and sensing skills.

As part of these processes, community champions and two types of communities emerge: those of citizens and those of developers. Through their active engagement, the narrative evolves and gets refined over time. As these two types of communities get more and more on-board, they generate value through data and applications, which in most cases, benefit both the local context, e.g. through local impact; and the core global platform, e.g. through the development of new scalable applications. Those are described separately below and examples from the Dnipro case are again provided as supporting evidence.

7.4.2 Citizens Communities

The most straightforward contribution to local impact is the one from the citizens communities. People adopting the sensors start producing data, which collectively generates new knowledge about air quality in an area. This knowledge is then leveraged to provoke actions, i.e. impact. One example comes from Bulgaria where, "*from* *not being discussed in politics, air quality became one of the most relevant aspects. Politicians themselves are racing for who measures more*".

In Dnipro, the citizen initiative got an early echo from the local media as the sensing activity started in a particularly challenging period from an air quality point of view (i.e. the Autumn season impacted by high levels of wood burning – related pollution): "*we got a huge impact from the press. And we were just citizens*". Later, as data was being collected, the local community provoked important actions: "*we made impact on the largest pollutant in our city. They decided to invest huge money in ecological modernization*". Over time, the community developed "*the largest tool of environmental data in the country. Our public visibility and trust put pressure on the government to build a more professional systems network. And Luftdaten is helping a lot in building the air quality network which is a big part of our campaign, for a clean and safe environment*".

It is noted, however, that groups and individuals within those communities evolve over time and so does their role and contribution: "*I think of a physics professors, a former engineer at* [a big company]*, that first built a sensor for himself, then for his family, then schools, then created a group and placed more and more. They then start combining their effort. Then they start to train themselves on the data, what other data could be combined (e.g. transport data, weather data) and use new analytics tools*". In this way, even ordinary individuals can eventually become part of the developers' community which is tackled next.

7.4.3 Community of Developers

"In terms of contributions there are always two elements: one is translation into other languages and the second is by some other people knocking at the door with new code about a new functionality, again because this is open source. Also, the API, to the best of our knowledge, is now enabling more than 30 different applications".

Facilitated by the fully open source software and hardware solution and by the central resources provided, developers typically assume one or more of the following roles:

- Adapt the platform to the local context ("*these hundreds of developers adapt it to their skills, cultures and languages*").
- Develop software solutions or applications that improve the technical side of the core platform.
- Develop new services or applications on top of the data provided in the platform.

The latter two entail different processes and contributions to scaling and are therefore discussed separately.

With respect to applications improving the system as a whole, these come from local communities that, as part of implementing their local project, develop new solutions to improve the technical side of the platform and the user experience. As an example, at some point the *"process of writing the firmware on the device used was made of a series of multiple steps*". This process was substantially improved through a new lean flashing tool contributed by a developer from the local community in Poland: "*he shared it with us, others have translated it, and we are now trying to distribute to everyone*".

With respect to other applications, a wide variety of contributions emerged so far. These further strengthen the value of the platform, usually with something new: "*some wrote an app for Alexa kits, some others did mobile applications for Android and integrate data from us, and it is now used by 42,000 people. Some others were simpler and for example did the map with smiles instead of the colours. Somebody else did it for Bristol and created a bar to select what time range of the data should be displayed and creates a gif animation*". These apps, besides being a clear example of scaling in themselves, attract new communities to the platform, thus increasing the likelihood that new applications will emerge, finally sustaining over time the virtuous cycles described above. To better understand these important processes in terms of scaling, an example of a chat-bot system, the SaveEcoBot[36], developed by the community in Dnipro is provided below.

Following the vision of providing people with "*fast-food information on their environment*", the local community in Dnipro developed a chatbot which merges data from different sources (including local data from the LD/SC platform) to provide users with the information they want in an automatic fashion. Over time the application

36 https://www.saveecobot.com/en/maps

has been enriched and new features have been added such as its ability to send notifications "*for example suggesting closing the window if the levels are too high*". Once developed and tested, the solution is highly scalable across countries. Other local communities manifested interest in adapting it to their countries, and that was relatively easy to do: "*I created a multi-language and multi-country support on the chatbot. You just need to translate it and the data can be taken already from the Luftdaten platform*". In summary, by adding a feature to allow changing the language interface and the local map, the original chatbot can be adapted by anyone as the data is available from the platform. The application is currently available in Ukraine, Georgia and Bulgaria, in five different languages. Interestingly as the chatbot scales it gets more echo and interest thus gaining value itself (which ultimately adds value to the original LD/SC platform). This was the case of scaling it to the Bulgarian context. During this process, a major social network company (that has its Eastern European headquarter in Sofia) became a partner. This resulted in a wider audience and in new features added to the chat-bot. As an example, this company developed specific "*stickers* [that are now] *available in three countries; they stimulate users to use these environmental stickers that will then start a chat about air quality*". Currently the application counts a total of 420,000 users registered across the three countries. "*Before the partnership we had 35,000*".

In summary, the communities of developers play an important role in enabling scaling of the LD/SC platform by feeding virtuous cycles which ultimately contribute to increase Prove of Value and Ease of Use. It is noted that also these communities and their needs vary over time. Sometimes individuals join a community as experts of a specific programming language or software programs, "*then the program might change, and the person is not an expert anymore*".

7.5 Openness

"It went viral because we focused on Open Source from the very beginning"

Openness is acknowledged by the interviewees to be a critical enabler of scaling in this case. Open source software and open hardware are the pillars upon which this ecosystem of communities is emerging. The open source community and specifically "*hackerspaces, maker spaces, and other civic tech communities*" are behind the development side. It was the combination of skills of these people that created the integrated platform as well as the sensor kits "*that only cost 45/50 euros depending on where you buy the parts from*". Interestingly it is not only the ability to access and change the software that fosters scaling. Open source software is also perceived as more trustable "*because every single person is able to check it, to check that there is not any malware in there*" or other security-related threats.

7.6 Target Context

One of the perceived elements enabling scaling of LD/SC is ingrained in its design: "with the shift from project to platform, this means global first. This is IoT on global scale. We have now 11,500 sensors but we are thinking about 50 million". Air quality is also by definition a global problem.

This case study report highlighted the centralised resources made available, which offer good insights on what local contexts require to appropriate the technology and the method and thus to adapt the initiative to the local context. In terms of inhibiting factors, it is perceived as being more challenging to scale the project in those countries where average salaries are lower, as the cost citizens need to sustain for the kit is always around 40 euros. Scaling could be also problematic to some countries where regimes are in place: "*we see in some countries some sensors popping up and then disappearing. From our analysis they are internet blocks in place and certain types of signals are not let through*".

7.7 Conclusions and Looking Forward

LD/SC and the Save Dnipro case offer a diverse perspective than those proposed before with respect to scaling and Citizen Science. In this case, the platform-driven approach has led to two types of distributed communities to create virtuous cycles attracting more and more contributions, and thus generating more and more value over time. The infrastructuring approach observed in FWW is still dominant, although less formal. One consequence of this leaner approach could be identified in the actual quality of the data generated. Looking forward, more communities and more sensors coupled with emerging technologies will likely improve the quality of the data. As the network will become larger, the data will eventually become big data. At this point algorithms can be designed to enable appropriate data validation processes thus eliminating automatically data that is not accurate. Once the quality of the data will be ensured, LD/SC might eventually gain a place amongst the global standards for air quality data monitoring and visualisation. At that point, virtuous cycles can potentially become network effects, like in the case of other open source solutions such as Linux or OpenStreetMap.

Beyond the Dnipro case, one context where scaling has not been as effective so far is that of public authorities and institutions. The core team has attempted several ways to start constructive collaborations for closing the loop from data to new policies. Despite an initial interest, these rarely succeed, and the reason, as stated by the project team, is the following: "*they show interest but never follow up, because we are not a company, and they do not know how to deal with you*". While public procurement mechanisms are beyond the scope of this analysis, these reflections suggest that trust between LD/SC and public authorities has not developed yet mainly because of regulations and bureaucracy than anything else. Looking forward, the core team advocates for "*an incentive mechanism for re-using our data and methods. We have APIs in the EU websites, but nobody is using them*".

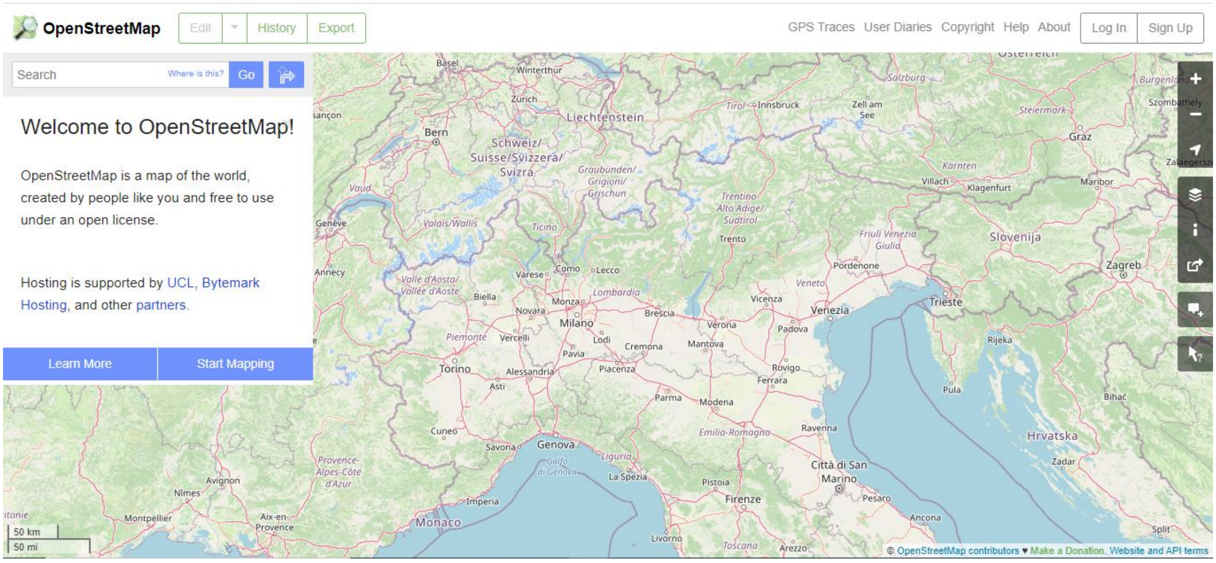
Another reflection emerges in relation to the future and the technologies that will come about. The focus of LD/SC will not change and will be drawn upon two main concepts (at multiple layers): trust and relationships: "*we can change tools or technology like we change T-Shirts. Our focus is always to keep it alive, which means building trust and relationships with the best possible technology*". Interestingly, trust in the system develops in parallel to scaling. One of the reasons why Save Dnipro adopted LD/SC was because "*it was trustable*". Then, we asked "*what makes it trustable*", and the answer provides an additional view on the value-based virtuous cycles generated by the communities: "*Luftdaten had more than 5,000 stations at that time. This was mainly in Germany, which has a reputation of being one of the most technical countries in Europe. And people are using it. There are a lot of applications, meaning that there is a lot of good data. All clues that there was something solid behind*".

Concluding, LD/SC is a great example of a global initiative with very little centralised resources. This lack unavoidably changes some dynamics for communities. In the past, big communication outreach often resulted in peaks of workloads that were not manageable. Looking forward, "*we are not running for big numbers, but for sustainability*". This happens at both the global and local levels. The recommendation for those championing the local communities is the following: "*if you would like to be part of the network, be slow and don't want to change a lot* [in a short amount of time]. *Just trust us, trust the community using it. We are not so fast, but we are building a solid community. And we are being systematic, with no steps back*". In other words, while several studies stress the importance in Citizen Science to keep the momentum with the community to be able to scale, expectations should be set, communicated and clarified to prevent participants from staving off the project. The aspiration for the future is to keep growing. The LD/SC team recently developed an API (that still needs to be translated) which will allow integrating data from noise pollution sensors onto the platform. The team will continue with its original mission of gathering and visualising raw data. An effort for improving engagement between the local communities is also being undertaken through the development of a "*cross-country sharing forum*".

8 OpenStreetMap: Scaling through Platform-enabled Network Effects

Prompted by the dominance of proprietary geographical and mapping data in the UK, OpenStreetMap (OSM)[37] was created in 2004 as a collaborative project for creating free and editable maps. From a UK-based project in early 2000, today OSM counts over 6 million members and is available in 96 different languages. The OSM Foundation (OSMF) has been overseeing its development since 2006. Despite that over time it experienced issues revolving around data quality (Haklay, 2010), OSM today is compared to other proprietary GIS data, fuelling some of the websites we visit every day, and becoming a more and more acknowledged standard behind several GPS devices and applications. OSM can be considered a compelling case study of a Citizen Generated Data platform whereby initial citizen science practices evolved into a complex ecosystem of contributions from a multitude of actors and entities (both public and private).

Figure 8. OpenStreetMap Homepage



Since 2004, the growth and scaling of OSM has been exponential. Driven by a demonstrated value of OSM in the UK, OSM today is the result of mapping data crowdsourced through several different means. Major contributions came from communities of volunteers that input data into the system. This data is integrated with data from other sources, e.g. open government data, and initiatives, so-called Mapathon competitions, increasingly contribute by adding additional value either through improving existing maps or adding new ones. Several major partnerships (e.g. Yahoo! and Google sponsoring the 2007 OSM Conference[38]) and contributions / donations (e.g. Automotive Navigation Data donating data about Dutch, Chinese, and Indian roads[39]) appear to be an important element. Over the last decade, OSM has been at the core for multiple initiatives supporting humanitarian organizations when facing natural or other disasters (e.g. the 2010 Haiti Earthquake, the civil war in Mali in 2013, the Ebola pandemic in 2014, and the Covid-19 one in 2020). This evolution allowed for additional services and functionalities to be added over time on the increasingly rich datasets. One of the most popular is the route planning feature added to OSM in 2015. Also, OSM has allowed other now popular software and applications to emerge, e.g. maps.me[40], Marble[41].

One important aspect of OSM is its orientation to fostering local knowledge. The granular information and the width of the data available today is a result of this strategy. This OSMF's vision in this direction is to set up a network of national and regional "*Local Chapters*" across several countries. Instances include, among others, OSM Belgium, the Swiss OSM Association, OSM France. These are clear examples of embedding the idea of national and regional champions in the overall governance structure of OSM (indeed each Local Chapter can appoint a representative in the OSM advisory board). Also, regardless of the geographical area, working groups

37 https://www.openstreetmap.org/

38 https://2007.stateofthemap.org/

39 https://wiki.openstreetmap.org/wiki/AND_data

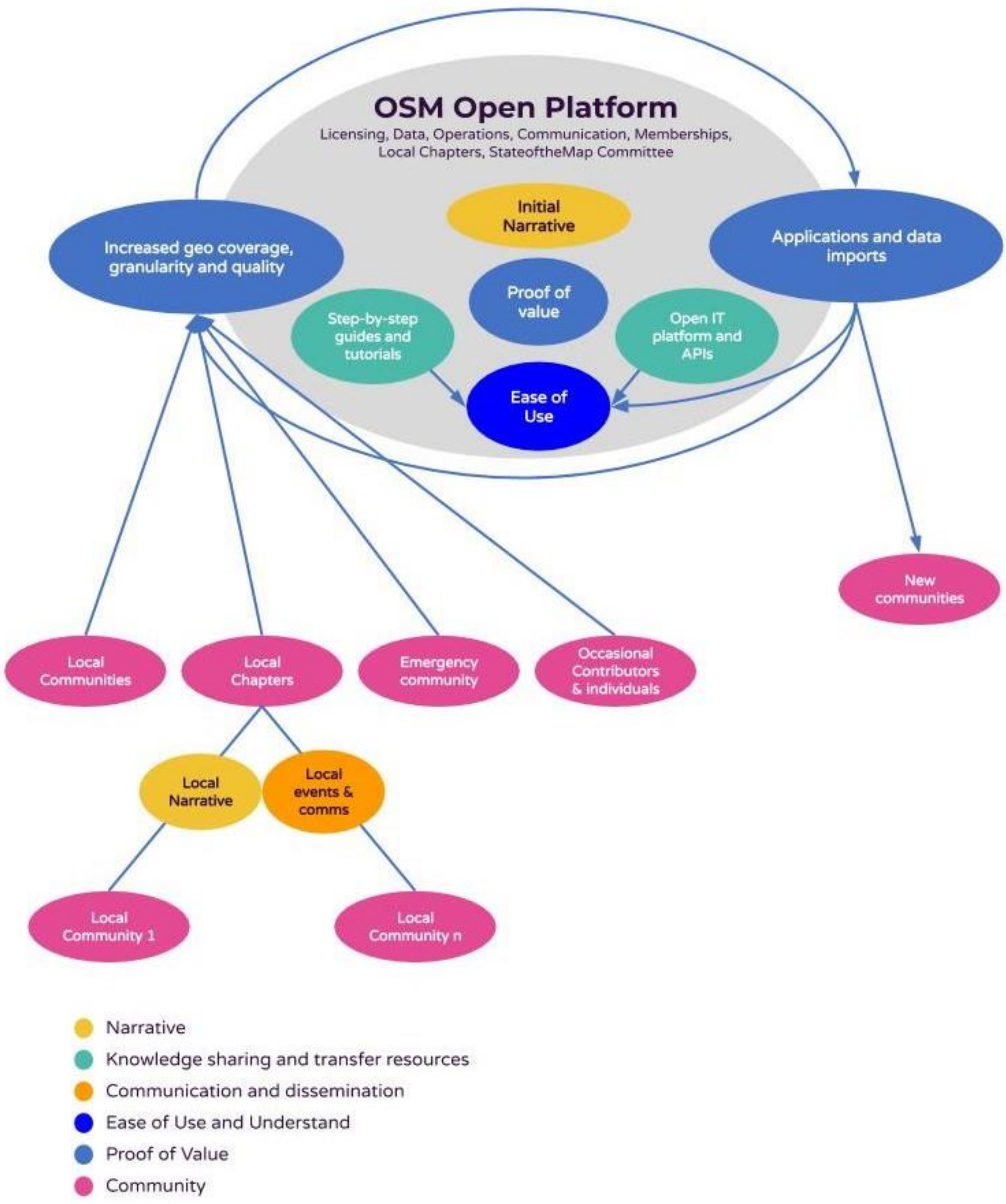
40 https://maps.me/

41 https://marble.kde.org/

within OSM are established across contexts based on specific themes such as licensing, data management, communication, operations, and engineering.

With respect to scaling, the following elements emerged as critical: (1) the initial Proof of Value; (2) the Platform-based Governance Structure in place to strengthen the balance between a global centralised approach and context-specific bottom-up actions; the centralised roles of (3) Knowledge Sharing and Transfer Resources that makes the interaction with OSM Easy to Understand and implement, and of (4) Communication and Dissemination efforts; (5) the complex role of the different local Communities including the Local Chapters; (6) the Platform-enabled Network Effects that generate over time; and (7) the role of Openness. Consistently, this report includes seven sub-sections dedicated to each of these elements. Finally, as in the other case study reports, we discuss general characteristics of the Target Context before some reflections looking forward are proposed. Figure 9 below summarises the key elements of the OSM scaling scenario. These are then extensively described throughout this section.

Figure 9. OSM: Platform-enabled Network Effects



8.1 Initial Proof of Value

The first prompt for scaling appears to be the result of initial efforts undertaken in the UK in the early 2000s. In part, the interviewees acknowledge that maps, by definition, can be seen as scalable resources as these can be re-used as a foundation for a huge variety of applications and services, e.g. in the context of "*better sanitation, navigation, land management etc*." In addition, the OSM bottom-up approach, has proven successful in the initial context and this triggered international adoption. A wide variety of communities and businesses has been contributing to the map ever since, with each contribution adding value to OSM, to a point where OSM has become today the standard for plenty of applications across contexts and domains. These additional services, in turn, entail network effects, as each additional contribution adds value to the overall platform and that additional value fosters the development of more and more applications on top of it. Network effects, and thus these cycles reinforcing Proof of Value over time, are at the core of the OSM scaling process today (see dedicated section below). However, before delving into this aspect, the role of communities and of the centralised platform in taking OSM to a point where it became the standard for these applications, must be understood.

8.2 Platform-Based Governance Structure

As mentioned above, the OSM governance has two main interrelated entities: the global / centralised, and the local / decentralised. While the Local Chapters are dedicated to galvanising local communities and ensuring that local knowledge is contributed (see next section), the engine behind OSM, i.e. the platform, is centralised. The OSMF oversees the overall organization and is responsible for organising the, "*extremely valuable and important*", annual conference. Also, at a centralised level, global Working Groups make sure that issues and common decisions are taken with respect to specific topics such as licensing, data, operations, and communications (see below). These groups also intervene in case of exceptional "*local circumstances*". An example is "*a case where an open data import from a country was under a different license than the OSM one. When trying to import that data, there is a lot of grey water there, which is where the board is very useful to provide guidance in a top down way*".

The presence of the working groups also ensures that duplication of efforts is minimised. "The local chapter will take care of the local knowledge. The technical issues tackled locally are also local such as a very specific data issue [e.g. example of 'malghe' below] and make sure that once uploaded on the database is typologically correct, the metadata is correct etc."

To achieve a balance addressing these top-down (from the OSMF and the Working Groups) versus bottom-up (from the Local Chapters) decision making tensions, "*every year all the chapters around the world meet at the State of the Map Conference organised by the OSMF. The board meeting at the conference is open to everyone to attend. Certainly, it would not be top-down. It still preserves a bottom up approach*". The following example is useful to clarify how these bottom-up versus top-down tensions are resolved within OSM:

"Road network data in Canada became open data a few years ago. There was an important import made. Then there was somebody in northern Quebec that had been working for years on OSM and suddenly all his data is overwritten. A huge discussion took place. This is not how huge imports should be done. This created a methodology for OSM: if you want a big import the first step should not be to discuss how to get it on the database; it should be seen what is already there? How do I contact my community? How do I do it in a way that it complements and updates what is already there? It would become a negotiation process then. This would become a conversation with the local community first, and then with the working groups and with those that have had similar experiences in the past, until consensus is achieved".

In terms of scaling, resources to ensure Ease of Use and (most) Communication efforts are also centralised. These are tackled separately below.

8.3 Ease of Use and Knowledge Sharing and Transfer Resources in OSM

A further reason why OSM scaled is because "*you don't have to be a senior developer to contribute*". Usability and user experience are driven at the OSMF level. Then, internally, they divide tasks, e.g. "*those that focus on the APIs*".

In general, both interviewees agree on the fact that the right resources are in place to ensure it is easy for users to contribute a small piece of data and see that immediately appearing on the map. "*The tools are good. Step by step guides, video tutorials, wiki pages, especially for those with low digital skills. Then there are sessions on how to contribute to OSM*". Also, it is easy for people to participate as the only resources needed are an internet connection and a web browser. Overall, "*the contribution in OSM is way easier to make compared to Wikipedia. It does not require much intellectual effort*".

While the relevance of both Ease of Use and Understand as well as of Knowledge Sharing and Transfer Resources towards scaling is clear and well-agreed upon, three important reflections emerged. First, there are different levels of contributions and each comes at different effort and skills required. The suggestion given by OSM is to start simple and gradually build confidence: "*do not take an 8-lane roundabout as your first edit. Start with mapping a local shop or school. But the support material is there. Very often in Citizen Science these protocols are the last things being created whereas these should be the first*". The local chapters provide the face-to-face interaction side of these teaching and learning processes. Second, what often creates a barrier, and makes it more difficult for people to contribute, "*is that it looks like everything is done*". For example, "*in Berlin they have everything mapped down now to the traffic lights sequence*". "*They mapped even the blades of grass*". Third, the perception is that the more the contribution solves a personal problem, the less relevant is

Ease of Use, i.e. people are more willing to undertake a learning journey to be able to contribute if their contribution addresses a personally experienced problem. This aspect suggests an important scenario that moderates the impact of Ease of Use and Understand on scaling.

8.4 Communication

From the interviews it does not emerge that there is an extensive global communication effort. There is an acknowledgment that a volunteers-based organization like OSM does not have the resources for massive advertisement and communication campaigns. Formal plans for communication and dissemination are mainly implemented through email distribution and social media channels. Every Local Chapter has its own and there are some at the global level too. Some of the latter are "*by topic or interest, e.g. for those interested in software, in the legal side, etc*." However, given that in OSM there are "*several channels to enter and several applications, people tend to develop ties communicating internally*", within those applications and their social media. At both the local and global level both interviewees argue about the importance of people knowing the project "*hoping these people will spread the voice*" – one stated.

8.5 The Multifaceted Community of OSM

The notion of "*community in OSM is a very complex matter*". Being an open project makes it accessible to anyone, regardless of their geographical location, gender, interests, skills, or any other characteristic. Also, from a time perspective, volunteers can engage at any point in time: "*I always tell them: do not be intimidated by those that have done millions of edits. We say: every edit count"*. The OSMF itself does not enforce exclusive rules. Rather it focuses on maintaining the fundamental principles of openness at the foundation of the project. In terms of contributions, however, both interviewees acknowledge that the so-called 90-9-1 theory (Nielsen, 2006) applies to OSM, whereby the vast majority of users are mere consumers of content.

All in all, a wide variety of diverse communities revolve around OSM. From the analysis of the interviews, we identified: (1) individual contributors; (2) the Local Chapters and the related local communities emerging from their local efforts; (3) other local communities (independent from the Local Chapters); and (4) communities that gather in response to emergency situations. Given their diversity, as well as their collective importance for understanding scaling of OSM, these are tackled separately below.

8.5.1 Individual contributors

"There are a lot of people that make a few contributions every year. But there are enough of them at scale to make a very large set of contributions. People often focus on who makes all the work and who does nothing. But it is the middle where the scaling also happens"

Although OSM is a truly global application ("*if you are someone in Trento, there is nothing stopping you to work on OSM South America, or Australia*"), individual contributors most times focus on the locality they know and experience. This is argued to be the core value of OSM as "*although there is nothing to stop you to work from the outside, you must always respect and build upon the local knowledge*, [...] *and local knowledge is good for the detail*". It is inferred that individual contributions might happen through a concentrated effort in a limited amount of time, and that this is more visible in rural areas than in urban ones, "*where you have less contributions but are more stable over time*". Also, peaks of individual contributions usually happen as a result of specific events and presentations, where "*people get interested, register, make an edit and that is it*". Others, instead, might be occasional contributors with vested interest, e.g. "*sometimes I see commercial sites that register with their actual name and add their store or hotel on the map as their only edit*". This latter aspect is an indicator of the value of the map which drives additional contributions, i.e. additional value, i.e. fuelling network effects. Sometimes, individual contributors get in touch with their peers, often, in the same geographical area. Among these interactions, a figure that might emerge is the "*tyrant of the territory - I am from here, I know better than you my city*", suggesting that, in some cases, participants might lose their motivation over time.

8.5.2 Local Chapters

"The idea is: you take care of your area, I take care of mine, and suddenly we have covered the whole world. That is just looking after your own localities"

As described above, as the approach to reach local knowledge, Local Chapters are formally appointed within the OSM governance structure. This choice, according to one of the interviewees was a cornerstone to enable scaling of OSM as a whole: "*it would be difficult to reach the local if you had a European one. You need to understand the local conditions*". In OSM, these structures allow "*focusing on the local while developing the global*". This model was firstly implemented in the UK and Germany. Over time, these became the "*poster child*" for other countries to copy. These structures approach local knowledge in different ways. The two most prominent are:

- By organizing local events: these can vary from presentations to actual hands-on activities with the local community, e.g. "*mapathons, hackathons etc*." These, at the Local Chapter level, are typically periodic initiatives focusing on specific topics and "*sub-projects*". An example from the Irish Chapter refers to an event on "*mapping all Irish monuments*". A task like this requires very specific local knowledge and this approach has proven successful. The goal often "*is thematic engagement* [e.g. Irish monuments], *and not a complete open book*".
- By establishing partnerships with local entities. An example of this is the partnership in Italy created with the CAI (i.e. the local Italian Alpine Association).

A challenge of this approach to local knowledge is in that "*OSM is so open that there is not a standard for everything*". A good example of this is "*malghe*", which are typical houses in the north of Italy where mountaineers stop for, for instance, to taste and buy fresh milk and cheese. While "*the communities inserted those places in Trentino*", there was not a unique reference to these peculiar houses. However, given the popularity of these locations in those places, over time users "*defined an exhaustive set of tags that the communities now associate to malghe*", thus suggesting an emergence of standard from the interactions between community members and OSM.

Finally, the Local Chapters sometimes assume a critical role in enabling the contribution of communities outside their localities, usually by providing the OSM and related digital knowledge to complement the contextual knowledge of those communities. An example is that of a European Local Chapter helping a community in Malawi: "*the local community might be 10 people in the country. What they need there is people with skills and knowledge to work on the project. Skills can come from the outside, but we do not understand how the local road system works. But the local people do. So, we empower them*".

8.5.3 Other Local Communities

In OSM other communities can emerge around particular themes or geographical areas independently from the Local Chapters. These communities often configure a new citizen science project that stems out of OSM. An example among many refers to when people, conscious of the current gender balance priority, started an investigation on how many Brussels' streets were entitled to men and how many to women. The result was visualised based on the new application enabled by a query to the OSM database combined with their input (made possible by the linked data in the platform). Another example refers to the NYC Public Library, which, as part of their citizen science agenda, developed TimeSpace[42], an effort whereby citizens collectively build the map of NYC as it was across periods in the past. Some other communities are more localised, such as the Polimappers from Politecnico di Milano[43].

Overall, these emergent communities contribute substantially to scaling of OSM by adding new perspectives and applications, therefore adding value to the map, thus enabling and stimulating new communities to contribute to it.

8.5.4 Emergent Communities in response to Emergency Situations

The reason why this community type has been separated by the other, more locally established, communities relates to the fact that often "*people from around the world gather to help communities under threat*" – i.e. a global community for a local effort. These are typically to help with natural disasters or geopolitical issues. As some examples, there are OSM communities emerging in response to the 2010 Haiti Earthquake, the civil war in Mali in 2013, and the Ebola pandemic in 2014. Among others, HOT (Humanitarian OSM Team)[44] is acknowledged to be one of the most successful communities worldwide. HOT is an NGO, "*a charity initiative*"

42 http://spacetime.nypl.org/

43 https://wiki.openstreetmap.org/wiki/PoliMappers

44 https://www.hotosm.org/

able to gather significant adherence ("*especially in Africa and South America*") and "*had an exponential scaling effect on OSM*".

More generally, OSM communities tend to react to exceptional problems and circumstances. A clear example comes from Italy during the recent Covid-19 crisis. During the lockdown period, communities started to review and update the data to ensure that "*all pharmacies were mapped and opening hours as well. That is a bottom up approach. OSMF would never say: 'okay we have Covid-19 and we need all pharmacies to be mapped'. That came from the locals, who produced a huge effort to update the data*". An interesting difference between OSM-based efforts and others (e.g. "*there are at least 30/40 efforts in Italy alone to map shop's opening hours during the Covid-19 crisis*") is in that, "*while others' contributions will disappear after the crisis, the data contribution and the tags on OSM will remain*". This reflection suggests a key role of these contributions towards scaling OSM as a whole.

Concluding, these sub-sections give insights on the variety of communities involved and their role in scaling OSM. However, according to the interviewees, a full understanding of the motivations behind people's contributions "*is still a golden question for research on OSM*". The situation has evolved from 2004 where mapping data was not available and people contributed for addressing this lack (although it must be underlined that there are still some countries "*where governments have cartographic data but they will not allow normal citizens to have it*"). Besides exceptional circumstances, such as the natural disasters or the disruptions exemplified above, "*how long people are involved for and why is still a question to be answered*".

8.6 From Proof of Value to Network Effects

Scaling through communities helped OSM to develop value over time. Value in this sense is meant as the amount, accuracy, and level of detail of GIS data made available for free through the OSM platform. At some point in time, OSM became attractive as an alternative and valuable open source mapping platform for a variety of actors and companies. As these got involved, initial contributions to the map were made through what the interviewees called "*data imports*". In these cases, companies such as several from the navigation industry, IT corporate, as well as government agencies, started donating their data to OSM to improve its coverage and accuracy. These are effectively win-win strategies for both the companies (who can now rely on a richer, and open map that do not have to maintain) and for OSM (who benefited substantially from these massive contributions). Examples include navigation companies that instead of covering their data gaps by acquiring it from third parties, have now a much better integrated source for their applications. These were just some of many "*massive imports*". "*Microsoft also donated imagery data from BING, and that was a huge jump in terms of scaling OSM*"[45]. These donations had a ripple, or network, effect: the more donations, the more value which, in turn, stimulates more donations. The improvement of value over time due to these data imports also contributed to increasing the potential of OSM to become a well acknowledged standard for map-enabled applications. For competitive reasons that go beyond the scope of this analysis, "*companies like Facebook, Microsoft, and other giants are also in now*", e.g. by participating and co-sponsoring the annual conference.

These cycles of improvements, over time increased the value of OSM as the foundation on top of which a huge variety of applications have started to be developed. OSM has achieved a point where "*it is convenient, because otherwise someone would need to buy the data or to start from scratch*". Importantly, two types of applications are generally developed: (1) "*external*" applications that use OSM as a foundation for other services; and (2) applications that improve the management of the data, and the overall effective technical functioning of the platform. While both have an impact on scaling, they are fundamentally different types of contributions. The first is more straightforward: OSM is becoming the standard for the myriad of applications that use mapping data. With respect to the second, two (among many) examples are proposed.

The first good (and useful for this analysis) example is MAP with AI[46] recently developed by Facebook[47]. In this application, "AI is used to extract content from satellite images and enrich the existing map. Also, they developed another app where users can go and insert the data that they could not get from these satellites". The value added in this case is not only the new data on the platform, but also the quality of this data ensured by the process that is put in place: "unlike OSM, they set up a strict pipeline to verify the veracity and validity of the data". Such pipeline works as follows: first, it validates the data, e.g. if you insert data about a street, it needs

45 Further information available here: https://wiki.openstreetmap.org/wiki/Bing_Maps

46 https://mapwith.ai/#14/-7.02455/110.34703

47 https://wiki.openstreetmap.org/wiki/Facebook_AI-Assisted_Road_Tracing

to pass the "validation street test"; second, they run logic analysis, e.g. "if data about a building is inserted and there is no street then gives error"; third, NLP (Natural Language Processing) is used to check spelling and typos; fourth, they run trust reputation of the users based on their history of contributions. Clearly, as a result, the OSM dataset is cleaner and richer.

As a second example, at some stage, the OSMF and the relevant Working Group was experiencing critical feedback from the communities about the APIs in place: "*I see many complaints about APIs not being addressed, but you can't make everyone happy*". The solution, interestingly, came from other companies that work on OSM, that develop software for critical processes, e.g. "*facilitating large data imports, which is crucial for OSM*".

These two examples show that as OSM becomes the standard for big companies, these increasingly develop the vested interest in fostering the development of the standard. As Facebook and others adopt OSM, they want to improve it and keep it sustainable. However, assuring the level of accuracy required is something that entails the investment of significant efforts, talents, and resources which are likely to need "*a commercial business model to be sustained*".

In summary, OSM is scaling to a point where big companies adopted it and it is now an important building block for several of their applications. Like for Linux in the Open Source world, it becomes their interest to keep OSM alive and to improve it, thus suggesting that, besides the network effect generated by their applications, these employ resources that ultimately benefit and improve OSM itself. Holding this position, however, does not come without risks. For example, other companies could "*fork it and do another one*". At the moment, it is not convenient for them, suggesting OSM surpassed (for now) the network effect tipping point. Interestingly, one interviewee argues that "*one of the companies is monitoring who contributes the most on OSM, and then invites them into their own one*". Also, the fact that companies are investing on OSM creates strong debates within the OSM communities. "*While this has a great potential to scale OSM data, there is also where the tension is. Is it really a genuine contribution? What happens if* [one of these companies] *loses interest in a few years? What happens if either OSM or them changes the licenses? Things can get very complicated*".

8.7 Openness in OSM

Openness is at the core of OSM across all perspectives. The platform is open source, data is open, communities are open, and even the board of directors is open to all local chapters. It can be argued that an open approach is the most important pillar upon which the whole project is built.

An aspect that deserves attention is the role and the complicated landscape of open licenses. The examples above showed that sometimes situations might lead to "*grey waters*" whereby the lack of a unified open standard for the overall open data ecosystem might create a barrier. OSM currently uses ODbL (the Creative Commons Open Database License from the Open Knowledge Foundation), which is argued to be a "*good improvement from the previous one; it is similar to the LGPL of the Open Source*". In brief, "*the data bank is always open, derivative products need to cite the source, which sounds easy, but* [in a large scale and messy ecosystem like the OSM one] *is complicated*".

8.8 Target Context

Today OSM can be considered a global platform. However, some considerations can be made in relation to the fact that scaling is (today) more effective in those areas, typically in developing countries, that have very limited, or not fully accessible, mapping data. Also, while some urban areas are somewhat reaching saturation, data from rural places is sometimes lacking, not updated, or inconsistent.

Some of the issues that affect global scaling revolve around language. For example, "*Russia has a language that is only spoken there*", suggesting that a Local Chapter should be in place to promote scaling in those countries speaking their own languages.

Interestingly, given the wide diffusion of OSM, some political problems might crop up. These might once again revolve around language or the delicate topic of disputed borders. As an example of the former, in an effort to scale an OSM-based app to Greece, "*the local community asked to change the map because the part from Macedonia is in Cyrillic*".

Ultimately, an interesting reflection emerged in relation to differences in social values: "the idea of common good and collaborating for the common good isn't everywhere as clear as in most European Countries. [Another country] for example shows that there are people willing to work hard for the common good but there are a series of other factors which might suppress that type of action. In other countries you might get people that do not want to get involved because there might be repercussions on developing alternative programs available maybe in a regime".

8.9 Conclusions and Looking Forward

All in all, OSM represents a compelling case study encompassing several elements emerged from MS/SCK, LD/SC, and FWW. As in MS/SCK the starting point was a local Narrative in the UK that helped to form Communities that, through their action, created Proof of Value. Like FWW, OSM has a formal infrastructuring approach through the establishment of the Local Chapters that, enabled by the centralised resources available, kickstart local Citizen Science interventions. As in LD/SC, over time various communities of citizens and developers add value to the platform, and this value attracts more and more communities to contribute thus creating virtuous cycles. Then, OSM went a step forward as the value achieved today attracts not only communities of citizens and developers but also the contributions from several actors from both the private and public spheres. These cycles enabled OSM to achieve network effects which allowed it to scale to a point where it gained a place among the most acknowledged mapping standards worldwide.

Although partially covered by new (mainly third party) applications, one of the main future challenges (at least in urban areas) of OSM will be to motivate people and communities to do what is needed the most in terms of contributions: updating the data. There is still very old data in OSM and that causes problems when OSM becomes a product for business needs, e.g. navigation, or if others are using it on their own website. This updating process was described through the concept of "*Map Gardening: why do we go and look for the new thing when we would benefit from gardening, curating what we have*". The interviewee then raises a critique to those that "*are exaggerating; there are places where they are mapping even blades of grass. We don't need it*". However, "*Map Gardening is not sexy for participants, as it is to do something new*". Linked to this argument, OSM today would benefit from additional data "*like civic numbers*" that, for the same reason, have rarely been contributed by most communities. In addition, there is a risk of saturation of the map-related open data ecosystem. As open government data movements are taking momentum, "*what happens if in some time we get to a saturation point of Geo Open Data? How do we motivate contributions when people can already access the data?*" Finally, in some parts, data quality remains a challenge and "*this is where AI and machine learning can kick in as a solution*".

9 Reflections and Recommendations

This report tackled the important topic of scaling and spreading in Citizen Science. This topic has been underexplored in the discipline so far, and this led to take a grounded based approach to the literature through the development of a solid theoretical framework informed by three well-acknowledged theories from different fields of study. This framework has been tested, enriched, instantiated, and contextualised leveraging a multiple case study of four diverse settings representing examples of scaling in Citizen Science. The rich data gathered allowed for the generation of thick scaling scenarios for each case respectively. While the in-depth knowledge generated about those cases is, by definition, contextual and situated, an additional effort to position these scaling scenarios within the framework was made in order to formalise the learning from each case in a more generalisable language and format.

9.1 Reflecting on the Framework

From a general perspective the case studies demonstrate the validity of the framework and of the elements established within it. Therefore, this way to unbundle scaling in Citizen Science and its enabling factors has proven valuable. However, the case studies demonstrate that each element can play different roles in fostering scaling of Citizen Science interventions. These roles can vary depending on the context, the nature of the interventions as well as the scaling stage (i.e. a time perspective) the specific initiative is at. This reflection suggests that the framework can be considered as a valuable, scientifically grounded (both from a trans-disciplinary theoretical point of view and from an empirical perspective) solution to structure our mindset to: (1) design new projects that are scalable by design; (2) assess scalability potential of existing initiatives; and (3) frame future research initiatives to further explore the process of scaling in Citizen Science.

For future research in this field we recommend researchers to carefully reflect on what the unit of analysis of their studies should be. In this way, it must be noted that diffusion of innovations and other adoption theories are commonly used as a lens to explore and understand collective adoption of an innovation in its entirety. In the context of scaling Citizen Science impact, we argue that diffusion is not limited to full replication of previous pilots or projects. Rather, sub-elements of an intervention might scale such as a particular community, a technology, or a specific method or practice. For example, is a hypothetical situation where a Do-It-Yourself (DIY) sensor technology co-created in Project A for measuring air quality in a marine environment is reused in Project B to analyse the effect of air quality on livestock health, a case of scale? Such reflection adds an important question which remains open: what are the elements that can be subject to scaling and spreading? In other words, this suggests that scaling and spreading include but are not limited to full extension (in the case of scaling) or full replication (in the case of spreading) of a given intervention. Rather, sub-elements of a given intervention can be the subjects of scaling and spreading. This was observed to some extent in the cases studied in this research, whereby the scaling process to new contexts always entailed an adaptation of the original project to the local values, culture, legal environment, existing efforts, and, most importantly, to the local matter of concern. It is only by doing so that the cases considered were able to feed value back to the initiative by meaningfully engaging local communities (although the strategies and tools to do so varied substantially across the cases considered).

Another important learning from the case studies comes from the fact that none of the initiatives studied fully relied on one, or few, elements to achieve their scaling status. Rather, their experiences show that, while some elements might appear more dominant than others (e.g. Narratives for MS/SCK or Proof of Value for OSM), scaling is in the end the result of a dynamic balance and configurations amongst the enablers' constructs defined. In certain boundary conditions clear links emerged between constructs (e.g. Ease of Use and Understand is often enabled by various Knowledge Sharing and Transfer Resources in place) but also trade-offs might occur. We reflect on some of these for each dimension below.

9.1.1 Elements intrinsic to the initial project to be scaled or spread

Proof of Value appeared to be relevant in fostering scaling across all cases. This was expected and demonstrates that value and impact remain cornerstones for Citizen Science initiatives to scale. MS/SCK, however, carries an important learning as for local impact to happen, a certain amount of scaling through communities needed to take place. In other words, for the initial impact to act as the engine behind scaling and spreading of the initiative (or the core technology used within it), a community needs to form and act in the first place, which requires a certain amount of scaling in itself. All cases considered in this research entail a form of digital data collection, storage and visualisation. In these terms, Proof of Value is often associated with the quality of this data and, as a consequence of these attributes, its usage (e.g. new application). Ensuring data quality appears as remaining a key challenge for Citizen Science interventions. Two different, but equally important, dimensions emerge as relevant to ensure data quality:

Establish processes and procedures to control data inputs. This is in turn approached in different ways across the cases. OSM, given its position, relies more and more on third-party applications to check the consistency of the data contributed. LTD/SC is not at that point (yet) and is aiming to increase the volume of contributions to enable meaningful quality check by comparisons. FWW, instead, has put in place both manual, time and resource consuming, quality checking processes as well as preventive measures (e.g. making sure that participants have a minimum level of knowledge). The latter approach, while seemingly more effective in this way, has implications on other elements, specifically Openness and Ease of Use. Indeed, these manual quality check processes do not leave room for FWW to provide open access to the live data generated by citizens (i.e. minor negative correlation with Openness) and require more effort than other cases for communities to join (i.e. minor negative correlation with Ease of Use). Across all cases, the hope looking forward is that a shift to Big Data scenarios (i.e. high volume, velocity, and variety) coupled with new AI (or machine learning) – based technologies might provide a scalable way to address these challenges.

Fostering the communities of contributors to undertake efforts in maintaining and updating the data over time. While the hope looking forward is similar to the previous challenge (i.e. "*AI will solve it*"), the problem currently revolves around motivating communities to update existing data to preserve its value. This appears still to be an issue, as Citizen Scientists are acknowledged to be more inclined to do something new ("*it is more sexy*").

Because of the nature of Citizen Science, i.e. opening science to lay people, Ease of Use and Understand is also acknowledged to be critical by all interviewees. All cases demonstrate that significant effort has been (and is constantly being) invested in making it easy for everyone to participate and be involved. Across these efforts, we identify two critical building blocks to address this construct: (1) the provision of consistent Knowledge Sharing and Transfer Resources (see below); and (2) the usage of technologies that simplify the task(s) to be undertaken. We believe the latter might have significant implications on the overall Citizen Science discipline. In particular, we note that this "*digitization of Citizen Science activities*" trend, if it continues at a similar pace, might change significantly the role of citizens (and more generally of lay participants) and the nature of their involvement in Citizen Science interventions. Indeed, as more and more tasks are being performed by technologies, sometimes in an autonomous fashion, there is a risk that the involvement of participants could shift towards more passive modes of participation. Based on our analysis, this typically occurs during the data collection and analysis phases. In parallel, to enable scaling and spreading of a citizen science initiative, the existing literature acknowledges the need to ensure that all users understand the possibilities and limitations of the technology used. Citizen Science practitioners need to be able to make sense of the data gathered, or the observation outcomes from different data collection technologies such as sensors (Schade et al., 2019).

This reflection sheds light on an important trade-off: while technologies might make tasks easier to perform through automation, this can in turn affect the sense of ownership in participants and thus their level of meaningful participation in scientific inquiries. In this way, it is important to consider another important relationship in the framework with the Communities construct. Indeed, new forms of engagement might be needed to sustain meaningful levels of participation, sense of ownership and overall motivation of citizens. These might include co-design of the technology itself (Balestrini et al., 2017), of the experiment (Buyx et al., 2017), and design data sharing rules (Grant et al., 2019; Eleta et al., 2019). As a final effect, the latter reflection creates another important dilemma and trade-off between off-the-shelf and fully co-created technologies, and their effect on scalability in Citizen Science. Indeed, while reasonably off-the-shelf technologies might facilitate scaling and spreading if compared with those specifically co-designed as part of a Citizen Science pilot, such an approach would further limit the role and the subsequent level of engagement of participants. In summary, characteristics concerning complexity and ease of use, can influence the way a project is approached and designed, the type of participation and, unavoidably, its outcomes. By proposing some of the emerging challenges deriving from existing trends, we do not mean that projects that make use of more complex technologies are less likely to scale up or spread. However, we argue that these require a different approach, as different types of technologies leveraged in a project might attract different types of citizens.

9.1.2 Elements supporting the spreading and up-scaling processes

In terms of Communities, as expected, their role in scaling is to ensure that the project is adapted in a way that is embedded in the local culture and locally experienced issues and opportunities. One further key learning with respect to communities refers to the fact that, in order for these to sustain over time (thus fostering scaling), they must evolve in their nature, composition, and guiding motivations for citizen scientists to participate. The role of champions (more or less formally established) remains critical, thus confirming earlier literature. Motivation and participation should be supported by appropriate narratives specifically (co)designed for all potential stakeholders.

Narratives are shown as having a potentially key role to scale communities to jumpstart an intervention. However, Narratives alone were not emerging as being enough for sustaining scaling over time. Rather, these appear to play a key role at the beginning of a project to engage all relevant stakeholders. To promote scaling, Narratives must be supported by actions, and must adapt over time to the underlying context and the progress achieved. At some point in time, to enable scaling, Narratives need to be somehow achieved through impact – i.e. Proof of Value. This, in turn, makes what has been until that stage a story-telling driven action, a tangible intervention with evidence of results. In parallel, Narratives appear to be effective also if, and only if, these are supported by thoughtful and articulated Communication and Dissemination efforts which are reflected upon next.

Communication and Dissemination was also acknowledged by all interviewees as critical in achieving and sustaining scaling. However, somehow surprisingly, in three cases the role of this construct was far from being dominant. In MS/SCK, substantial effort has been dedicated to leveraging communication to scale communities and the different Narratives. In the remaining three, communication and dissemination are not prioritised against other, usually more technical, elements when competing for the limited resources available. Rather, the core, centralised, teams tend to rely on local communities and champions to undertake these tasks. These reflections suggest two important considerations:

Communication and dissemination activities tend to be more relevant (if compared to other elements) before Proof of Value has been achieved and established. This, in turn, acts as the magnet for media to start promoting, or in some cases endorsing, the initiatives themselves, thus contributing to mass communication of the project without the need for the team to invest resources and time.

Communication is a fundamental building block to form communities at the local level. The limited resources usually available from the core teams do not allow these people to get the required knowledge to shape a locally embedded Narrative and to communicate this effectively. However, the centralised teams can provide scalable resources as templates that local communities can easily adapt to their situated contexts, issues, and opportunities. These can take various forms like webinars, templates for presentations, specific guidelines on how to run events, among others.

With respect to Knowledge Sharing and Transfer Resources, all cases have implemented, in different ways and at different levels, a set of openly available resources that generally serve three purposes: (1) making it easy for anyone to join as a citizen scientist regardless of the individual's experience and expertise in the subject; (2) act as scalable resources that substitute an otherwise impossible to deliver support for the communities across different activity types, including communication; and (3) make it possible to fully replicate an intervention by providing tools and case studies that instantiate their application.

This set of resources is particularly critical to enable scalability of FWW and specifically its "*Train the Trainer*" approach to scaling. Today, however, as highlighted in the literature review above, there are a plethora of toolkits available online at different levels. Several funded projects develop these resources as a legacy of the interventions explicitly to foster scaling and replicability. The result is that the discipline might be overflowed with toolkits and this, instead of facilitating scaling or the kickstart of new actions, represents a barrier as potential adopters may find it hard to navigate these complex and multiple solutions (Balestrini et al., 2020).

One important reflection emerges with respect to these elements supporting the scaling process. The case studies demonstrate that over time, as the original intervention scales, more diverse communities get on board as a result of several different aspects, e.g. the evolution of the project, change into technologies used and specific focuses etc. All cases show that the actual scalability of narratives, communication efforts, engagement strategies, and various toolkits becomes more problematic. In fact, these are often designed for the initial community (e.g. corporate employees and then research institutions in FWW, Local Chapters in OSM) and must be therefore adapted to accommodate the more diverse groups that get involved as scaling occurs. As an extreme case of plenty of diverse communities involved, OSM shows how hard it can become to effectively satisfy everyone's request and need. As an example, as the OSM user base grows, unavoidably, requests for technical changes grow in parallel and are often contradictory. The core team (in most cases a charity organization) does not always have the capacity to manage these diverse communities at a large scale. These processes are argued to be sustained by significant effort, talents, and resources, which often require an active role by established entities and/or by commercial private organizations. With respect to the latter, the projects studied in this research showcase different roles played by the private sector in enabling and/or strengthening several elements of the framework. We believe that future research should specifically investigate the role of private companies in fostering scalability of citizen science, as this topic remains currently underexplored.

Regarding the role of established entities, we highlighted the strongly advocated role of international networks for enabling spread in Citizen Science (see section 4.2.2), and particularly in the provision of a socio-technical infrastructure. From a technical point of view, citizen scientists are often asked to possess or develop key IT competences, including data collection and storage, privacy and security, data analysis and interpretation, among others. Also, these competences rapidly evolve over time, as exemplified by the emerging paradigms of IoT, blockchain and AI. Nowadays, consistent and integrated IT infrastructures supporting Citizen Science projects across topics and geographical areas are not always present. This applies to both the hard (digital) infrastructure and the application side. For example, the market today is flooded by a multitude of sensors that vary in their quality and features. At this point, a clear reference point to effectively navigate this complex landscape of options is lacking.

According to the theoretical statements provided above, these challenges can be tackled by setting close cooperation between public and private partners, at both the local and international level, to enable the sharing of knowledge and expertise, with the ultimate goal of delivering cyberinfrastructure support by offering, for instance, analysis and visualization tools to be shared among interventions. However, there is a need for a common agreement for a blueprint to establish process architecture and collaboration systems for citizen science technological development. To-date, such initiatives exist, but are often piecemeal, rather than integrated and built on synergies among the actors across these networks. In this way, it is worth mentioning, beyond the Citizen Science discipline, the effort of the European Open Science Cloud (EOSC)[48]. This is an online environment with open and seamless services to store, manage, analyse and re-use research data, across borders and scientific domains. The EOSC approaches open data with FAIR principles, meaning that data should be Findable, Accessible, Interoperable and Re-usable. The EOSC also promotes open data sharing, advocating that it should become the default option for all EU-funded scientific research.

9.1.3 Elements of the Target Context

The case studies show that the relevance of Matter of Concerns is prominent in enabling scaling. However, the way these manifest themselves and the level of alignment across contexts vary in the cases considered. In MK/SCK, on the one hand, it could be argued that for it to be relevant, the context needs to be experiencing issues that can be addressed through the SCK (e.g. air or noise pollution). On the other hand, Narratives are sensitive to different socio-cultural places and, instead of being prescriptive, must be adapted to the local Matter of Concern as well as to the local situation depending, for example, on the attitude of the public sector towards the intervention. In FWW, interestingly, the aligned Matter of Concern is usually the lack of data about water quality, as opposed to, as the theories would predict, the severity of the water quality problem in the context. Similarly, OSM today appears to scale more in those places where mapping data is not available (e.g. developing countries and rural areas). In MS/SCK, while the actual matter of concern was noise pollution, it was the lack of data about noise levels that actually gave purpose to the project. Lack of available data on a given issue is therefore normally a trigger for Citizen Science projects

With respect to Alignment of Social Values, a common thought among most interviewees refers to the difficulty of scaling in those countries where an acknowledgment of the potential role of citizen engagement has not taken off (yet), e.g. where public administrations have less experience in transparency and citizen engagement protocols such as open government or participatory policy making. In those cases, citizens might be afraid of repercussions from the state if they decide to join. One case also shared an experience whereby in some countries "*from our analysis there are internet blocks in place and certain types of signals* [i.e. citizen-generated data] *are not let through*". The attitude of the local public sector agencies can also vary across contexts and based on how the intervention is designed. FWW offers examples whereby impact (e.g. new water-related policies) might require restricting measures to a locally important industry. In those cases, political or economic

48 https://www.eosc-portal.eu/

tensions might prevent local authorities to embrace the outcomes of that Citizen Science intervention. Other political problems emerged in OSM in the context of disputed borders.

Language also appears as a potential barrier. Typically, this is resolved by the local communities that, as part of their effort to join a project, are accountable for making it available in their language. Finally, one of the key components of all Citizen Science initiatives considered here is in that it must be cheap for citizens to participate. However, we argue that what might be perceived as low-cost in certain countries (or by certain people within these countries) might not be valid across the board, especially in those countries where the average salaries are low. This aspect might impede a global scaling, unless specific funding mechanisms are put in place to facilitate participation from these publics.

With respect to cultural aspects, a citizen engagement culture is not only a requisite for scaling to happen but could also facilitate this process by having already citizens and champions in place with experience in Citizen Science. However, local cultures and local engagement methods require local people to lead and orchestrate the related Citizen Science interventions. All cases tackle this issue through establishing, formally (e.g. Local Chapters in OSM or local projects in FWW) or informally (e.g. the LD/SC local communities), local groups that can galvanise and form communities appropriately.

Finally, from a legal perspective, the cases did not experience particular issues. We argue that this is (also) because all cases somehow emanate from Europe where regulations are in place to prevent what are acknowledged to be the main potential legal challenges in Citizen Science (e.g. management of personal data). One interesting reflection emerged about how sometimes the legal landscape of emerging technologies (e.g. IoT in MS/SCK) might be blurry, and how the lack of specific laws regulating the usage of these technologies might lead to ethical issues rather than legal ones.

As a general reflection with respect to the Target Context, it appears that one critical component of a scalable Citizen Science intervention resides in its nature. All cases are designed in a way that a scalable set of resources (typically a data platform, support resources and toolkits) can be adapted to local needs, cultures, and priorities. All the cases studied seem to have found a good balance between centralised efforts and local adaptations. One of the keys is in the actual value proposition of these case studies. Indeed, although from different fields, all provide the opportunity to generate data about phenomena that can, by nature, be adapted to locally experienced issues or opportunities. Mapping, noise, air, or water quality data are relevant worldwide and open up endless possibilities to act upon this data to foster local changes or new applications.

9.1.4 Citizen Science, Openness, and Scaling

Openness emerged across all cases as an important cornerstone for achieving scaling. Open Source software and open hardware allow local communities and projects to adapt technologies used to the local conditions, needs, values, priorities, and required features. Open data enables others to re-use the data generated by citizens thus adding value to the platform over time.

It is worth discussing some examples of "*extreme open source communities*" emerged during the OSM case study. In some cases, their involvement results in "*being exclusive and not inclusive*". The example refers to some of these "*extreme*" communities that are very strict in their rules for participation. In one case, contributions from Windows operating systems or other proprietary software or apps were not allowed. This raises questions such as: how many Citizen Scientists out there are using Linux? How many would be willing to undertake such a learning curve to be part of a Citizen Science intervention?

The OSM case study offers further insights for an interesting reflection as it shows that scaling might, at some stage, reach a tipping point where the subject becomes the standard for companies to develop products and services upon it. This means that likewise OSM became a widely used mapping standard for companies like Facebook, TOM TOM, among many others to be used for a huge variety of applications, the SCK eventually becomes the standard for noise pollution monitoring and mapping, FWW for water quality and LD/SC for air quality. At that point in time, to achieve and maintain the required quality of the subject (e.g. OSM) to sustain their, sometimes commercial, applications, the contribution of companies with greater capacity and resources becomes: (1) massive; (2) fast; (3) far more granular and accurate; (4) and reaching a form of saturation of the original subject (e.g. "*in Berlin you have only left blades of grass to map now*" – OSM). This in turn might decrease the value of the (ordinary) citizens' incremental contributions as well as their motivation to develop something that is already there. These reflections suggest important questions for the Citizen Science community:

At what stage of a project – e.g. ideation, piloting etc. – does Citizen Science as a discipline play a bigger role? Does its incremental impact fade away over time as these solutions scale?

Given the previous question, should Citizen Scientists target those products and applications developed on top of the original solutions to start a new scaling cycle? If so, how would the nature and the composition of the communities adapt to this shift? What licensing approach would be the most appropriate for ensuring that those applications remain open source while keeping the openness of the original solution?

How do we keep community members motivated when they see their contribution being overwritten by new and reliable technologies such as AI? Will these be staving off future citizen science projects? How will this affect the strength of the discipline as a whole?

These were proposed as open questions to several Citizen Science experts during a presentation of this study. The general feedback received does not necessarily support the idea that Citizen Science might be more relevant during early stages of an idea. Rather, the suggestion is that the relevancy of the discipline might evolve together with the project and subsequently attract different citizen scientists with different motivations at each stage. Others acknowledge that the "*dilemma of scaling vs. maintaining social support and enthusiasm*" (quote from one participant) deserves further attention from future research.

9.2 Looking Forward: IT trends

Looking forward, new research has begun to discuss how the emerging concepts, promises and risks related to new technological paradigms might affect and be applied in Citizen Science. In this report we reflect on the potential impact to that Artificial Intelligence (AI) and Blockchain / Distributed Ledger Technologies (DLT) may have on Citizen Science.

9.2.1 Blockchain and Distributed Ledger Technologies

With the proliferation of citizens' generated data, important questions related to the management of this data emerge. In particular, routinely collected data for Citizen Science research can potentially raise ethical concerns (Clark and Weale, 2011), beyond formal legal compliance (Carter et al., 2015). Several important questions remain underexplored today. For example, how do we maximise the value of data while mitigating risks related to privacy, security, and misuse? How can we ensure that participant's expectations and concerns are taken into account? How can we ensure integrity of the data collected?

In first approximation, emerging blockchain and DLT technologies seem to hold the promise for new ways to address these challenges. In the context of Citizen Science and DLT, smart contracts have been used to improve data governance. The idea behind these developments is that citizens may want to contribute data to a given entity without revealing their identity while demonstrating that they are entitled to contribute such data (e.g. they are residents of a city or trusted data providers, etc.). Also, a citizen may want to apply specific privacy enhancing licenses over this data for it to be shared under conditions that she or he establishes. This was the approach followed in the Citizen Science Pilot of the H2020 Decode project[49] in Barcelona, possibly one of the first documented experiences of using DLTs in the context of environmental Citizen Science.

The DECODE Citizen Science pilot followed a participatory design approach where citizens collectively discussed data governance models and decided under which conditions their data should be shared. These discussions informed the technology design. The Decode wallet technology was integrated into the data platform and architecture. This integration enabled the community to compile, encrypt, and store the collected data, while also allowing them to decide which information they shared, with whom, and under what conditions. The Decode project is a good example to showcase how DLTs could be leveraged to change the approach on how and by whom data is governed. Beyond this example, however, the discussion is just starting to emerge (within and beyond the discipline of Citizen Science). We expect that blockchain and other forms of DLTs will assume a key role in addressing data governance issues once the maturity of these technical solutions will improve.

9.2.2 Artificial intelligence

Early stage AI applications in Citizen Science are mainly focused on augmenting analytical capabilities to be conducted on the data collected by citizens. Typically, these include classification tasks enabled by image

49 https://decodeproject.eu/

recognition and knowledge capabilities (in those projects that entail citizen observing and inputting through submissions of videos and/or images). For instance, “camera trap” - based on wildlife monitoring (Green et al., 2020), would fall within this category. In this case, AI would automate the task of identifying, counting, describing, and subsequently classifying wild animals.

Although the camera-trap example is very specific, it must be noted that the application of AI to this context is the result of a learning and maturity curve which occurred over time. In other words, the application of AI today has been made possible by the gradual evolution of its building blocks, i.e.: first, through the development of deep learning techniques to automate camera-trap image processing (Norouzzadeh et al., 2018); second, through the introduction of machine learning algorithms to enable the classification of these images (Tabak et al., 2019).

In terms of actual Citizen Science projects, iNaturalist[50] is argued to be a good example of forefront application of AI to augment analytical capabilities (Weinstein, 2018) in relation to image processing of animals and plants (Van Horn et al. 2018). Although not yet fully implemented in Citizen Science, we expect that forms of AI other than image processing will proliferate in the near future, such as those of Natural Language Processing and Robotic Systems.

Beyond augmenting analytical capabilities, AI is expected to play a role across other aspects of Citizen Science interventions. A structured overview of expected applications is provided in (Ceccaroni et al., 2019). Still, some of these may be seen as a natural evolution of already existing applications. In this way, for example, AI is believed to enable better ways to make content available in any language, reducing information overload for citizens, and to augment simulation and testing phases before “real-world deployment”. In addition, another branch of AI-based applications is believed to substantially change the orchestration of Citizen Science projects. Ceccaroni et al. (2019) provide three ideas in this way, which we try to elaborate.

The first can be articulated as AI to enable adaptive management of the contribution of Citizens; in this case the application refers to AI to autonomously assign time and location-specific tasks based on an in-depth understanding of the status of the context and/or the phenomenon being observed. The example proposed in the paper is about AI triggering an observation request by humans when no satellite coverage is detected due to clouds.

The second concerns the usage of AI to personalise participation in Citizen Science intervention. This could be done through the development of customised experiences leveraging personalised incentives to trigger one’s motivation to participate.

Finally, AI is expected to play a role in providing training capabilities where access to human support is limited due to, for example, lack of advanced expertise or cultural/language barriers.

From the case studies presented in this report, the hope for new AI applications reside more into improving the quality of the data generated by the citizen scientists, which still remains a key challenge.

Taken together, these (upcoming) developments are likely to change substantially the nature and the scope of future Citizen Science projects. Above we already discussed what some of the risks or unintended consequences of automating tasks could be. The role of actors and technologies after the establishment of AI is yet to be known. Hopefully, the contribution of AI will help in increasing scientific validity and in widening acknowledgement of the overall Citizen Science discipline. For example, we, in alignment with the interviewees contributing to this analysis, hope AI will help address one of the key critiques to the overall Citizen Science discipline, that is about the quality, validity, trustworthiness and reliability of the data and knowledge generated.

50 https://www.inaturalist.org/

10 Conclusions, Limitations, and Future Avenues

To address the current lack of knowledge and consolidated definition of scaling and spreading in Citizen Science, we proposed in this study an integrated, scientifically and empirically grounded, framework as well as four diverse and rich scaling scenarios from existing Citizen Science initiatives.

Overall, we trust that this framework presents several contributions to the discipline. We envisage and encourage its application and subsequent refinement by practitioners and scholars interested in the topic. For example, when deciding to adopt or when developing a specific technology for a Citizen Science intervention, taking into account the drivers proposed in our framework makes it possible to adopt technologies that are scalable by design, which coupled with a scalable methodology and approach, can radically augment the replicability potential of the overall project.

We hope this framework will be tested and subsequently refined by researchers that aim at investigating Citizen Science and scalability in the future. In particular, we believe it can serve as the foundation to investigate: to what extent a Citizen Science intervention (or a specific technology) is likely to scale (i.e. in a predictive manner); or the rate of spread and diffusion of an existing or finished project (or technology) and the peculiarities of such processes (i.e. in a prescriptive manner). In both these cases, the relevance and the extent to which each construct influences scaling and or spreading could be investigated through large sample quantitative studies.

In terms of limitations, this study tackled a very complex and multifaceted topic in a relatively short amount of time which allowed for considering only four case studies. While their richness and depth (impossible to achieve if more cases are considered) lends to the core contribution of this report, the scaling scenarios proposed are not meant to be exhaustive. We believe that other Citizen Science projects might underpin different scaling processes. These might identify other potential valuable dynamic combinations of the constructs defined and, why not, the emergence of new ones. Also, the broad scope of the task for this study resulted in the application and extension of the framework to a very broad set of technologies. We recommend future research to separately investigate specific technology clusters in order to achieve a greater level of depth in the analysis.

As a final remark we propose the following two reflections to the Citizen Science community.

First, what does success in Citizen Science mean? Very often, success is related to impact and scaling. This analysis demonstrates how these two elements appear to be interrelated, somewhat sequential, and cyclical whereby initial impact fosters scaling which in turn, fosters additional impact. However, as these cycles occur over time, significant changes from the original intervention typically happen. For example, as saturation of the subject increases (e.g. coverage and granularity in air or noise pollution mapping) the sources of value from communities tend to evolve from being coming from ordinary lay citizens to more skilled and technical people, and ultimately from organizations from both the private and public realms. Should this point where the outcome of Citizen Science becomes a standard that is commercially adopted be considered as the ultimate success? Or should the notion of success be stretched forward to a point where a standard prompts other Citizen Science projects? If the latter, would these follow similar scaling scenarios as the original intervention or should these be considered as part of the same, somewhat endless, scaling process? As another perspective, should we distinguish between success at the individual (citizen scientist) and at the initiative level, where the latter is the cumulative result of success across the different types of participants and communities that get engaged over time?

Second, some questions remain open in terms of long-term sustainability of Citizen Science efforts and interventions. The infrastructuring approach observed across the case studies highlights the need for more appropriate funding mechanisms that allow the sustained evolution of both centralised and decentralised actors simultaneously by leveraging synergies over time (as opposed to both sides competing for the same funding and short term impact). Continuity of efforts appears to be a key to maintain value over time and thus to foster scaling. Citizen Science efforts are often led by NGOs or charity organizations. These typically operate in a limited resources environment and rely on public funding to sustain and evolve. One reasonable solution could be to, as value from Citizen Science initiatives manifests itself, embed the outcomes of Citizen Science interventions within the relevant branch of public service provision. This resonates as, since the value is sufficient to attract commercial companies (that make use of these outcomes for their own products and services), one would expect that public sector agencies would also uptake these valuable innovations to improve the management of each relevant area (e.g. across the different public environmental and water authorities).

However, these scenarios appear to be struggling to take off for two reasons. First, public sector agencies often show resistances that can be attributed to different reasons such as the political problems highlighted above, or even a general attitude against change. Second, current procurement rules are, for obvious reasons, strict and often do not leave room for formal collaboration between public councils and entities that are not registered companies. In this way, one could argue about the need for organisations behind Citizen Science interventions to evolve from being charity-based or research funded into formally established entities. Nevertheless, the fact that these are often charities was described across the case studies as a key advantage to develop trust in the communities whose engagement would otherwise be problematic. Hence, this challenge remains currently open.

We suggest that future research should investigate and establish new governance and institutional mechanisms to promote formal partnerships between Citizen Science initiatives and the public sector in the long run. While maybe not in terms of long-term public procurement agreements, we argue these partnerships could focus on experimenting the large-scale deployment of the Citizen Science outcomes. If successful, these might lead to the development of new tenders which, why not, could be targeted to those citizens that originally developed the solution thus creating new social entrepreneurs that might in turn create new jobs, commercial business models, and ultimately local economic growth.

References

Abe Y., 2014. Safecast or the Production of Collective Intelligence on Radiation Risks after 3.11, The Asia-Pacific Journal 12, 7.

Agarwal, R. and Prasad, J., 1997. The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. Decision sciences, 28(3), pp.557-582.

Ajzen, I., 1991. The theory of planned behavior. Organizational behavior and human decision processes, 50(2), pp.179-211.

Ajzen, I. and Fishbein, M., 1980. Understanding attitudes and predicting social behaviour. Prentice-Hall, Englewood Cliffs, NJ.

Anaf, S., Drummond, C. and Sheppard, L.A., 2007. Combining case study research and systems theory as a heuristic model. Qualitative Health Research, 17(10), pp.1309-1315.

Aoyama, M. and Kojima, H., 2013, June. LISA: linked services architecture based on the linked data and service broker. In 2013 IEEE 20th International Conference on Web Services (pp. 617-618). IEEE.

Asingizwe, D., Poortvliet, P.M., Koenraadt, C.J., Van Vliet, A.J., Murindahabi, M.M., Ingabire, C., Mutesa, L. and Feindt, P.H., 2018. Applying citizen science for malaria prevention in Rwanda: An integrated conceptual framework. NJAS-Wageningen Journal of Life Sciences, 86, pp.111-122.

Balestrini, M., Bird, J., Marshall, P., Zaro, A. and Rogers, Y., 2014, April. Understanding sustained community engagement: a case study in heritage preservation in rural Argentina. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 2675-2684). ACM.

Balestrini, M., Diez, T., Marshall, P., Gluhak, A. and Rogers, Y., 2015. IoT community technologies: leaving users to their own devices or orchestration of engagement? EAI Endorsed Transactions on Internet of Things, 1(1)

Balestrini, M., Rogers, Y., Hassan, C., Creus, J., King, M., and Marshall, P. 2017. A City in Common: a Framework to Orchestrate Large-Scale Citizen Engagement around Urban Issues. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (pp.2282-2294), ACM.

Balestrini, M.E., 2017. A city in common: explorations on sustained community engagement with bottom-up civic technologies (Doctoral dissertation, UCL (University College London)).

Balestrini, M., Maccani, G., and Righi, V., 2020. Tell me and I forget, teach me and I may remember, involve me and I learn: the role of toolkits in citizen science. The European conference for citizen and participatory science 2020, Trieste, Italy.

Balka, K. 2011. Open Source Product Development. The Meaning and Relevance of Openness. Gabler, Wiesbaden.

Benkler, Y., 2002. Freedom in the commons: Towards a political economy of information. Duke LJ, 52, p.1245.

Benkler, Y. 2006. The wealth of networks: How social production transforms markets and freedom: Yale Univ Press.

Berg, B.L., 2001. Qualitative research methods for the social sciences. Boston, MA: Pearson.

Beza, E., Reidsma, P., Poortvliet, P.M., Belay, M.M., Bijen, B.S. and Kooistra, L., 2018. Exploring farmers' intentions to adopt mobile Short Message Service (SMS) for citizen science in agriculture. Computers and electronics in agriculture, 151, pp.295-310.

Bjögvinsson, E., Ehn, P. and Hillgren, P.A., 2012. Design things and design thinking: Contemporary participatory design challenges. Design issues, 28(3), pp.101-116.

Bowser, A., Wiggins, A., Shanley, L., Preece, J., and Henderson, S., 2014. Sharing data while protecting privacy in citizen science. interactions, 21(1), 70-73.

Bristol Citizen Sensing Programme, 2016. A Future in Common: Understanding and Framing Commoning Strategies for Bristol.

Buyx, A., Del Salvio, L., Prainsack, B., Völzke, H., 2017. Every participant is a PI. Citizen science and participatory governance in population studies. Int. J. Epidemiol., 1-8. http://doi:10.1093/ije/dyw204.

CASE, 2008. Developing the Field of Social Entrepreneurship, Durham: Center for the Advancement of Social Entrepreneurship. Available online at:http://www.caseatduke.org

Carter, P., Laurie, G.T. and Dixon-Woods, M., 2015. The social licence for research: why care. data ran into trouble. Journal of medical ethics, 41(5), pp.404-409.

Castelluccio, M., 2008. Enterprise Open Source Adoption. Strategic Finance.

Ceccaroni, L., Bibby, J., Roger, E., Flemons, P., Michael, K., Fagan, L. and Oliver, J.L., 2019. Opportunities and Risks for Citizen Science in the Age of Artificial Intelligence. Citizen Science: Theory and Practice, 4(1).

Clark S, Weale A. 2011. Information governance in health. Nuffield Trust.

Clark, C., Massarsky, C., Schweitzer Raben, T. and Worsham, E., 2012. Scaling social impact: a literature toolkit for funders. Social Impact Exchange, Growth Philanthropy Network and Duke University.

Compeau, D.R. and Higgins, C.A., 1995. Computer self-efficacy: Development of a measure and initial test. MIS quarterly, pp.189-211.

Cooperrider, D. and Whitney, D.D., 2005. Appreciative inquiry: A positive revolution in change. Berrett-Koehler Publishers.

Corburn, J., 2005. Street science: Community knowledge and environmental health justice. The MIT Press.

Coulson, S., Woods, M., Scott, M. and Hemment, D., 2018. Making Sense: Empowering participatory sensing with transformation design. The Design Journal, 21(6), pp.813-833

Crabtree, A., Chamberlain, A., Davies, M., Glover, K., Reeves, S., Rodden, T., Tolmie, P., and Jones, M. 2013. Doing innovation in the wild. In Proc. of the Biannual Conference of the Italian Chapter of SIGCHI, ACM, 25.

Craglia, M., and Granell, C. 2014. Citizen Science and smart cities—Report of summit, Ispra 5–7 February 2014. JRC Technical Report.

Crall, A.W., Newman, G.J., Stohlgren, T.J., Holfelder, K.A., Graham, J. and Waller, D.M., 2011. Assessing citizen science data quality: an invasive species case study. Conservation Letters, 4(6), pp.433-442.

Creswell, J.W., 2007. Qualitative inquiry and research design: Choosing among five approaches. (2nd ed., pp. 53-84). Thousand Oaks, CA: Sage Publications, Inc.

Darke, P., Shanks, G. and Broadbent, M., 1998. Successfully completing case study research: combining rigour, relevance and pragmatism. Information systems journal, 8(4), pp.273-289.

Davies, A. and Simon, J., 2013, September. How to grow social innovation: A review and critique of scaling and diffusion for understanding the growth of social innovation. In 5th International Social Innovation Research Conference (pp. 2-4).

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, pp.319-340.

Davis, F.D., Bagozzi, R.P. and Warshaw, P.R., 1992. Extrinsic and intrinsic motivation to use computers in the workplace. Journal of applied social psychology, 22(14), pp.1111-1132.

DeSantola, A. and Gulati, R., 2017. Scaling: Organizing and growth in entrepreneurial ventures. Academy of Management Annals, 11(2), pp.640-668.

Dewey J., 1954. The Public and Its Problems. Athens, OH: Swallow Press.

DiSalvo, C., Lukens, J., Lodato, T., Jenkins, T., and Kim, T. 2014. Making public things: how HCI design can express matters of concern. In Proceedings of the 32nd annual ACM conference on Human factors in computing systems (pp. 2397-2406). ACM.

Dittrich, Y., Eriksén, S. and Hansson, C., 2002. PD in the Wild; Evolving practices of Design in Use. In Proceedings of the 7th biennial Participatory Design Conference, PDC 2002, 124-134. June 23-25, 2002. Malmö, Sweden. CPSR.

Diez, T., and Posada, A. 2013. The fab and the smart city: the use of machines and technology for the city production by its citizens. In Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction (pp. 447-454). ACM.

Ehn, P. 2008. Participation in design things. In Proceedings of the 10th biennial Anniversary Conference on Participatory Design, PDC 2008, 92-101. October 1-5, 2008, Bloomington, Indiana, USA. ACM.

Eisenhardt, K.M., 1989. Building theories from case study research. Academy of management review, 14(4), pp.532-550.

Eisenhardt, K.M. and Graebner, M.E., 2007. Theory building from cases: Opportunities and challenges. Academy of management journal, 50(1), p.25.

Eleta, I., Clavell, G.G., Righi, V. and Balestrini, M., 2019. The Promise of Participation and Decision-Making Power in Citizen Science. Citizen Science: Theory and Practice, 4(1).

English, P.B., Richardson, M.J. and Garzón-Galvis, C., 2018. From crowdsourcing to extreme citizen science: participatory research for environmental health. Annual review of public health, 39, pp.335-350.

European Commission, 2011. Open Data: an engine for innovation, growth and transparent governance communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. Brussels, Belgium.

Fishbein, M. and Ajzen, I., 1975. Belief, attitude, intention and behavior: an introduction to theory and research. Massachusetts, Addison-Wiley Publishing Company.

Flyvbjerg, B., 2006. Five misunderstandings about case-study research. Qualitative inquiry, 12(2), pp.219-245.

Fontana, A. and Frey, J.H., 2000. The interview: From structured questions to negotiated text. Handbook of qualitative research, 2(6), pp.645-672.

Foster, Sheila R. and Iaione, Christian 2016. The City as a Commons, Yale Law & Policy Review: Vol. 34: Iss. 2, Article 2.

Foulonneau, M., Martin, S. and Turki, S., 2014. How open data are turned into services? In Exploring services science (pp. 31-39). Springer International Publishing.

Frosterus, M., Tuominen, J., Wahlroos, M. and Hyvönen, E., 2013. The Finnish Law as a Linked Data Service. In The Semantic Web: ESWC 2013 Satellite Events (pp. 289-290). Springer Berlin Heidelberg.

Fuster Morell, M., 2010. Governance of online creation communities. Provision of infrastructure for the building of digital commons. Social and Political Science Department. (PhD thesis). European University Institute (Florence).

Fischer, G., 2003. Meta-design: Beyond user-centered and participatory design. in C. Stephanidis, & J. Jacko (Eds.), Proceedings of HCI International 2003, Vol. 4, Lawrence Erlbaum Associates, 88-92. June 2003, Mahwah, NJ, Crete, Greece.

Fritz, S., See, L., Carlson, T., Haklay, M.M., Oliver, J.L., Fraisl, D., Mondardini, R., Brocklehurst, M., Shanley, L.A., Schade, S. and Wehn, U., 2019. Citizen science and the United Nations Sustainable Development Goals. Nature Sustainability, 2(10), pp.922-930.

Gallaugher, J., 2019. Information systems: A Manager's guide to harnessing technology. FlatWorld.

Gharesifard, M. and Wehn, U., 2015. Participation in citizen science: Drivers and barriers for sharing personally-collected weather data via web-platforms. ICT, SOCIETY AND HUMAN BEINGS 2015 WEB BASED COMMUNITIES AND SOCIAL MEDIA 2015 and, p.63.

Grant, A.D., Wolf, G.I. and Nebeker, C., 2019. Approaches to governance of participant-led research: a qualitative case study. BMJ open, 9(4), p.e025633.

Green, S.E., Rees, J.P., Stephens, P.A., Hill, R.A. and Giordano, A.J., 2020. Innovations in Camera Trapping Technology and Approaches: The Integration of Citizen Science and Artificial Intelligence. Animals, 10(1), p.132.

Greenhill, A., Holmes, K., Woodcock, J., Lintott, C., Simmons, B., Graham, G., Cox, J., Ohlsson, E. and Masters, K., 2016. Playing With Science: Exploring How Game Activity Motivates Users Participation on an Online Citizen Science Platform. Aslib Journal of Information Management, 68(3), pp. 306-325. doi: 10.1108/AJIM-11-2015-0182.

Guo, W. and Kraines, S.B., 2010, October. Enriching city entities in the EKOSS failure cases knowledge base with Linked Open Data. In Computer Information Systems and Industrial Management Applications (CISIM), 2010 International Conference on (pp. 404-409). IEEE.

Haklay, M., 2010. How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets. Environment and planning B: Planning and design, 37(4), pp.682-703.

Haklay, M. 2015. Citizen science and policy: A European perspective. Washington, DC: Woodrow Wilson International Center for Scholars.

Hannemann, J. and Kett, J., 2010, August. Linked data for libraries. In Proc of the world library and information congress of the Int'l Federation of Library Associations and Institutions (IFLA).

Hartwick, J. and Barki, H., 1994. Explaining the role of user participation in information system use. Management science, 40(4), pp.440-465.

Hecker, S., Haklay, M., Bowser, A., Makuch, Z. and Vogel, J. eds., 2018. Citizen science: innovation in open science, society and policy. UCL Press.

Henderson, A., and Kyng, M. 1991. There's no place like home: Continuing Design in Use. In Greenbaum J. and Kyng, M. (Eds.). Design at Work: Cooperative Design of Computer Systems. Lawrence Erlbaum Associates, 219–240.

Herschel, M. and Manolescu, I., 2012, October. DataBridges: data integration for digital cities. In Proceedings of the 2012 ACM workshop on City data management workshop (pp. 1-4). ACM.

Holstein, J.A. and Gubrium, J.F., 1995. The active interview (Vol. 37). Sage.

Hsu, Y.C., Cross, J., Dille, P., Tasota, M., Dias, B., Sargent, R. and Nourbakhsh, I., 2019. Smell Pittsburgh: Engaging Community Citizen Science for Air Quality. arXiv preprint arXiv:1912.11936.

Jones, N.B., Herschel, R.T. and Moesel, D.D., 2003. Using "knowledge champions" to facilitate knowledge management. Journal of Knowledge Management, 7(1), pp.49-63.

Jurisch, M.C., Kautz, M., Wolf, P. and Krcmar, H., 2015, January. An international survey of the factors influencing the intention to use open government. In 2015 48th Hawaii International Conference on System Sciences (pp. 2188-2198). IEEE.

Kaartinen, R., Hardwick, B. and Roslin, T., 2013. Using citizen scientists to measure an ecosystem service nationwide. Ecology, 94(11), pp.2645-2652.

Karasti, H. and Syrjänen, A.L. 2004. Artful infrastructuring in two cases of community PD. In Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices-Volume 1, 20-30. July 27-31, 2004, Toronto, Canada. ACM.

Karasti, H., 2014, October. Infrastructuring in participatory design. In Proceedings of the 13th Participatory Design Conference: Research Papers-Volume 1 (pp. 141-150). ACM.

Kera, D., Rod, J., and Peterova, R. 2013. Post-apocalyptic Citizenship and Humanitarian Hardware. Nuclear Disaster at Fukushima Daiichi: Social, Political and Environmental Issues, 97.

Kim, S., Mankoff, J., & Paulos, E. 2013. Sensor: evaluating a flexible framework for authoring mobile data-collection tools for citizen science. In Proceedings of the 2013 conference on Computer supported cooperative work (pp. 1453-1462).

King, R., 2008. Cost-Conscious Companies Turn to Open-Source Software, BusinessWeek, December 1, 2008.

Kosmala, M., Wiggins, A., Swanson, A. and Simmons, B., 2016. Assessing data quality in citizen science. Frontiers in Ecology and the Environment, 14(10), pp.551-560.

Lacy, S., 2006. Open Warfare in Open Source, *BusinessWeek*, August 21, 2006.

Lakomaa, E. and Kallberg, J., 2013. Open data as a foundation for innovation: The enabling effect of free public sector information for entrepreneurs. Access, IEEE, 1, pp.558-563.

Latour, B. 2007. Reassembling the Social: An Introduction to Actor-Network-Theory. New York: Oxford University Press.

Lauckner, H., Paterson, M. and Krupa, T., 2012. Using constructivist case study methodology to understand community development processes: Proposed methodological questions to guide the research process. The Qualitative Report, 17(13), p.1.

Le Dantec, C.A. and DiSalvo, C., 2013. Infrastructuring and the formation of publics in participatory design. Social Studies of Science, 43(2): 241-264.

Le Dantec, C. A., 2016. Designing publics. MIT Press.

Lessig, L. 2004. Free culture: How big media uses technology and the law to lock down culture and control creativity. Penguin.

Lindman, J., Rossi, M. and Tuunainen, V.K., 2013, January. Open data services: Research agenda. In System Sciences (HICSS), 2013 46th Hawaii International Conference on (pp. 1239-1246). IEEE.

Liu, H.Y. and Kobernus, M., 2017. Citizen science and its role in sustainable development: status, trends, issues, and opportunities. In Analyzing the Role of Citizen Science in Modern Research (pp. 147-167). IGI Global.

Love, D., Moller, H., Ivanov, D. and Myall, D., 2018. Using Citizen Science to Promote Electric Vehicle Uptake in New Zealand, Society of Automotive Engineers of Japan.

Making Sense, 2018. Citizen sensing: a toolkit.

Manzoni, M., Vohland, K., Schade, S., Tsinaraki, C., Dusart, J., 2019. Citizens Science and Environmental Monitoring: Benefits and Challenges, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-09557-6.

Markham, S.K. and Aiman-Smith, L., 2001. Product champions: Truths, myths and management. Research-Technology Management, 44(3), pp.44-50.

Marttila, S., Botero, A. and Saad-Sulonen, J., 2014, October. Towards commons design in participatory design. In Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts-Volume 2 (pp. 9-12). ACM.

Marttila, S. and Botero, A., 2013. The 'Openness Turn' in Co-design. From Usability, Sociability and Designability Towards Openness. In Smeds & Irrmann (eds.). CO-CREATE 2013 - The Boundary-Crossing Conference on Co-Design in Innovation, 99-110. June 16-19, 2013, Espoo, Finland.

Matheus, R., Ribeiro, M.M. and Vaz, J.C., 2012, October. New perspectives for electronic government in Brazil: the adoption of open government data in national and subnational governments of Brazil. In Proceedings of the 6th International Conference on Theory and Practice of Electronic Governance(pp. 22-29). ACM.

Mazumdar, S., Ceccaroni, L., Piera, J., Hölker, F., Berre, A., Arlinghaus, R. and Bowser, A., 2018. Citizen science technologies and new opportunities for participation. UCL Press.

McMillan, R., 2008. Gone in Two Minutes. InfoWorld, March 27, 2008.

Merkel, C. B., Xiao, L., Farooq, U., Ganoe, C. H., Lee, R., Carroll, J. M., and Rosson, M. B. Participatory design in community computing contexts: Tales from the field. In Proc. PDC 2004, vol. 1, ACM (2004), 1–10.

Measuring Impact of Citizen Science (MICS), 2020. Retrieved on 14//02/2020 from: https://mics.tools/case-studies.

Miles, M.B. and Huberman, A.M., 1994. Qualitative data analysis: An expanded sourcebook. Sage.

Moore, G.C. and Benbasat, I., 1991. Development of an instrument to measure the perceptions of adopting an information technology innovation. Information systems research, 2(3), pp.192-222.

Nakicenovic, N. and Grübler, A. eds., 2013. Diffusion of technologies and social behavior. Springer Science & Business Media.

Norouzzadeh, M.S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M.S., Packer, C. and Clune, J., 2018. Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. Proceedings of the National Academy of Sciences, 115(25), pp.E5716-E5725.

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S. and Crowston, K., 2012. The future of citizen science: emerging technologies and shifting paradigms. Frontiers in Ecology and the Environment, 10(6), pp.298-304.

Nielsen, J. 2006. Participation Inequality: Encouraging More Users to Contribute. Jakob Nielsens Alertbox.

Nov, O., Arazy, O. and Anderson, D., 2011, July. Technology-mediated citizen science participation: A motivational model. In Fifth International AAAI Conference on Weblogs and Social Media.

Oh, J., 2013. Literature Review—Open Data in New Zealand. University of Auckland.

Ostrom, E., 1990. Governing the commons: The evolution of institutions for collective action. Cambridge university press.

Palka, W., Jurisch, M., Leicht, M., Wolf, P. and Krcmar, H., 2013, June. Classification Schemes for Open Government Data Provision. In European Conference on e-Government (p. 608). Academic Conferences International Limited.

Redström, J. 2008. RE: Definitions of use. Design Studies, 29(4): 410-423. doi:10.1016/j.destud.2008.05.001.

Ricadela, A., 2007. The Worth of Open Source? Open Question, *BusinessWeek*, June 26, 2007.

Righi, V., Sayago, S. and Blat, J., 2017. When we talk about older people in HCI, who are we talking about? Towards a 'turn to community' in the design of technologies for a growing ageing population. International Journal of Human-Computer Studies, 108, pp.15-31.

Rittenbruch, M., Foth, M., Robinson, R. and Filonik, D., 2012. Program your city: designing an urban integrated open data API. In Proceedings of Cumulus Helsinki 2012 Conference: Open Helsinki–Embedding Design in Life (pp. 24-28). Cumulus International Association of Universities and Colleges of Art, Design and Media.

Rogers, E.M., 2010. Diffusion of innovations. Simon and Schuster.

Rotman, D., Preece, J., Hammock, J., Procita, K., Hansen, D., Parr, C., Lewis, D. and Jacobs, D., 2012, February. Dynamic changes in motivation in collaborative citizen-science projects. In Proceedings of the ACM 2012 conference on computer supported cooperative work (pp. 217-226).

Ruddick, S., 2010. The politics of affect Spinoza in the work of Negri and Deleuze. Theory, Culture & Society, 27(4), 21-45.

Saga, V.L. and Zmud, R.W., 1993, October. The nature and determinants of IT acceptance, routinization, and infusion. In Proceedings of the IFIP TC8 working conference on diffusion, transfer and implementation of information technology (pp. 67-86). Elsevier Science Inc.

Schade S, Herding W, Fellermann A, Kotsev A, Gerboles M, and Borowiak A., 2019. Joint Statement on new opportunities for air quality sensing - lower-cost sensors for public authorities and citizen science initiatives. Research Ideas and Outcomes 5: e37478.

Schultze, U. and Avital, M., 2011. Designing interviews to generate rich data for information systems research. Information and Organization, 21(1), pp.1-16.

Stake, R.E., 2013. Multiple case study analysis. Guilford Press.

Star, S.L. and Ruhleder, K. 1996. Steps toward an ecology of infrastructure: Design and access for large information. Information Systems Research 7(1), 111–134.

Stephenson, M., Di Lorenzo, G. and Aonghusa, P.M., 2012, March. Open Innovation Portal: A collaborative platform for open city data sharing. In 2012 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), (pp. 522-524). IEEE.

Tabak, M.A., Norouzzadeh, M.S., Wolfson, D.W., Sweeney, S.J., VerCauteren, K.C., Snow, N.P., Halseth, J.M., Di Salvo, P.A., Lewis, J.S., White, M.D. and Teton, B., 2019. Machine learning to classify animal species in camera trap images: applications in ecology. Methods in Ecology and Evolution, 10(4), pp.585-590.

Tagle, M., Rojas, F., Reyes, F., Vásquez, Y., Hallgren, F., Lindén, J., Kolev, D., Watne, Å.K. and Oyola, P., 2020. Field performance of a low-cost sensor in the monitoring of particulate matter in Santiago, Chile. Environmental Monitoring and Assessment, 192(3), p.171.

Taylor, S. and Todd, P.A., 1995. Understanding information technology usage: A test of competing models. Information systems research, 6(2), pp.144-176.

Taylor, A., Cocklin, C., Brown, R., and Wilson-Evered, E. 2011. An investigation of champion-driven leadership processes. The Leadership Quarterly, 22(2), 412-433.

Taylor, A. S., Lindley, S., Regan, T., Sweeney, D., Vlachokyriakos, V., Grainger, L., & Lingel, J. 2015, April. Data-in-place: Thinking through the relations between data and community. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 2863-2872). ACM.

Teli, M., Bordin, S., Blanco, M. M., Orabona, G., and De Angeli, A., 2015. Public design of digital commons in urban places: a case study. International Journal of Human-Computer Studies, 81, 17-30.

Thompson, R.L., Higgins, C.A. and Howell, J.M., 1991. Personal computing: Toward a conceptual model of utilization. MIS quarterly, pp.125-143.

Van Horn, G., Mac Aodha, O., Song, Y., Cui, Y., Sun, C., Shepard, A., Adam, H., Perona, P. and Belongie, S., 2018. The inaturalist species classification and detection dataset. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 8769-8778).

Venkatesh, V. and Morris, M.G., 2000. Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. MIS quarterly, pp.115-139.

Venkatesh, V. and Davis, F.D., 2000. A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science, 46(2), pp.186-204.

Venkatesh, V., Morris, M.G., Davis, G.B. and Davis, F.D., 2003. User acceptance of information technology: Toward a unified view. MIS quarterly, pp.425-478

Venkatesh, V., Thong, J.Y. and Xu, X., 2012. Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS quarterly, 36(1), pp.157-178.

Volten, H., Devilee, J., Apituley, A., Carton, L., Grothe, G., Keller, C., Kresin, F., Land-Zandstra, A., Noordijk, E., van Putten, E. and Rietjens, J., 2018. Enhancing national environmental monitoring through local citizen science. UCL Press.

Walsham, G., 1995. Interpretive case studies in IS research: nature and method. European Journal of information systems, 4(2), pp.74-81.

Weinstein, B.G., 2018. A computer vision for animal ecology. Journal of Animal Ecology, 87(3), pp.533-545.

Wilde, E., 2010. Linked Data and Service Orientation. In Service-Oriented Computing (pp. 61-76). Springer Berlin Heidelberg.

Zaltman, G., Duncan, R. and Holbek, J., 1973. Innovations and organizations. John Wiley & Sons.

Zolait, A.H.S. and Sulaiman, A., 2008. Incorporating the Innovation Attributes Introduced by Rogers' Theory into Theory of Reasoned Action: An Examination of Internet Banking Adoption in Yemen. Computer and Information Science, 1(1), pp.36-51.

Zuiderwijk, A., Janssen, M. and Dwivedi, Y.K., 2015. Acceptance and use predictors of open data technologies: Drawing upon the unified theory of acceptance and use of technology. Government Information Quarterly, 32(4), pp.429-440.

List of abbreviations and definitions

AI	Artificial Intelligence
API	Application Programming Interface
DLT	Distributed Ledger Technology
FWW	FreshWaterWatch – Case Study 2
LD/SC	Luftdaten and Sensor.Community – Case Study 3
MS/SCK	Making Sense and Smart Citizen Kit - Case Study 1
OSM	OpenStreetMap – Case Study 3
OSMF	OpenStreetMap Foundation

List of figures

Figure 1. Summary of Methodology 12
Figure 2. A Framework of Enabling Factors for Scaling in Citizen Science 19
Figure 3. MS/SCK: Scaling Communities through Narratives 32
Figure 4. Overview of FWW Projects 37
Figure 5. FWW: Infrastructuring through the Train the Trainer approach 38
Figure 6. Maps.Sensor.Community World Map 43
Figure 7. LD/SC: Platform-Enabled Virtuous Cycles 44
Figure 8. OpenStreetMap Homepage..51
Figure 9. OSM: Platform-enabled Network Effects..52

List of tables

Table 1. Taxonomy of Community Roles 24

Annexes

Annex 1. Summary of Clusters and root constructs

Overarching category	Constructs	Root Constructs
Elements intrinsic to the initial project to be scaled or spread	Proof of value	Relative Advantage, Observability (Rogers, 2010); Performance Expectancy (Venkatesh et al., 2012).
	Ease of Use and Understand	Complexity (Rogers, 2010); Effort Expectancy (Venkatesh et al., 2012); Perceived Ease of Use (Davis, 1989).
	Openness	Open Data, Open Source Software, and Openness more generally
Elements supporting the spreading and scaling process	Development and Dissemination of Narratives and consistent Communication Material	Communication channels (Rogers, 2010); Narratives and Communication Outreach (Ruddick, 2010; Balestrini, 2015).
	Community and Champions	Opinion Leaders (Markham, 2001; Rogers, 2010); Community Building and engagement (Rotman, 2012); Participatory Orchestration (Merkel et al., 2004; Crabtree et al., 2013; Balestrini et al., 2017).
	Knowledge Sharing and Transfer Resources	Facilitating Conditions (Venkatesh et al., 2012; Thompson et al. 1991).
Elements of the target socio-technical context	Alignment of Matter of Concern	Matter of Concern (Liu and Kobernus, 2017; Balestrini et al., 2015).

	Alignment of Legal Norms	Compatibility (Rogers, 2010); Normative Pressure (Venkatesh et al., 2003);
	Alignment of Social Values	Compatibility (Rogers, 2010);

Annex 2. The Framework and the Role of Technologies

Overarching category	Constructs	Scaling of technologies – key assumptions	Scaling by technology – key questions
Elements intrinsic to the initial project to be scaled or spread	Proof of value	Technologies with proven positive impact are more likely to be adopted in other interventions.	How can existing technologies increase proof of value of a given Citizen Science practice or outcome?
	Ease of Use and Understand	Technologies that are easy to use and understand are more likely to scale compared to technologies with opposite characteristics.	How can existing technologies increase ease of use and/or understand of a given Citizen Science practice or outcome?
Elements supporting the spreading and scaling process	Development and Dissemination of Narratives and consistent Communication Material	Technologies that underpin narratives are more likely to spread and scale. Technologies which are consistently communicated and disseminated are more likely to scale.	How can technologies enable or improve consistent communication and dissemination activities?

	Community and Champions	Technologies supported by communities and champions are more likely to scale.	How can technologies foster the creation of communities and champions?
	Knowledge Sharing and Transfer Resources	Technologies for which knowledge sharing and transfer resources are available, are more likely to scale.	How can technologies enable and/or augment knowledge sharing and transfer resources?
Elements of the target socio-technical context	Alignment of Matter of Concern	Technologies that have been proven successful in addressing a matter of concern are more likely to spread to contexts experiencing the same issue.	Not prominent in the scaling by technology discourse (unless technology is the actual aligned matter of concern)
	Legal Alignment	Technologies that are more compatible with the target context's legal framework are more likely to scale.	How can technologies foster legal alignment across contexts?
	Alignment of Social Values	Technologies that are more compatible with the target context's social values are more likely to scale.	How can technologies foster alignment of Social Values across contexts?

KJ-02-20-911-EN-N

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office of the European Union

doi:10.2760/00926

ISBN 978-92-76-25157-6