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From Needs to Knowledge

A reference framework for smart citizens initiatives

AMS project report

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Content

Project title

From Needs to Knowledge: a reference framework for smart citizens initiatives

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Management summary

Citizens are a fundamental component for the success of the smart cities vision. The *actor-observant* duality of people in urban environments is one of the key arguments of the smart cities debate: how can citizens be empowered in the detection, analysis, and solution of modern urban challenges? How can public authorities support collective awareness, encourage social deliberation, and drive positive behavioural change? How can inclusive decision making processes be enabled that are also effective and sustainable? Which role can universities and private organizations play in this picture? These questions help frame the multi-actor and multidimensional nature of the *smart citizen* discourse and point to some of the most important challenges that affect the systematic and durable success of *smart citizen* initiatives.

In this white paper we outline a conceptual framework aimed at providing a foundation for the *smart cities* versus *smart citizens* debate. This document is targeted at readers who are interested in the topic, but it does not require any advanced conceptual or technical knowledge in this field. Our goal is to inform the development of future *smart cities* efforts centred around citizens by identifying and relating important areas of research and experimentation.

We engaged in discussions with eight key actors of the smart cities arena. They are stakeholders having different background in, experience with, and opinions about the challenges and opportunities offered by the involvement of citizens in the management of modern cities. We survey the state-of-the-art and the state-of-the-practice in *smart citizens* initiatives, focus on the emerging domains of *citizen sensing*[1], social mobilisation, and social innovation and deliberation. We identify four main actors in the

[1] "A modality of citizenship that emerges through interaction with computational sensing technologies used for environmental monitoring and feedback". Since this is an emerging research domain, the vocabulary is still inconsistent. Both in literature and in our interviews we encountered for instance crowd sensing, citizen science, and participatory sensing [Gabrys 2014]. In this paper we use citizen sensing to denote the general concept; citizen science when a scientific objective is supported, and participatory sensing when citizens are invited to contribute to environmental challenges generally monitored by public authorities.

smart citizen discourse (*public authorities and civil society organisations*, *academia*, *the private sector*, and *citizens* themselves); we describe their roles and needs; and we analyse three key challenges (*participation*, *inclusiveness*, and *quality and trustworthiness*) that they face when engaging in smart citizens initiatives.
We then discuss a unified vision for *smart citizen* initiatives. The vision builds on a generalised, nine-step model of citizen participation, and it includes the notion of the *Urban Knowledge Collider* (UKC), a socio-technical system supporting collaborative actions, assessments, and decision-making in urban environments. We use the experience of the Amsterdam Smart Citizens Lab (ASCL) as a use case, by relating it to the general model and describing the outcomes of a recent, real-world crowd-sensing initiative.

Chapter 1. Introduction

From 2008, the recurrent theme of the Smart City has rapidly entered the debate about the future of the cities we live in. Envisioned as a technological solution to problems including logistics, sustainability, well-being and crime, it stresses the potential for improving efficiency, comfort and control as much as it ignores notions of agency (enhancing the power of citizens to change things), participation (empowering people to solve problems collectively), and inclusion (involving a wider spectrum of people in decision making processes). Recently, this technology-centred view has given way to a more nuanced, citizen-centred approach to smart cities, recognising that citizens are the lifeblood of the city ecosystem. They live the urban environment, and contribute to its existence and development. They produce and consume resources and services, build and break relationships, and foster their well-being in the pursuit of a better quality of life.

> "The urban environment is increasingly conceptualised as a complex techno-social network. The city, however, only meaningfully exists when it is occupied by a sustained stream of people. In this sense, people are the core of the city."
>
> [Foth 2012]

Because citizens are at centre stage, they also have a privileged viewpoint over the status of the city and can be considered to be the most accurate sensory receptors of the city's nervous system. They are a core part of the urban fabric; as such, they can observe and feel changes that affect their well-being and quality of life, and promptly react to unsustainable variations. These changes might be of environmental, public safety, infrastructural, or personal nature. For instance, citizens might sense problems related to air or water quality, or with noise; they might also witness criminal activity or find issues with roads, traffic, and other public properties (e.g. parks). Furthermore, they have the capacity to act upon their insights by changing their own behaviour, convincing others to do so, or engaging in public policy debates and actions.

The fact that citizens are both actors and observers of the cities they live in has become widely recognized as the key argument to acknowledge the central place of citizens in the smart cities debate. The term smart citizen (or smart community) characterises inhabitants of a city that engage in collective awareness building [Sestini 2012], meaning that through social media and decentralised, open urban infrastructures, they take an active role in the sensing of, organisation of, and response to both long-standing and emerging urban issues.

Advances in Web-based communication (e.g. social media, social deliberation platforms) and physical sensing technologies (e.g. Arduino-powered, low cost sensors) allow smart citizens[2] to engage in data collection, information creation, and decision making in the city. At the same time, city administrators and policy makers can use these developments to enhance their understanding of the city and foster positive behavioural change.

"In 2014, one hundred "Amsterdammers" were equipped with low cost, open source sensor Smart Citizen Kits measuring temperature, humidity, light, sound, carbon monoxide and nitrogen dioxide. During several months, the measurements of these kits were sent to the online platform *smartcitzen.me* and the Amsterdam City Dashboard. Meanwhile, meetings were held where participants got up-to-speed on the hard and soft science of air quality measurements, as well as the politics behind them. In this way, networks of citizens and partner institutes were established that still exist today.

Based on the learnings of this project, Waag Society, Municipality of Amsterdam, RIVM (National Institute for Public Health and the Environment), HvA (Amsterdam University of Applied Sciences), AMS Institute and the Amsterdam Sensemakers community established the Amsterdam Smart Citizens Lab in 2015. It's goal is to enable citizens to build and use open source technology to collectively understand their environments, based on their own interest and efforts, while being helped by environmental experts and technologists. The Lab had its first edition from May till December 2015, in which over forty people regularly participated."

The Amsterdam Smart Citizens Lab is described in detail in a separate result from the From Needs to Knowledge Stimulus project [Laurence 2016]

[2] http://futureeverything.org/wp-content/uploads/2014/03/smartcitizens1.pdf

As suggested in an EU-commissioned study on Digital Social Innovation [Bria 2015], there is a growing motivation for citizens to collectively engage in participatory sensing that stems from their acknowledgement that environmental issues, such as increasing levels of air and noise pollution, have detrimental effects on their health and well-being. The public motivation is strengthened by the sense that existing institutions and authorities cannot be relied on to tackle these detrimental events. At the same time, many official institutions themselves increasingly understand that they need the collaboration with citizens to come up with richer data and therefore a more complete understanding of the urban condition. This should, in turn, lead to enhanced policies and healthier cities.

Many initiatives, like the development and deployment of the *SafeCast* radiation level sensors after the Fukushima nuclear power plant disaster in 2011 and the Amsterdam implementation of the Smart Citizen Kit in 2014, have showed some of the potential of this paradigm shift in smart cities research and practice. On the other hand, experience shows that there are several problems and open issues that hamper the large-scale and sustainable transformation of citizens into smart citizens.

This paper sheds light on several aspects of the domain of citizens sensing. It is targeted at readers who are interested in the topic of smart cities versus smart citizens, but it does not require any advanced conceptual or technical knowledge in this field. We have interviewed eight stakeholders of different backgrounds, and studied the motivation of the participants in the Amsterdam Smart Citizens Lab. Based on this research and recent literature, we identified trends, successful practices and challenges for smart citizen projects in the near future.

In Chapter two we introduce several examples of smart citizen initiatives, categorized under social mobilisation, environmental monitoring and citizen science, and deliberation and citizen innovation. Then we describe the actors typically found in the smart city landscape, categorized under public authorities and civil society organisations, academia, the private sector, and citizens themselves.

Based on these categories, we define common challenges in smart citizen initiatives, participation, inclusiveness and participation bias, and quality and trustworthiness. Chapter three presents a unified vision for smart citizen initiatives. It outlines a generalised model for smart citizens initiatives in nine discrete steps. Then, the Amsterdam Smart Citizens Lab model is described and related to the general model. Finally, we introduce the notion of the Urban Knowledge Collider, or UKC. UKCs allow relevant urban stakeholders to engage with each other and leverage their collective expertise and experience in an environment combining virtual worlds based on physical models, real-time, multimodal data streams, and sophisticated visualisation tools to support actions, assessments, and decision-making.

Finally, Chapter four presents our general conclusions and recommendations.

Chapter 2. Opportunities and Challenges in Smart Citizen Initiatives

The advent and massive diffusion of social networks, Wiki's, and other Web-based social interaction systems has sparkled an unprecedented level of activity and contribution of citizens to the public discourse. At the same time, these systems enable a better and more symmetric dialogue between citizens, public authorities, research institutions, and the private sector.

Thanks to a closer dialog with the population, public administrations can benefit from a more effective control over the urban area and its resources, faster and targeted collection of relevant data, and more timely reaction to potentially hazardous events. Citizens, on the other hand can foster their own "political programme" by being involved in the planning, execution, and quality evaluation of public services; providing feedback and suggestions; participating in the construction, curation, verification, and even analysis and enrichment of urban-related information; and, in general, experiencing a more inclusive role in the administration of the public good.

How can these different organisations and individuals learn and benefit from the vast amounts of aggregated and shared data? And how can the resulting information and understanding support different and valuable perspectives on common problems or interests eventually lead to new and innovative solutions? This Chapter first provides an overview of previous initiatives that featured the successful involvement of smart citizens in scientific and societally relevant campaigns. From these experiences, success factors, obstacles, and challenges emerge. The perspectives of eight professionals who were interviewed about their vision on smart cities and smart citizens shed further light on these opportunities and challenges and conclude this Chapter.

2.1. Examples of Smart Citizen Initiatives

This section provides an overview of successful involvement of smart citizens in scientific and societally relevant initiatives. To account for differences in purpose and expectations, the survey distinguishes three classes of projects, namely Social Mobilisation, Environmental Monitoring and Citizen Science, and Deliberation and Citizen Innovation.

Social mobilisation can be defined as a planned decentralised process by which individuals or communities are engaged into achieving a specific development goal through self-reliant efforts. The process involves a range of players engaged in interrelated and complementary efforts and seeks to empower individuals and groups for action. It is typically initiated as a response to external stimuli, like in the aftermath of natural disasters [Liu 2011, McCormick 2012], hunting down wanted outlaws on the run, reacting to health threats that need instant attention, or rallying supporters to vote in a political campaign [Pickard 2010].

A typical example of spontaneous social mobilisation is the volunteer work of radio amateurs in the aftermath of Hurricane Katrina, performed to provide emergency dispatch services in areas that experienced severe communication infrastructure damage [Krakow 2005]. During the Haiti Earthquake of 2010, the Ushahidi platform allowed the coordinate action of Haitian citizens and international volunteers to aggregate and organize (temporal and geospatial) reports of the damage and the disaster-affected population's urgent needs in order to create an accurate and unmediated view of the emerging situation [Meier 2013].

A successful example of centrally initiated, yet autonomously executed social mobilisation is the famous DARPA Red Balloon challenge[3]. The challenge was set to explore the roles the Internet and social networking can play in the solution of broad-scope, time-critical problems through (urgent) social mobilisation. The challenge was to identify the locations of 10 moored, 8-foot, red, weather balloons positioned in 10 fixed locations in the continental United States. Balloons were placed in public sites, visible from nearby roads. DARPA personnel in the location issued certificates validating each balloon location. The challenge demonstrated the variety, efficiency, and effectiveness of crowdsourcing solutions to a distributed, geo-located, time-urgent problem [Tang 2011]. A team from the Massachusetts Institute of Technology (MIT) won the challenge in 8 hours, 52 minutes, 41 seconds; their strategy involved the creation of a platform for viral collaboration that used recursive incentives (financial rewards) to align the public's interest with the goal of winning the challenge. Other teams relied on cyberspace-search techniques purely based on mass-media advertisement and social media recruitment without explicit incentive mechanisms. These engagement techniques were

[3] http://archive.darpa.mil/networkchallenge/

less expensive, but also less performing, especially in situations where participants could not be recruited in advance.

Environmental Monitoring and Citizen Science

Citizen science can be defined as scientific research conducted, in whole or in part, by amateur or non-professional scientists[4]. Thanks to lower barriers for entry due to the ubiquity of cheap software and hardware solutions, as well as means of communication, it is now common for large crowds to volunteer their time and resources, following their intrinsic motivation of contributing to “real science”. Citizen scientists have worked with professional scientists to collect data for centuries. Today, many examples can be found in domains such as astronomy, biology, and environmental monitoring—NASA’s Clickworkers program and the Galaxy Zoo initiative, for instance. The former, launched in 2000, asked participants to look at images of the Martian surface from the Mars Global Surveyor spacecraft and record the positions of craters in order to determine the age of surface features [Kanefsky 2001]. Galaxy Zoo is a project that aims at providing visual morphological classifications for nearly one million galaxies, extracted from the Sloan Digital Sky Survey.

The project is still ongoing and managed to engage hundreds of thousands individuals in the creation of millions of classifications [Lintott 2008]. A recent survey involving more than 11 thousand Galaxy Zoo volunteers showed the breadth of motivations that can move citizens in the participation of these initiatives—from learning to fun, from interest in the topic to community building, from teaching to pure altruism.

A pervasive example of citizen science initiatives belongs to the realm of environmental monitoring, where citizens voluntarily participate in the collection of physical data by means of observations or through the creation and deployment of physical sensors. The process of citizen engagement in environmental monitoring is often referred to as participatory sensing, to underline the role played by large groups of people in gathering, analysing, and sharing local knowledge. The idea is simple: although there exist governmental agencies that monitor physical properties such as rainfall, noise levels, air pollution, etc., these agencies are limited in their sensing capabilities by the number of deployed sensors, usually static and located in public spaces. The goal is to complement (or even substitute) such an expensive and scattered sensing infrastructure, thus “filling in the sensing gaps”. Knowledge is temporally and spatially characterised, so to provide thematic maps of urban environments such as: “crowdedness maps”, to show how crowded are places in the city at different times; maps of noise levels; maps of areas with available parking lots; emotional maps, reporting where people feel happy and/or safe [Tisma 2015]; or simply maps of city-related issues[5], used to facilitate city governance. Participation in environmental monitoring is often achieved by means of mobile phones and/or mobile infrastructures, humans control and direct the use of embedded sensors, and interacting with Web-based tools to create information maps of a studied phenomenon.

[4] https://en.wikipedia.org/wiki/Citizen_science
[5] http://www.wired.com/2014/03/potholes-big- data-crowdsourcing-way-better-government/

By engaging citizens in sensing activities, these agencies can obtain a much more accurate picture by increasing the number of sensors on the ground and thus include measurements from private spaces like cars or homes. On the other hand, citizen participation, when properly stimulated, can lead to awareness and mobilisation, thus simplifying the application of unpopular yet necessary policies.

While literature and practice are full of examples of participatory sensing projects, we decided to focus on six that we deemed relevant due to their scientific nature, or due to their level of maturity and spread of application. The Dutch citizen science phenology network (called Nature's Calendar, the "Natuurkalender"[6] [van Vliet 2014]) is a successful example of a long-running citizen science initiative. This project was started in 2001 to catalogue phenological changes as indicators of ecological impacts due to climate change, and it involves the general public in monitoring the timing of life cycle events (e.g. first flowering of plants and first appearance of butterflies).

The initiative not only aims to monitor climate-induced changes in the timing of yearly-recurring life cycle events, and determine ecological and socio-economic impacts of phenological changes; it also increases public awareness of these changes and their impacts. It then develops and implements tools and methodologies that allow the society to adapt to the changes, such as facing health effects of hay fever season. In 2013, 8.500 volunteers contributed to observing and recording the timing of phenological events (of plants, birds, butterflies, dragonflies, wasps, amphibians, mammals, and reptiles) in their own streets, gardens, and surrounding properties.

SafeCast is a network of concerned citizens created after a devastating earthquake and tsunami struck eastern Japan on March 11, 2011 and caused the meltdown of the Fukushima Daiichi Nuclear Power Plant. To compensate for the lack of accurate and trustworthy radiation information, SafeCast is a remarkable example of a grassroots DIY (Do It Yourself) project that, in the words of its own founder, does not aim at "... *singling out any individual source of data as untrustworthy, but rather to contribute to the existing measurement data and make it more robust. Multiple sources of data are always better and more accurate when aggregated.*" By January 2015, SafeCast had aggregated and published more than 27 million measurement data points[7], providing information on nuclear risks and air pollution in several countries including Japan, China, South Korea, Macao, Australia, Ireland, Austria, and the United States [Yasuhiko 2014]. The SafeCast network put particular emphasis on events and activities (e.g. workshops, hackathons, etc.) as an important part of communication, community building, and recruitment. Social media proved to be a very useful tool to link the capabilities of network members with the needs of concerned citizens while playing a role in enhancing collective intelligence.

The NoiseTube project [Maisonneuve 2009] relied on GPS-equipped mobile phones to investigate a participatory and people-centric approach to noise monitoring. The goal was to create a low-cost, open platform to measure, annotate, and localise noise

[6] http://www.natuurkalender.nl/
[7] http://safecast.org/downloads/safecastreport2015.pdf

pollution as it is perceived by the citizens themselves to inform government officials and the general public. Authors recognise the importance of enabling citizens with measurement tools to test their personal noise exposure in their daily environment, raise awareness of environmental issues, and, ultimately, effect change. The NoiseTube platform was designed with multiple requirements in mind. First, the platform needed to support local democracy and citizen science by providing a virtual and virtuous environment of participation and accountability. By making participants and their activities visible to one another, NoiseTube created awareness, accountability, a heightened level of motivation via social comparison, and the perception of self-efficacy by showing the value of participants' contributions. Second, the platform aimed at enabling *opportunistic participations*, i.e. the extemporary involvement of citizens due to motivations that are neither based on volunteering, community belonging, nor personal interest, but instead by, for example, curiosity.

The WideNoise smartphone application [Becker 2013], developed in the context of the European project *EveryAware*[8], has been designed and experimented to record both objective and subjective data related to noise. The application allowed users to record, monitor, analyse, and submit noise pollution reports. Participants were also required to provide both the noise sampling component and the perception tagging, i.e. feelings about their current environment defined over four categories (love/hate, calm/hectic, alone/social, nature/man-made). Participants could also try to guess the level of noise around them, thus gamifying the sampling experience. The project had a top-down recruiting method: participants were involved using both virtual (online advertising, local media) and physical (e.g. flyers, posters) recruitment tools. The WideNoise application is currently available on the Apple store[9] and the Google Play store[10], however, being developed in the context of an EU-funded project, further development of the app (and the initiative) is uncertain.

CitySourced[11] is an example of a civic engagement platform that found a commercial (and sustainability) dimension by centralising and valorising citizen engagement with urban problems. CitySourced provides a mobile app in order for citizens to identify and report non-emergency civic issues, such as public works, quality of life, and environmental issues. As of 2014, the application has been deployed in 7 countries (United States, Canada, Australia, Panama, United Kingdom, United Arab Emirates, and Bermuda), and used by 40+ million users[12]. The application allows citizen to take a (geo-located) picture related to an issue (e.g. crime, graffiti, potholes, broken street lights) using the smartphone's camera, categorizes the problem using the application's pull-down menus, then submits the incident to the city's work order queue. Municipalities subscribe to the dataset generated by CitySourced to improve services at affordable costs. CitySourced also incorporates a Civic Crowdfunding Platform for organisations to raise funds for civic projects, thus opening to the possibility of citizen-sponsored projects, possibly executed by professionals or external companies.

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[8] http://www.everyaware.eu/

[9] https://itunes.apple.com/app/id657693514. Last access: December 2015

[10] https://play.google.com/store/apps/details?id=eu.everyaware.widenoise.android. Last access: December 2015

[11] http://www.citysourced.com

[12] https://en.wikipedia.org/wiki/CitySourced

In 2014 the Smart Citizen Kit [Balestrini 2014], developed by Fablab Barcelona, was introduced in Amsterdam by a consortium consisting of the Waag Society, Amsterdam Smart City and the Amsterdam Economic Board. The Smart Citizen Kit consists of an open source hardware device, a website where data are being visualised, an API, and a mobile app. The low-cost sensors in the hardware device measure CO and NO2, temperature & humidity, light intensity, and noise levels. This kit was used for the ASCL (see the inset in Chapter one).

Deliberation and Citizen Innovation

The concentration of people in cities is believed to create a critical mass of diversity that, in turn, should provide opportunities for innovation in new technologies, services, and business models [Glossop 2007]. Participation and collaboration between public authorities, citizens, and the private sector is seen as essential in the development of smart communities and, ultimately, smart cities. Examples include the generation, organisation, and selection of ideas and initiatives through community-wide discussion and deliberation, often performed with online voting and debates, campaigning, and petitioning [Medaglia 2012]. Studies suggest a correlation between cities' adoption and implementation of sustainability policies and public participation in policy formulation [Portney 2010]. Online-mediated approaches to social deliberation are particularly relevant to local communities, as a means for increasing transparency and participation on local policies and shared resource planning and management. Citizens, but also entrepreneurs and public servants, can play a central role in providing latent yet first-hand knowledge about a city's problems; rules and procedures become potential spaces for experimentation, where changes are often inspired by such new knowledge.

To increase political engagement, recent years have seen an increase in the number and nature of technologically driven participation projects. Urban Living Labs were born as public spaces within which city governments engage citizens and steer co-design processes towards the development of innovative city services [Eskelinen 2015]. To tap the latent knowledge of their citizens, governments and (local) administration develop, host, and control proprietary systems that allow users to receive information, discuss issues at hand, submit new issues and proposals, and vote on them.

For instance, the Avoin Ministeriö (Open Ministry) [Christensen 2015] Finnish initiative is a website that allows users to draft citizen initiatives and deliberate on their content. Avoin Ministeriö has been instrumental in creating support for several of the most successful initiatives during the period, showing that the website has been a key actor during the introductory phase of the Citizens' initiative in Finland.

In other instances, third-party partnerships (often driven by universities) act as the middleman in offering solutions that benefit both cities and their citizens. For instance, the MK: Smart[13] smart city project developed an innovative solution to support growth in Milton Keynes. The core of the project is a "Data Hub" that supports the acquisition

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[13] www.mksmart.org

and management of data including data about energy and water consumption, transport data, data acquired through satellite technology, and social and economic datasets [Gooch 2015]. The goal of the project is to act as a growth catalyst for all the parties involved in the Smart City discourse. For instance, it serves as a data-driven innovation and incubation centre, providing hands-on support for business development, demonstration facilities, and an incubation space. It also offers education on city-related matters targeted to a wide range of audiences, from local schools to higher education students and businesses.

D-CENT[14] (Decentralised Citizens ENgagement Technologies) is a European project bringing together citizen-led organisations that have transformed democracy in the past years, and helping them in developing the next generation of open source, distributed, and privacy-aware tools for direct democracy and economic empowerment. It focusses on four areas: notifying citizens about issues that matter to them; helping citizens to propose and draft civic solutions and policy collaboratively; helping people make collective decisions; and implementing transparent reward schemes for those who participate. D-cent has so far developed tools for collaborative policy making, setting citizen priorities, and assisting in participatory budgeting, open authentication and identity management, and open blockchain reward schemes.

The Open Cities project[15], co-funded by the European Union, aimed at validating how to approach Open & User Driven Innovation methodologies to the Public Sector in a scenario of Future Internet Services for Smart Cities. The project started in November 2010, ran for 30 months, and involved experiments in seven major European cities: Helsinki, Berlin, Amsterdam, Paris, Rome, Barcelona, and Bologna. Partners leveraged existing tools, trials, and platforms in Crowdsourcing, Open Data, Fiber to the Home and Open Sensor Networks. Open Cities developed the methodology of Urban Labs that facilitates companies to use the public space as a testing ground for new services; it developed a new open data store, mobilised app developers in several hackathons (which were then quite new) amongst which Apps for Amsterdam, and it performed several pilots in crowdsourcing issues of concern by citizens-notably in Amsterdam as well.

[Schuurman 2012] presents an attempt to use a crowdsourcing platform to better understand the process of generating, evaluating, and selecting innovative ideas for Smart City innovation. In the context of a project created in and for the Belgian city of Ghent (the Mijn digitaal idee voor Gent, or Ghent Living Lab), citizens could submit and evaluate ideas for smart city innovations. Representatives of the city evaluated all of these crowd-sourced ideas on three criteria: innovativeness, feasibility, and user benefit. Researchers found crowd-inspired ideas to score relatively low on innovativeness, although the benefits derivable from such ideas were found to be more beneficial than the benefits achievable from ideas created by a selection of Smart City professionals. This indicates that while ideation through crowdsourcing does not yield radical, breakthrough ideas, users seem better able to create ideas that provide solutions to their problems compared to experts.

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[14] http://dcentproject.eu/
[15] http://opencities.net/

[Desouza 2012] reviewed 20 “citizen apps” created by developers external to the current urban discourse. Findings shown that this sort of grassroots initiative have the potential to be the source of social improvement; on the other hand, their creations require expertise that is not readily available to the average citizen. These “citizen apps” were developed with citizens in mind but not necessarily with their involvement, thus creating a gap between the needs imagined by the developers and the needs actually perceived by citizens.

Most of the time, such technologies are not created ad-hoc. They are adapted from previous functions to support discussion and deliberation initiatives. An example of such re-purposed technologies is social media applications: active engagement (e.g. by means of online polls or Facebook game applications) tools are now standard for informing citizens of services, public policies, and for education purposes. “Passive” analysis and interpretation of ongoing discussion on social media can provide administration with better insights about their territory, thus helping to elicit potential issues before they become real problems. An important barrier to adoption is the great heterogeneity that characterizes the representation, semantic, and resolution of Web data sources. This is of particular importance to the social discussion and deliberation processes, which can largely benefit from the simultaneous combination of heterogeneous urban information as well from a normalisation of the adopted terminology.

Several academic initiatives proposed integrated solutions for integration, creation, and interpretation purposes. An example of initiative devoted to this purpose is the SocialGlass project. SocialGlass is a Web-based platform that supports the analysis, integration, and visualisation of large-scale and heterogeneous urban data with application to city planning and decision-making. The development of SocialGlass was motivated by the non-scalable character of conventional urban analytics methods as well as by the interoperability challenges present in contemporary data silos [Psyllidis 2015a, Psyllidis 2015b]. The platform provides services for the semantic enrichment and integration of user generated data, municipal records, and sensor and social media inputs. SocialGlass provides a coherent representation framework that simplifies the usage of urban data and unlocks their combined value.

The list of initiatives reported in the previous section is just a sample of a vast corpus of experiments, projects, and collaborations that dates back at least eight years. Altogether, they provide a clear message: smart citizen initiatives, in all their forms, can contribute in a significant way to the development of cities and, ultimately, to the improvement of city life. A lot could be extrapolated from the experience, successes and failures of such an amount of work: while this white paper is not intended to provide an exhaustive account of all the initiatives developed so far, we consider it as a first step towards the creation of a public repository of smart citizens initiatives that could be used as reference and inspiration for future endeavours.

2.2. The Actors of the Smart City Landscape

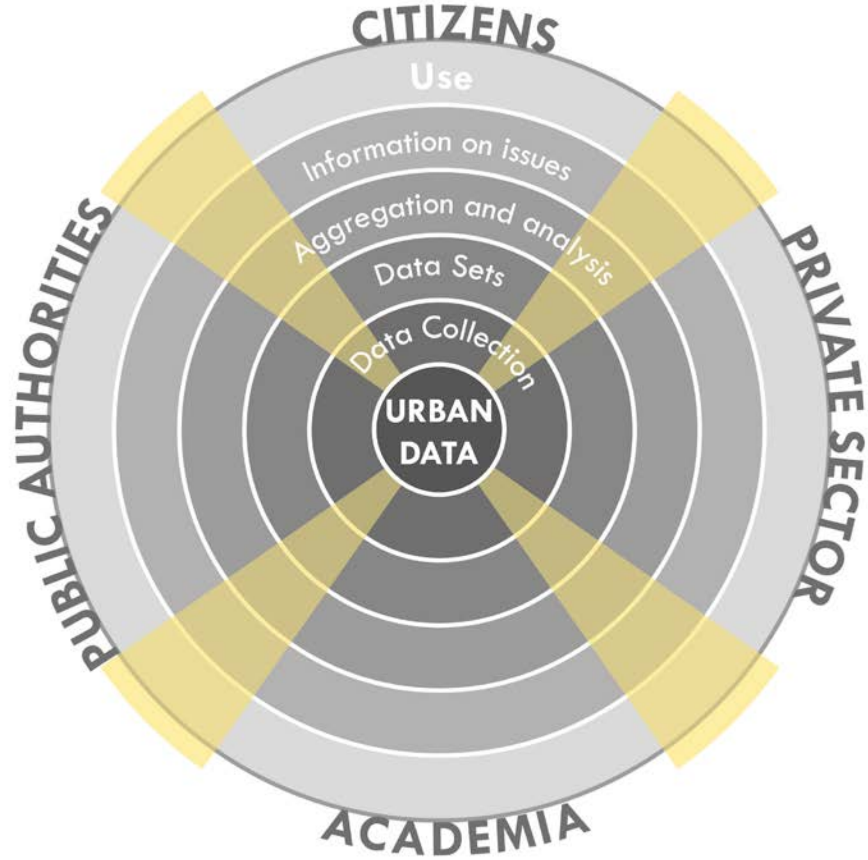


Figure 1. The actors

The previous chapter examined successful involvement of smart citizens in scientific and societally relevant initiatives in a range of domains. We now take a closer look at the actors involved in smart citizen projects: public authorities and civil society organisations, academia, the private sector, and the citizens themselves. Although the needs of these four stakeholder groups differ, their goals often overlap. An example given by Ger Baron, CTO of the Municipality of Amsterdam, illustrates this: "*We all want better and more accurate meteorological data because we all want to know if we need an umbrella today or not. Digital data by themselves tell us nothing, but what they mean to us is what matters*".

This chapter presents views of professionals on the common goals of actors who participate in the smart citizen discourse and also on differences in their needs. These differences concern the information time frame/scale and their ultimate objectives when participating in a project in relation to their responsibilities.

Public authorities and civil society organisations: develop vision and support

Governments increasingly adopt new ways of thinking about participation, the environment and governance. These ideas reach beyond traditional consultation towards functional, collaborative, and transformative participation in which local people make and implement decisions with support from “experts” when needed. However, the role of public authorities is a major topic within the citizen sensing debate. As pointed out by Ton Dassen (PBL, Netherlands Environmental Assessment Agency): *“With the breakdown of institutions, societal developments and innovations are more diffuse and less predictable. Traditional policy development is not effective anymore: the government has lost power. It can only react and cannot anticipate. The society moves now a lot faster than the governmental policy processes”*.

Many Western European governments are increasingly eager to stimulate or facilitate forms of community-based monitoring (CBM) and citizen science. Cuts to government services have led to a reduction in environmental monitoring which means that some important data are no longer being collected by government agencies [Conrad 2011]. Besides providing complementary forms of knowledge, citizens fill gaps in monitoring tasks through community based monitoring (CBM), for instance on water quality and tropical forests [Conrad 2011].

Local, every day, non-scientific knowledge can sometimes do more justice to the local context than abstract scientific knowledge, and it may even help solve environmental problems more effectively [Johnson 2015]. Local citizens are the real experts on their surroundings and well-being in relation to the environment, so how can public authorities make better use of this collective knowledge acquired through individual- or community-based data collection?

National research institutes such as the Dutch RIVM (National Institute for Public Health and the Environment) are closely following the impact of ICT developments, especially sensor technology, on society. Hester Volten (Researcher Air Quality at the RIVM) remarks that at the moment authorities such as the ministries have as yet no strategy to utilise these opportunities. Traditional monitoring networks, such as those on air quality, produce the data required by European legislation and measurement requirements. The urge to involve citizens in monitoring is therefore not strong. However, using citizen data may have benefits in a number of ways: because of the higher number of samples, the spatial resolution and accuracy of the measurements will increase with relatively low costs. This allows local authorities to intervene and address very local problems a specific street or neighbourhood, for example. Ultimately, citizens’ understanding and awareness of environmental problems will improve.

The dissemination of knowledge and data has already empowered citizens to a certain extent, and the increasing empowerment of self-organisation has its consequences for policy makers. According to Ger Baron, the role of the government in the future is still unclear: “*Who will be responsible for this change? The government’s role will be smaller, not in terms of responsibility, but in terms of taking actions. More will be done* *by other segments of society*”. But the role of the government might be to give guidance to smart citizen initiatives.

Learning how to support such initiatives is a great challenge for public authorities that are already convinced about the positive aspects of citizen participation in data collection. The Municipality of Amsterdam is investing in its data capacity by increasing the ICT team from 10 to 40 people in the coming year. New professionals will focus on data analytics, application development, prototyping, and prediction. According to Ger Baron, “*data is complimentary for the municipality, to be combined with existing material and therefore revealing impact that now goes unnoticed. The unexpected combination of different data sets might give us new useful perspectives on things. This is what citizen science is about: adding different perspectives to an analysis in order to enrich the result*”.

Academia: cooperate and progress

Smart Cities, Smart Citizens, Open Data, Big Data: researchers are involved in developing technology, designing applications, and studying how they affect the individual, society and the environment. Smart Citizens are not only objects of study or users of these innovations. They also contribute directly to research projects as data producers, either by allowing their behaviour to be tracked and analysed or by actively participating in data collection in, for instance, citizen sensing projects.

Knowledge is no longer the sole concern of scientists. Members of the public are actively weighing the usefulness and relevance of scientific information. Moreover, public trust in environmental research is sometimes low, leading citizens to investigate how they can measure environmental quality themselves, as illustrated by successful initiatives described in Section 2.1. What do academics think about Smart Citizens and their role in society? What are the major challenges for the near future?

> "A smart city is an adaptive city, which has a high capacity to react to changes. Adaptation is the key, either by evolution or by learning. Citizens play a major role by reacting on events, listening and absorbing information. This learning should be done in a community, in combination with other parties. The learning capacity of the whole constellation of stakeholders is the key.”
>
> **Arnold Bregt**, professor at Wageningen UR and principle investigator at AMS Institute

Arnold Bregt, professor at Wageningen UR and principle investigator at AMS Institute believes that “*experiments and pilots on citizen science are important, and are part of the continuous process of learning. In this process, governance and communication – for instance good feedback to citizens – are the most important instruments to improve* *citizens' involvement*". Citizens are more than instruments for data collection. Participatory sensing is a cyclic process involving different stakeholders and requires reciprocity. "*I do not believe in citizen science as an independent action; it is always a combination between citizens and organisations which generate, validate, and use the data.*"

Bregt explains that intrinsic motivation, for instance emotional attachment to the topic, and personal relevance may contribute to continued engagement of citizens. However, "*The professional organisation must keep on stimulating citizens and provide them with something in return: feedback makes people engaged.*"

Research is also needed to understand the impact of environmental factors on the perceived well-being of citizens, and on the subjective, qualitative or quantitative data that citizens may want to collect. Citizens are often involved in issues that are very local, pertaining to their microenvironment and are interested in the experience of noise nuisance and effects on their health and well-being—not just the measuring of decibels. Although smartphones, sensor networks, and open data facilitate access to a huge amount of data, users are generally not able to interpret and combine these data themselves and turn them into meaningful information without help from experts in (geo-)ICT, and data analysis.

The subjective experience of well-being is an important factor relevant to Quality of Life (QoL), which is a constant societal concern, also in the European context. [Costanza 2008] defines Quality of Life as "the extent to which objective human needs are fulfilled in relation to personal or group perceptions of subjective well-being". The Eurostat article Quality of life[16] distinguishes a set of 8+1 indicators for QoL, including Health, Natural and living environment, and Overall experience of life. The EU-FP7 project, "European Framework for Measuring Progress," stresses the importance of new data sources, including non-official data, to measure people's well-being and societal progress in a more comprehensive way. This aligns with European intentions in developing dynamic information flows of social and environmental interaction by exploiting, among others, social networks and user generated information [Annoni 2011].

Citizens themselves can act as sensors and analysts of their environments by interpreting sensory data, facilitated by Web 2.0, and mobile technology that produce real time geolocated data (Boulos et al. 2011; Elwood et al. 2012; Goodchild & Glennon 2010). Examples in the Netherlands include: assessments of malodours of livestock; their impact on individual well-being, health, and activities; the experience of regularly occurring earthquakes as a result of gas extraction; and the experience of noise, as included in the WideNoise application mentioned earlier (EveryAware project [Becker 2013]).

Involvement by academia will be required to support production, collection and use of subjective data on perceptions of well-being and health in relation to environmental

[16] http://ec.europa.eu/eurostat/statistics-explained/index.php/Quality_of_life_in_Europe_-_facts_and_views_-_overall_life_satisfaction

factors, for instance through example questionnaires and scales. This support is necessary because the intrinsic subjectivity and multidimensionality of perceived well-being and other quality of life-factors complicate the measurement and use by non-experts. Moreover, if the method for assessment of these constructs is not considered valid and reliable, and it does not lead to understanding of its determinants, the results will neither be taken seriously nor effective in governance processes.

The Private Sector: looking for opportunities

The independent character of the Smart Citizens' initiatives and the societal or environmental benefits related to the results trigger citizens who desire to make a positive contribution to society. This may partly explain the shy participation of the private sector in the field of citizen sensing. Companies seem to be underrepresented in Smart Citizen initiatives and were hardly mentioned during the interviews conducted for this vision document. This is not necessarily negative. As Jonathan Carter points out: "*Thankfully most of the Smart Citizens' projects are, so far, non-commercial. Once it becomes highly commercial, one feels that they are placed in a sort of fake, made up community and the social impact makes less sense. The pioneer status of the experience is very motivational*."

The private sector is already involved in producing and utilising urban data, but not yet in structural cooperation with citizens and the public sector. Without a strong drive, companies will not change their strategies or processes. Joost Eijkman, Strategy advisor at the Dutch water company at Evides explains that his company has a monopoly in the region and therefore no real urge to investigate clients' needs extensively. However, utility companies that also want to improve their customer relations are aware of the developments in the fields of sensors and smart citizen technologies and want to accommodate citizen demand for changes in society.

Even for private companies that do not operate for profit, there are numerous barriers slowing them from getting involved with citizens and data. According to Joost Eijkman: "*The government should stimulate and make all data and information (of general interest) they produce and own available and accessible. At the moment, privacy policy is still an issue. For example, water usage information that could help other parties when shared cannot be made available. Deciding when to make information accessible, supporting collection, and facilitating exchange of information is very important.*"

Privacy and ownership naturally emerge as important issues here. According to Ton Dassen (PBL), all parties should discuss delicate problems like data ownership and the power acquired by companies who own urban data: "*The government must be very critical about the companies that gather data in the city – which data do they have, where do they come from? What data should be open to all? But this process goes wrong many times, and companies are still in control. We lack arguments and understanding of how to deal with data streams property. It is still a very delicate topic.*"

Citizens: experts on their environment

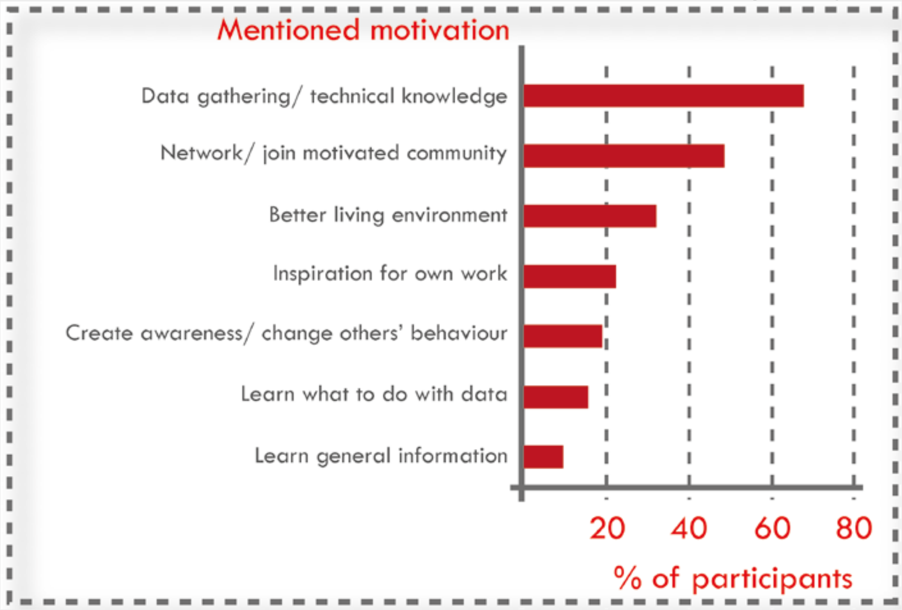
The motivation of citizens and communities to collect urban data is related to their personal well-being and concerns their immediate environment. Citizens and local communities are increasingly involved with their living environment and require means to understand and influence the physical and social processes in their surroundings. Ultimately, they strive for impact: they want to improve or change a situation or process. Many grassroots initiatives and citizen communities have originated from the desire to bring about changes. Some initiatives have a long existence, such as “De Kracht van Utrecht”, a citizens’ initiative aiming at improving the Dutch city of Utrecht and its immediate environment, encompassing ca. 650.000 inhabitants, with innovative integral proposals related to transport and the environment. Others however are volatile and temporary, appearing as a result of a sudden concern or opportunity.

Numerous ICT platforms have been developed in the last few years to help citizens and local communities to exchange and sometimes map information and ideas. Although platforms specifically directed at collecting and mapping environmental data do exist and some are successful, they usually do not support the integration of data originating from different sources such as open data, self-collected data, or social media data. Moreover, ‘subjective’ data, such as personal perceptions on well-being, social capital, cohesion and belonging, and other important components of several so-called Quality of Life Indicators, are generally not available at all for local citizens and communities or cannot be integrated with the other data. Quality of Life (QoL) is an important societal concern in European policy. When combined, these data may enhance understanding of cause-and-effect relations of human behaviour and environmental quality and lead to new perspectives for action.

One of the main arguments of the citizen sensing enthusiasts is the potential power that data – and the freedom to collect it – could give to the population in general. Social and environmental benefits resulting from these initiatives are often mentioned as the initial motivation of citizens. But citizens cannot achieve this on their own: the connection with public authorities and other organisations is needed. They provide the feedback that will keep the relationship between actors alive. According to Hester Volten, Air Quality Scientist at RIVM (National Institute for Public Health and the Environment – the Netherlands): “*People like to hear from the government that they are going in the right direction. But they do not put all responsibility for environmental issues in the hands of the government any longer; they feel responsible for contributing to solutions as well*”.

Case Study - The Amsterdam Smart Citizens Lab & Motivation

“During the first meeting of the ‘Amsterdam Smart Citizens Lab’, at the Waag Society, around 30 volunteers were asked what motivated them to attend that meeting, and to volunteer for the experiment. Even though the outcome for the environment was a motivation for more than 30% of the citizens, the most common aspect mentioned was not the subject of the experiment, but the challenge of playing with data. Around 70% of the citizens mentioned ‘Data gathering’ or ‘learning technical skills’ as their main drive for participating. The second most mentioned factor (50%) was meeting another citizens interested in the same topics and joining a community.”



[For more information, see Laurence 2015]

2.2. Common Challenges in Smart Citizen Initiatives

Previous sections introduce examples of experiments, projects, and collaborations with a focus on the *smart citizen* topic while highlighting the needs and opportunities for each of the involved actors. However, despite the success of single initiatives, it is not clear yet how citizens could systematically, reliably, and consistently be involved in a larger socio-technical system that includes all the actors in the smart city scene. This section focuses on three interrelated problems that were common to all previous *Smart Citizen* initiatives and that are, as of today, in great need of better understanding and solutions: *participation*, *inclusiveness*, and *quality and trustworthiness*.

Participation

Finding, motivating and retaining participants is always a major challenge for any participatory system. Indeed, technology-related aspects are important: usability and an engaging user experience, especially with mobile phone applications, are crucial to motivate users to contribute [Maisonneuve 2009]. However, participation is an aspect of smart citizen initiatives that requires more than purely technological solutions. Different types of initiatives demand for different engagement strategies that vary according to purpose (from sensing to awareness and from deliberation to citizen science) and locus-of-control (top-down for official initiatives; bottom-up for grassroots ones).

A general issue is the participation skewness, or the uneven distribution of contributions among participants. Many studies report that only a small portion of users are actively involved in initiatives, while lurking behaviours are common. For instance, the option to deliberate on the Finnish website Avoin Ministeriö (Open Ministry) [Christensen 2015] was used by about 7% of the users; the rest were only passive readers or supporters of initiatives by others.

There is no single best way to engage with citizens to spark interaction and contribution [Eskelinen 2015]. Effective citizen sensing projects commonly build on the existing relationships people have with their environment or with their day-to-day experience [Gooch 20015]: for instance, mobility-related topics are the easiest for people to relate to given that all citizens experience different types of transport; on the other hand, environmental topics such as energy and water are more challenging to promote, as for many citizens the main concern is cost (i.e. save money) over environmental impact. An essential aspect is the identification of clear needs that are also shared by the involved stakeholder: too often are smart city projects not led by end users or stakeholders with clearly defined needs, but by entities promoting a technology or an infrastructure [Lea 2015]; top-down Smart City projects often fail when there is no grassroots engagement.

According to ***Dan Hill***, the success and usefulness of citizens' initiatives and contributions relates to the scale of the issue they intend to address. Citizens are generally focused on short term, local, and relatively simple concerns. Long-term, large-scale, and complex concerns necessarily require higher level governmental management.

> “Cities have series of scales for decision making processes, but we have not rethought these processes after we started using the new media that we now use. Cities invented the decision making system in the 1800s, and that was a different time. Now we have to adapt it.”
>
> **Dan Hill**, associate director at Arup
> and former Executive Director of The Future Cities Catapult, London.

Incentives should be well-aligned with the aims of the crowdsourcing challenge: either internal rewards, such as visibility, or even external rewards, such as money and prizes. Counter-intuitively, monetary payment could be a way to bootstrap smart citizen initiatives when (and if) participation is driven by the perceived value of a shared resource [Loke 2015]. This is the case in platforms where reciprocity of contribution is a key driver for participation. Take, for instance, online Question Answering platforms like Quora and Yahoo! Answers: there, the success of the platform is tightly related to the presence of a community active in answering questions posted by other users; in turn, such a community is motivated to participate only if the platform hosts valuable content. Once the shared resource itself has adequate value, payment may no longer be needed as access simply becomes a sufficient incentive for people to contribute.

A related issue is the long-term maintenance of the user community that is involved in the evolution of a project. According to ***Arnold Bregt***, it is relatively easy to get citizens involved in a pilot study related to innovative information. However, to move beyond the pilot phase to a structural process is not easy: “*The main challenge of citizen science is continuity. Initiating is not a problem: the start of a project or pilot is new and attractive. Nevertheless, after one or two months, enthusiasm dwindles, and the data flows stop. With volunteer citizens, participation cannot be mandatory. Keeping the community alive and ensuring data continuity is the most important challenge.*”

Participation is known to decrease over time (the so-called *crowd out* effect) if there is no incentive scheme strong enough to retain participants beyond the initial enthusiasm. In the WideNoise [Becker 2013] project, for instance, participation was mainly driven by case studies or public advertising of the application. The best use case benefitted (on average) from less than 2 measurements per device/day with non-normally distributed engagement between participants and a relatively steep disengagement curve. A possible solution to the issue is the adoption of incentive strategies that foster active engagement. For instance, the MK:Smart project [Gooch 2015] adopts an approach based on the combination of technical Hackathons and a set of targeted meetups. Real-world interactions stimulate the creation of stronger ties among community members, but also between the project and the community.

One of the most overlooked aspects of long-term sustainability is the ability to demonstrate, in quantifiable terms, the success of an initiative and its results [Eskelinen 2015]. This demonstration shall occur both externally, to the outside world, as well as internally, to participants and partners. In both cases, the goal is to build trust between stakeholders and, consequently, in the initiative itself. This is true especially when public authorities are involved; in such cases, it is essential to create conditions for the fruitful engagement of stakeholders. When public authorities are in the loop, the nature of political trust changes, from a commitment to fulfilling promises (delivering policy objects) to a commitment to openness, transparency, inclusiveness and shared ownership (delivering policy processes) [Eskelinen 2015]. Failure to deliver such promises might lead to negative effects that extend beyond the boundary of the project.

As ***Ton Dassen*** points out, "*the way groups of citizens gather to organise things may sometimes be positive for society, sometimes negative. Many of these initiatives may indeed have a good impact in society, but the government now needs to identify them and learn how to support them. The hierarchical structure of public authorities, however, does not easily connect with the flat network structures in society.*"

In the case of the Avoin Ministeriö (Open Ministry) project [Christensen 2015], those who were dissatisfied with Parliament rejecting the initiative experienced a significantly more negative development in political trust compared to those who did not explicitly support the initiative. Those who were dissatisfied with the way Parliament handled the initiative also experienced more negative developments in political legitimacy compared to those who were satisfied.

Inclusiveness and Participation Bias

For a smart citizen initiative to be successful, participation must be broad and include all categories of people and sectors of society affected by a problem at hand.

Several issues might hinder the inclusiveness (i.e. the property of including everyone and everyone's opinions) of smart citizens initiatives [Arniani 2014], thus generating *bias*, that is, the inclination or outlook to present or hold a partial perspective, often accompanied by a refusal to consider the possible merits of alternative points of view. As the improvement of quality of life should be available to all citizens, the exclusion of categories of people, or sectors of society, could prevent an initiative to fully capture the extent of a problem or the possible consequences of a proposed solution.

Many of the interviewees agree that broad participation and representativeness of several societal groups in data collection projects are challenges. Citizens that volunteer smart citizen initiatives are often not a fair sample of society. As ***Arnold Bregt*** points out: "*We have had success stories during experiments, but in these cases the citizens who participated were mostly professionals or techno-enthusiasts related to the field*." ***Hester Volten***, researcher at the RIVM, confirms this. The successful iSPEX project[17] involved citizens to measure air pollution with their smartphone. The campaign was targeted at interested citizens who had no technical expertise or knowledge of air quality and pollutants. However, a large number of the participants were male, highly educated, and had experience with scientific research [Land-Zandstra 2015].

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[17] http://ispex.nl/en/

Jonathan Carter, owner of technology company Glimworm, organiser of the Amsterdam based Sensemakers meetup, and volunteer in citizen science experiments, himself an example of this phenomenon, agrees with these observations: "*The groups that participate in citizen science experiments have similarities because they react to open calls which attract like-minded people who want to learn how to make new things and have a social conscience. The experience attracts and feeds a certain feeling of independence.*"

A representative example of exclusion factor is the presence of digital divide issues [Paskaleva 2011]. Lack of access to Web-based systems or lack of skills in their usage could reduce the awareness of certain social and environmental issues. That may even prevent relevant stakeholders who are "disconnected" from having their voices heard.

Kyra van Onselen is senior advisor at the Dutch Ministry of Economic Affairs, and actively involved in activities around the innovation of information services. In our interview, she cites *Jan-Hendrik Dronkers*, who expressed at the Architecture Biënnale in Rotterdam (2014) that: "*successful innovative initiatives are often developed by citizens who have an advantage in, for example, knowledge, or through their network. If the government supports these initiatives, or gives preference to them, this may disadvantage groups who do not have the required level of knowledge and expertise.*"

Although datasets relating to the condition or use of the urban environment are collected and published online at an increasing pace, they are not easily accessible or usable for individuals without expertise in ICT. This especially affects groups who already are disadvantaged with respect to social equality, quality of their living environment, health, and access to decision making processes. Moreover, as [Becker 2013] observes, the provision and production of environmental information rely heavily on a 'top-down' approach in which public authorities collect the data and release it to the public. This strengthens the impression that data collection belongs to the official domain.

Citizens are often not aware of the range and availability of data on the (urban) environment. A recent study in the Netherlands for instance showed that findability, understandability, and usability of open datasets are low. Citizens' engagement with open datasets is further hampered by non-prioritisation as target groups: the respondents in this study, who are involved in the Knowledge Network Open Data, do not consider citizens as an important user group at the moment. They also do not expect citizens to be a primary user group in the future but think public sector organisations will remain the most important user group [Meijer 2014].

Another obstacle for citizens in using available datasets is the level of knowledge required to understand their data and metadata. Explanations of specific terminology and how the data should be interpreted are generally not included in the datasets. Downloading and using the datasets again demands experience with data formats and sometimes requires expert software. [Poore 2013] summarizes: "*Many people find traditional metadata hard to manage, hard to produce, hard to use, and based on an outmoded static model of the way the Internet works*." Metadata is usually published in discovery services, or metadata registers that allow users to search collections of metadata and provide information to access the dataset. Not only do these discovery services require specialist skills [Bulens 2013], accessing the dataset associated with this metadata record generally requires expert knowledge about Open Spatial Consortium (OGC) implementation specifications, Internet GIS client software, and/or coordinate reference systems. [Poore 2013] observes that major changes in the traditional methods of structuring, generating, and validating metadata are now taking place as a result of the proliferation of data collection by users and sensors: the metadata is simplified and object-based, allowing for flexibility and rapid development. The ability to freely download both data and metadata will support emergent use. However, at this moment these developments do not solve all problems for non-expert users in communities.

Differences in cultural background might also play a role in encouraging/discouraging people in being part of the public debate. Institutional and/or working conditions might influence the time available for participation. Altogether, these issues might lead to the well-known (and feared) preferential attachment effect, where only people who are already engaged in an issue participate in the initiatives.

Another important exclusion factor is the lack of alignment between the vision and goals of stakeholder, with the vision of the citizens called for participation. For instance [Gooch 2015] reports that out of 101 ideas around improving the local community, none matched initiatives within the MK:Smart project, highlighting how bottom-up processes result in very different ideas from top-down programs.

Quality and Trustworthiness

A major issue in collaborative Web-based systems is measuring and improving the quality of human contributions, which requires estimating the quality of the contributors and combining different (and potentially conflicting) opinions and point of views. As for participation and inclusiveness, technology-related aspects play an important role: for instance, the type of communication channel used to report feedback can influence the amount and quality of contributions. [Christensen 2015] reports that the adoption of SMS-based communication, instead of Web-based one, helped lower the amount of irrelevant commentary and noisy feedback, as only people who were serious in voicing their feedback were willing to pay for it.

The DARPA challenge demonstrated, at scale, how tapping into crowd knowledge could yield a wealth of data. More data, however, does not necessarily produce more rational decision making, as data can be very noisy. The problem of “noisy” data can be caused by at least three problem sources of technical, psychological, or sociological nature.

From the technical point of view, a common pitfall is the quality of data gathering infrastructure: amateurs often collect data through cheap, unverified, uncalibrated sensors, thus requiring proper adjustments and verification mechanisms. In the NoiseTube [Maisonneuve 2009] project, the correctness of the sensor data generated using the mobile application needed calibration against professional equipment (e.g.

sound level meters, and GPS receivers respectively for noise and position measurement accuracy).

Hester Volten (RIVM) recognises this problem. Monitoring experts often hesitate to accept and include data collected with uncalibrated sensors and without pre-planned spatial and temporal planning. However, she emphasizes that data analysts should learn to deal with data that are of lesser quality but available in large quantities. This requires a change in attitude and time to develop expertise: monitoring experts and data modellers should collaborate to embrace these new developments and opportunities.

Another concern is when the data collector has no commitment to *epistemic objectivity*, i.e. reporting a phenomenon of interest neutrally and truthfully, free from individual biases, interpretations, and feelings. This lack of objectivity might be incidental or deliberate. In the former case, the observer has no pretence about neutrality or comprehensiveness, and so naively focuses on a specific aspect of the reality under observation; this often happens in crowdsensing projects conducted through photographic social media like Instagram or Flickr: there, an image frames what the photographer wants to show, not necessarily the whole environment. Different is the situation where the observation is gathered as a response to a specific problem; for instance, if the issue at hand is traffic, participants might be more prone to document traffic congestion than traffic-free periods.

Well-known human cognitive biases may exhibit systematic and predictable skewness, which, if overlooked, may threaten the validity of human-assigned tasks and the outcomes and validity of community processes. For instance, anchoring and sequential effects (the dependency of responses on prior information) are well-known issues in decision making processes that have been extensively studied in fields such as cognitive psychology, neuroeconomics, and game theory [Sanfey 2007, Hozer 2010]. Moreover, personal interest may affect the objectivity of data collection, for example in cases of noise pollution when the discomfort of individuals may differ to a great extent.

Prior experience and expertise can also play a role in the way people conceptualise phenomena (e.g., classify objects in a domain). In the WideNoise project [Becker 2013] it has been observed how perception of the environment changes after repeated usage of a reporting application due to learning bias coming from the recognition of different noise levels. Also, noisy environments were qualified as more hectic and less lovable by experienced users, compared to novices. Studies show that the views of regular contributors (e.g., citizen scientists) differ from those of experts (e.g., scientists), affecting accuracy and validity of contributions. Sometimes, even experts have divergent opinions: in a recent study on OpenStreetMap[18], authors found a relatively small (Kappa=0.21) agreement on classifications of spaces as either park, grass, garden, or meadow among domain experts [Ali 2014]. When collaborating, participants do not necessarily provide a truthful outcome, as often the ultimate goal is consensus. So the individual, and very importantly, opinions may go unheard.

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[18] http://www.openstreetmap.org

To conclude, it is important to consider bias as an intrinsic property of data observations. Trying to actively remove bias might produce the undesired effect of changing the behaviour of those taking part itself, a phenomenon known in social science as the Hawthorne[19] effect: users may be more cautious with their contributions if they think that they are being tested for bias rather than just being asked to report their measurements. Therefore, there is a serious need for data collection, integration, and verification methods that are able to account for bias in data.

[19] https://en.wikipedia.org/wiki/Hawthorne_effect

Chapter 3. A Unified Vision for Smart Citizen Initiatives

Smart Citizen projects all seem very different from one another, with different aims, participants, tools, and conclusions. However, there are also plenty of similarities among them. We strongly advocate the reuse and capitalization of existing knowledge, as means to accelerate innovation and progress. The reuse of data should be made as easy as possible, but also information about data (dimensions, resolution, completeness, accuracy), and data sources (trustworthiness, responsiveness) should be as accessible and as transparent as privacy laws admit. Often such metadata comes with the data itself, but one could also share only the metadata to facilitate future data collection without using data that was collected earlier. Also, it is fundamental to re-use and collaboratively improve the tools used by each of the steps of a smart citizen process. For example, software and hardware (modules) for data collection, tools and infrastructure for data storage, analysis and visualisation that are useful for one citizen sensing project are very likely also useful to another. Finally, an important outcome of any smart citizen project, besides actions, is the knowledge drawn from the data which can sometimes be used in other contexts as well.

First, we present common steps in citizen sensing projects, both using analyses from the literature (e.g. [Willett 2010]) as well our own experiences as participants or organizers. By structuring this so-called *From Needs to Knowledge (FNK) process*, it becomes easier to think and talk about cross fertilisation of knowledge, data, metadata, methods, tools, and experiences between different smart citizen projects. The steps of the *FNK* process are presented in Section 3.1 using a “running example’’. We describe a fictional case where a citizen, a young mother, wants the city to install security cameras in nearby streets. In this example we focus on a bottom-up initiative to illustrate the process, but the steps are the same for processing the needs of other actors. Section 3.1 also describes the organisation of the first edition of the Amsterdam Smart Citizens Lab, reporting its execution in the context of the proposed 8 steps process. In Section 3.2 we make a proposal for an *Urban Knowledge Collider* (*UKC*), a novel breed of socio-technical systems aimed at supporting smart citizen initiatives by offering services such as: a centralized knowledge repository for ongoing and completed projects; methods and tools for planning, executing, and controlling smart citizen projects; and methods and tools for collecting, aggregating, assembling, analysing, contextualising, visualising, discussing, and sharing data managed by such projects. The ultimate goal of the *UCK* is to bridge the gap that exists between state-of-the-art solutions, and the actual needs of all the actors involved in smart citizen initiatives.

3.1. From Need to Knowledge in Nine Steps

> The mother, let's call her Eve, attends a meeting of a local society that supports citizens in the use of digital media to fulfill their needs. When Eve is asked if she perceives a need, she answers that she wants security cameras and that she wants to collect data on burglaries to show that this is necessary. After some discussion, it becomes clear that her need is to feel safe, and that she currently doesn't feel safe in her neighbourhood. It also turns out that her feeling is shared by many others, and there is a common willingness to do something about this.
>
> A group of interested people is formed.

This illustrates that there is often a ``question behind the question''. The objective of the very first step in the process should be to get the fundamental need on the table. Often considerable effort is needed to understand that underlying question, since in general people are unwilling or unable to do so without prompting, or with the help of storytelling and other techniques. Furthermore, there is not always one clearly-identifiable and easily-recognisable need.

STEP 1: FORMULATING THE NEED

Understand the fundamental need

> An unsafe feeling in a neighbourhood may be caused by a large number of factors. Being all experts by personal experience, an intense discussion of potential underlying reasons follows. In the end there is agreement among the people in the group that night-time darkness, convenient hiding places such as porches, and lack of social control, contribute most to an unsafe feeling.

At this point, the group realizes that expert knowledge, for instance from the city council or the police, is required to understand which features of the neighbourhood add to this unsafe feeling. They decide to invite an expert for the next meeting. However, their main interest lies in the perceived safety, a subjective feeling, which only residents themselves can judge and contribute.

> The main goal now becomes to determine when and where the residents experience negative feelings most, and why. The group decides that they need a list of such locations, and data on how these locations are experienced, especially when it is dark.

The group now has arrived at the second important step in this process, i.e., that of identifying which data they need, and will try to collect information to analyse and better understand the problem. In this case, they will need to formulate criteria like the number of responses they think are necessary, which period and which specific locations they should cover, etc.

STEP 2: IDENTIFICATION OF UNKNOWN VARIABLES AND THEIR PROPERTIES

Make clear what data is required and
with what resolution, accuracy, timeliness, etc.

> Since the main goal of the project is to collect personal experiences, the group decides to elicit responses from residents and visitors to the neighbourhood regarding their perceptions of locations at specific times.

This third step in the process is to identify other relevant data sources. The group could have decided to also search for statistics about the occurrence of criminal activities in the neighbourhood or to collect data on positions of lampposts using input from local or governmental agencies.

STEP 3: DECIDE ON THE DATA SOURCES

Select appropriate data sources. What relevant data is already available? Shall new data be collected? Is citizen sensing a serious option?

> The budget available for the project is low, and the group does not want to postpone the project. It is therefore decided that a mobile application, previously used for making local weather reports, is going to be repurposed. The student that wrote the weather app claims that it should be easy enough, because the functionality is very similar: the user evaluates her perception of safety by submitting a score and the cause of this perception, and shares his/her location automatically. After a few weeks of work, the app is made available and announced in a local newspaper together with a brief summary of Eve's story.

The story of the mobile app illustrates that often ad hoc decisions are made on how to gather the data. In a way it is an interesting example, because of the reuse of a tool that has been developed for another cause. The landscape of potentially useful tools is changing quickly, and the selection of the tool can influence not only development costs, but also usability of the result and, thereby, user participation. Selecting the right tool is very important, and the development of tools for crowd sensing has received a lot of attention in the past years as indicated in the examples in Section 2.1.

Figure 2. From needs to knowledge in nine steps

STEP 4: SELECTION OF DATA COLLECTION METHODS AND TOOLS

In what way should the data be collected to retrieve the data with the required quality, resolution and continuity? What software and hardware should be used?

Many people appear to be moved by Eve's story, and download the app in the first few days after the news item appeared. The link is also shared via social media. The second day the server has some issues because of a number of simultaneous connections (and some data is lost), but this is quickly fixed, and after that there are no more technical issues. A large number of locations are stored (over 100) and rated (almost 5000 ratings) in two weeks time. However, closer inspection of the contributions leads to a number of unexpected issues: some locations are from a completely different city, some locations are within just a few meters from each other (but are rated differently), many ratings are given during lunch time (i.e., not in the dark), a large number of locations is rated while the actual location of the reporting user is significantly different (so it raises the question of whether this is an accurate report of the feeling of that person), and there is one person who contributed almost 10% of the ratings. After two weeks no new locations and almost no new ratings are added.

Even in this rather simple scenario where the collected data consists just of a location and a rating, we see a number of potential problems with the data collection: the infrastructure should be able to support the collection, and measures need to be taken to deal with out-of-scope, noisy, incorrect or even abusive contributions.

In this case, the data are stored at a university computer the student still had access to. Although the used infrastructure is not scalable, this appeared to be sufficient. Regarding the data itself, fortunately, in this case also some metadata such as the current location, time, and (IP) address from each contribution are collected. This facilitates further processing of the data. In hindsight, even more measures could have been taken: for example, users could be asked to motivate adding new locations in particular when they are near others that have been submitted before.

Obviously, data collection is a next essential step in citizen sensing. In fact, it is so important that it often leads to new insights regarding the infrastructure, user interface, and of course, the (meta)data that need to be collected. Before launching the application, a trial run with a small group of people must always be conducted before doing the actual data collection to discover such issues and improve this step.

STEP 5: DATA COLLECTION AND ANNOTATION

How is data stored? Is the infrastructure robust and scalable (if needed)? What (meta)data are collected to enable filtering, integrating, and/or labelling of noisy, incorrect, or even abusive contributions?

During the next group meeting, the student announces that he has found a job and will not be able to contribute further to this project. He puts all collected data in a large CSV file and brings it with him on a USB stick. Also, he presents the data and his first observations with a few slides.

Eve discovers that ratings were made for only a few locations close to her home, and they are very limited in number. More importantly, the issues with the data make it clear that no strong conclusions can be drawn directly. A number of suggestions are given to deal with these issues, but it is clear that processing these requires data analysis skills, and there appears to be nobody who immediately and enthusiastically rises to this challenge.

After data collection, the next step in the process is to decide on how to analyse the data. In most cases this is a complex decision, requiring both understanding of statistics as well as experience with a supporting tool (this could be a spread sheet program like Excel, but also a statistical and visualisation tool). Also this step includes reasoning on when data should be ignored and what data can be aggregated. Often this involves several iterations: analysis reveals outliers that are manually investigated and possibly leads to a new rule for filtering incorrect data. Filtered data is then analysed, etc.

STEP 6: SELECTION OF DATA ANALYSIS METHODS AND TOOLS

What are appropriate methods for analysing the data? How to decide which part of the data to ignore? What can be aggregated? What are useful visualisations of the data? Which tool(s) can support all of this?

When Eve leaves that evening, she does not only feel unsafe, but also disappointed. After all the effort, it seems that the collected data will not help her in her cause. Still, the data demonstrated that the feeling of vulnerability is shared by other citizens in her neighbourhood as well.

Eve has clear ideas about the desired next step: sensemaking and extraction of actionable knowledge. The collected data needs to be analysed against the background of known facts and previously collected results. Like in the second step, an expert could contribute to this discussion significantly because of his/her domain knowledge and experience on interpreting the statistics.

STEP 7: SENSEMAKING AND EXTRACTION OF ACTIONABLE KNOWLEDGE

What observations can be made? What conclusions can be drawn? How does this relate to known facts?

STEP 7a: IDENTIFY PATTERNS

What observations can be made? What patterns occur in the data? Which observations are unexpected? What questions can be asked and answered?

STEP 7b: INFER/PREDICT

What conclusions can be drawn? How strong are they supported (statistical significance)?

STEP 7c: VALIDATE AND SYNTHESIZE

How do results compare with known facts, other studies and sources? Combine results and summarise.

Since there is no one to analyse the data and integrate them, Eve decides to call the local council to ask to take up her issue regarding safety as well as the collected data. She gets referred to John, a member of the city council who has safety in his portfolio. They meet and he is very enthusiastic about the initiative. Together they look at the collected data and identify some locations that are also mentioned in recent police reports.

Thus eventually Eve and John go through the steps of identifying patterns, combining these with other data sources and drawing conclusions, although in a lightweight manner.

Finally, the newly acquired knowledge may lead to action.

STEP 8: ACTION

What actions to take? Who to communicate the conclusions to? What to ask? How to formulate?

Eve and John first discuss fixing broken lights, cutting bushes, and increasing police patrols. John makes calls to the responsible persons and departments, and some of these changes are in effect the next week. They also discuss placing more lights, street cameras, and closing alleys for the general public among a number of other potential follow-ups. John brings these ideas up for discussion in a meeting of the city council. The number of respondents to the citizen initiative appears an important argument in the discussion, and eventually most of the ideas are included in an update of the development plan for the area to be executed in the years to come. Eventually, Eve is very happy with the results.

Of course, the story does not end here. Some of the proposed improvements are applied by the city council, but others are expensive and budget cuts or changes in local policy may interfere with the planned interventions. The council will require more information. What is the effect of the measures on the perceived safety in the neighbourhood? Are they cost effective? How can the citizens themselves contribute? Answering such questions could lead to follow-up projects for evaluation of the measures, which again follow the discussed steps. In fact, after each of the steps a reflection and evaluation of the results may give a reason to revisit an earlier decision.

STEP 9: EVALUATION AND REFLECTION

What is the effect of the actions taken? What can be improved in the decisions in all steps of the process?

When this process is run for the first time by a specific group of people for a certain cause, it is very likely that results are not as good as desired. However, this is not necessarily a problem when the project is also regarded as a learning process. Like in software design, a more agile approach, where such cycles through these steps are planned from the start, could actually lead to better results more quickly (see also the figure above).

In the story of Eve’s concern about safety, citizens and (local) public authorities are the main actors. The public authorities may also be interested in extending the data collection, analysis, and actions to other districts in the city and ensuring continuity for monitoring safety throughout the coming years.

In the story, academia does not play any role, but it is likely that research on public safety and environmental design could greatly benefit from the collected data to examine the influence of environmental features on perceived safety. In general, expert knowledge can support the effectiveness and quality of the sensing activities and experts (either professionals in the field or researchers) should be invited to participate in projects in an advisory role.

This example does not easily relate to actors in the private sector. Still, one could imagine security companies using the data to estimate market potential for new products (cameras, home alarm systems, pepper sprays) or services (security patrols) in a specific neighbourhood. Furthermore, local shopkeepers, restaurants, and bars may show interest in such initiatives if they too are concerned about the reputation of the area.

This identification of a common description of the process now allows the design of a framework to support all aspects of this process. This framework is presented in the next section.

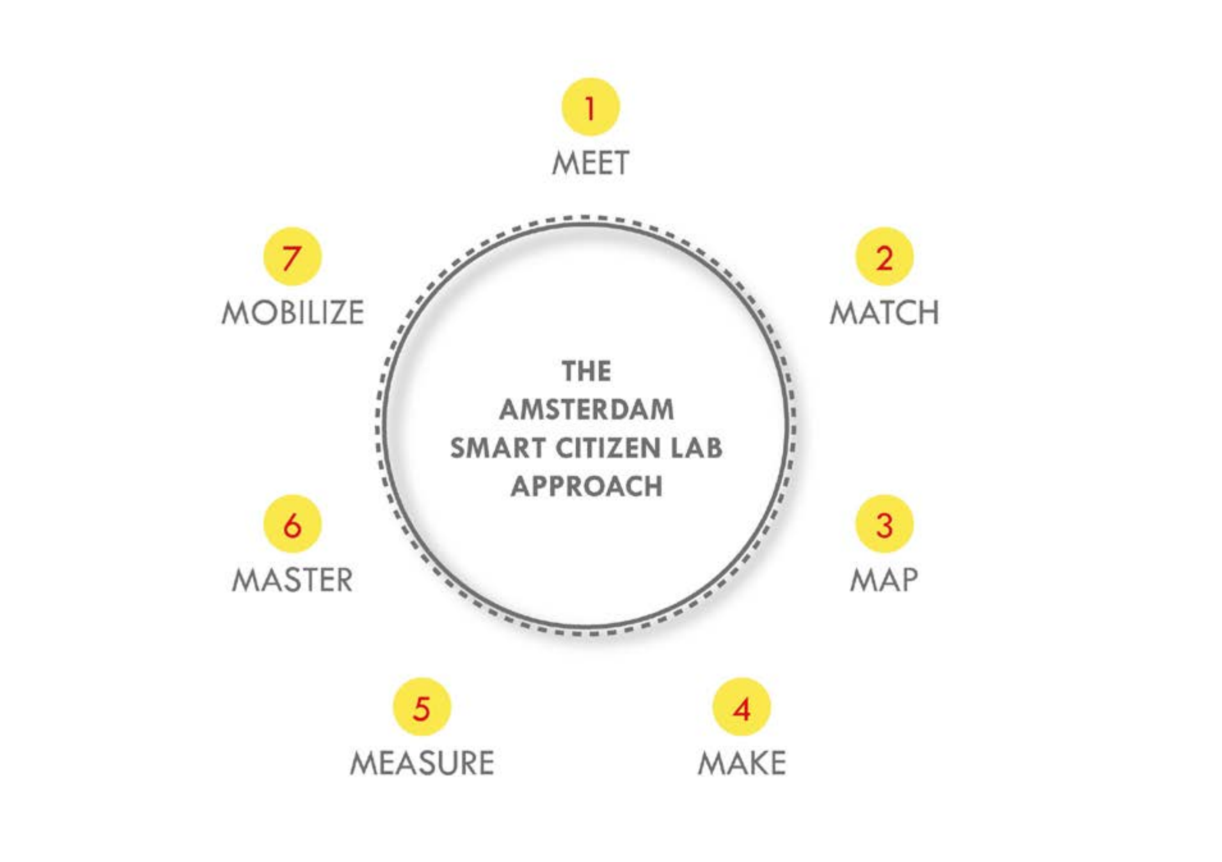

Figure 3. The Amsterdam Smart Citizens Lab first edition used a seven-stage process that is described in detail in [Henriquez 2016].

First, after an open invitation in the local newspaper and online in the newsletters of partner institutes, people sign up and meet at a space in town that is perceived safe (to speak up) and neutral (without its own hidden agenda). A collection of presentations and creative exercises is used to introduce the participants to each other and prime them for possible questions, approaches, and outcomes, as well as on the roles they will have to take to turn the lab into a success. This step precedes step one of the *From Needs to Knowledge* process.

Step two consists of encouraging people to form groups based on shared interests, experience, and levels of commitment. To make the resulting groups more effective and possibly self-sufficient, care is taken to mix people with different (levels of) expertise and backgrounds. It was made clear that the groups themselves will be responsible to get to the desired results, so they should self-organize as much as possible, for example by using on-line tools for sharing calendars, blueprints, and progress. This step corresponds to step one of the *From Needs to Knowledge* process.

The next step is helping the groups to understand and map in more detail the problems, opportunities, and possible solutions. The help of experts from relevant agencies, universities, and companies is sought and valued since problems related to the environment are complex in nature, and much is already known. This step ends with developing a sensing strategy: what is to be measured, in which quantities, and which technologies are used to get there. This step relates to step two and three of the *From Needs to Knowledge* process: data request(s) and data sources, as well as step four: collection methods and tools.

The fifth step consists of carrying out the measuring strategy devised in step three with the hardware and software developed in step four. It starts with calibrating the hardware and deploying the sensor(s) in one or more locations during a specific amount of time as prescribed in the strategy. Typically, things turn out differently than expected in terms of the actual data collected, which gives rise to ad hoc changes in the measuring strategy and sometimes to changes in the hardware and software. The data are collected for further analysis. This step corresponds to step five of the *From Needs to Knowledge* process: data collection.

Step six consists of mastering the data: analysing and possibly visualising them to understand what they mean. Typically, existing software is used to perform this step. Depending on the complexity, the help of external experts is sought. They then consult on or even perform technical procedures for cleaning and analysing data as well as interpret and give credibility to the results. This step entails both step six and seven of the From *Needs to Knowledge* process: analysis methods, tools, and sensemaking and the extraction of executable knowledge.

The final step entails mobilizing either citizens and/or public authorities to take action on the findings. This is potentially a huge step, involving (mass) media, spokespersons, ambassadors, political parties, and spin doctors. Depending on the desired results and vested interests, this is also the hardest step that might take years to reach. Small-scale mobilisation however is also possible, consisting of changing one's behaviour or convincing neighbours to do so. This step corresponds to step 8 of the *From Needs to Knowledge* process: getting to action.

3.2. The Vision of an Urban Knowledge Collider

The vision of an Urban Knowledge Collider (*UKC*) is of an integrated Web-mediated socio-technical system for urban computing at scale. *UKC*s have smart citizens and the other actors of the *From Needs to Knowledge process* at the centre of the data creation and valorisation processes. In the same way that CERN's Large Hadron Collider smashes together protons to discover new particles and to test new theories of fundamental interactions, the UKC will collect, disaggregate, and re-integrate data from a complex network of sensors, people, and machines to produce new understanding of cities, their dynamics, and their citizens. To achieve such a goal, we advocate a move towards trans disciplinary and experimental approaches that combine information, cognitive and social sciences, and political science to account for the shortcomings of previous smart citizen initiatives. A holistic approach can play a pivotal role in bridging theory and experiments, but also different urban actors.

The vision of an *Urban Knowledge Collider* extends previous efforts by fully acknowledging the central role that data and people have in the creation and maintenance of collective urban knowledge that is accessible and exploitable in an inclusive way. In [Dana 2008] for instance, authors envision the creation of a so-called "data commons", that is a data repository generated through decentralised collection, shared freely, and offering a host of new applications, new data types, and data processing tools. In his doctoral dissertation [Stevens 2012], Matthias Stevens presents the notion of a *Community Memory*, which is "a medium for recording and archiving information relevant to a commons that is managed by a community and for diffusing this information among members or communicating it to those threatening the commons and thus the community". Also in Stevens' vision, the *Community Memory* system could be enhanced with new 'intelligence', for example by creating maps, explicating dependencies between information items in order to bring out trends and predict future evolutions, or by simulating future states of the world. A recent report from the Digital Social Innovation project [Bria 2015] highlights the need for systems that are self-sustaining, self-directed [King 2014], and able to involve humans and technology to solve problems that require the cooperation of a variety of actors. The report underlines the importance of an open perspective over common data to foster innovation and break the competitive advantage gained by proprietary access to data and data lock-in "as long as the privacy and data protection of all citizens is preserved and that communities are entitled to share the value and social benefits of public assets".

Drawing from the lessons learned by previous smart citizens initiatives [Boulos 2011], and integrating the input of relevant actors in the Smart City landscape (Chapter 2), we give a set of requirements for an Urban Knowledge Collider. Such requirements cover a broad spectrum of functional and non-functional properties of the imagined socio-technical systems.

Ultimately, a *UKC* should provide *effective*, *efficient*, and *sustainable* production of and access to urban knowledge. In this respect, we advocate a UKC to possess the following properties:

DATA-DRIVEN:

data are more and more the fulcrum of modern decision-making processes, but they are often isolated in public or private data silos. The UKC should be able to cater for the differences in data formats/ access policies and facilitate the resolution of interoperability issues across usage domains.

INCLUSIVE:

all relevant actors must be included and given the means to do so. *Data literacy* should be a fundamental aspect of inclusion. The UKC should be able to accommodate actors at varying levels of expertise in domain-specific (e.g. air pollution) and technology-specific (software, hardware, statistics) aspects. In this respect, an important requirement is the alignment of language and terminology, so to bridge the vocabulary gaps that exist between technicians and scientists and citizens. *Knowledge parsimony* should be enforced as a guiding principle to design solutions that do not overwhelm participants with unnecessary (and unnecessarily complex) information.

HORIZONTAL:

allowing open and transparent, yet secure and privacy-aware exchange of information between relevant stakeholders.

SEMI-STRUCTURED:

allowing for a broad spectrum of use cases (social mobilisation, environmental monitoring, citizen science, social deliberation) with a different locus of control. The system should be able to accommodate the voluntary contributions of citizens, possibly without the constraints of pre-defined forms and templates, and without limitation in times and modalities; at the same time, it should be able to orchestrate sensing campaigns possibly defined over structured information needs.

REAL TIME,

as information has to flow back and forth in real-time, allowing the creation of evidence-based dialogues between relevant urban actors.

TRUST AND REPUTATION-AWARE:

stakeholders need to have visibility on the qualities of the actors that can provide value to them. Aspects related to uncertainty, provenance, relevance, and trustworthiness must be pervasive components to enable rich and sound data analysis. The relationship between producers and users is bidirectional, incorporating feedback about the quality/usability of the data.

GEO- AND TIME-AWARE:

the temporal and geographical dimensions are essential to contextualise and valorise the gathered information, both for local and city-wide initiatives.

ACCESSIBLE AND UBIQUITOUS:
the interaction with the system (and between actors) should be possible both on-line (supporting the widest possible variety of devices and communication modalities) and *in-situ*, to enable serendipitous, opportunistic, and organized communications. Also, the system should provide tools that help community members draw on their personal knowledge by making suggestions about possible formulations of queries or by guiding them in their exploration of the data.

INCENTIVE-DRIVEN:
finding the right incentive framework is key for the success of any Smart City initiative involving people. Therefore, any data- and interaction-related aspect of the system must be designed considering the psychology and science behind how and why people engage, and how people interpret information, make decisions, and take action. From problem elicitation to action, from on-boarding to retainment, each aspect of a smart citizen initiative should be underpinned by a set of incentives that foster inclusion and participation.

DURABLE AND SUSTAINABLE BY DESIGN:
to drive change, smart citizen initiatives must be designed with long-term sustainability in mind. To this end, financial and technical issues should be considered in advance and become part of the overall system design.

Indeed, the list of requirements above is not exhaustive, as one can easily imagine additional *social* or *technical* properties to be addressed. However, we claim these features to be essential in future state-of-the-art smart citizen initiatives.

Architecture

How should an urban knowledge collider look? *UKC*s must allow all relevant urban stakeholders to engage with each other and leverage their collective expertise and experience. The resulting environment must combine:

HETEROGENEOUS AND MULTIMODAL DATA STREAMS automatically produced by sensors and manually produced by citizens – by means of (on-demand) participatory sensing/crowdsourcing; released by municipalities, economical or environmental agencies; and made available by private organizations;

DATA PROCESSING AND ASSIMILATION PIPELINES, based on state-of-the-art techniques for social data aggregation, analysis, enrichment, and sensemaking;

VISUALISATION TOOLS to support actions, assessments, and decision-making;

ENGAGEMENT AND RETAINMENT STRATEGIES designed to support the *From Needs to Knowledge* process and foster its long-term sustainability;

COMMUNITY MANAGEMENT SYSTEMS, integrating physical communities with virtual communities of urban stakeholders and interest-bearers (e.g. visitors and tourists, public and private organisations related with topics close to the local interests of the territory, etc.);

EXPERTISE MANAGEMENT SYSTEMS, identifying, engaging, and funnelling experts and expertise.

Transversal to all these components, proper data access and provenance techniques provide the capabilities required to preserve the *privacy* of the involved individuals, while at the same time enabling the assessment (in terms of quality and trustworthiness) and valorisation of the generated knowledge.

Figure 4 shows a possible high-level architectural framework, cantered around an *urban knowledge warehouse* built on top of linked data repositories and domain ontologies. The warehouse should be capable of seamlessly managing data coming from a variety of sources (e.g. social networks, pre-existing data sources such as geographical and territorial information systems, satellite images), applications (e.g. Wikis, citizen sensing apps), and actors (citizens, public organisations, experts). In this way for some complex questions, a chain of dependencies on earlier projects and results could be created. On the one hand, this allows reaching conclusions to such complex issues more quickly. On the other hand, such dependencies create additional potential causes for errors if the way the earlier data is aggregated is not fully understood. The *urban knowledge warehouse* should keep track of dependencies and support awareness of such potential errors.

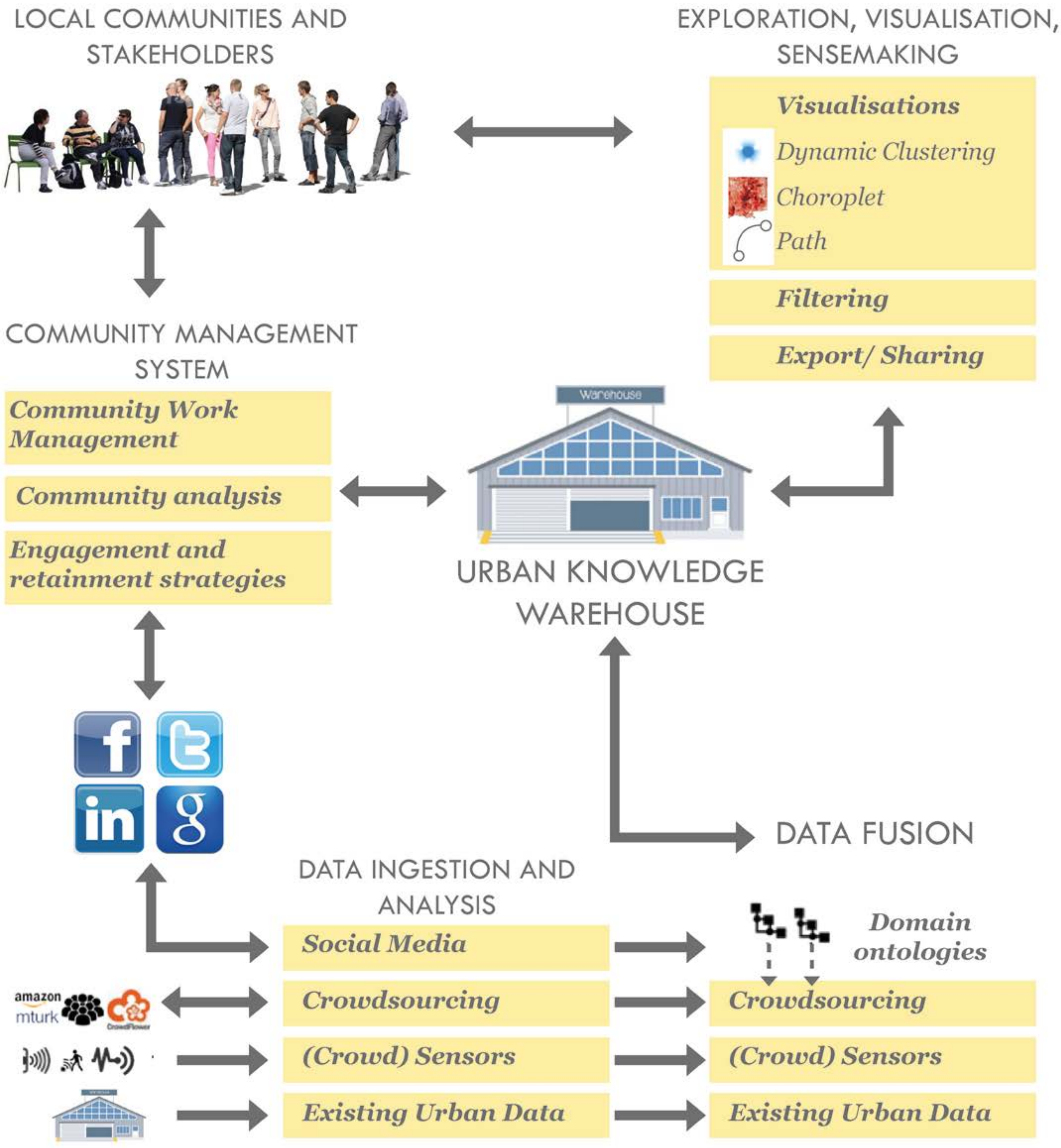

Figure 4. An urban knowledge warehouse

A set of applications is executed upon the *urban knowledge warehouse*, such as community data analysis, participative idea and process management, and alerting. This architectural principle, which is widely applied in other domains, still constitutes a fundamental research challenge in urban informatics, where there exists heterogeneity in data and information format, quality, and volume. The architecture should support processing pipelines that intertwine tasks executed by machines, individuals, and communities. This entails the definition of novel task management strategies capable of scheduling, launching, monitoring, and finalizing tasks allocated to urban actors at different levels of automation, expertise, and collaboration. Methods drawn from data science -- e.g. semantic annotation and enrichment, (social) media analysis -- must be employed to tackle issues pertinent to integration, anomaly detection, and data veracity. In addition, human computation [Law 2011] techniques play a highly beneficial role when it comes to the efficient interpretation of personally-, contextually-, or culturally-biased analyses of raw data. This is particularly crucial for social Web data, as their content is often unstructured in terms of machine readability and processing [Psyllidis 2015 a, Psyllidis 2015b]. As identified in the previous section, a key issue is sustained motivation of citizens. *Mechanism design*, which can be seen as the inverse of game theory, studies how to construct systems that provide incentives to the actors to provide the required information or perform the appropriate action to get as close to the system's goal as possible [Nisan 2007]. However, existing work focuses on economic agents that aim to optimise a known goal and have a (linear) interest in monetary rewards [Yang 2012]. How to build systems for which it can show, in advance, that *people* are appropriately motivated is still very much an open problem [Polevoy 2014].

The effectiveness and success of a UCK as described above depend of course not only on the quality of its design and implementation but also on contextual and external factors. The experts interviewed pointed to the importance of support by public authorities and research organisations. The example projects discussed in Chapter two confirm this. The projects also reveal other success factors. These are often related to the motivation of the participants, such as the urgency of a situation, a serious concern, financial incentives, competition or the ability to be in control. Any project on citizen sensing should begin with fundamental questions on why and for whom the initiative began.

Chapter 4. Conclusions

The amount and variety of smart citizens initiatives rose dramatically over the past years with many successes demonstrating the potential of this new paradigm, but it came with several failures as well. Often, successful examples are short-lived and raise concerns on the long-term sustainability of citizen involvement in the Smart Cities discourse.

This white paper delved into this apparent paradox in order to identify challenges and opportunities that may advance the state-of-the-art in smart citizen initiatives. First, the potential of—but also issues with—these initiatives is identified from the literature, interviews with stakeholders, and example cases—one of which we analysed in significant depth (ASCL). To subsequently arrive at a proposal for unleashing the full power of smart citizens, we abstract a framework for a common process as well as for a socio-technical system that allows the identification of specific research questions. In this Chapter we summarise these contributions and conclude with a discussion of future work.

Literature analysis and interviews with key stakeholders in the Smart Cities discourse allowed us to confirm the promising nature of smart citizen initiatives, as testified by a number of successes in at least three relevant domains. In *social mobilisation*, the involvement of citizens helps to involve more stakeholders in decision making and understanding the decisions made. In *environmental monitoring / citizen science*, it helps to acquire more accurate data without significant investments, for citizens as well as for other organisations. This can contribute to *citizen innovation, citizen agency (feeling responsible and able to act), and social cohesion.*

The active involvement of smart citizens is important to different actors in different ways: public authorities and civil society organisations, academia, the private sector, and the citizens themselves. However, according to interviewees representing these actors, for the paradigm to be pervasively used in an urban context, improvements are needed. First, there is a significant challenge regarding motivating citizens to *participate* on a more permanent basis, especially for causes that require long-term involvement. Second, participating citizens are typically not a representative sample of the society, because both interest in data collection and knowledge/experience required to collect, aggregate, and draw sensible conclusions are necessary. This could quickly lead to an *inclusiveness and participation bias*. Third, the data collection is conducted by amateurs who usually do not follow rigorous methods. This results in data that is typically noisier than professionally collected data. Additionally, participants may be biased *because* they have a cause, and this leads to further issues regarding the *quality and trustworthiness* of the collected data.

With proper tools and guidelines for technical issues as well as the social and institutional setting, the effects of these challenges can be mitigated. To identify gaps in the available supporting tools and guidelines we describe the common steps in a citizen sensing process. Together these steps form the *From Needs to Knowledge Process*.

In this (cyclic) process we identify nine main steps. First, the information need is formulated. This determines which data must be collected and what the best source is for that data. Then appropriate methods and tools for the data collection have to be selected. Only then the data as well as the metadata can be collected and stored. Methods and tools for visualising and analysing the data need to be found and applied. Afterwards, observations can be made: identifying patterns, inferring conclusions, predictions, and validating or even combining with other sources. Based on these results, actions can be taken. One such action could be the identification of a new information need. In fact, a critical reflection in any stage of this process could require a change in earlier steps.

We propose a socio-technical conceptual framework to collect, disaggregate, and re-integrate data from a complex network of sensors, people, and machines to produce new understanding of cities, their dynamics, and their citizens. This so-called *Urban Knowledge Collider (UKC)* should provide *effective*, *efficient*, and *sustainable* production of and access to urban knowledge. In order to achieve these goals, a *UKC* should be *data-driven* (resolving interoperability issues of different data sources), *inclusive* (all relevant actors should and must be included), *horizontal* (allowing open, transparent, secure, and privacy-aware exchange of information between relevant stakeholders), *semi-structured* (allowing for a broad spectrum of use cases), *real-time* (allowing dialogues between relevant actors), *trust*- and *reputation-aware* (giving feedback and maintaining meta information on the quality of data), *geo- and time-aware* (keeping track of location and time), *accessible* and *ubiquitous* (enabling interaction whenever and wherever the actors are), *incentive-driven* (considering the psychology and science behind how and why people engage), and *sustainable by design* (supporting processes taking care of financial and technical issues also in the long term).

To make the *UKC* a reality, several research challenges must be addressed. For instance, from a computer science point of view, issues related to data integration, data quality, provenance, and trustworthiness are yet to be solved. How to scale-up smart citizen initiatives while making them inclusive and sustainable in the long term is an open problem that calls for transdisciplinary and experimental techniques which combine information, cognitive and social sciences, and political science. We advocate for a holistic approach—able to mitigate the shortcomings of previous smart citizen initiatives; bridge the gap between theory and experiments, but also between the perspective and needs of the different urban actors; and formally define the limitations and preferred applications of this emerging collaboration paradigm.

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Annex

Interviewed stakeholders

Dan Hill	Associate Director/ Head of Arup Digital Studio Arup - London, United Kingdom
Ton Dassen	Head of Department Spatial Planning and Quality of the Local Environment PBL – Netherlands Environmental Assessment Agency
Hester Volten	Scientist Air Quality RIVM – Dutch National Institute for Public Health and the Environment
Ger Baron	Chief Technology Officer City of Amsterdam
Arnold Bregt	Professor Geo information Science Wageningen UR
Joost Eijkman	Strategy Advisor Evides Water Company
Jonathan Carter	Co-founder and technical director Glimworm
Kyra van Onselen	Senior advisor innovation and information Dutch Ministry of Economic Affairs

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