Citizen Science in Water Quality Monitoring

Developing Guidelines for Dutch Water Authorities for Contributory Mobile Crowd Sensing

MSc Thesis - Ellen Minkman

TU Delft

Citizen Science in Water Quality Monitoring

Developing Guidelines for Dutch Water Authorities for Contributory Mobile Crowd Sensing

by

Ellen Minkman

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Preface

Some ten years ago I visited the Oosterscheldedam with my family. I was impressed and mused "I wonder how they make this." My father replied: "than you should become a civil engineer." And so it happened.

In 2007 I came to the TU Delft for a bachelor in civil engineering, which I finished a few years later with a bachelor thesis on farmer resistance in irrigation. After another year of courses I finally acknowledged that I was mainly interested in interaction with society. In 2012 I decided therefore to start a double degree in water resource management and science communication.

My internship in Kenya gave me the first opportunity to integrate the two fields in a research-oriented project. I used this experience to fully integrate my two graduation projects into one thesis at the intersection of water management and science communication.

While still in Kenya I had two write a news article about Mobile Canal Control, meanwhile renamed Mobile Water Management. This TU Delft spin-off company had developed a mobile phone application that enabled people to measure water levels without expensive or complex equipment. In the article they mentioned the opportunities that this application offered, as non-experts could use it as well. In my enthusiasm I added a line to my email with the news article to involved person: "PS. would it be possible to graduate on this topic?"

Peter-Jules van Overloop reacted enthusiastic and at the science communication department the reactions were equally positive. The project formulation phase took longer than planned, but offered us the great opportunity to participate in the Delta Water Award. Our idea, of using a mobile phone application to have citizens monitor water quality, was received positively by the jury and with a nomination for the Delta Water Award III in the pocket the real work could start.

I started to do explorative interviews to explore the possibilities for research and the Award. An interest of water managers in citizen science was apparent, accompanied by a hesitation to start off with citizen science. We did not win the Delta Water Award, but were able to present a conference paper at the EWRI Conference in Austin Texas, and the interviews brought focus: there was a clear need for evidence based guidelines for practitioners and scientific understanding of the implications of citizen involvement via citizen science in water resource management.

The result is in your hands. This thesis integrates the two fields, but also links theory and practice. The thesis is written with both an audience of academics and of practitioners in mind, as the research findings lead to the formulation of guidelines. I would like to finish with expressing my hope that these guidelines will be able to set the first step citizen science as common practice in water resource management.

Ellen Minkman
Delft, 20th of August 2015

Acknowledgements

This thesis would not have been possible without the contribution of many people. I would like to start with expressing everything I owe to Peter-Jules van Overloop, who supervised me on behalf of civil engineering. His believe in the involvement of citizens in mobile model predictive canal control got the ball rolling. His supportive and contagious enthusiasm and everlasting belief that the project would be successful kept me going. Due to his sudden passing in February 2015 I cannot handover these appreciations in person, but I am glad that I could make a contribution to his work.

The next person that I am indebted to is Martine Rutten. Martine, I cannot express how grateful I am that you took over the supervision. My primary supervisor of science communication, Maarten van der Sanden, was my second solid rock. Thank you for the many inspiring contributions, creative thoughts and suggestions.

I also owe the rest of my supervisors. Caroline Wehrmann, thank you for giving me the most encouraging feedback when I needed it. Nick van de Giesen, thank you for your support and sharing interesting links throughout the project. A honourable mention for Steven Flipse, as his availability for the green-light meeting is the only reason my thesis was printed in August. In Dutch we say al good things come in three: Judith Kaspersma, thank you for giving me the opportunity to pitch my case in her workshop, for your participation in the Q methodological approach and, last but not least, for being part of my graduation committee.

Another person deserving a special mention is Hajo Heusinkveld. Hajo, last week you told me you were not sure if you had done enough to support me, which I have to disagree with. I enjoyed working with you, despite the saddest cause that brought us together.

I would like to give many thanks to the 163 respondents who took the effort to start my questionnaire and my greatest respect for the 60 who completed it. I also want to thank all participants who agreed to participate in my 'card game' and in particular the people who did a great effort to recruit their colleagues to participate. The result would not have been the same without the experts at Universiteit Leiden, Unesco-IHE and TU Delft who took the time to discuss my work or help me with the questionnaire.

All errors are entirely on my account as I had this amazing group of excellent peer reviewers who took the time to read my texts and helped me a great deal in improving it. During my thesis I had the luxury of having two wonderful groups of study mates at water management and science communication. I had a wonderful time at both graduation rooms. The support of my classmates was inspiring and helpful, but Melanie: your company and suggestions made it happen!

My friends Jeroen, Marlies, Martine, Roos, Dorien, Nick: thank you so much for testing my Q sort statements. I also appreciate the help of the anonymous contributors to the online pre-tests and I owe a lot to Lotte, Annemarie and my parents for trying out the survey. My much-loved aunt Annemarie: thank you for spreading the survey among your friends. I feel sorry I could not include their contribution in the end.

A good research mentions whether it has received any financial support, therefore this seems an excellent place to acknowledge my main sponsors: mum and dad, I am glad you gave me the opportunity to expand my knowledge by supporting me in two masters.

Last but definitely not least, Jeroen, thank you so much for your never-ending support across borders. Knowing that you would fly back to me on my graduation day gave me wings.

Executive summary

The Dutch water management system is of high quality, but faces three challenges. In its 2014 report the Organisation for Economic Co-operation and Development (OECD) highlights the *"long-standing excellent track record of Dutch water governance"* (OECD 2014, p. 19), but also signals *"a striking awareness gap among Dutch citizens related to key water management functions, how they are performed and by whom."* (OECD 2014, p. 21). Climate change is likely to result in rising sea level, a decreasing availability of fresh water and water quality issues (RIVM 2014). Urbanisation will decrease the population in rural areas and consequently increase the expenses per capita in these regions (UvW 2015a). As a result the support base for investments in water infrastructure is eroding and there is a low perception of local risks (OECD 2014).

Increased levels of citizen participation, for example via public consultation, and new forms of governance will be needed to cope with abovementioned current and future challenges. Citizen science is introduced as a new form of citizen participation in water resource management where citizens collect, analyse or interpret data in a scientific way. Dutch water authorities have interest in using citizen science. The growing interest in citizen science is accelerated by a rapidly progressing technological development. Cheap and easy-to-use devices are increasingly available and enable a non-expert, such as citizens, to collect water quality data. Citizen science using smartphones and other devices, called mobile crowd sensing (MCS), is suggested as an interesting innovation for water authorities; an increasing amount of (external) sensors becomes available to measure water quality indicators, for example to measure temperature, electric conductivity and turbidity.

Existing citizen science projects are often not documented in peer-reviewed articles and Dutch practitioners wonder why they should turn to citizen science and how it should be implemented. This thesis aims to support water authorities with practical guidelines on how to start a citizen science project in water quality monitoring. This will be done by increasing scientific knowledge on citizen science and motivations to engage in it, both from the water authority's and the citizens' viewpoint, and by translating research findings into tangible design conditions for practitioners to set up a citizen science project. Special attention is given to MCS as an emerging sub-class of citizen science.

A design-based research approach using mixed methods

A design-based research approach was applied to develop design principles for practitioners, using six different methods in a mixed methods research set-up. The findings in the study were translated to a guideline for practitioners on the set-up of citizen science in water quality monitoring using the Seven-Layer Model for Collaboration (SLMC, Briggs et al. 2009). The SLMC is a design pattern, used to bridge theory and practice, while taking context into account. In each layer research findings from multiple steps were taken into account. The figure below (Figure 1) illustrates how the research methods are integrated with the model to develop the guidelines.

The first two methods were used to find an answer what a water authority should consider to formulate a citizen science scheme. A literature review (method 1: KSF and MSC) was used to identify key success factors (KSF) for setting up citizen science from literature from different fields and countries. Subsequently a case study comparison (method 2: cases) took place to identify the generalizability to the Dutch situation of each KSF.

An important factor is to know why people want to engage in citizen science in water resource management. This was studied from both the perspective of citizens and water authorities. Forty motivations and barriers that citizens may experience were identified in previous studies and were mapped on the Self-Determination Theory (Ryan & Deci 2000) for this study. The relative importance of these motivations was inquired via a quantitative survey in a Dutch case study (method 3: survey). Water authorities' viewpoints on citizen science were identified using a Q methodological approach (method 4: Q) and the viewpoints were studied in-depth using structured interviews (method 5: incorporated in Q).

Mobile crowd sensing (MCS) is a special application of citizen science using smartphones as measurement devices. The exclusive characteristics of MCS were described in the mentioned literature review (method 1: MCS). In MCS, besides technological issues, it is important to know why people are willing to use the MCS device. A Technology Acceptance Model (based on Ventaketsh & Bala 2008) was used to identify drivers and barriers for citizen intention to use mobile crowd sensing (method 6: TAM).

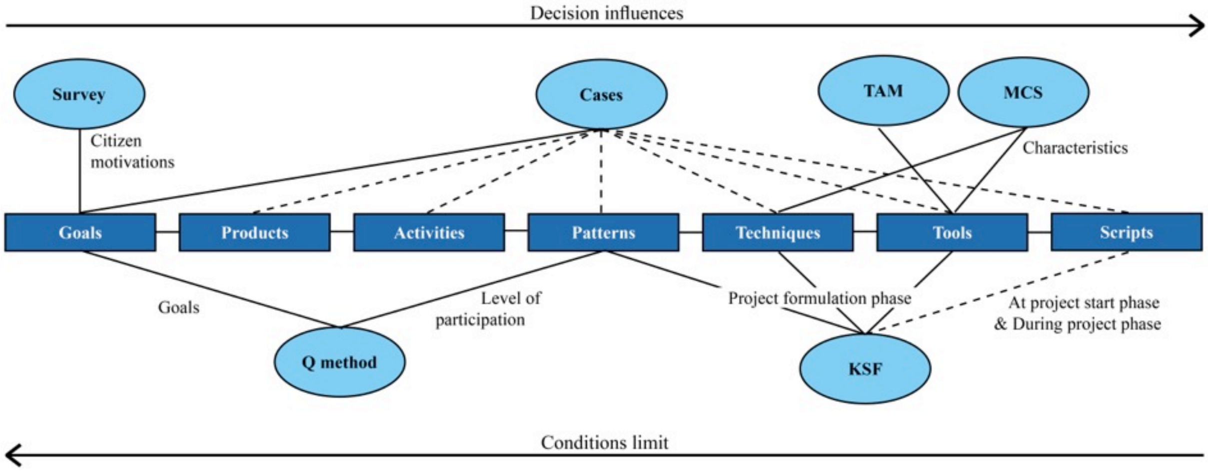

Figure 1 – Overview of the Seven-Layer Model of Collaboration and the integration of the research methods within the model that are used to develop the guidelines. The solid lines (–) represent integration of research conclusions, where dashed lines (--) indicate illustrative use of findings.

A framework of key success factors at different phases of the project

A framework of key success factors was formulated, based on a literature review of existing knowledge in the fields of citizen science and online crowdsourcing. Key success factors were identified at the level of the participant, at the level of the organisation and for the set-up as whole. The framework is further divided into four time steps: when deciding to use citizen science, during project design, at the start of the project and during the project. An important success factor is to set the goals of the project.

Nine different goals for citizen science were identified in literature (Tulloch et al. 2011): Raise Awareness, Education, Policy Development, Management, Increase Knowledge, Improve Methods, Serendipity, Recreation, Social Research and Policy Development. The latter is split by Hollow et al. (2015) into discover alternative policies, educate citizens about a situation, measure public opinion about an alternative, create a support base and provide legal justification of a chosen policy. The goals influence the characteristics of a citizen science project, such as required level of data quality, time-span, governance structure and level of citizen involvement.

A comparison of key success factors (see chapter 4) in four case studies in citizen science confirmed literature findings to a great extent. The topics of the citizen science projects were garden wildlife, water quality, particulate matter and groundwater and surface water levels. The latter two projects made use of mobile crowd sensing.

Making a contribution and time constraints as main motivation and barrier for citizens

To gain insight in why people participate in citizen science thirty possible motivations and barriers were obtained from literature. These originate from a wide range of projects and were categorised according to the Self-Determination Theory from Ryan & Deci (2000). A survey with 60 respondents investigated Dutch citizens' motivations and barriers to participate in a hypothetical project on water quality monitoring. In this project citizens would monitor turbidity and chemical and biological indicators.

According to the survey the most important reasons to participate in water quality monitoring are: contribute to conservation (97%), contribute to science (84%) and discover new things (80%). Least important are improve one's reputation (7%), financial compensation (9%) and increase the chance of a job via participation (10%). The main barrier to participate is a lack of time (40%), followed by personal reasons (19%). The results suggest that respondents with a higher intention to participate mainly report intrinsic motivations, while extrinsic motivations are mentioned more often by respondents with a lower intention to participate. The latter group further reported a lack of time (60%) and physical constraints (15%) more often than the respondents with a high participation intention (respectively 32% and 2%).

The abovementioned results are context specific and exploratory in nature, but match the conclusions of similar studies. To set up a successful citizen science project, alignment of goals between water authorities and citizens is important and this thesis's findings can provide initial understanding of citizen motivations.

'Citizen participation for data collection', 'the water authority in control' and 'education and local knowledge' as three different viewpoints on citizen science in water authorities

A Q methodological approach was used to gain insight in how water authorities feel about citizen science. In this Q methodological research 33 participants ranked 46 statements from 'most agree' to 'most disagree'. The researcher composed this set of statements, based on semi-structures' statement interviews with water authorities and organisations, a focus group with citizens and a workshop for water experts.

Three viewpoints on citizen participation in water quality monitoring were identified. These viewpoints are: A) 'Citizen participation for data collection', where data collected by citizens is considered valuable for several purposes, including improving management, methods and raising awareness; B) 'Water authority in control', where citizen science is considered important in raising awareness and data are merely illustrative or indicative for water management; and C) 'Education and local knowledge', where the emphasis is on the area-specific knowledge that citizens have and the educational value of citizen science projects.

In these viewpoints support is found for application of citizen science in water management, especially as a means to raise awareness among citizens. Additional interviews revealed that the ultimate goal could be a change of citizen behaviour, for example by increasing behaviour that contributes to maintaining a good water quality. Support was further found to use citizen science for five other goals besides raising awareness: knowledge generation, improving monitoring methods, management, public education and create a support base for policy.

Although the support for citizen science is convincing, indications were absent for a support base citizen involvement in the full monitoring cycle. Citizen involvement is often classified on three levels with increasing citizen participation: contributory, collaborative and co-created. The three viewpoints consider citizen involvement valuable in data collection (all three), analysis of measurements (viewpoint A and C) and in the case of viewpoint A also the analysis of the dataset. These activities point at contributory projects and support is lacking for collaborative and co-created projects with higher levels of citizen involvement.

Mobile crowd sensing as a special application of citizen science

In literature reasons for water authorities to turn to mobile crowd sensing (MCS) were determined. A majority of the Dutch population possesses a smartphone and technological developments increase the availability of internal and external sensors for smartphones. MCS is a special application of citizen science, where a mobile device, often smartphones, supports data collection and transmission. It is suggested, based on literature, that water authorities might prefer MCS to wireless sensor networks, for its mobility, lower costs and scalability. Water authorities should be aware of the challenges accompanied with MCS though. The most prominent challenge is to balance privacy issues with data trustworthiness. As an organisation with the status of a local government, a water authority may have access to privacy sensitive data. Whether MCS is preferred depends on the required level of data accuracy and whether data is required near real-time.

A Technology Acceptance Model for citizen intention to use a smartphone application
Besides relevance to ambitions of the end-user (the water authority), it is important that a technological tool suits the user. It was investigated what drivers are for citizens to use such mobile crowd sensing (MCS) devices. Models can support such examination; in this thesis a Technology Acceptance Model (TAM) was applied (Venkatesh & Bala 2008) to assess drivers that influence citizen intention to use an MCS application.

In a survey a specific context was provided to respondents, centring on a smartphone application to monitor chloride, phosphate, turbidity and biological indicators (plant species). The basis of TAM consists of four main elements: the perceived usefulness of the application, the perceived ease of use when using the application, behavioural intention to use the application and the actual use. The latter was omitted, because it concerned a hypothetical case. It was found that usefulness is the most important for behavioural intention. Several drivers to these elements were investigated and job relevance and result demonstrability of the technology were the most important drivers for this usefulness. The findings confirm other studies on technology acceptance, as the mobile crowd sensing technology should be useful rather than free of effort.

The TAM is a single example out of many models that might be used to investigate intention to participate or use a certain mobile application. The findings of the model are representative for this specific context and specific set of respondents. The demonstrated use of the model rather serves the general idea is to show the value of using (scientific) models in the project design phase.

Guidelines for water authorities
This thesis demonstrated which considerations are important for water authorities in order to decide whether citizen science is appropriate to use. Water authorities can use the formulated guidelines as guidance in the set up of a citizen science project. These guidelines provide an answer to main question of how a citizen science project for water quality monitoring by Dutch regional water authorities should be designed.

The findings of this study were combined following the design pattern of the Seven-Layer of Collaboration Model (Briggs et al. 2009) to formulate guidelines for practitioners in water authorities. These guidelines combine answers to the questions why water authorities and citizens would engage in citizen science and how a project should be set up. The guidelines start with a description of citizen science to clarify the topic. An important first recommendation for water authorities is to make an informed decision whether citizen science is suitable for the goal to be achieved.

Another important recommendation is to collaborate with strategic partners that can increase the audience reached, that can fill gaps in knowledge, skills and resources and can increase the credibility of the project. Available scientific knowledge should not be overlooked and can contribute to strategic decisions this thesis demonstrated.

Besides partners the motivations of citizen should be incorporated in the project design to attract citizens to start or continue contribution, as the project thrives or fails with sufficient citizen participation. A pilot or test period is advisable to test whether the project matches citizen motivation and which barriers they perceive and to adjust the set-up were necessary. Whatsoever the goal of the citizen science project is, using the data is an important motivation for citizens and sufficient feedback should be given on this data usage and the importance of individual and collective contributions.

Additionally the project should match organisational and citizen capacities. The governance structure should match organisational capacity and the level of interaction, while collaboration practices and technologies (for example mobile crowd sensing) should match the facilities of the organisation and capabilities of citizens. An important pitfall is that citizen science is considered a cheap alternative to collect data, but expenditures in terms of time investment and coordination should not be underestimated.

The guidelines close off with practical advice on how to sustain citizen participation for a longer period, in particular by alignment of local projects and the constant recruitment of citizens.

Scientific relevance of the thesis
This thesis offers insights in the rather unexplored field of citizen science deployed by water authorities. The use of Q methodology is an enhancement of the research methods toolbox for water managers and science communicators. The combination of methods used in this thesis is unconventional for both science communication and water resource management research.

This research contributed to insight in citizen motivations and barriers to participate in citizen science, it revealed the current viewpoints on the topic by water authority employees and explored the potential for mobile crowd sensing as a specific application of citizen science in water quality monitoring in the Netherlands.

The thesis has made a strong link between theory and practice via the integration of the separate parts of the research in practical guidelines. Testing the guidelines in a practical set up would be an excellent start to further develop the knowledge on how to implement citizen science in water quality monitoring.

Practical relevance of this thesis: an answer to future challenges?
In this study the applicability of citizen science to raise awareness and change governance structures was studied. The outcomes of this thesis provide strong indications that citizen science in the form of data collection by citizens can contribute to bridging the awareness gap as defined by the OECD (2014) and the Dutch Water Authorities (UvW 2015a). Citizen science certainly has potential to transform governance structures, but there is still a long way to go before higher levels of citizen involvement become common practice in water quality monitoring becomes common practice. The formulated guidelines are a tangible outcome of this research that can aid water authorities in starting citizen science.

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Part 0 – Introduction to the research

In this part of the thesis the topic will be introduced. In Chapter 1 it will be discussed why water authorities consider citizen science as a form of public participation and what challenges they face. The accompanying research questions are presented in Chapter 2. In Chapter 3 a description follows of the research methods applied to achieve the goals of this study.

Chapter 1 Introduction to citizen science in water resource management

The Dutch water management is an international example (OECD 2014). Yet the Dutch water management system is not fully prepared for the future; governance structures should be adjusted to keep up with a changing climate and a changing society (OECD 2014, UvW 2015a).

1.1 An awareness gap, urbanisation and climate change as future challenges

Climate change predictions for the Netherlands not only forecast a rise of sea level, but also an increase of current water quality challenges (RIVM 2010). Average temperature and variation within seasons will increase (RIVM 2010). Salinization, acidification and eutrophication are in line with expectations and habitat fragmentation will further increase the pressure on the ecosystem (RIVM 2010). It is expected that innovations in water quality monitoring are needed, such as novel approaches to generate knowledge and to incorporate it in water resource management (Buytaert et al. 2014).

Apart from physical pressures, such as climate change, the Dutch water authorities are facing societal challenges as well. The OECD warns for *"a striking awareness gap among Dutch citizens related to key water management functions, how they are performed and by whom."* (OECD 2014, p. 21). Dutch citizens take the excellent water management for granted (OECD 2014). The country has not experienced a major water calamity over the last sixty years. The flooding of 1953 was the last large-scale flooding event (e.g. De Kraker 2015) and since the 1990s water quality in the major rivers has improved (e.g. ICPR 2014). Citizens' behaviour, as a consequence, does not contribute to water resource management efforts of the water authorities; flood defences are violated by property development and pollution is common (OECD 2014). At the start of the millennium the Dutch government already identified that citizens and interest groups do not recognise water risks (Tielrooij 2000). Risks of this lack of awareness include ill-informed decisions by property owners and a decreasing support to invest in flood defence and water quality management (Tielrooij 2000; OECD 2014).

The decreasing support for investments in water management is persistent in rural areas (UvW 2015a). The Netherlands is facing an increasing urbanisation (CBS 2014), caused in particular by young families that move to cities (UvW 2015a). In urban areas with a decreasing population per capita costs of water management increase as a consequence, because the water authorities are organised as regional governments.

1.2 Towards new governance structures with a higher level of citizen participation

The OECD (2014) advises to face these challenges with a renewed focus on governance and by investing in active stakeholder involvement. The governing body Dutch Water Authorities (Unie van Waterschappen, UvW) installed the 'Committee Oosters' as a response to the OECD report. Committee Oosters formulated a vision on governance and the role of water authorities therein (UvW 2015a). The committee concluded that fixed administrative structures are inadequate to solving future challenges, such as consequences of climate change and societal awareness.

The committee states that instead the network-oriented society requires collaboration with other government layers, industry, interest groups and citizens. This collaboration with citizens is visualised in ten examples of public participation in the booklet "Waterbeheer doen we samen: Waterschappen voor de burger." ("We do water management together: Water authorities for citizens." UvW 2015b). Four of these projects are a specific type of citizen participation, being citizen science projects, where citizens participate in data collection, interpretation or analysis.

1.3 Citizen science and mobile crowd sensing in water resource management

Citizen science is not a new phenomenon, but revived in the 20th century and gained popularity worldwide over the past two decades (e.g. Bonney et al. 2009; Silvertown 2009; Roy et al. 2012). Many fields adopted citizen science and water resource management is about to join (Buytaert et al. 2015).

The involvement of citizens in scientific processes entered a new era in the 20th century. The most well known (e.g. Cohn 2008, Silvertown 2009) citizen science project is the Christmas Bird Count, which started in 1900 as a volunteer-based inventory of winter bird populations (Link et al. 2006). The Christmas Bird Count can be considered one of the first contemporary citizen science projects. The renewed attention for citizen science in the past 20 years is fuelled by the knowledge-driven society (Lidskog 2008) and by changing scientific grant regulations (Silvertown 2009).

1.3.1 A fading lay-expert divide and budget cuts fuel modern day citizen science

A first cause that explains the rise of citizen science is that increased accessibility to knowledge means the knowledge barrier between experts and laypeople is fading (Lidskog 2008). In the knowledge driven society people have access to information that may demonstrate that traditional experts, such as governments and scientists, could be incorrect. Citizens are becoming co-producers of knowledge instead of passive receivers of information from experts (Lidskog 2008). In the knowledge-driven society people have access to all kinds of information via the Internet.

The second explanation can be found in budget cuts and the requirement of societal relevance for research grants (Silvertown 2009). This triggered the involvement of citizens in research processes. Amateur scientists provide a workforce that allowed scientists to collect or analyse large amounts of data and conduct long-term monitoring (Cooper et al. 2007).

1.3.2 Barriers and opportunities in the water sector

Recognition of the importance and application of citizen science in water management is upcoming, but lingering (e.g. Cohn 2008; Fraternali et al. 2011). Many fields adopted citizen science over the course of the 20th century, with ecology (e.g. annual bird counts) and environmental monitoring as front-runners (Silvertown 2009). Fraternali et al. (2011) describe the potential of amateurs taking part in data collection, data analysis and the process of decision making in water resource management. The rise of robust, cheap and low-maintenance sensors further enhances opportunities for citizen science in the more complex arena of water management (Buytaert et al. 2014).

The potential of such sensors is emphasised by studies that suggest that quality of data collected by citizens varies along the equipment used (Buytaert et al. 2015). pH and electrical conductivity (EC), for example are relatively simple to measure thanks to advanced, easy-to-use equipment (Nicholson et al. 2002; Shelton 2013). Dissolved substances, such as phosphate, are in general analysed in complicated (laboratory) analysis, which makes it more difficult to obtain good results with citizen science (Buytaert et al. 2015). Previous studies suggest that the less complex it is to take a measurement, the more accurate the data will be.[1] According to Buytaert et al. (2014) the need to use expensive and complex measuring devices formed a logical explanation for the underrepresentation of water management in citizen science. Especially in water quality monitoring the need for such equipment complicated the application of citizen science. The increasing availability of easy-to-use sensors increases the potential of citizen science in water quality monitoring.

[1] *This is illustrated by Nicholson et al. (2002) who describe measuring EC and pH (both with electronic devices) results in accurate results compared to expert data, while reading a log-scale turbidity tube and performing a total phosphorus analysis in the lab leads to much difference between volunteer and expert data. Shelton (2013) data collection with a YSI Professional Plus, a handheld multi-variable instrument to measure temperature, EC and dissolved oxygen.*

1.3.3 An introduction to mobile crowd sensing

Easy to use equipment may enhance citizen science in water quality monitoring, mobile phones increase the set of opportunities as well. An average phone has more computational power and sensors than the whole of NASA in 1969 (Kaku 2011). Common smartphones are equipped with sensors for inertia, acceleration, sound (microphone) location (GPS), ambient light and proximity and have additional functionalities such as a compass, camera, gyroscope and light (Lane et al. 2010).

Applying these phone sensors in measuring schemes is referred to as mobile sensing (MS). Such sensors have the potential to replace many conventional instruments used in science, such as traditional compasses and GPS devices (Lane et al. 2010). It is suggested that these emerging sensing technologies could enhance the development of smart water management, which integrates anticipative and integrative water management (e.g. Hill et al. 2014). Buytaert et al. (2014) describe the potential for hydrology (including water quality monitoring) in terms of obtaining more data and increased data coverage of remote areas. An example is the plugin sensor of Sensorex (www.sensorex.com). This is a multifunctional monitoring device that combines the collection of information pH, Oxidation Reduction Potential (ORP), temperature, Electric Conductivity (EC) and GPS locations.

Figure 1.1 – Example of mobile sensing devices. A plug-in sensor is used to measure pH, Oxidation Reduction Potential, temperature and Electric Conductivity.

The two previously described concepts (citizen science and mobile sensing) meet each other in mobile crowd sensing (MCS). MCS can be considered a subset of citizen science. In MCS large groups of citizens perform measurements in a scientific context with their smartphone internal sensors and (optionally) external devices.

1.4 The growing interest of water authorities in citizen science

So far citizen science and mobile crowdsourcing is discussed in a scientific context. A recent development is the increased application of citizen science by decision makers (Conrad & Hilchey 2011). The available literature is scarce (a majority of projects is not documented in peer-reviewed articles - Conrad & Hilchey 2011) and limited to scientific contexts.

On November 27, 2014 a workshop[2] on big data was organised at a conference at the water authority of Delfland, the Netherlands. Participants indicated that they expect that the inclusion of citizen data will be beneficial for Dutch water management in the near future. In particular they see an important role for smartphones and mobile crowd sensing. Participants did mention though that they are not sure how to motivate citizens, what information to collect and how to incorporate additional information in current information flows.

1.4.1 Citizen science in science vs. citizen science in water resource management

The uncertainties expressed by the workshop participants at the water authority of Delfland can be explained by a lack of practical and scientific knowledge about citizen science organised by authorities. In traditional citizen science projects only two parties are involved: the citizen scientist and the scientists. A scientist or research institute calls for assistance of citizens in their charitable, scientific activities, which match citizens' interests (Rotman et al. 2012; Edwards 2014).

[2] *See http://doorbraakprojectenmetict.nl/agenda/symposium-fysieke-digitale-delta.*

Once authorities start to act as information requester, the situation sketched before changes. Authorities have a practical interest in the collected information compared to scientist, for example for decision support (Wehn & Evers 2014). Citizen science data that is used for decision support by authorities can be considered as a way of stakeholder involvement (Bäckstrand 2003; Almoradie 2014). Citizen science stands or falls with sufficient participation levels though.

1.4.2 Insufficient insight in motivations of citizens in citizen science

Extensive research has been done on citizen motivation to participate in citizen science and mobile crowd sensing projects in a scientific context. It is uncertain how citizens view participation in projects initiated by authorities, but Case studies in the Netherlands and the UK suggest though that citizens consider flood protection and water quality management as a task of the authorities and not a community task (When & Evers 2014).

Insight in citizen intention to participate and information on factors that influence this intention in the Dutch context are essential, but missing. Most literature focuses on other types of citizen science (e.g. Rogstadius et al. 2011; Roy et al. 2012) and available literature in a context of water management mainly originates from the USA, where community based water monitoring is common practice (e.g. Overdevest et al. 2004; Conrad & Hilchey 2010). This international example cannot be translated to the Dutch case, due to differences in governance, scale and problems faced. For example, the watersheds in the USA are apolitical areas, operated by volunteers or state-owned organisations. Water authorities in the Netherlands, on the contrast, are regional government bodies; they levy taxes and are led by a board of politicians.

Adoption of citizen science as a form of public participation in Dutch water management thus requires insight in the Dutch system of regional water authorities. The next section elaborates on this system of Dutch regional water authorities.

1.5 An overview of regional water management in the Netherlands

The Dutch system of water authorities finds it origins in the 1100s. Local authorities agreed on the control and maintenance of local flood protection in water boards (Mostert 2013). Anno 2015 there are 24 water authorities in the Netherlands. At the moment their responsibilities reach beyond flood defence. In 1970 the Surface Water Pollution Act (Wet Verontreining Oppervlaktewaterer, WVO) was issued and formally made water quality management a task of the water authorities. In the 1990s wastewater treatment was added as a responsibility of the water authorities.

The water authorities are not solely responsible for water management on a local level. Two other local authorities have responsibilities concerning water management: municipalities and provinces. The tasks of provinces are on the higher level of planning and regulation, while municipalities are mostly concerned with planning on a local scale and transport and drainage (OECD 2014). See Figure 1.2.

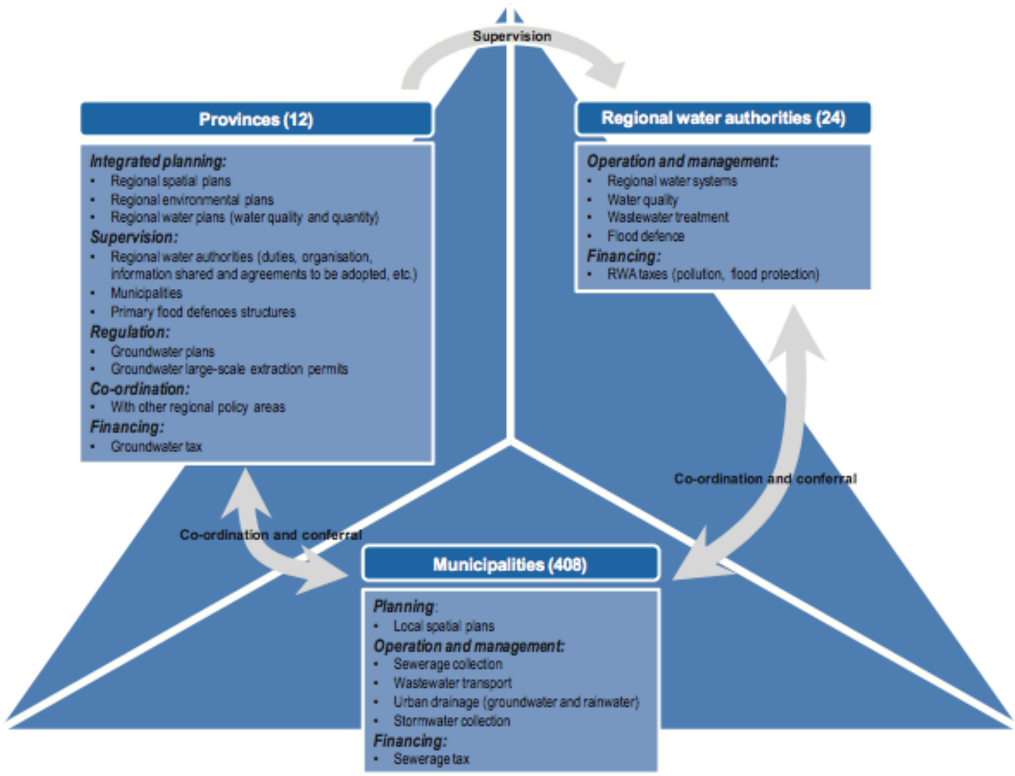


Figure 1.2 – Responsibilities of local governments (municipalities, water authorities and provinces). (OECD 2014)

Water management without borders

The demarcations of water authorities do not follow institutional borders of provinces of municipalities, but are defined by natural borders. These borders go beyond the national border as well, since the area of the Netherlands is located in four international river basins[3]: Ems, Meuse, Rhine Delta and Scheldt (Figure 1.3). As a consequence the Netherlands have to comply with a set of European legislation, many of which a responsibility of the water authorities.

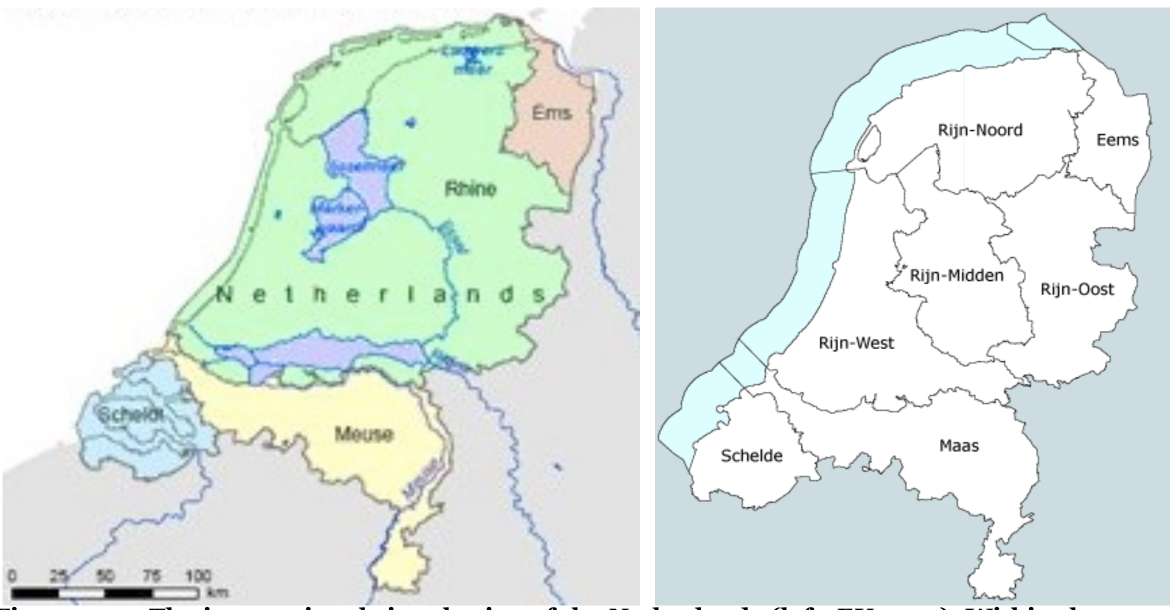


Figure 1.3 – The international river basins of the Netherlands (left, EU 2015). Within the country the Rhine basin is divided into Rhine-North, -East, -Middle and -West (right, CBS 2008).

[3] A river basin comprises the area that contributes to the river, by directing all the water in that area to the river until it discharges into a sea or ocean.

1.5.1 Water quality management in a European context

Member states are obliged to European legislation on water management, the most inclusive is the Water Framework Directive (WFD, Directive 2000/60/EC). Regarding water quality the WFD sets standards for a good ecological and chemical status of water bodies, based on biological quality (e.g. fish population); hydro-morphological quality (e.g. riverbank structure); physical-chemical quality (e.g. nutrients concentration) and chemical quality (e.g. pesticides). Countries are required to have achieved 'a good ecological potential or good ecological situation' before 2015.

The implementation of the WFD in the Netherlands requires water authorities to implement management strategies to improve water quality. Water authorities could implement interventions, such as physical measures that are expected to increase water quality. They are furthermore responsible for regular monitoring of groundwater and surface water quality. The official monitoring networks requires using certified methods and standardized reporting to the national government and the European Commission. Monitoring of water quality primarily takes place in two fields, as water quality can be assessed in two ways: either via chemical composition or via ecology.

Chemical quality
Chemical water quality is assessed by the determination of concentrations of substances. National and international legislation mainly determine how this should be measured and evaluated, although water authorities can do other measurements for their own purposes.

In general there is a standardised network of monitoring points. This is usually monitored monthly on a fixed time and location. Water samples are taken by laboratory personnel and analysed in the laboratory. Besides this main network there is a rotating scheme. The areas in this scheme are monitored for one entire year out of every three. An inquiry at the water authorities learns that most water authorities have outsourced the laboratory activities including sampling (see Figure 1.4).

Figure 1.4 – Laboratories of water authorities. The northern water authorities have their own laboratories, while the south-western, western and eastern water authorities have joined forces in shared laboratories: respectively Aquon, Waterproef and Aqualysis. The southern water authorities make use of independent laboratories. (picture made by author 2015)

Ecology
Ecological water quality is assessed by the presence of certain species of flora and fauna. Ecologists or aquatic biologists monitor the ecology. Water authorities can either outsource this to laboratories or they have ecologists among their employees. They collect information about certain indicator species that thrive at a certain water quality. An example of a species that only occurs in water bodies with a good water quality is *Stratiotes aloides* (water soldier, see Figure 1.5).

Figure 1.5 – Stratiotes aloides (water soldier)

1.6 Chapter summary: a lack of literature on citizen science in the Netherlands and of guidelines to set up citizen science projects

Summarizing this chapter it can be concluded that there is a need for practical guidance for water authorities regarding citizen science. As a response to the OECD (2014) report, the UvW provided a booklet with ten examples of public participation (UvW 2015b), four of which a form of citizen science. The examples provide insight in the range of possibilities, but do not offer guidelines to set up citizen science. Furthermore, the available information concentrates on scientific contexts, creating a lack of information on citizen science by decision makers at government levels such as water authorities. Finally, such projects need sufficient levels of participation, but understanding of citizen motivation to participate is lacking.

Chapter 2
Problem statement and research question

In the previous chapter an introduction to Dutch regional water management was given with respect to its organisation and future challenges. This chapter describes the problem and defines an aim and research question.

2.1 Problem statement

Citizen science has existed for over a century and has been thoroughly studied in its traditional form where scientists involve citizen volunteers in their research. Recently water authorities in the Netherlands have shown interest in citizen science, seeing it as a means to increase the awareness about water issues and the importance of water resource management in the Netherlands. The rapid technological developments increase the availability of low-cost and easy to use water quality monitoring equipment, thus enhancing the potential for citizens to perform measurements.

This novel interest of water authorities in citizen science poses a challenge as well. There is a lack insight in the range of applications for citizen science in Dutch water management. Regional water authorities are unsure which challenges they will face when they engage in citizen science. An important question is further which decisions have to be made when setting up a citizen science project and what implications of these decisions are.

So far citizen science has mainly has been applied by universities, research institutes and nature conservation organizations. Examples on watershed management mainly originate from the USA with a different organisational structure where it comes to water management and other practical cases of citizen science remain often unstudied in scientific literature.

Literature scientific literature on and practical examples of how citizen science in Dutch water management is done, is hampering the introduction of citizen science by Dutch water authorities.

2.2 Research aim

The main aim of this research is therefore <u>to gain insight in the motivation to engage in citizen science, both from the perspective of water authorities and citizens, and to develop design guidelines that can guide water authorities in setting up citizen science project.</u>

2.3 Research question

The research aim is translated into the following research question:
How can a citizen science project be designed for water quality monitoring initiated by Dutch regional water authorities, with special attention to the potential role of mobile crowd sensing?

Five sub-questions are formulated to support this question. The first three focus on citizen science in general:

1) *What key success-factors are available from existing literature for setting up a citizen science project in general and mobile crowd sensing in particular?*
2) *What motivations and barriers do Dutch citizens perceive regarding participation in citizen science in a water quality monitoring project?*
3) *What are different viewpoints of Dutch water authorities regarding the application of a citizen science in water quality monitoring?*

The rapid technological developments increase the availability of cheap sensing devices, which may provide opportunities for large scale citizen science in water quality monitoring. One of these devices is the smartphone. Mobile crowd sensing will therefore be a special focus point of this thesis and concerns the two other sub-questions.

4) *What distinguishing characteristics of mobile crowd sensing influence the design of a citizen science project?*
5) *What are the main positive and negative drivers of Dutch citizens in acceptance of smartphone applications for water quality monitoring that influence the design of a citizen science project?*

Positioning the sub-questions in an interaction scheme
In the interaction between citizens and water authorities there is information about measurements ('Data'). In the current situation the water authority collects that data. Interaction between citizens and water authority leads to the dissemination of data. In a citizen science project, citizens collect the data and transfer this to the water authority. In mobile crowd sensing an MCS tool acts as an intermediary between citizens and the water authority.

Each sub-question is positioned at its respective position. Questions 1 and 4 relate to the whole situation, while 2 and 3 act on the level of the individual citizen or water authority employee. Question five concerns the interaction between the citizen and the MCS tool.

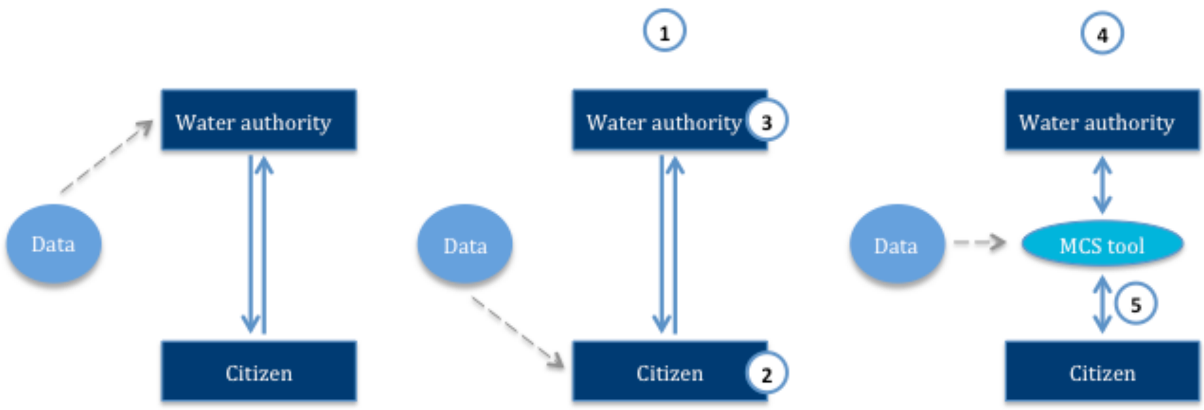


Figure 2.1 – Overview of the interactions between citizens and water authorities and the positioning of the research questions.

Chapter 3
Research methodology

In the previous chapters the research was introduced and a lack of insight in the application of citizen science for Dutch water authorities was identified as the main problem. This research aims to provide insight in citizen science from both the viewpoint of citizens and of water authorities and to develop guidelines for water authorities. In this chapter the research methodology is outlined.

3.1 A design-based research methodology using mixed methods

The main research method is design-based research (DBR), but is also referred to as design research (Anderson & Shattuck 2012). DBR originates from the field of education research and is a form of applied research. This makes DBR a most suitable approach for a research that aims to be valuable to practice (Anderson & Shattuck 2012; McKenney & Reeves 2013), which is the case in this thesis, given the objective stated in Chapter 2.

Characteristics of DBR are defined by Anderson & Shattuck (2012) DBR and include that DBR is a) situated in a real world context; b) has considerable impact on practice; c) focuses on design and testing of interventions; d) involves a collaborative partnership between researchers and practitioners; e) uses mixed methods; f) involves multiple iterations and g) evolve from and lead to design principles. The aims of this thesis match with a majority of characteristics of DBR.

DBR was considered suitable for this thesis, as it aimed to produce guidelines on citizen science for practitioners at water authorities in a specific real world context, namely water quality monitoring, based on scientific findings. This makes this thesis compatible with characteristics a, b and c.

To develop these guidelines a design pattern was preferred as design method (characteristic g), because it helps bridging the gap between theory and practice, plus that it allows takes context into account (Van Diggelen & Overdijk 2009). The actual pattern used to design the guidelines, was selected after completing the other research steps. The design method was selected afterwards, as insight in the shortcomings of the existing knowledge and practices was required to do so. In 3.5 the chosen design pattern is introduced and its relation to the other research steps is explained.

DBR was indeed supported by a mixed methods approach (characteristic e) for two reasons. First, it offered completeness, because it allows considering the research question from different angles (Bryman 2012). Second it allowed choosing the best research method for each research sub-question (Anderson & Shattuck 2012; Bryman 2012).

Methods applied in the mixed methods approach
In this mixed methods approach design-based research was used to answer the main question, this was based on six research methods used to answer the sub-questions.

These methods are listed below and their relations to the sub-questions and relation to each other are presented in Table 3.1. The used methods for data collection are:

1) A systematic literature review, on topics: motivation and key success factors.
2) Semi-structured interviews, with people from case study organizations.
3) A quantitative survey, based on motivations mapped on the Self-Determination Theory.
4) A quantitative survey, based on the Technology Acceptance Model.
5) A Q methodological approach, based on:
    - Semi-structured interviews
    - Focus group meeting
    - Workshop
6) Structured interviews, with Q participants (P-set).

This thesis makes use of a design-based research methodology. The main problem described before is best tackled by practical design suggestions, because citizen science is different in each context and for each topic. Since there is relative few information available on the application of citizen science by water authorities in water quality monitoring, the methods used in this study are rather exploratory and do not aim at theory development. The design principles that form the primary output of this study are therefore guidelines rather than a best practice.

Research approaches are determined for each sub-question to answer the research sub-questions and achieve the research objective. Various methods were combined. Methods include a literature review (see section 3.2), a quantitative survey (section 3.3), an application of the Technology Acceptance Model as described by Venkatesh & Bala (2008) (section 3.3 as well) and a Q methodological approach (section 3.4). The outcomes of these separate methods were combined to develop design principles (section 3.5).

The literature review will be used to answer sub-questions 1 and 4 and contribute to sub-questions 2 and 3. Key success factors in literature were compared to four cases. Motivations and barriers were used as input for the survey (see next heading). Purposes were gathered in an overview and will be compared to the outcomes of the Q methodological study.

Table 3.1 – Overview of the used methods to answer the research question.
A double arrow indicates a comparison, a single arrow that A serves as input for B.

Question	Literature	Cases	Survey	TAM	Q
PART I					
1: Key success factors	(1) ⟷	(2)			
4: MCS characteristics	(1)				
PART II					
2: Citizen motivations and barriers	(1)[1] →	→	(3)		
5: Technology acceptance drivers	(1)[1] →	→	→	(4)	
PART III					
3: Authority viewpoints					(5) (6)

[1] *Used to compose a theoretical framework*

Absence of ethical issues

There were no ethical issues identified in the followed methodology, as there are no human experiments involved that place a physical or emotional burden to participants. The people involved in the various interviews and the survey are anonymous in the thesis and the topics discussed are considered uncontroversial.

Detailed description per research method

This section introduced the main research method and announced the research methods for each sub-question. The remainder of this chapter contains a detailed description of the used research methods, both for data collection and data analysis. A summary is included for the methodology of research questions 2, 3 and 5, as the descriptions of the Technology Acceptance Model and the Q methodological approach are quite lengthy. The full method descriptions of questions 2, 3 and 5 can be found respectively in Part II, Part III and again Part II.

3.2 Methodology of Part I: literature review and case study comparison on key success factors

In the previous section the main outline of the methodology was presented. In this section a detailed description is given of the methodology of part I, concerning the literature review and case study.

3.2.1 A literature review to identify key success factors and mobile crowd sensing characteristics

The literature review aims to answer research sub-questions 1 (*"What are key success factors to set up a citizen science project in general and mobile crowd sensing in particular, according to literature?")* and 4 (*"What distinguishing characteristics of mobile crowd sensing influence the design of a citizen science project, according to literature?").* The first goal is to identify the different types of citizen science and what decisions should be made when setting up a citizen science or mobile crowd sensing (MCS) project. The second goal is to identify characteristics of MCS that introduce additional challenges, opportunities and purposes compared to citizen science in general.

The main topic of this thesis is citizen science in water resource management, with a focus on water quality and MCS, indicated with an A in Figure 3.1. In the introduction it was already mentioned that, to the author's knowledge, literature on citizen science in water resource management is scarce. The author makes two assumptions to solve this issue. First, the author considers water management as a subset of environmental monitoring, as both deal with natural resource management. In Figure 3.1 the black circle is therefore placed within the larger circle of environmental monitoring. Second, the author assumes that MCS characteristics are indifferent of the topic of sensing. Two other fields will therefore be studied to substitute A: citizen science in environmental monitoring (B) and MCS (C).

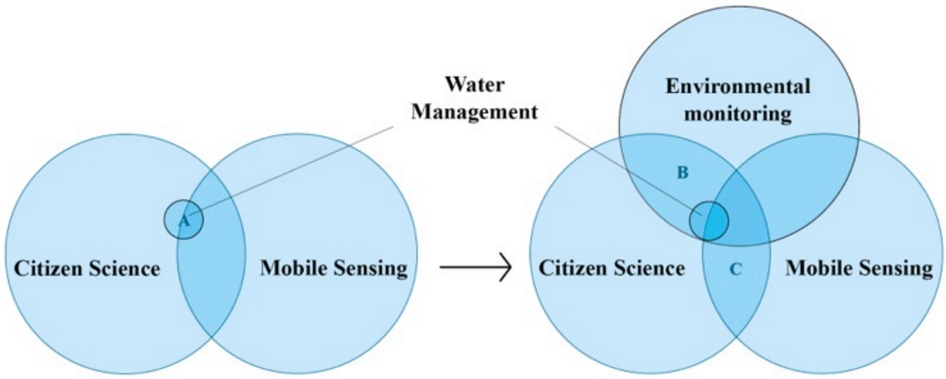


Figure 3.1 – A (on the left) is the topic of interest, which is insufficiently studied for a literature review. B and C (on the right) are the substitute topics, used to approximate A.

A systematic literature review

To answer the research questions above a systematic literature review was carried out, as it is less prone to bias than a narrative review (Bryman 2012). The search terms used in Web of Science and Google Scholar can be found below. On top of this literature search in the search engines, literature has been obtained via references in the selected articles and via experts consulted.

The literature was assessed with a protocol following the dimensions suggested by Bryman (2009, p. 103): 1) year conducted, 2) location, 3) sample size, 4) data collection methods and 5) main findings. All items found were assessed on their relevance and validity. Literature was only included if:

- It is a peer-reviewed article, quality conference paper or research report of a trusted organisation;
- It is published in the year 2005 or later;
- The findings to include originate from the results, discussion or conclusion section;
- The topic is related to environmental monitoring (including ecology and atmospheric sciences);
- It the study took place in a developed country.[4]

[4] According to Buytaert et al. (2014) citizen science projects in developing countries often focus on raising awareness and scientific literacy, compared to well-being of communities in developing countries.

Sources of literature for the literature review
Three types of documents were taken into account: peer-reviewed scientific articles, conference papers and reports. Three main topics were included: the goals of the party organising citizen science; the participating citizens' motivations to participate and experienced barriers; and key success factors when organising citizen science.

Two search engines were used to obtain abovementioned documents. Primarily Web of Science was used, because of its high standards. Additionally Google Scholar was used because of its feature of automated full-text search. Critical examination of the publication source of the results was required though, due to this automatic nature.

Search terms used in Web of Science
The starting point for each search was the following advanced search:

> TS = ("citizen science" OR "participatory monitoring" OR "participatory sensing" OR "human sensing" OR "human computing" OR crowdsensing OR "crowd sensing" OR crowdsourcing OR "crowd sourcing" OR "public participation" OR "community based monitoring") AND SU=(Environmental Sciences & Ecology OR Computer Science OR Behaviroral Science OR Water Resources OR Government & Law OR Plant Studies OR Remote Sensing OR Meteorology & Atmospheric Sciences OR Urban Studies OR Biodiversity OR Science & Technology Other Topics OR Engineering OR Communication). Refined by: Document types: ARTICLE

This resulted in over 8000 results, which was not feasible to study. The terms public participation, human computing and human sensing were omitted after a quick scan of the results. Additionally specific search terms were added, accompanied with their synonyms. Within the results was searched for 'water'. An overview of the initial and specific search terms can be found in Figure 3.2, accompanied by the number of results per search.

Additional articles were found via references in the documents retrieved in the procedure described above. Furthermore experts at Leiden University, Unesco-IHE and Texas State University were approached, which led to new (unpublished) articles.

Synthesis of literature findings
The found literature was initially selected based on title and abstract. A list of included literature and an assessment of the before mentioned criteria can be found in Appendix B. The literature findings were combined in a framework of key success factors.

3.2.2 Case studies on citizen science and mobile crowd sensing

In the previous section it was described how a literature review retrieved key success factors. The literature used originates from different fields and originates from different locations. A case study was performed and served two goals: first to assess the applicability of the key success factors in a Dutch context and second to evaluate the relative importance of each factor (i.e. is the factor crucial or optional). The case study will be a critical case study as its purpose is to develop "a better understanding of the circumstances in which the hypothesis will and will not hold." (Bryman 2012, p. 70). The hypothesis in this case study is: "All identified key success factors in literature are needed for a successful project."

Case selection criteria
Case studies struggle with generalizability; therefore a multi-case study was applied. Three to four cases were considered sufficient and feasible. All cases should comply with three criteria. First, the case should be recent, i.e. started the past two years, since the design of the project is the main focus of this study and interviewees will be able to remember design considerations. Second, the case should be Dutch, as the Netherlands is the core focus of this thesis. Third, all cases have to be operating in the field of environmental monitoring or resource management. The cases should additionally represent a variety in:

- type of citizen science (contributory, collaborative or co-created, see Bonney et al. 2009b);
- organising party (research institute, (local) government or citizens);
- scale (number of participants, geographical scale);
- citizen science and mobile crowd sensing;
- topics of monitoring.

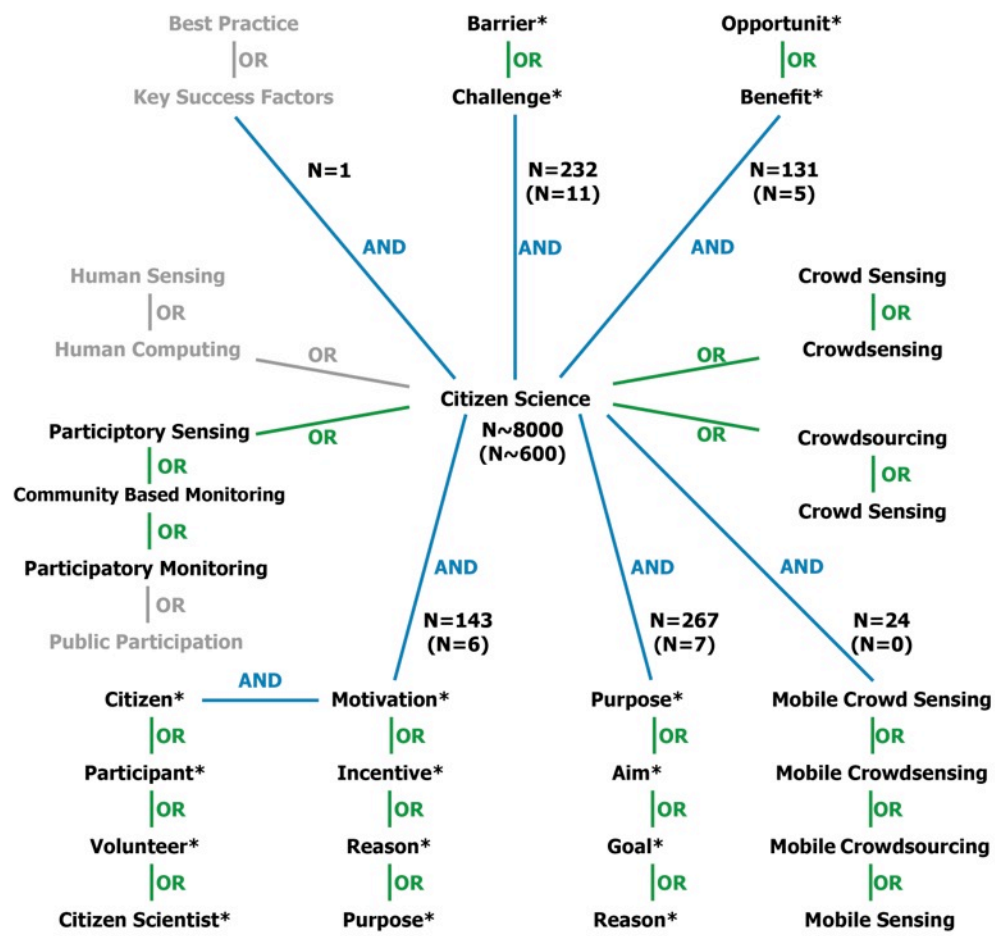


Figure 3.2 – Overview of search terms.

Terms in grey were omitted. OR indicates synonyms, which were incorporated parallel in each search. Topics connected via AND indicate different searches. Asterisks (*) indicate that any character, a group of characters or no character at all can follow. N indicates the total number of studies retrieved, (N) represents the results filtered on 'water'.

Case and interviewee selection

Five potential cases were identified searching the Internet and via the network of the researcher:

A.	Tuintelling (Garden Count)	via Internet
B.	iSPEX	via network
C.	Crowdsourcing in Reeuwijkse Plassen (CiRP)	via network
D.	Muggenradar (Mosquito radar)	via Internet
E.	Waarneming.nl (observation.nl)	via Internet

Case A, B and C were selected. Case A was selected primarily because one of the organising parties (Vogelbescherming Nederland) is experienced with the annual citizen science project of the garden bird count. Case B was selected, because it is the only short-term project and because it makes use of mobile crowd sensing (MCS). Case C was selected because it is a local project and because it is the only project organised by a water authority. The remaining two cases were excluded as they had similar characteristics as the Tuintelling.

The interviewees were preferably project leaders and/or closely informed from the start of the project. In case A this was possible. In case B interviewee #1 was involved from the start and interviewee #2 joined later, but was involved in the social scientific research. In case C interviewee #1 is the current project leader and interviewee #2 was the project leader when the project was formulated.

Data collection
Typical data sources for case studies are document reviews, in-depth interviews, a questionnaire and focus groups (Rosenberg & Yates 2007). The research question is qualitative in nature, therefore the three cases were studied via qualitative, semi-structured interviews with two project members and analysis of literature and case websites (if available). The interviews were recorded, transcribed and coded. The full interview is added in Appendix A.

The interviews lasted approximately one hour and consisted of four phases. In the first phase the researcher introduced herself and the research, and asked permission to record the interview. In the second phase the interviewee was invited to introduce himself/herself and the project.

Table 3.2 – Characteristics of the three selected cases and the two omitted cases.

	Tuintelling	iSPEX	CiRP	Muggenradar	Waarneming.nl
Type	Contributory	Contributory	Collaborative	Contributory	Co-created
Organisation	Nature conservators	Various organisations	Governmental	Research institute	Nature conservators
Participants	>1000	>3000	10	2500	unknown
Started in	2015	2013	2014	2014	2009
Long/short	Long	Short	Long	Long	Long
Scale	National	National	Local	National	National
Terminated	No	Yes	No	No	No
MCS	No	Yes	Yes	No	No
Topic	City wildlife (various)	Particulate matter	Water quantity	Mosquitos	Ecology (various)
Interview	Vogelbescherming	RIVM	Water authority Rijnland	-	-

In the third phase, after this introductory phase that acted as ice breaker, the questions were asked in five themes. First, the reason to start the project and goals of the project were inquired. This was important as it enabled comparison to the identified goals in literature. Second, the interviewee was asked whether the selected key success factors from literature were present in the project (see below). Third, the collaboration with partners and stakeholders was inquired, as this relates to the governance structure at hand. Fourth, the challenges encountered were discussed, which can be used to relate the absence or success of key success factors. Finally, the interviewee was asked if there are any additional key success factors that were not discussed before.

In the fourth phase the interviewee was given the chance to share any final thoughts or remarks. The fifth phase consisted of thanking the interviewee and informing him/her on the follow-up, which consists of analysing the results and asking the interviewee to reflect on this document.

The selection of the key success factors:

Project formulation:
- goals,
- time span,
- hypotheses
- Measuring method and validation
- Community for volunteers
- Insight in people's motivation

Start:
- Training and clear task
- Recruitment and marketing

During:
- Feedback
- Retain volunteers
- Involvement of citizens in data analysis
- Other data collected
- Evaluation
- Increased task level

Table 3.3 – Overview of interviewees

Project	Interviewee	Organisation	Relation to project
a) Year Round Garden Count	#1	Vogelbescherming	Project leader
a) Year Round Garden Count	#2	Vogelbescherming	Team leader conservation program for city birds
b) iSPEX	#1	RIVM	Project leader
b) iSPEX	#2	RIVM	Social scientist
c) Crowdsourcing in Reeuwijkse Plassen	#1	Water authority Rijnland	Multi project manager (at project start)
c) Crowdsourcing in Reeuwijkse Plassen	#2	Water authority Rijnland/ Royal Haskoning DHV	Project leader

Data analysis: coding and case comparison
The six transcribed interviews resulted in a dataset of 39000 words in total. This data was coded using open coding with a mixture of pre-coding and post-coding (Bryman 2009). The overview of these codes can be found in Appendix C.

The pre-coding was based on the framework of key success factors. The three time steps (before, start and during) of the framework of key success factors formed code categories (e.g. 'Best practice - start' is code category 7) and the key factors are a code itself (e.g. hypothesis is code 6C). An exception was made for key success factor 'define goals', which became category 2. This was needed as the interview inquired about the different goals the project had and thus resulted in sub-codes. The other categories were also pre-defined, based on the themes covered by the interview questions.

The post-coding was based on themes that were identified while coding and comparing the interviews. These themes resulted in codes in a pre-defined category. For example code 11A was added as a code, as the challenge of collaborating with partners was discussed in the interviews of cases A and B.

Case comparison
The case's goals and challenges experienced were compared to literature. Challenges encountered (and how they were overcome) and lessons learned undiscovered in literature were translated into additional key success factors to complement the best practice of the literature section.

3.3 Methodology of Part II: survey on motivations, barriers and smartphone acceptance

The previous section presented the research methods for sub-question 1 and 4. This section outilnes the research method for sub-questions 2 ("*What distinguishing characteristics of mobile crowd sensing influence the design of a citizen science project?"*) and 5 ("*What are the main positive and negative drivers of Dutch citizens in acceptance of smartphone applications for water quality monitoring that influence the design of a citizen science project?"*). A survey was issued to shed light on the motivations and barriers that citizens perceive to participate in citizen science and to identify main drivers to use a mobile crowd sensing (MCS) application.

In this survey the questions on motivations and barriers were combined with the questions for the Technology Acceptance model. In this section first the general characteristics of the survey will be discussed, subsequently the motivations and barriers and finally the use of the Technology Acceptance Model. This section provides a summary, a full methodological description with the corresponding theoretical frameworks can be found in Part II.

3.3.1 The set up of the survey among citizens

A quantitative survey was composed to answer research sub-questions 2 and 5. A quantitative method was chosen, since citizen science and mobile crowd sensing (MCS) assume a large number of participants. General citizens are the survey's target audience. The first part focussed on motivations and barriers, halfway the survey MCS was introduced.

A hypothetical project on water quality monitoring was used as a vignette to provide equal context to all respondents. Several water authorities and a nature manager were approached to act as 'initiator' of the citizen science project. Regional nature manager Zuid-Hollands Landschap (ZHL) agreed and the multi-purpose study was spread online among 13 000 subscribers of ZHL's newsletter. The survey questions are therefore in Dutch, as this is the mother tongue of the target audience.

The built-up of the survey is shown in Figure 3.3. The seven components of the survey are described in the next paragraphs. The full survey can be found in Appendix D.

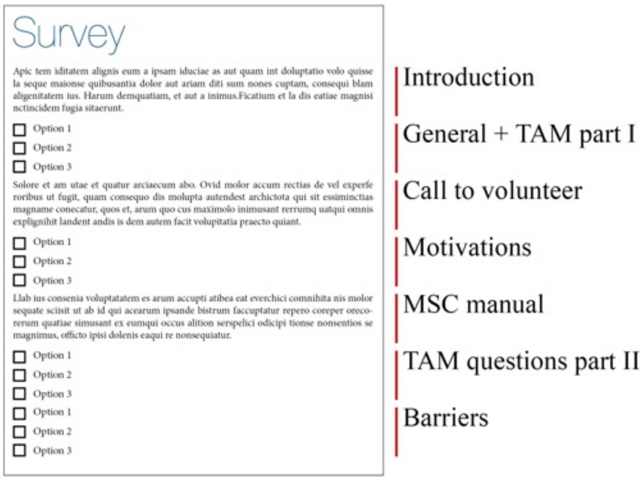


Figure 3.3 – Overview of the survey built-up. The questions about motivational factors and barriers are combined with the questions on the Technology Acceptance Model (TAM).

Introduction - In the introduction the research and the concept of citizen science were introduced. The several parts of the survey were announced and the respondents were informed that their responses and personal information would be treated anonymously and will not be shared with other parties. The survey was spread on behalf of nature manager Zuid-Hollands Landschap (ZHL).

General + TAM part I - In the second part of the survey information is collected about the respondents demographics (age, gender, educational level and place of residence), their mobile device use and experience and their trust in the nature manager ZHL. Respondents without access to smartphones or tables and without experience using such mobile devices were given the choice whether to continue. This part inquired about the following constructs of the Technology Acceptance Model (TAM): *Smartphone Anxiety* (SA), *Smartphone Playfulness* (SPLAY), *Trust in Mobile Communications* (TMC) and *Satisfaction of Past Interactions* (SPI) with and *Reputation* (REP) of the ZHL. A full description can be found in the theoretical framework in Chapter 8.

Call to volunteer - The participants were shown a text with a call for volunteers. Next they were given more information on a specific citizen science project in water quality monitoring. In this project the volunteers will monitor ecological indicators, turbidity with a Secchi disk and chemical water quality indicators.

Motivations - Participants were asked about their intention to participate in this project on a 7 point Likert scale. The motivations and barriers found in the literature study were translated into questions. Respondents were asked to choose from a list which motivations and a-motivations they experience. They were subsequently asked to identify the three most and three least important motivations. This list was based on the literature review as described before.

MSC manual - In the second part of the survey a fictitious email was shown where ZHL announced to use a smartphone application for monitoring. Subsequently the manual of this fictive application was shown to the respondents.

TAM questions part II - The questions that relate to the TAM were presented next. These questions inquired about the TAM constructs: *Relative Advantage* (REL), *Perceived Ease of Use* (PEOU), *Smartphone-Self Efficacy* (SSE), *Perceived Usefulness* (PU), *Perceptions of External Control* (PEC), *Result Demonstrability* (RES), *Subjective Norm* (SN), *Image* (IMG) and *Trust* (TRU).

Barriers - In the final part of the survey respondents were asked what barriers they perceive to participate. Additionally they could indicate what functions of the app they appreciate and what additional functions and activities they would like to see in the citizen science project.

3.3.2 Pre-testing the survey

The survey was pre-tested and evaluated to increase validity of the questions. First, 28 bachelor students were asked to fill out the survey and comment on the questions. This pre-test indicted that the survey can be completed within 20 minutes, which was the set maximum to prevent fatigue and drop out of respondents. Second, sixteen people assessed texts and images on clarity and attractiveness in an online form. This was done, as the survey makes use of a written description of a technology, the application. A positive or negative impression of this description may decrease the validity of the results. A negative bias was proven unlikely, as the evaluation report was moderately positive and adjustments were made to further increase readability of the texts. A description of the pre-test results can be found in Appendix F.

3.3.3 Questions on motivations and barriers

The questions on motivations and barriers originated from a theoretical framework, which was based on literature findings on motivations and barriers in citizen science.

Theoretical framework
To answer research question 2 a theoretical framework of motivations and barriers was made. This theoretical framework is based on the Self-Determination Theory of Ryan & Deci (2000). Motivations were identified in literature, using the search terms on motivation as described in the literature review (see Figure 3.2). It was

Data collection
The motivations and barriers in the theoretical framework were translated into Dutch and were presented to respondents in the first column of a table. Respondents had to indicate whether they found an (a)motivational factor important or unimportant in the second column. In the third column they could indicate what they considered the three most important and the three least important factors. This presentation was chosen as it requires the least space and provides a clear overview of all motivations to respondents.

Data analysis
One-way Anova was used to compare the means of respondents with a high and low participation intention. However, only 60 participants filled out the full questionnaire, which is rather low for such a comparison. Because motivations of non-participants are rarely captured, but proven to be different from participating citizens (Gharesifard & Wehn 2015), it was decided to include the results anyway. Differences in motivations between people with a high and a low intention are interesting, because they could shed light on possible project features that may stimulate the latter group to participate.

3.3.4 Questions on acceptance of smartphone technology

Besides the introduced questions on motivations and barriers, the survey contained questions to identify citizen's drivers to adopt mobile crowd sourcing. A theoretical framework was composed, based on an adjusted version of the Technology Acceptance Model 3 by Venkatesh & Bala (2008).

Alternatives would have been to use the Consumer Acceptance of Technology model (CAT; Kulviwat et al. 2007), the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al. 2003) or the Theory of Planned Behaviour (Ajzen 1991). An adjusted TAM3 was chosen, because of its completeness and inclusion of a distinction between the pre-use (anchors) and after-use (adjustments) phase. This allows focusing on the set-up of a project using a certain technology rather than the whole process of technology acceptance in one step. Moreover, TAM3 is very suitable in a design-oriented study, since the authors included suggestions of interventions, such as changes in the design and training of the users of the technology under review. Moreover, the TAM is the most used theory in academic literature that aims to explain adoption of mobile technology and services (Sanakulov & Karjaluoto 2015).

Theoretical framework
The theoretical framework is an adapted version of the Technology Acceptance Model 3 (TAM3, Venkatesh & Bala 2008). Hypotheses were formulated about the applicability of an adapted TAM3 on a mock-up application and the inclusion of trust as a driver. The theoretical framework can be found in chapter 8.

Data collection
Context specific hypotheses were formulated and tested with validated and standardised 7-point Likert scale questions adopted from Venkatesh & Bala (2008), Pavlou (2003) and Charter & Bélanger (2005).

Data analysis
The hypotheses were assessed via Partial Least Squares regression analysis using SmartPLS (version 3.2.1). The assessment steps of Sarstedt et al. (2014) were followed to evaluate the model.

3.3.5 A preview to results: a low, but acceptable response rate

The survey was sent to 13 000 people. 160 responses were received and 60 respondents completed the full questionnaire including the TAM questions, while 70 participants filled in the motivations and barriers part. Three respondents made use of the drop-out option after the 'General + TAM I' part.
The response rates is fairly low being respectively 1.2% and 0.5% for the total number of responses and the finished surveys. 60 is a rather small sample size, but sufficient for PLS-SEM, which is suitable for small sample sizes (Hair et al. 2013).

Additional efforts to increase responses
It was decided to analyse the results despite the low response rate, because the model intended to identify drivers in a very specific context and translate them into design principles. Moreover, three additional channels were used to spread the survey and increase the number of responses: via the local nature manager Natuur- en Vogelwerkgroep Krimpenerwaard, via bird research institute SOVON and via relatives living in the area. This effort resulted in six additional respondents. Since some adjustments were made to match the context to this new target audience, these five entries were not taken into account.

3.4 Methodology of Part III: a Q methodological approach within water authorities

In the previous sections the methods for research sub-questions 1, 2, 4 and 5 were presented. This section will discuss Q methodology, the method used to answer sub-question 3 ("*What are different viewpoints of Dutch water authorities regarding the application of a citizen science in water quality monitoring?*"). The full method description can be found in Chapter 10, this section is a summary.

Q methodology is used to describe a population of viewpoints and is therefore a suitable methodology for the third sub-question. Q methodology is in between qualitative and quantitative approaches, since it makes use of statistical factor analysis of a relatively small sample size (Van Exel & De Graaf 2005). Each factor represents a different viewpoint.

3.4.1 Data collection for the Q methodological approach

A Q methodological approach is used to identify different viewpoints of water authorities regarding citizen science in water quality monitoring. Mobile crowd sensing was not taken into account in the statements, because it is considered one out of many applications of citizen science. The approach as described by Watts & Stenner (2005) is followed. 33 participants (the 'P-set') were asked to rank 46 statements (the 'Q-set'). The researcher selected and modified quotes from interviews, a focus group meeting and a workshop to generate this Q-set. See Appendix I for the selection procedure.

The actual ranking process is referred to as 'Q sort'. The sorting process typically has four stages:

- An introduction by the researcher, where the procedures is explained.
- An initial sort, where participants place rate each statement as 'agree', 'disagree' or 'neutral'.
- The final sort, where participants are rank the statements from most agree (column +4 in Figure 3.4) to most disagree (column -4 in Figure 3.4).
- A post-sort interview, where participants can elaborate on the order of the statements.

3.4.2 Data manipulation and interpretation

A factor analysis as described by Brown (1980) and Watts & Stenner (2012) was followed to extract the final factors. Interpretation was done following the guidelines of Watts & Stenner (2012) and Gallagher & Porock (2010).

The final factor arrays are interpreted using so-called 'crib sheets' that identify distinguishing factors for each factor. The researcher interprets these statements and thus the interpretation part is subjective in nature. Post-sorting interviews took place to be able to identify underlying values and assumptions that enhanced the factor interpretations. Participant's afterthoughts were recorded, transcribed and categorised per statement and per factor. Interview quotes were used to perform a second round of interpretation of the final factors following the approach of Gallagher & Porock (2010). For example where it concerned the statement that 'citizen science is suitable to raise awareness' the interview fragments led to the identification of underlying goals of behavioural change, outreach and create a support base.

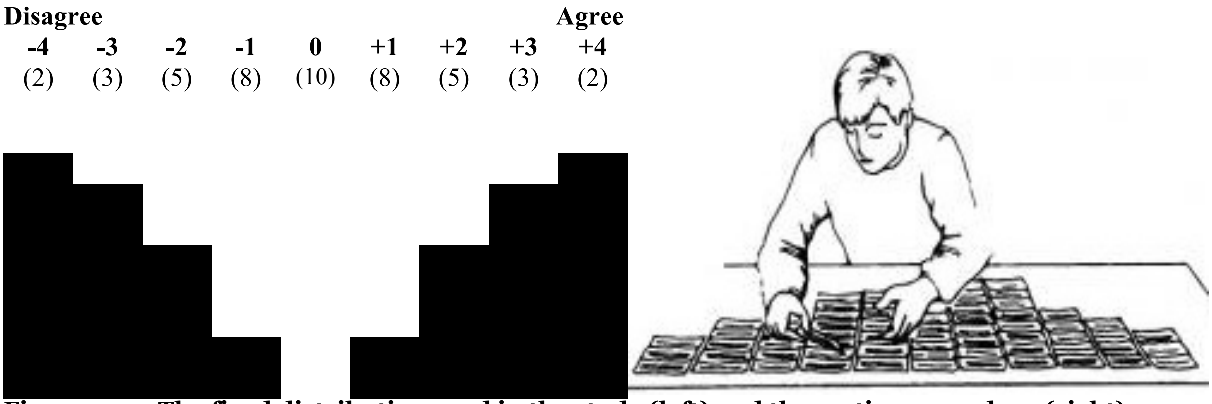


Figure 3.4 – The fixed distribution used in the study (left) and the sorting procedure (right).

3.5 Methodology of Part IV: Synthesis and design

The aim of this thesis was to develop guidelines on citizen science for water authorities as a tangible output. The previous sections described a wide range of research methods, used to answer equally broad research sub-questions. The methods and models used in Part I, II and III were theory oriented, while the guidelines are practical oriented. A design pattern was used to combine the findings into a practical design.

A design pattern helps bridging the gap between theory and practice in a specific context (Van Diggelen & Overdijk 2009), making it appropriate for the synthesis to guidelines. Design patterns originate from architecture, but are also commonly used in software engineering, design of interactions and educational design (Van Diggelen & Overdijk 2009). An existing design pattern will be used, because developing a new design pattern is impractical and out of scope of the thesis.

3.5.1 Selecting the design pattern: Seven-Layer Model of Collaboration

Two criteria were used to select the design pattern. First, the design pattern should be fit for collaboration design, as the researcher got the impression that challenges and success factors in setting up a citizen science project relate most to collaboration between citizens and water authorities (although with a power difference) and collaboration among partner organisations. Second, the design pattern should be linear in nature, as the design of the guidelines focuses on the initial project set-up.

The Seven- Layer Model of Collaboration (SLMC; Briggs et al. 2009) matched these criteria. The SLMC design pattern defines seven areas of concern for the design of a collaboration process (see Figure 3.5). This model provides a top-down approach, with bottom-up boundary condition; a layer influences the choices in the layer below, while it puts constraints on the layer above. Following the approach as described by Briggs et al. (2009) first goals, deliverables, stakes and resources are analysed. Subsequently a set of activities is chosen, with selected techniques and technologies to implement these activities.

There are two main advantages of using this model. First, it allows making structured and transparent design choices. The second advantage is that the model explicitly includes tools as a layer, which is useful for the inclusion of mobile sensing technologies.

3.5.2 Synthesising the research findings into practical guidelines

In the synthesis the research findings are integrated and synthesised into practical guidelines. This step was based on the researcher's interpretation of the outcomes of the research steps, but the Seven-Layer Model of Collaboration (SLMC, Briggs et al. 2009) was used to guide this synthesis. The integration of the research components and the SLMC is presented in Figure 3.5.

In the various research steps a systematic literature study was performed to obtain information on key success factors and the characteristics of mobile crowd sensing (MCS) influencing a project's set-up. The application of these key success factors was evaluated in a four-case study. From these case studies key persons were selected and interviewed to gain deeper understanding of the specifics of these cases. The results from the literature and case studies are used as an input for the survey. Additionally, Q methodology was used in order to obtain insight in the range of viewpoints on citizen science from the perspective of water authorities. This resulted in a diversity set of information, which is integrated using the SLMC, and synthesized in design guidelines.

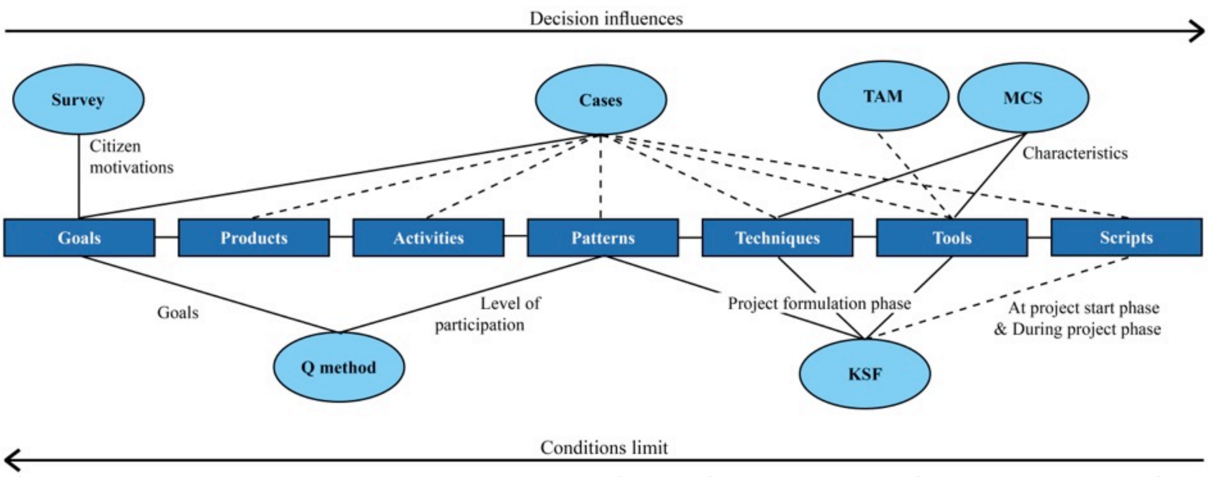


Figure 3.5– The Seven-Layer Model of Collaboration (Briggs et al. 2009; in dark blue) combined with the research components (light blue). Dashed lines (--) indicate illustrative use of findings.

3.6 Chapter summary: design-based research using mixed methods

In this chapter a design-based research method was outlined, using a mixed methods approach of six different methods: a literature review, semi-structured interviews, two quantitative surveys and a Q methodological approach using structured post-sort interviews.

The remainder of this thesis is split into four parts, three of which providing answers to sub-questions: Part I to sub-questions 1 and 4, part II to questions 2 and 5 and Part III to sub-question 4. Part IV hosts the synthesis, where a design pattern is used to translate the research results to guidelines for practitioners at Dutch water authorities.

Part I – Literature review & case studies

Part 0 introduced the research topic and outlined the methodology. In this first part of the research outcomes an answer is formulated to research sub-question 1 "*What key success-factors are available from existing literature for setting up a citizen science project in general and mobile crowd sensing in particular?"* and sub-question 4 "*What distinguishing characteristics of mobile crowd sensing influence the design of a citizen science project?".*

These questions will be answered by identifying key success factors for citizen science and by determining characteristics of mobile crowd sensing that affect the set-up of a project. Citizen science models, motivational factors, barriers that citizens may perceive, challenges and opportunities are obtained from literature (Chapter 4). Subsequently, these findings are compared to three existing projects to identify the importance of the key success factors and supplement the framework of success factors with missing factors (Chapter 5). In the final chapter of this part the conclusion and discussion are presented (Chapter 6).

Chapter 4 Results of the systematic literature review to identify key success factors

In the previous chapters the topic of citizen science in water resource management was introduced. Research questions and aim were formulated and the research method was outlined. In this chapter the results are presented of the systematic literature review to identify key success factors.

Insight in the manifestations of citizen science is important to be able to understand what the applicability of the key success factors to water resource management. This chapter will therefore include an overview of the typologies of citizen science. The additional characteristics of mobile crowd sensing (MCS) will be discussed as well.

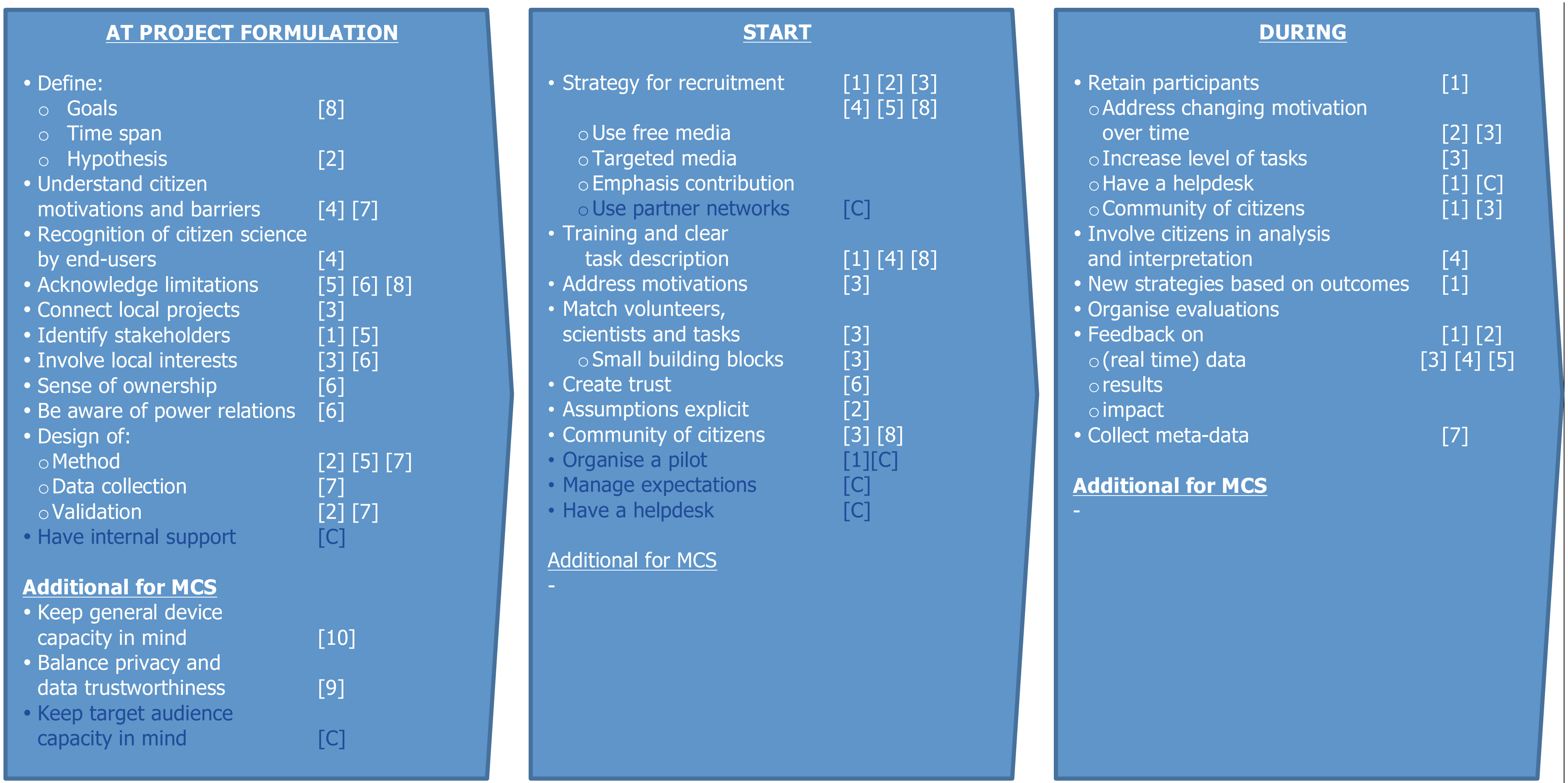
4.1 Developing a framework of key success factors

The largest citizen science scheme is that of bird monitoring, which takes place in many countries on various temporal and spatial scale. The method of the Cornell Laboratory of Ornithology (CLO) has become a frequently cited example (e.g. Cooper et al. 2007). Scientists at the laboratory define the research question, citizens follow protocols to collect data, which is subsequently analysed and interpreted by scientists. Bonney et al. (2012, p. 979) describe the program model, which consists of nine steps: 1) choose a scientific question, 2) form a diverse team, 3) develop, test and refine protocols, data forms and educational material, 4) recruit participants, 5) train participants, 6) accept, edit and display data, 7) analyse and interpret data, 8) disseminate results and 9) measure outcomes.

This model is inclusive, but limited in scope. The CLO model describes the process from project formulation and project start to the dissemination of the results, but it is based on a single case in a field quite different from water quality monitoring. Whether these key success factors are general and all-encompassing needs to be evaluated.

Several other authors mention success factors for citizen science in environmental monitoring (e.g. Silvertown 2009; Rotman et al. 2012; Roy et al. 2012) and for water resources or climate studies (Buytaert et al. 201; Muller et al. 2015). The result is a long list of key success factors, originating from various project types, view angles and contexts. Common grounds can be identified in this enumeration. Three time frames can be extracted: during project design, at the project start and during implementation.

Based on the knowledge so far, a framework of key success factors was developed (see Figure 4.1). The framework also includes additional key success factors that are typical to mobile crowd sensing (MCS), which is described in 4.4. The next chapter describes a case study, where the key success factors in the framework are compared to three practical examples. In this case study some additional factors were identified. These are added to the framework and marked with a [C]. The following sections describe the factors per time frame.



[1] Bonney et al. 2012 [2] Silvertown 2009 [3] Rotman et al. 2012 [4] Roy et al. 2012 [5] Conrad & Hilchey 201 [6] Buytaert et al. 2015
[7] Muller et al. 2015 [8] Cooper et al. 2007 [9] Het et al. 2015 [10] Lane et al. 2010 [11] Ganti et al. 2011 [C] Case studies 2015

Figure 4.1 – Key success factors of citizen science projects and mobile crowd sensing based on literature. The additional key success factors found in a three-case study (as described in Chapter 5) are included in this scheme as well.

4.1.1 Key success factors at project formulation phase

The project formulation phase is used to define and develop the project. At the start of setting up a citizen science scheme the project outlines have to be defined as the facilitating organisation formulates goals (Cooper et al. 2007; Silvertown 2009).

A main challenge is the low acceptance of citizen science data by end-users, related to issues of accuracy and reliability (Roy et al. 2012). The low cost instrumentation used in citizen science places additional challenges on precision and accuracy (He et al. 2015). Methods of data collection therefore should be well-designed (Silvertown 2009; Conrad & Hilchey 2011; Bonney et al. 2012; Rotman et al. 2012; Roy et al. 2012; Muller et al. 2015). Silvertown (2009) notes that virtually all projects validate the incoming data, although methods are not always standardised or well designed. Rotman et al. (2012) suggest standardized methods so that local projects can be integrated and allow for data validation. Organizations may set certain locations to collect data or accept data from random locations. Although the first seems more important if an explicit hypothesis is tested, although Silvertown (2009) believes that all organizations should have a hypothesis in mind, even if it is superficial.

Several authors state that the possibilities for methods are restricted by internal and external limitations (Cooper et al. 2007; Rotman et al. 2012; Muller et al. 2015), stating various organisational, economic, social, physical, cultural and ethical barriers. Cooper et al. (2007) consider the organisational capacity the constraining factor, as it determines the extent to which data can be collected, analysed and stored. Rotman et al. (2012) mainly stresses the importance of motivational limitations. Conrad & Hilchey (2011) suggest that the organisation identifies inventories its skills and resources (including funding). The ones lacking are limitations to the project, but could be filled by strategic partnerships. These partnerships are part of a stakeholder assessment that should always take place (Conrad & Hilchey 2011).

An important factor is that the end-user should acknowledge the importance of the citizen science project (Rotman et al. 2012), in order for the project to be successful. End users often have a perception of low quality of citizen science information (Roy et al. 2012) and data is often not used in the end (Conrad & Hilchey 2011). Managers focus on the utility of data (Conrad & Hilchey 2011). Issues with data accuracy include data fragmentation and lack of participant objectivity (Conrad & Hilchey 2011). Projects often lack pilot studies and do not address sample size adequately or quality control and fortify these issues (Conrad & Hilchey 2011). On the other hand, a focus on protocols that provide optimal data for end-users could make the project unattractive or too demanding for participants (Roy et al. 2012). Data collection protocols should focus on processes alongside monitoring tasks (Conrad & Hilchey 2011).

With respect to citizens it is mainly important to acknowledge possible power relations (Buytaert et al. 2014) and incorporate interests to allow for ownership of the project (Rotman et al. 2012; Buytaert et al. 2014). Rotman et al. (2012) suggest incorporating local issues to trigger this interest. It further offers an opportunity to show citizens why their (continuous) contribution is needed.

Connecting local projects, such as happens with the annual bird count, will lead to large data pool (Rotman et al. 2012). Shared standards for data collection, analysis and sharing will create a large scale effort.

4.1.2 Key success factors at project launch phase

At the start of the project the organising party should put effort in marketing and recruitment of participants (Cooper et al. 2007; Bonney et al. 2012; Rotman et al. 2012). A variety of media can be used to this end, ranging from press releases and magazine articles to flyers and presentations (Bonney et al. 2012). This recruitment strategy can be general or targeted ad specific groups within society (Cooper et al. 200'7). In the latter case it is important that the recruitment methods match the desired audience and strategic partnering can be useful to reach the target audience (Bonney et al.

2012). This notion is important, as the typical profile of citizen scientists is far from a cross-section of society.

Citizen scientists, like other volunteers, are higher educated, middle aged and employed (Edwards 2014). Citizens are further more like to actively participate with jobs related to environment (Koehler & Koontz 2008). As a consequence socio-economically deprived areas are underrepresented in citizen science participants (Hobbs & White 2012), which was reflected in studies concluding that volunteers often have higher level incomes (Koehler & Koontz 2008; Houwelingen et al. 2014). A large opportunity can be found reaching new groups of citizen scientists and increase their literacy (Roy et al. 2012; Conrad & Hilchey 2011). These community groups may be difficult to reach though, as they are less involved with science (Rotman et al. 2012). A lack of interest by the public in general is one of the main bottlenecks for citizen science projects (Conrad & Hilchey 2011).

Once participants are recruited, the participating citizens should be instructed how to collect the data (Cooper et al. 2007; Bonney et al. 2012; Roy et al. 2012). Training participants is important for three reasons. First, it is essential to have participants digest the materials (Bonney et al. 2012; Roy et al. 2012). Second, it provides citizens with confidence in their own data collection skills (Cooper et al. 2007; Bonney et al. 2012; Roy et al. 2012). Third, it ensures that citizens continue skill development (Roy et al. 2012). Several authors agree on the two types of training given, ranging from supportive material (e.g. instruction videos or example material) to personal instructions (e.g. workshops) (Cooper et al. 2007; Bonney et al. 2012; Roy et al. 2012). In case of projects on a large geographic scale it is beneficial to offer training regionally (Bonney et al. 2012; Roy et al. 2012).

In the launch of the campaign motivations to start participating should be addressed (Rotman et al. 2012). The organisation should further communicate clearly about assumptions and expectations (Silvertown 2009) in such a way that trust and legitimacy between actors is established (Buytaert et al. 2014).

Participants should be matched to suitable tasks, which can be done in two ways (Rotman et al. 2012). Creating a pool of citizen science projects could serve this, as the citizens can choose which projects suit them best. Additionally breaking down tasks into smaller building blocks would allow a better match between citizens and tasks as well and allows citizen to have control over their level of contribution. This second option will also enhance recruitment, as it implies offering a concrete task.

4.1.3 Key success factors during project execution

As soon as the project is running measurements will be flowing into the database and has to be treated according to the developed protocols for data analysis and interpretation (Bonney et al. 2012).

During the project execution it is important that the used tools enable the collection of metadata (Muller et al. 2015)

The results should not only be disseminated within a professional circle, but also provided to citizens in an understandable manner. This key success factor was fairly mentioned by all authors (i.e. Cooper et al. 2007; Silvertown 2009; Conrad & Hilchey 2011; Rotman et al. 2012; Roy et al. 2012; Buytaert et al. 2014). Results should be actively distributed among citizens (Cooper et al. 2007). Several authors suggest a graphical representation of the results. Spatial maps were the most common method to display results of environmental citizen science monitoring according to Roy et al. (2012). Bonney et al. (2012) stress the importance of visualisation in result feedback. Providing citizens insight into trend lines is suggested to increase activity of participants (Bonney et al. 2012). Some author (Conrad & Hilchey 2011; Rotman et al. 2012) suggests that not just the results should be communicated, but also the use in management; i.e. how, where and to what extent the results were applied in practice.

In long-term project the participants should be retained as much as possible, as it leads to participants with a higher level of experience and consequently more reliable data (Cooper et al. 2007). Two schools can be distinguished here. Cooper et al. (2007) emphasise on organisational support for participants. They advice to provide rapid response to questions via a helpdesk and to establish an online community for participants. Rotman et al. (2012) emphasise to increase task levels to keep challenging participants and to acknowledge the role of citizen motivations and how they change over time. Organizations should identify points where citizens reconsider their participation, such as after an initial monitoring cycle, and identify which motivational factors are important at that time. The program should be adapted accordingly. A more detailed description on (changing) citizen motivation is given in Chapter 6.

The organisation can involve citizens in the interpretation and analysis of outcomes as an educational means according to Bonney et al. (2012), although Buytaert et al. (2015) merely see it as a way to increase citizen power on decision making.

Although citizen science data has the potential to overcome spatial and temporal representativeness of standard data (Muller et al. 2015), the need for adequate documentation of the observation context challenges the composition of a sampling strategy (Buytaert et al. 2015). In general, the processing, interpretation and use of citizen science data in assimilation to traditional knowledge is difficult, especially because it is hard to quantify uncertainties (Buytaert et al. 2015). Defining the role of citizen science data in decision support is a challenge as well (Buytaert et al. 2015).

After the project is terminated the output should be measured, the project should be evaluated (Bonney et al. 2012) and results disseminated (Bonney et al. 2012). An evaluation could measure scientific outcomes, such as journal publications, and educational outcomes, i.e. whether scientific literacy increased. The organising party should formulate new strategies based on the outcome (Cooper et al. 2007).

4.2 A typology of citizen science based on involvement in research steps

The key success factors are predominantly based on projects that involve citizens solely in data collection, but data collection is just one step in the research process. Citizen involvement could reach beyond this step, for example Cooper et al. (2007) suggested involvement of citizens in goal-setting and Bonney et al. (2012) in data analysis. Citizens may be involved in this goal-setting as well to enhance adaptive management practices (Cooper et al. 2007). This involvement of citizens in other steps than data collection leads to other typologies of citizen science than the well-known CLO model (Bonney et al. 2012).

Bonney et al. (2009) suggest there are basically three levels of citizen involvement possible: contribution, collaboration and co-creation. In a contributory project, citizens are mainly involved in data collection, the research question and design is the done by scientists or experts. In collaborative projects citizens are involved in the analysis and can be involved in the design and dissemination of results as well. In co-created models citizens are involved in all steps of the research process and may even initiate the project. The vast majority of reviewed studies for the framework of key success factors consider contributory projects. Even the occasional co-created projects were part of multiple-case studies, where contributory projects dominated the results. The framework of key success factors lacks how-to factors for collaborative and co-created projects, for example on success factors to engaging citizens in hypothesis development.

The classification of Bonney et al. (2012) is frequently cited, incorporating studies included in the literature review (e.g. Rotman et al. 2012; Roy et al. 2012) and can be considered a standard classification. Earlier Cooper et al. (2007) proposed a similar model, although they included science shops, where citizens ask a question and experts conduct the rest of the research.

Table 4.1 – Three basis models for citizen science (Bonney et al. 2009)

	Contributory projects	Collaborative projects	Co-created projects
Choose or define question(s) for study			x
Gather information and resources			x
Develop explanations (hypotheses)			x
Design data collection methodologies		(x)	x
Collect samples and/or record data	x	x	x
Analyse samples		x	x
Analyse data	(x)	x	x
Interpret data and raw conclusions		(x)	x
Disseminate conclusions/translate into action	(x)	(x)	x
Discuss results and ask new questions			x

Who initiates the project influences what resources are needed, but also the governance structure at hand. Conrad & Hilchey (2011) identified three types of governance structures in environmental management. In consultative governance projects the government, such as a regional water authority, initiates the project and uses citizens to collect data for monitoring. Advantages are short-term successes accompanied with the potential to build long-term data series. However, the projects are often dependent on government funding and little other stakeholders are involved. In a collaborative structure a more diverse range of stakeholders is involved, such as business, universities, governments and private landowners. Citizens have more decisional power in this governance structure. Transformative structures often emerge out of a crisis situation and the community initiates and funds the project. Such projects may be successful if there is sufficient community and stakeholder support, but could also struggle with credibility issues and capacity shortage and monitoring is often not administered by legislation.

A majority of the citizen science projects in the reviewed studies is of the contributory type. Governance structures other than the consultative governance structure were not identified. This observation is not remarkable, as the contributory are relatively ease to organise, coordinate and facilitate (Bonney et al. 2012) and the consultative governance structure provides allows organizations to stay in control (Conrad & Hilchey 2011). These higher levels of involvement are recommended though if citizen science is to be used to increase environmental democracy and involve citizens in local issues (Roy et al. 2012).

Buytaert et al. (2015) provides an overview of examples of citizen science in hydrology and water resource management s. A vast majority of the programs, including most that collect water quality data, are of the contributory type. They suggest the main objective of scientists would be data collection and outreach, although in resource management citizen science data will be used mainly for decision making. Policy development is interesting in the light of water resource management, as it may be a way to give body to public participation and increase awareness (OECD 2014).

4.3 A typology of citizen science based on goals

Given the above relation between goals and project set up, it is remarkable that setting goals is mentioned as a key success factor by a single author, namely Cooper et al. (2000). The goals determine the characteristics of the citizen science scheme to a large extent (Wiggins & Crowston 2011). Wiggins & Crowston (2011) created a classification of citizen science, based on the goals of the project. They based their findings on a multiple case study in environmental monitoring. The goals they distinguished are education, resource management, data collection to increase knowledge and to create outreach.

These goals (Wiggins & Crowston 2011) are far from an inclusive set of goals. Although in fact ecological knowledge generation, improving monitoring methods and increasing awareness are most often mentioned goals, there are less common goals of recreation, serendipity and social research (Tulloch et al. 2013).

Knowledge generation refers to increasing understanding about a system, a theory or species (Tulloch et al. 2013). This can be structured goal with an hypothesis or a project aiming for serendipity: discovering unexpected relations or events (Tulloch et al. 2014). In resource management knowledge generation may be closely related to management goals, where a topic is monitored primarily to support management decisions and actions (Tulloch et al. 2013). Citizen science enables organizations to monitor at places where otherwise there would be no monitoring possible, since citizen science is a low cost manner of data collection (Conrad & Hilchey 2011). Innovations in water quality monitoring are fuelled by the rise of cheap analysis toolkits (Buytaert et al. 2014). Citizen science data could be combined with the increasingly available automatic measurement of proxies or UAVs (Unmanned Aerial Vehicles), because cheap and easy-to-use analysis are not available for all parameters (Muller et al. 2015). Adding observation and identification of macro invertebrates to citizen based monitoring is an opportunity for monitoring (Buytaert et al. 2015).

Citizen science can act as an early warning or detection system, for example to indicate places that require the priority of the authorities (Conrad & Hilchey 2011). A risk here is that there will be unnecessary monitoring, because authorities feel they should monitor for the sake of monitoring (Conrad & Hilchey 2011).

Citizen science could also be used to improve monitoring methods, as it allows to test multiple monitoring methods on a large scale or to optimise existing monitoring methods (Tulloch et al. 2013).

Nearly all citizen science schemes have education as goal. This was demonstrated in the typology of Wiggins & Crowston (2011), where education was either an explicit or an implicit goal in all identified types of citizen science. Education is not included in the top three citizen science goals in bird monitoring programs (Tulloch et al. 2013). Bonney et al. (2012) refer to it as scientific literacy, which matches the definition of Tulloch et al. (2013) to increase public knowledge with education.

Participation in water quality monitoring has not proven to increase citizen's level of knowledge (Overdevest et al. 2004). Overdevest et al. (2004) did find that participants felt more connected to the community and were more often involved in activities such as talking to acquaintances about the project or attending public meetings. Citizen science can also lead to increased levels of harmony, trust and cooperation in society (Conrad & Hilchey 2011). This relates to the goal of recreation, which is mainly used for communities to increase their well-being, including creation of a community feeling and undertaking activities together (Tulloch et al. 2013). The evolution of such community structures can be studied in citizen science as well. Social and economic research can be included as a goal of citizen science and may for example study citizen's behaviour. (Tulloch et al. 2013).

Sharing scientific knowledge can be used by policy makers as well to achieve the goal of raising awareness about an issue, although it could also be a bottom-up goal, when citizens use data collection it to raise an issue and influence policy making (Tulloch et al. 2013).

Citizen science is increasingly used by policy makers and thus suits goals of policy making (Roy et al. 2012; Hollow et al. 2015). Governments can meet their desire to be more inclusive with citizen science, and changes in policy and legislation may be more supported (Roy et al. 2012). Hollow et al. (2015) divide the goal of policy development into five sub-goals, divided into 'early stage' policy development (i.e. citizen science contributes to decision making) and 'later stage' policy development (i.e. citizen science can be used to persuade citizens towards a certain alternative.

Policy makers could use citizen science in early stages of policy development to identify a problem together with citizens and search for alternative solutions together ('discover') (Hollow et al. 2015). Alternatively, the policy maker could use citizen science to educate people about the situation at hand ('educate about situation') or to measure what the favoured alternative is among citizens ('measure public opinion') (Hollow et al. 2015). It must be acknowledged though that citizen science is most likely to attract citizens that are already interested in the topic and thus measured the public opinion will be biased (Buytaert et al. 2012).

In later stages, when there is a preferred alternative, citizen science can be used to create a support base for the desired alternative among citizens ('persuasion'). Citizen science could further be used to justify the chosen alternative, as the collected data may support the decision taken. (Hollow et al. 2015).

The goal of the citizen science project also influences the proposed time span of the project. A distinction can be made between long-term and short-term monitoring (Wiggins & Crowston 2011; Tulloch et al. 2013). Wiggins & Crowston (2011) relate the choice for a long-term or short-term project to the goals of the program, while Tulloch et al. (2013) make the distinction in the light of application of the data. Long-term monitoring programs often take place for longer periods at specific sites (longitudinal monitoring) while short-term projects (cross-sectional monitoring) typically collect data on a wide range of topics on a set period of time (Tulloch et al. 2013).

Table 4.2 – Project goals of general monitoring programs and citizen science programs (based on Tulloch et al. 2013 and Hollow et al. 2015).

	General monitoring	Citizen Science
Increasing knowledge	X	X
Improving methods	X	X
Raising awareness	X	X
Management	X	X
Public education	X	X
Social research	X	X
Recreation	X	X
Serendipity		X
Policy development	-	X
(I) discover alternatives		x
(II) educate about situation		x
(III) measure public opinions		x
(IV) persuasion/support base		x
(V) legal justification		x

4.4 Mobile crowd sensing characteristics

In general the key success factors and typologies of citizen science are applicable to mobile crowd sensing (MCS) as well. The main difference between MCS and citizen science is that it makes use of mobile wearable devices that upload data directly to an application server (He et al. 2015). According to He et al. (2015) 'mobile' in mobile crowd sensing should refer to mobile wearable devices, instead of phone or smartphone, because new devices such, as the Google Glass or Galaxy Gear, can be used for mobile crowd sensing as well.

A typical MCS activity consists of three phases (Lane et al. 2010; He et al. 2015): sensing, learning and dissemination. This typical architecture of MCS is represented in Figure 4.2. In the sensing phase data is collected, which is interpreted in the learning phase. The final phase is of the dissemination of the results, but can be used to actively encourage change of behaviour as well (Lane et al. 2010).

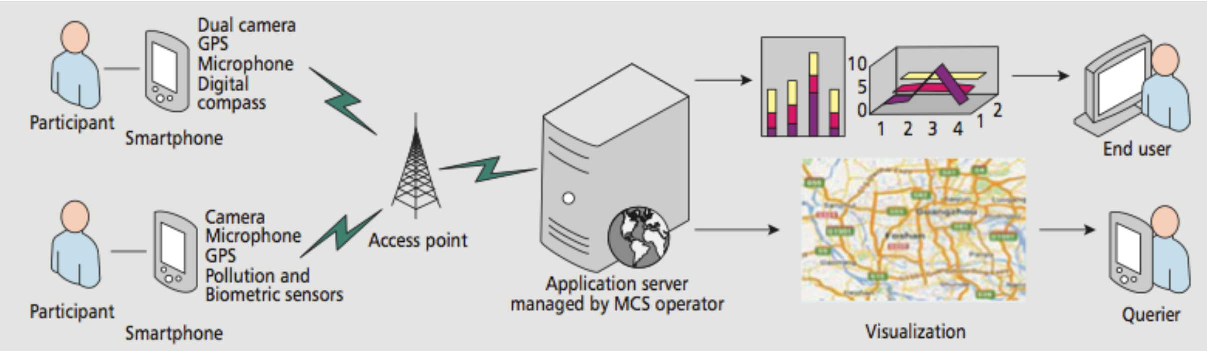


Figure 4.2 – Typical architecture of mobile crowd sensing, where data is collected by participants, uploaded to the server and accessed by end users and accessible to the questioner (He et al. 2015).

Mobile sensing can be considered a sub-set of citizen science, but could be compared likewise to wireless sensor networks (WSN). An example of a WSN is the automatic sensors that are used by water authorities to monitor water quality online. There are differences between MCS and WSN. The main benefits of MCS over WSN are that it is highly mobile, highly scalable, costs are low and humans (citizen scientists) are around to interfere in the monitoring when necessary (He et al. 2015).

The scalability of MCS (Khan et al. 2013; He et al. 2015) offers a lot of opportunities, more than in general citizen science, but these should be thought-out. It should be kept in mind that devices differ in communication features and storage and processing capacity (Khan et al. 2013). An application should be able to take these differences into account and adapt to system updates or new models.

The hardware of the used mobile devices and the sensors built in were not designed for these kind of activities (He et al. 2015). Limitations of the hardware should be kept in mind.

Muller et al. (2015) mentions as advantage that MCS enables monitoring on a high spatial resolution. This can be, for example useful in the high variability of urban areas. Additionally, there are more and more devices on the market that can be connected to a smartphone. Examples are the plugin sensors of Sensorex (www.sensorex.com) and iQwtr: a device to measure the Secchi depth using a smartphone extension box (Ghezehegn et al. 2014). However, a reliance on novel technologies may lead to an exclusion of potential participants (Roy et al. 2012).

In mobile crowd sensing data accuracy is a major concern as well (e.g. Lane et al. 2010; Khan et al. 2013; He et al. 2015). Methods to increase data accuracy, such as participant reputation building and exclusion of participants that repeatedly enter erroneous data, conflict with the other challenge of privacy (He et al. 2015).

Privacy is of a larger concern than in general citizen science, because more sensitive data is available (He et al. 2015). For example IP addresses and participant's movements may disclose someone's home address or office. Especially in situations where images or audio material is shared, personal information may be disclosed as well.

Two additional key success factors were distilled from these characteristics for the project formulation phase. It will be essential to keep the general device capacity in mind and to balance privacy and trustworthiness.

4.5 Chapter summary: key success factors and citizen science typologies

In this chapter a framework is created of key success factor at three stages of citizen science project development, namely at project formulation, at the project start and while the program is running. All authors mentioned providing training to participants and to develop a sound monitoring method. It was further described that goals determine other project characteristics to a large extent. Three levels of engagement in the research process were described and it was noted that a majority of the reviewed studies relate to lower levels of involvement. Mobile crowd sensing characteristics were further studied and two specific key success factors were added to the framework.

In the next chapter the applicability of this framework of success factors will be evaluated in three case study.

Chapter 5 Results of the three-case study to assess the applicability of the framework of key success factors

In the previous chapter literature was reviewed to extract key success factors. Sources range over a variety of citizen science: from online crowdsourcing to environmental monitoring and from contributory to co-created projects. To see whether these key success factors are applicable in practice, a case study comparison with four projects was held. Two projects concern general citizen science, the other two mobile sensing. In each pair a project in the field of ecology or environmental sciences and one project in the field of water resources is included.

The case study focuses on three aspects. The first topic is the purpose of the project, especially with regard to the goals regarding citizens and data. Second, the collaboration with partner organizations was investigated, since this sheds light on the governance structure. Third, a reduced version of the key success factors was discussed. The challenges encountered and lessons learned were also discussed. Information was collected in interviews and on project websites.

5.1 Case descriptions

In this section the three cases will be discussed. A factsheet will be presented per case, the reason to start the project is discussed and a summary of findings regarding the key success factors is presented. A detailed description of the cases, based on interview fragments and including quotes, can be found in Appendix D.

5.1.1 Case A: Tuintelling (Garden Count)

The first case is the Tuintelling, a citizen science program around city wildlife.

Fact sheet

Interviewed organisation	Vogelbescherming Nederland (2 interviews) **Interviewee #1:** project leader Tuintelling **Interviewee #2:** team leader conservation program city birds
Team members	Zoogdier Vereniging EIS (Kenniscentrum Insecten en Andere Ongewervelden) De Vlinderstichting Ravon (amphibians, reptiles and fish) Sovon Floron
Partners	VARA Vroege Vogels (national radio show)
Purpose	Management Outreach Data collection Awareness
Topic	Garden birds
Time span	2015-present
Spatial scale	National
Number of participants	3300 (March 2015), with an aim of 5000 (by end 2015)
Participants stereotype	Elderly women Higher educated people
FTE investment	2-3 FTE (distributed over the team organisations)

Project background

The Tuintelling (Year Round Garden Count) has been a wish for almost a decade. Interviewee #2 had visited the British Trust of Ornithology (BTO) and was inspired by their year round citizen science project. The project remained an idea for years, but recently it was decided to implement such a project. The programme is co-organised by other organizations, specialised in mammals, amphibians and insects and thus concentrates on city wildlife in general.

Project content

Citizens can choose what species they will monitor, birds or one of the other classes, and they indicate whether they will do a 'week list' (where they report qualitatively on all species seen) or a 'time count' (where they count the number of animals per species in a certain time slot, ranging from 5 tot 30 minutes). They enter their counts on the website www.tuintelling.nl, a website commonly hosted by the organising partner organisations.

Table 5.1 – Overview of the key success factors and their occurrence in Year Round Garden Count. An X marks that the factor was convincingly identified and (x) indicates that a success factor was considered, but it was either not applied or it did not have the desired effect.

Key success factor		Identified in Year Round Garden Count
PROJECT FORMULATION		
Define goals	X	Increase knowledge; Management; Awareness; Change behaviour; Create a support base
Define time span	(x)	It was defined that the project is open-ended.
Define hypothesis	(x)	There are expectations, but no fixed hypotheses.
Define measuring method	X	The measuring method is based on existing protocols and tested.
Define validation method	X	The data is validated by an experienced and specialised organisation.
Have insight in motivation	X	A questionnaire was spread to gain insight in motivations and needs to continue participation. Additionally a pilot of six months was held.
START		
Offer training	X	The website provides protocols and instructions on how to measure.
Define a clear task	X	Citizens were recruited via the partner's networks and national media.
Recruitment and marketing		
Establish a community	(x)	There are plans to establish an online community in the near future.
DURING	X	There is a comprehensible strategy to provide feedback, both on the results and on the importance of continued contribution.
Provide feedback	X	There is a strategy to continue recruitment with strategic partners.
Retain volunteers		The data is analysed by experts.
Involve in data analysis		Citizens are not involved, as it is already known how to analyse data.
Increase task level	X	Participants can opt to monitor more species classes or report more details.
Other data collected	X	Garden characteristics and home address.

5.1.2 Case B: iSPEX

The second case is iSPEX, a mobile crowd sensing project around particulate matter.

Fact sheet

Interviewed organisation	RIVM (2 interviews) **Interviewee #1:** scientist air quality, project leader **Interviewee #2:** scientist in public administration, spatial and psychology scientist
Team members (iSPEX consortium)	Universiteit Leiden KNMI (Dutch Royal Meteorological Institute) Sterrewacht Leiden SRON (Netherlands Institute for Space Research) TU Delft NOVA
Partners	Longfonds (Lung Fund) KIJK (science magazine for youth) Academische Jaarprijs (Academic Year Award) Avantes CNG Net Milieudefensie (an environmental organisation)
Purpose	Education Increase knowledge Improve methods Social research
Topic	Particulate matter (air quality)
Mobile sensing	iSPEX application (iOS only)
Time span	2012-2015 (data collection in 2013; scientific paper in 2014; social scientific paper expected in 2015)
Geographic scale	National
Number of participants	3187 unique participants (6000 measurements in total).
Participants stereotype	Higher educated men (often engineers)
FTE investment	10 (during project), currently <1 FTE

Project background
iSPEX is a smartphone plugin that mimics the measurements of a big SPEX measuring device that measures particulate matter. iSPEX emerged out of the idea to show the general public this device. This idea was submitted for the Academische Jaarprijs (Academic Year Award), an award for the best science communication project.

Project content
iSPEX is named after the iSPEX device, a "low-cost, mass-producible optical add-on for smartphones with a corresponding app." (Snik et al. 2014, p. 7351). iSPEX was a single event citizen science project organised by the iSPEX consortium (including the National Institute for Public Health and the Environment, RIVM). In 2013 people could purchase the iSPEX smartphone accessory and place it on top of their iPhone. They were able to measure particulate matter in the atmosphere using a special smartphone application. Around 3000 people participated (Land-Zandstra et al. 2015, unpublished) on two dedicated measurement days in July and in September 2013. In 2014 the iSPEX consortium published a paper that describes the monitoring method.

Table 5.2 – Overview of the key success factors and their occurrence in iSPEX. An X marks that the factor was convincingly identified and (x) indicates that a success factor was considered, but it was either not applied or it did not have the desired effect.

Key success factor		Identified in iSPEX
PROJECT FORMULATION		
Define goals	X	Education; Increase knowledge; Improve methods; Social research
Define time span	X	It was decided beforehand that iSPEX would be a single-event.
Define hypothesis		There were no expectations about the quality of the results, but there was a hypothesis about how many measurements would be needed to average results.
Define measuring method	X	The measuring method was clearly defined beforehand.
Define validation method		The validation method was defined along the way.
Have insight in motivation		There was no insight in citizen's motivation beforehand.
START		
Offer training	X	An online instruction video and instructions in the application.
Define a clear task	X	The interviewees reported no incidents of iSPEX being too complex to use.
Recruitment and marketing	X	Via national media and partner networks. In the second measurement round via an email to registered users.
Establish a community		There was no community for volunteers established.
DURING		
Provide feedback	X	Direct feedback via an interactive map. The feedback of the final results took longer than expected (a year), which was depreciated by some participants.
Retain volunteers		Retention of participants was not necessary as iSPEX was a short-term project.
Involve in data analysis		Citizens were not involved in data analysis.
Increase task level		The task level remained constant, as the task did not change.
Other data collected	X	Location and time of the measurement

5.1.3 Case C: Crowdsourcing in Reeuwijkse Plassen

The third case is a mobile crowd sensing project on surface water and groundwater dynamics.

Fact sheet

Interviewed organisation	Hoogheemraadschap van Rijnland (Water Authority) **Interviewee #1:** current project leader (currently involved) **Interviewee #2:** multi-project manager for the plan of implementation (involved at project definition)
Team members	-
Partners	Mobile Water Management
Purpose	Policy development Education Data collection
Topic	Water levels
Mobile sensing	Mobile Water Management application (iOS and Android)
Time span	2014-2016
Geographic scale	Local
Number of participants	Currently 10
Participant profile	Senior, male citizens
FTE investment	Unknown

Project background

Part of the Reeuwijkse Plassen (lake area of Reeuwijk) is a Natura 2000 area (see also Appendix D). Water authority Rijnland has been taking measures to comply with the Water Framework Directive (WFD) of the European Union in the period 2010-2014 (Hoogheemraadschap van Rijnland 2009). Fifteen sub-projects were implemented in this 25 million euro project. The sub-project of installing a more flexible water level faced resistance of residents and interest groups. A feedback group was installed to discuss the plan of implementation and balance nature, recreation and interests of stakeholders. The water authority was challenged by misperceptions of citizens regarding the water system and distrust against the information spread by the water authority. Water authority Rijnland was inspired by another water authority that used participatory monitoring, i.e. citizens that perform the actual monitoring task of collection data. The specific set-up in Reeuwijk was defined by the water authority in combination with Mobile Water Management (MWM), a spin-off company of TU Delft.

Project content

The field of interest of the project is 10 senior citizens monitor groundwater water levels in their backyards and monitoring surface water levels in their surroundings. They use an application of Mobile Water Management (MWM). Participants take a picture with their smartphone of a staff gauge. The picture is uploaded to a server and an image recognition algorithm processes the picture and returns a value. The groundwater levels are currently measured with using echo sounds. A beep is send into a monitoring tube and based on the echo the water depth is determined using specialised software. Participants can choose when and how often they upload pictures and thus collect data.

Table 5.3 – Overview of the key success factors and their occurrence in Crowdsourcing in Reeuwijkse Plassen. An X marks that the factor was convincingly identified and (x) indicates that a success factor was considered, but it was either not applied or it did not have the desired effect.

Key success factor		Identified in Crowdsourcing in Reeuwijkse Plassen
PROJECT FORMULATION		
Define goals	X	Policy development (discover, persuade and justify); Education; Increase knowledge
Define time span	X	2 years
Define hypothesis	X	The small influence of surface water levels on groundwater levels is small.
Define measuring method	X	Areas of interest were defined; the monitoring method was chosen in advance, although it was improved along the way.
Define validation method	X	Automatic loggers at the same location to overlay both data sets.
Have insight in motivation	(x)	No formal investigation in motivations was held, but citizen concerns were known beforehand.
START		
Offer training	X	All participants received individual training at project start and after a change of monitoring method.
Define a clear task	(x)	The interviewees reported that some participants struggle with using the application and taking measurements.
Recruitment and marketing	(x)	No extensive marketing campaign was held, although participants were attracted via the feedback group's interest groups and a local newspaper. The number of applicants was lower than expect.
Establish a community	(x)	No community was established, but a 'group feeling' was reported.
DURING		
Provide feedback	X	Participating citizens retrieve immediate feedback on the water level measured, they can consult an interactive map online and reflection meetings are organised.
Retain volunteers		The interviewees did not report a strategy to retain volunteers and it was deliberately chosen to stop recruitment after the project start.
Involve in data analysis	X	Citizens are invited to share their thoughts on the meaning of the results; when requested participants can receive and analyse the full data sets themselves.
Increase task level		The task level remained constant, as the task did not change.
Other data collected	X	Ground data was collected when the groundwater tubes were drilled, but citizens collect no additional information.

5.2 Comparison between cases and key success factors

In the previous section three cases were introduced. A summary of the interview results was presented and a checklist was filled in regarding the application of key success factors (see Table 5.4). In this case comparison the three cases will be compared on their application of the key success factors as introduced in Chapter 4.

In Table 5.4 an overview of the identified key success factors per case is given. Additionally the factors that were convincingly considered in each case are marked. In the remainder of this section the project characteristics and challenges encountered are summarised (section 5.2.1), as these may influence the applicability or success of a key factor (section 5.2.2). Each key success factor will be discussed following two steps; first a description is given per case and next the differences will be explained where possible, based on the case characteristics and challenges faced. Key success factors not identified in literature, but applied in at least two cases are described in section 5.2.3 and adopted in the framework on page 32.

Table 5.4 – Overview of the key success factors as identified in the case studies. An X indicates that a key success factor was successfully applied, while an (x) indicates that a success factor was considered, but it was either not applied or it did not have the desired effect.

Key success factor	Tuintelling (case A)	iSPEX (case B)	CiRP (case C)	All
PROJECT FORMULATION				
Define goals	X	X	X	X
Define time span	X	X	X	X
Define hypothesis	X	X	X	X
Define measuring method	X	X	X	X
Define validation method	X		X	X
Have insight in motivation	X		(x)	
START				
Offer training	X	X	X	X
Define a clear task	X	X	(x)	X
Recruitment and marketing	X	X	(x)	X
Establish a community	(x)		(x)	
DURING				
Provide feedback	X	X	X	X
Retain volunteers	X		(x)	
Involve in data analysis			X	
Increase task level	X			
Other data collected	X	X	X	X

5.2.1 Project background

In this section characteristics and challenges faced, based on the interviews, will be summarised per project. These differences are used in the next section to explain differences between the cases.

Characteristics of the three cases

The inspiration for case A, Tuintelling (Garden Count), came from a similar organisation in the UK that hosted a citizen science programme on year round bird inventories. The topic of case A is city wildlife and aims at long-term monitoring. Case A is facilitated by a group of seven nature conservation organizations, among which Vogelbescherming. Two people at Vogelbescherming were interviewed.

Case B, iSPEX, was initiated after a smartphone add-on was invented by accidence and was seen as a tool suitable to for mobile crowd sensing (MCS). The campaign was launched using the moment created by winning a prize for science communication. The topic of case B is particulate matter and was a short-term measuring campaign. A consortium of research institutes, universities and other organizations, facilitated case B. Interviewees work at RIVM, one of the partners. Case B is an MCS project, using participatory (active) sensing (Lane et al. 2010). Participants need an iPhone to participate, the free iSPEX application and an add-on to do measurements.

Case C, crowdsourcing in Reeuwijkse Plassen (CiRP), was inspired by a similar project, organised by another Dutch water authority. The use of mobile sensing arose spontaneously. The topic of case B is groundwater and surface water level dynamics and is a project oriented on long-term monitoring. Water authority Rijnland facilitates the project of case A. The former and current project leaders were interviewed. Case C is an MCS project, using participatory (active) sensing (Lane et al. 2010). Participants need a smartphone with iOS or Android and a free smartphone application to do measurements. The water authority has installed gauges in the field to facilitate the measuring.

All interviewees considered their citizen science scheme (so far) to be successful. All projects are contributory projects (Cooper et al. 2007), with a consultative governance structure (Conrad & Hilchey 2011), where the government/organisation leads the project and citizens are used to conduct the measurements/monitoring.

Challenges encountered

In case A, Tuintelling, the main challenge experienced in this project was to align goals of partners and combine experiences. This collaboration is one of the key success factors of the project, but also one of the main challenges. On the one hand there is a lot of expertise and experience in different fields available, because all organizations focus on different species. Additionally, some organizations have experience with inexperienced (Vogelbescherming) and others with experienced volunteers (SOVON). Moreover, all these organisations have their own members. On the other hand, this collaboration and exchange of information was challenging as well, as it was sometimes difficult to reach agreement. Another challenge is to provide sufficient feedback to participants (see above).

In case B, iSPEX, the main challenge proved to be to create internal support. iSPEX is a rather complex device that measures a topic that is difficult to simplify correctly. This resulted further in a challenge to manage expectations of citizens and partners. iSPEX measures 'all the particulate matter between the iSPEX device and the sun'. Based on iSPEX no conclusions can be drawn of pollution at street level. To align communications of partners about this was a third challenge.

In case C, CiRP, the main challenge was to recruit volunteers. Little attention was paid to recruitment as the interest organisations in the feedback group supported the idea. In the end, few participants joined via the interest groups. Having the application work and understood by participants was a second challenge. A lot of time is invested in improving the technology and training of participants, including personal training after an update of the software, although this also led to a sense of project ownership with the participants. An additional challenge emerged recently, as the water authority lost its communication channel with the termination of the feedback group.

5.2.2 Comparison: key success factors at project formulation

The case characteristics are summarised above. In this section a comparison is made between the case studies based on the key success factors in literature at project formulation.

Goals - *A key success factor is to establish clear goals in the project formulation phase.*

In case A, Tuintelling, the goals increase knowledge, management and raise awareness were stated explicitly. Awareness served two sub-goals, namely to change citizen behaviour and to create a support base for nature conservation.

In case B, iSPEX, the two initial goals were to educate citizens and increase scientific knowledge. Social research was added along the way and via a publication the iSPEX consortium aimed to establish a new monitoring method.

In case C, CiRP, the project was started to aid policy development. The project displays a mixture of three sub-classes of policy development defined by Hollow et al. (2015): to discover alternatives together with citizens, to persuade citizens towards a preferred alternative (in this case a flexible water level policy) and to justify the made preliminary decision of a flexible water level.

The key success factor 'have clear goals' was applied in all cases. All three had established clear goals, before starting the project. A majority of goals found in literature (Tulloch et al. 2013; Hollow et al. 2015) were identified in the project. Serendipity and recreation were not identified in any of the projects, although it could be argued that serendipity was implicitly present in case A, as the interviewees indicate that they have no clear hypothesis and let the results surprise them. Public education and increase knowledge were explicit goals in all cases. The nature of the citizen science schemes and its facilitator's characteristics can be used to explain the differences in other goals.

Management and raising awareness were only identified in case A, Tuintelling. The latter goal should ultimately change citizens' behaviour and creates a support base for conservation, were explicit goals. Members, funds and companies fund the facilitator Vogelbescherming and therewith indirect the citizen science program. The program and the facilitator will therefore benefit more from an increased support base and a contribution of citizens in the form of conservation behaviour than the other two cases, which are government funded.

Social research and new methods were reported exclusively in case B, iSPEX. The facilitating iSPEX consortium consists of primarily of universities and research institutes and is therefore more driven to generating scientific knowledge than the facilitators in the other cases. Two publications established these goals in iSPEX: an article about the new monitoring method (Snik et al. 2014) and a social-scientific publication under review on citizen motivations and learning (Land-Zandstra et al. 2015, unpublished). There are no intentions though to incorporate social-scientific survey in the up-scaled, European follow-up of iSPEX.

Policy development goals (as defined by Hollow et al. 2015) were identified solely in case C, CiRP. The facilitator of case C has decision-making power as a regional government body; the lack of decision-making influence in cases A and B explains the absence of these goals for these facilitators.

Table 5.5 – Identified goals of the three cases studied. Goals originate from Tulloch et al. (2013) and Hollow et al. (2015), except goals in bold that were added based on the cases.

	Citizen Science	Tuintelling (case A)	iSPEX (case B)	CiRP (case C)
Increasing knowledge	X	X	X	X
Improving methods	X		X	
Raising awareness	X	X		
Change behaviour		**x**		
Create support base		**x**		
Management	X			
Public education	X		X	X
Social research	X		X	
Recreation	X	-		
Serendipity	X			
Policy development	X			X
(I) discover alternatives	x			x
(II) educate about situation	x			
(III) measure public opinions	x			
(IV) persuasion/support base	x			x
(V) legal justification		x		x

Timespan – *A key success factor is to predefine the time span*

Case A, the Tuintelling, aims at continuous monitoring over decades. There no end of project defined as a consequence.

Case B, iSPEX, was a single-event project and is already terminated. The project had a clear time span, as there was one monitoring day in July and another one in September. Participants were encouraged to monitor on suitable days in between as well. It is still possible to take measurements with the iSPEX app and add-on, but the official measurement campaign terminated.

In case C, CiRP, it was determined to monitor for a period two years. The facilitating water authority agreed to monitor via citizen science for two years, although an evaluation and go/no-go is planned after the first year.

In all cases the time span was predefined, although it is defined as undefined in case A, Tuintelling. The time span is related to the goals of the project. For example in case A the citizen science programme aims to gain insight in city wildlife patterns, which requires multiple years to establish time series. In case C time series are required as well, but the relation between groundwater and surface water becomes apparent on a shorter time scale than wildlife patterns. In case B there was no need to collect data over a larger time span, as the main purpose of the data was to compare iSPEX measurements to measurements of the official monitoring network.

Hypothesis – *A key success factor is to have a hypothesis in mind*

In case A, Tuintelling, there was no measurable hypothesis on the topic of monitoring, but there are ideas about the results. It is expected that results will resemble the results of the British Trust of Ornithology (BTO), which has an established citizen science programme running for 20 year. There are additional organisational hypotheses, regarding the number of citizens that will remain active and regarding the required accretion of participants the coming years.

Case B, iSPEX is a single event project, thus there was no hypothesis formulated about a trend. As there were no prior experiments with iSPEX, the project did make estimations of the required number of data entries to obtain an averaged, reliable value.

In case C, Crowdsourcing in Reeuwijkse Plassen (CiRP) the facilitating water authority has a clear hypothesis in mind, being that groundwater levels are rather precipitation driven than related to surface water levels.

The level of prior knowledge can explain the variation in hypotheses. The Tuintelling in case A was initiated to increase knowledge on city wildlife, which is considered a blank space in wildlife knowledge. This citizen science scheme had to base expectations on similar projects, such as the BTO. In case B, iSPEX, a new device was used, where no prior knowledge was available and thus no hypothesis could be formulated. In the third case, CiRP, there was a high level of prior knowledge, as the hypothesis of this project is built on prior monitoring in the area and scientific knowledge on the relation between groundwater and surface water levels.

Measuring method – *A key success factor is to carefully design monitoring methods*

In case A, Tuintelling, the monitoring methods were based on existing wildlife monitoring protocols, on the existing protocol of the annual bird count and on the methods of the BTO that acted as example for Tuintelling. The monitoring protocols prescribe how and when to measure, in a fixed location and with a fixed frequency, although timing of measuring may vary. These were additionally tested in a pilot of six months by a group of citizens.

In case B, iSPEX, the measuring protocol was defined beforehand as well. Citizens could only submit measurements in a prescribed position, with the arm stretched and taking measurements at prearranged angles between a horizontally and vertically stretch. There were no limitations to location or frequency. The use of mobile crowd sensing (MCS) was a deliberate choice, as it enables the collection of data on a large scale, using an easy-to-operate device.

In case C, CiRP, the monitoring method was pre-defined, using the image and sound recognition software in the Mobile Water Management app. The locations were predetermined and fixed, but there were no requirements on frequency. The use of MCS was a deliberate choice, although the advantages of using MCS over traditional reporting schemes are indistinct.

The anticipated application of the data sets requirements to the quality of the data. This data quality requirement is influenced by the quality of measurements method and explains the difference between the cases. In case A, Tuintelling, a high quality dataset is needed to increasing knowledge and use the data to fine-tune management. Case B, iSPEX, had similar requirements as iSPEX aimed at testing new measurement instrument. A measurement method that ensures exact the same conditions for all contributing citizens was thus important. In case C, CiRP, the requirements to the dataset were less strict, as there is already an established base of knowledge on the topic of groundwater dynamics. This may provide an explanation for the less thorough choice of MCS as measurement method.

Validation method – *A key success factor is to carefully design validation methods*

In case A, Tuintelling, experts at the national database of Flora and Fauna validate the data. To validate the results at data entry, participants are restricted in values they can enter, as some values are known to be unlikely to occur. Furthermore there are plans to include an option for peer-review. Participants would be able to upload a picture of a species and other volunteers could help each other or correct other volunteer's conclusion.

In case B, iSPEX, several data entries were averaged and compared to the official monitoring network. There was no pre-established validation method nevertheless, as the facilitating iSPEX consortium had no experience with this type of data.

In case C, CiRP, the facilitator water authority Rijnland installed automatic loggers next to all monitoring tubes. The datasets were compared and that way the dataset is validated.

Experts validate the datasets in all three cases. The level of details in the planned validation method varies with the existing knowledge about the data and with the required quality of the dataset. For example Vogelbescherming, facilitating case A, and water authority Rijnland, facilitating case C, have experience with similar data and were able to base validation schemes on existing knowledge.

Insight in people's motivation

A key success factor is to have insight in volunteer's motivation and barriers

In case A, Tuintelling, a questionnaire was spread in 2014 to ask potential participants what they would like and dislike with regard to monitoring and what their needs are for a continuous contribution. A pilot of six months provided further insight in participant's motivation and challenges.

In case B, iSPEX, there was no analysis of the market potential held in iSPEX, because the facilitators were unaware of the possibility and were under time pressure. Insight in motivations was gained after the monitoring days in a survey among 1258 participants (39% of the total number of participants; Land et al. 2015, unpublished).

In case C, CiRP, no official investigation took place. The facilitator water authority Rijnland expected though that participants would mainly be interested to participate to increase their influence on decision making and to contribute to verification (or rejection) of the assumptions of the water authority that support this decision.

The key success factor to have insight in participant's motivations gained little attention in two out of three cases. Tuintelling (case A) did an intensive investigation in citizen motivations, because the scheme needs citizens to participate for a longer time. In iSPEX (case B) continued participation is of lesser importance, as it concerned a single event scheme. In CiRP (case C) the absence of insight in motivation might be an explanation for the fact that the project attracted a slightly disappointing number of participants (ten). iSPEX further illustrates that time puts a significant constraint to the possibility of investigating citizen's motivations. This time pressure may have played, although not stated explicitly, a role in CiRP as well, as the water authority has to keep up with a schedule of the larger implementation plan for the region.

5.2.3 Comparison: key success factors at project start

The previous section discussed the project formulation phase. In this section a comparison is made between the case studies based on the key success factors in literature at project start.

Training and clear task description – *Two key success factors are training and clear tasks*

Participants in case A, Tuintelling, are instructed via a clear task description on the project's website. Citizens register online and are immediately informed about the two different types of monitoring (week list or time count) and how to count in both of them.

Participants in case B, iSPEX, could review an instruction video on the website and the application guided them through the process. Mistakes in using the device, for example when the device is turned up side down, were recognised and corrected by the application as well.

Participants in case C, CiRP, have no access to a manual or instruction video. They received on-site demonstrations from the facilitating water authority and Mobile Water Management, the company that developed the software.

In all cases participants received training. In Tuintelling (case A) and iSPEX (case B) participants received remotely, online instructions, which is can be explained by the large geographical scale and the large number of participants in these schemes. Participants in CiRP (case C) are small in number (ten) and received personal instructions, which were time intensive, but improved the relation between the facilitating water authority and participants.

Recruitment and marketing – *A key success factor is to have recruitment strategies*

Participants in case A, Tuintelling, were recruited via the network of the facilitating organizations. To reach the general public there is an agreement with radio show Vara Vroege Vogels. There will be attention for the project regularly in this show on nature. Additionally the organisation looks for media attention in nature magazines, garden magazines and local media.

Participants in case B, iSPEX, were recruited via the network of the iSPEX consortium and partner organisations. The campaign got a lot of media attention after winning the Academic Year Award for science communication.

Participants in case C, CiRP, were recruited participants via a feedback group. This feedback group consisted of 25 different interest groups. The facilitating water authority Rijnland pitched their idea of crowdsourcing and encouraged the group members to participate or recruit other people. Additionally there was an advertisement in the local newspaper. Some participants have ties to these interest groups, others responded to the call in the newspaper.

All projects promoted their project and used media and partner networks to recruit participants. A scale difference can be identified; the two national schemes (Tuintelling and iSPEX) had alliances with multiple national partners and used national media to market the project, while the local scheme, CiRP, used local media and partners.

Community – *A key success factor is to establish a community of volunteers*

In case A, Tuintelling, no community is established for participants, although there are plans to start an online community. This community should encourage citizens to help each other and will incorporate a function to upload pictures for peer-validation.

In case B, iSPEX, interviewees reported that no community was established.

In case C, CiRP, there is no official community, but the facilitating water authority offers regular meetings to discuss project progress and the results. The intensive contact between facilitators and participants results, according to the interviewees, in a group feeling.

None of the cases studied have a community, although a community will be established in case A, Tuintelling and a group feeling is reported in case C.

5.2.4 Comparison: key success factors during the project

The previous sections discussed the phases project formulation and project start. In this section a comparison is made between the case studies based on the key success factors during the project.

Feedback – *a key success factor is to provide feedback on results, individual and group contribution*

In case A, Tuintelling, feedback on results is difficult, since it takes time to built time series needed for the project to draw conclusions on trend development. The organisation therefore emphasises the importance of continued participation of individuals. Project updates and an overview of the collected data are shared as well, to keep participants up to date.

In case B, iSPEX, participants received direct feedback as their measurement is immediately uploaded on an interactive map, with a colour code to indicate the level of aerosols. The feedback of the final results took almost a year, which was depreciated by some participants. No feedback was given on group or individual contributions, as the campaign did not aim at continued monitoring.

In case C, CiRP, participants receive direct feedback on the measurements they take. They can view time series in an online viewer. Feedback on the meaning of the data is given in group meetings.

All cases provide feedback on the results and in Tuintelling participants are also informed about the importance of their contribution to the project. Two factors challenge feedback on the results: long-term monitoring schemes that require a long build-up of time series, such as the Tuintelling, and schemes with complex data analysis, such as iSPEX.

Retain volunteers – *a key success factor is to sustain a sufficient number of participants*

In case A, Tuintelling, there is a strategy to maintain participants, by emphasising the importance citizen's contribution and by announcing that citizens will see differences next season. A drop out rate is not known yet, as the programme just started, but the facilitators already reach out to new audiences to sustain the participant level. The facilitator Vogelbescherming continues to seek media attention, for example via their media partner Vara Vroege Vogels (a nature oriented radio show).

In case B, iSPEX, registered users of the first measurement day were personally contacted by email to contribute on the second measurement day as well. A drop out of participants was reported though between the initial measurement day in July and the second day in September. Other strategies to retain participants were superfluous, as the campaign was terminated after these days. Furthermore, the questionnaire (Land-Zandstra 2015, unpublished) participants were asked about conditions for further participation.

In case C, CiRP, the facilitator focuses on personal contact as strategy to retain participants. Interviewees further indicated that are unable to facilitate more participants. Moreover, new participants would not be feasible, as monitoring locations are located on private property of participants and new locations would lack important historical time series. All initial participants are still in the project, although there are participants who did not do any data entry yet.

The project characteristics of time span and monitoring method influence the strategy to retain participants. Strategies to retain volunteers were applied in both long-term citizen science schemes, Tuintelling and CiRP. iSPEX had no interest in retaining or recruiting additional volunteers, as it was a single-event campaign. Besides strategies to retain participants, Tuintelling also reported a strategy to gain new participants.

Involvement in data analysis – *a key success factor is to involve citizens in data analysis*

In case A, Tuintelling, citizens are not involved in data analysis, because the facilitators know how to analyse the data. Existing infrastructure can be used to analyse the data.

In case B, iSPEX, citizens are not involved in data analysis, because the data analysis is complex and requires experts to do so. The organisation itself struggled with analysing the results in such a way that they could be translated to a map.

In case C, CiRP, the facilitator (water authority Rijnland) performs a rough analysis of the data, but invites citizens to have a look as well. They provided the raw dataset to participants that asked for it and discussed the preliminary results with citizens during a reflection meeting.

In Tuintelling and iSPEX citizens were not involved in data analysis, both for reasons of experience with the data analysis. In the first case the organisation has sufficient experience with analysing similar data, while in the second case the organisation had no experience with analysing this type of data and faced challenges themselves to analyse the data. In the third case of CiRP citizen involvement in data analysis was necessary to increase the credibility of the dataset, as citizens indicated to have insufficient faith in the results of previous monitoring by the water authority.

Increase task level – *a key success factor is to keep participants challenged*

In case A, Tuintelling, participants can increase the task level by selecting additional species to monitor or by collecting details (e.g. whether the observed bird is dead or alive).

In case B, iSPEX, a single measurement method was offered for a single-event project, thus there was no increase in task level possible.

In case C, CiRP, facilitator Rijnland has no intention to expand the monitoring task level, as participants already struggle with the current monitoring methods (mainly technology related issues).

An increased task level was available in case A only. The Tuintelling deliberately introduced this to serve participants with different levels of experience and ambition. In the other two cases no increased task level was available for participants, due to the length of the scheme (case B) and complexity of the measurement method (case C).

Other data collected – *a key success factor is to combine data collection of different topics*

In case A, Tuintelling, information is collected about garden size, garden characteristics and home address. The latter is combined with information from the Central Bureau of Statistics, for example average real estate value.

In case B, iSPEX, during the measurement days time and location of the measurements was automatically collected, but users had to register online. The questionnaire afterwards collected demographic information of participants.

In case C, CiRP, no additional information was collected by citizens or about citizens, but the water authority collected soil samples while drilling the monitoring tubes.

All three cases collect a limited amount of additional information. The collected information is used to support the data analysis and interpret results. For example in Tuintelling the garden characteristics are important, as was the location and time for iSPEX and the soil characteristics for CiRP.

5.2.5 Comparison between general citizen science and mobile crowd sensing

In the previous sections key success factors for citizen science in general were discussed. In the literature review of Chapter 4 a distinction was made between general citizen science and mobile crowd sensing (MCS). The specific key success factors for MCS will be discussed for the two MCS cases, iSPEX (case B) and Crowdsourcing in Reeuwijkse Plassen (CiRP, case C).

Two additional key success factors for mobile crowd sensing (MCS) were identified in literature, both for the phase of project formulation.

Balance privacy and data trustworthiness - *a key success factor is to balance these two*

In case B, iSPEX, privacy sensitive information was collected, as participants had to register online and their location at the time of measuring was documented. The interviewees reported that privacy issues were not into account by the facilitators.

In case C, CiRP, privacy sensitive information was collected as well, as participants had to register their phone and logging location. The latter corresponds to their place of residence. A time stamp and GPS location were recorded for each measurement, although participants could opt to upload data at a later time and on a different location.

In both cases the trade-off between privacy and data trustworthiness was in favour of data trustworthiness, as participants had to register, although for two different reasons. In iSPEX privacy was not considered an issue, although the consortium collected privacy sensitive information. In CiRP part of the privacy sensitive information was already available: Rijnland already knows where the participants live and the facilitating water authority Rijnland has a lot of personal interaction with their participants, for example in on-site instructions and during physical feedback meetings.

Keep general device capacity in mind – *a key success factor is to match device and task*

In case B, iSPEX, the application was available for iPhones only and participants had to order an add-on to monitor.

In case C, CiRP, the application was available for iOS and Android platforms. Participants do not need additional material, although measuring locations have to be calibrated.

In both cases the applications caused not problems on the devices it was intended for. Additional material or activities were required though before the application could be used properly.

5.2.6 Additional key success factors

In case A, Tuintelling, two additional success factors were mentioned. First, the interviewees valued the pilot, as it enhance the programme's set up. They are further glad that they took their time to think out the process thoroughly. Second, having a low threshold for citizens to participate was mentioned as a key success factor as well, especially because the project aimed at the general public and not a small group of enthusiasts.

In case B, iSPEX, having a fast-responding helpdesk was mentioned as additional key success factor, because it gave participants the feeling they were taken seriously.

In case 3, CiRP, the interviewees named the personal interaction with citizens as a key success factor, because it enhanced commitment from both citizens and facilitators. This was especially a success because it concerned one contact person throughout the project.

The interviewees mentioned a total of four additional key success factors. Two will be adopted in the framework of key success factors. The first is having a pilot, as this was mentioned in case A, but also applicable in case C, where the whole project is a pilot. The second is having a helpdesk, as both in case B and C the added value of having a point of contact was stressed, in case B in the form of an email address and in case C in the form of a contact person. Having a low threshold was not added, as the researcher considers it a different explanation of having a clear task for participants and taking citizen motivation into account.

5.3 Chapter summary: key success factors in three cases

In this chapter the framework of key success factors was applied to a case study. Project leaders of three citizen science projects in the Netherlands were asked whether a certain key factor was considered and/or applied successfully. This resulted in an assessment per key success factor, where differences between the cases were explained by differences in project characteristics and challenges faced. Two cases were mobile crowd sensing (MCS) projects and the additional key success factors for MCS were thus assessed as well. Finally newly identified key success factors were added to the framework.

The next chapter will provide the conclusion of findings in literature and the case study and comprises a discussion on the used methods and generalizability of the results.

Chapter 6 Conclusion and discussion of Part I

In the previous chapters key success factors were identified in a systematic literature review and compared to a three case study. In this chapter the conclusion (section 6.1) is drawn and the outcomes of this Part I are discussed (section 6.2).

6.1 Conclusion of Part I

A comparison between literature findings and a tree-case study was performed in Chapter 4 and Chapter 5. The cases studied were all contributory projects with a consultative governance structure. The case study confirms a vast majority of literature findings. The framework will therefore be applicable to the Dutch context as well and can be used by Dutch water authorities to set up a contributory citizen science project. The next sections present the conclusion of the comparison and the meaning for Dutch water authorities.

6.1.1 Key success factors: refining the framework of key success factors

First a summary is given of the key success factors that were confirmed generalizable. Applicability of key success factors for different project characteristics is discussed as well.

Establish goals as most important key success factors at project formulation
In the project formulation phase six key success factors have been investigated: to have clearly established goals, to define the time span of the project, to carefully design measurement methods, to carefully design validation methods and to have insight in citizen's motivation to participate. The first five goals were confirmed to be essential key success factors, as they were identified in both literature and all three case studies.

Having multiple goals is considered advantageous. The goals of public education and to increase knowledge were cited often in literature, which was confirmed in this study, as they were present in all three cases. In literature a set of nine goals was identified and all identified goals in literature, except recreation, were mentioned in at least one of the cases. No new goals were identified, confirming the completeness of the list of goals, although 'change behaviour' and 'create a support base for the facilitators work' are added as sub-goals of 'raise awareness' based on case A. The ability to define a hypothesis, measurement method and validation method is positively influenced by the availability of prior knowledge on the subject and experience in processing the type of data collected by citizens. The goal of the project determines the application of the data and thus further influences the requirements of data quality.

Insight in citizen motivation as a key success factor could be neither confirmed nor rejected by the case studies, but is suggested to be likely influence the number of participants.

Two key success factors for mobile crowd sensing (MCS) were identified in literature for the project formulation phase: match the task with device capacity and balance trustworthiness and privacy. Both were confirmed in the cases, although two remarks can be made. First, it is challenging to base an monitoring solely on the internal sensors of the smartphone, an external sensor or installations in the field may be necessary. Second, privacy is easily overlooked when designing for trustworthy data.

Two key success factors were added based on the cases. Firstly it is important to ensure internal support and regarding mobile crowd sensing and secondly to keep the target audience in mind when choosing a monitoring method.

Clear tasks, training and recruitment as key success factors at project start
Four key success factors were identified at project start in literature: provide training to participants, have a clear task, have a strategy for recruitment and marketing and establish a community for

volunteers. The first three are confirmed in the cases as important factors, but the latter is rejected as key success factor. Having a community for volunteers was identified as key success factor in literature, but was unsubstantial in the case studies.

Training was mentioned in literature as an important key success factor, which was confirmed by the case interviewees. Two types of training were identified: remotely, online training and personal instructions. The first is most practical for large-scale citizen science schemes with simple tasks, while the latter is time intensive, but pays off in terms of commitment. Literature mentioned free and targeted media for recruitment and marketing, which was confirmed in the cases, although using partner networks was added as a recruitment strategy.

Two additional key factors were added based on the cases considered a key success factor to have a helpdesk, but also to manage expectations of citizen regarding the measurements.

A set of five key success factors during the project
Five key success factors were identified in literature to continue the project: provide feedback to participants, retain volunteers, involve citizens in data analysis, increase the task level for participants and collect additional information. Citizen involvement in data analysis was mentioned as an important key success factor for continuous monitoring, but this was not confirmed in the case studies.

Citizen science schemes that require a long dataset build-up and schemes with a complex data analysis may struggle to ensure sufficient feedback on the results. The feedback on group and individual contribution is particularly important in schemes that require continuous participation. The strategies to retain volunteers differ from retaining existing volunteers to attract new participants. Attracting new participants is especially important for long-term cases. An increased task level is important to motivate participants to continue contribution, although it is especially important for long-term schemes and should only be applied after participants master the initial tasks. To collect additional information was mentioned as a key success factor and confirmed by the cases, as the additional information was needed to analyse or interpret the data properly.

6.1.2 Implications for Dutch water authorities

The key success factors that were identified in literature and subsequently confirmed in al three cases are considered general key success factors by definition of the author. These factors should at least be taken into account by water authorities. Additional factors may be applicable, based on the project specific characteristics.

Characteristics of citizen science: starting with goals
Citizen science projects can be classified in several ways. The goals of a project are most suitable as starting point to create the outlines of a citizen science scheme. The project goals largely determine in which steps of the research project citizens will be involved. Water authorities should take these aspects into account when they consider citizen science. The eventual goal will determine the characteristics of the projects in terms of time span, data quality requirements and research steps involved. Based on the goals of the project water authorities should carefully choose governance structures and decide in which steps of the research process citizens can be involved.

Characteristics of MCS: choosing active sensing and balancing data quality and privacy
Water authorities in the Netherlands are increasingly installing wireless sensor networks and MCS may provide as it is more flexible, easily scalable and low-cost. MCS can be divided into active and passive sensing schemes. For water quality active sensing will be required, since citizens have to enter values or operate sensors. Water authorities should be aware though that applications should match the capacities of devices, the organisation and the abilities of the participants.

The trade-off between privacy and data trustworthiness will be apparent in projects for water authorities. They have access to multiple databases, which enables them to combine for example tax information or addresses with participant data in the MCS project. Mutual trust will be needed; citizens need to be able to trust the water authority with their privacy sensitive data and water authorities have to trust the entries of participants in case of anonymous contribution.

6.2 Discussion of Part I

A conclusion is drawn on the key success factors for citizen science projects. In this section the methods used will be discussed, along with a reflection on the results.

6.2.1 Literature

A systematic literature review was performed to identify key success factors in literature. The systematic nature of the review allowed it to be conduced in a structured manner, but I may have missed articles that were excluded from the search, for example because they did not match the key search words. I tried to counteract this by including literature that other authors referred to multiple times. The report of Roy et al. (2012) was included this way and proved to be a valuable addition.

This report is considered grey literature and therefore was not a result in the search activities. It was accepted as a reliable source and included in the review for three reasons. First, the method description is clear and free of large scientific errors. Second, the respected UK Environmental Observation Framework issued the report. Third, some of the authors published peer-reviewed articles on similar topics.

The literature included further originates from a diverse background. The projects in environmental monitoring reveal a great range in topics; some are very specific and focus on specific species or topics, such as birds (Tulloch et al. 2011), koalas (Hollow et al. 2015) or water resource management (Buytaert et al. 2015). A generalisation was made from this diverse set of studies, which cannot be scientifically justified in this stage, but was necessary to draw conclusions.

The generalisation seems legitimate, as the included studies show a great deal of overlap with each other. All authors mentioned for example providing feedback. Furthermore, the amount of literature on citizen science in natural resource management is too scarce to create a literature overview. In this part of the thesis a generalisation is assumed, which was verified, using the case studies.

6.2.2 Cases

The case studies verified the assumption that the found key success factors are indeed applicable to a diverse set of projects. The cases included two projects in the field of water resource management and all projects had a certain level of compliance with the key success factors found. Two remarks have to be made about the potential subjectivity of interpreting the results.

First, the analysis was sensitive for a bias, as I may have been looking for desired or expected outcomes. The key success factors were predefined as a code with a clear definition when coding the interviews. This structured the identification of compliance with key success factors and thus reduced research bias.

Second, I had to rely on the interviews solely to assess the application of key success factors and the success of a project. Evaluation reports were unavailable or non-existing, which implied that this assessment is more subjective than an evaluation ideally is. Even though I was inquiring about descriptive information mostly, I had to rely on the personal opinion of interviewees. The factual information was based mainly on the memories of the interviewees as well, although this was verified with other data sources (e.g. the project website) as well. Interviewing two people per case and thus obtaining the same information from two sources reduced these effects. In all three cases the two interviewees had near-similar responses, supporting the assumption that subjectivity is no concern.

Two mobile crowd sensing (MCS) projects were included in the case comparison and had less insight in the motivations of participants than the other case. Whether this was related to the MCS nature of the project is doubtful; the other projects aim at continued participation with a large group of participants and thus benefit from such insights.

Within the two MCS projects, it seems that iSPEX is an example of the 'classical' image of mobile crowd sensing: a large group of anonymous contributors collects data over a large geographical scope. The project in Rijnland can hardly be called mobile *crowd* sensing, since the project only hosts 10 participants. This project is a pilot, which explains the limited number of participants and the limited compliance to many key success factors (see Table 5.3).

The lack of full compliance with several the success factors is confirming rather than rejecting some these factors. For example, the interviewees from Rijnland indicate that their participants struggle with the technology. The project's participants are above the age of 65 years and an eleventh participant could not participate as he lacks access to a smartphone. This suggests a mismatch between the target audience and the measurement method. One of the challenges of mobile crowd sensing is that it may exclude potential participants (Roy et al. 2012). This was confirmed by Chen et al. (2011) who found a small, but significant decrease in self-efficacy with smartphone use with increasing age. This supports the key success factor of matching the proposed tasks and used tools with the target audience's capacities.

The cases itself were from a diverse set of topics (city wildlife, particulate matter and water levels), but none included water quality monitoring. It can be argued that this is a weakness for generalizability, but I would argue the opposite. The key success factors originate from a broad background (although originating from environmental monitoring) and were verified in an equally broad case study. I believe that this justifies generalisation to all fields of environmental monitoring, including water quality monitoring.

Part II – Citizen motivations, barriers and smartphone acceptance

In the previous part (Part I) key success factors to setting up a citizen science scheme were discussed, used to answer sub-research questions 1 and 4. In this part an answer will be sought to sub-question 2 ("*What motivations and barriers do Dutch citizens perceive regarding participation in citizen science in a water quality monitoring project?*") and sub-question 5 ("*What are the main positive and negative drivers of Dutch citizens in acceptance of smartphone applications for water quality monitoring that influence the design of a citizen science project?*").

A survey was used answer these questions. The full survey (in Dutch) can be found in Appendix A. The first part of the survey inquired about respondents' motivations, barriers and intention to participate in a citizen science project on water quality monitoring (Chapter 7). In the same survey respondents were shown a manual of a smartphone application that was intended to aid monitoring. An adapted Technology Acceptance Model 3 (TAM3) was used to assess Dutch citizens' intention to use this smartphone application and identify key drivers for this acceptance (Chapter 8). In the final chapter (Chapter 9) conclusions are drawn and the survey results are discussed, the theoretical framework of the adapted TAM3 is described and the results are presented.

Chapter 7 Motivational factors and barriers affecting citizen intention to participate in citizen science

In Part I key success factors for citizen science projects were collected. One of the key success factors is to understand citizen motivation and barriers. In this chapter these motivations and barriers of are considered. Using a literature study, first a theoretical framework is developed based on the Theory of Self-Determination (Ryan & Deci 2000). Second a brief description of the survey is given, the full survey can be found in appendix E. The results are subsequently presented in the third section.

7.1 Theoretical framework

This chapter aims at providing a quantitative insight in motivations and barriers. Motivation for participation in online citizen science projects is well-studied, while less peer-reviewed articles are available for environmental monitoring. Therefore motivations of online crowdsourcing and volunteering in general will be incorporated in this section. Some of these studies review online crowdsourcing such as Galaxy Zoo (Raddick et al. 2010) and Amazon Mechanical Turk MTurk (Kaufmann et al. 2011; Rogstadius et al. 2011; Chandler & Kapelner 2013). Edwards (2014) stated that citizen scientists in environmental monitoring are best compared with formal volunteers when it comes to motivation.

Over 40 motivations and a-motivations were found and clustered based on the Self-determination Motivation Theory of Ryan & Deci (2000). The model in Table 7.1 is an extension of the model proposed by Kaufmann et al. (2011) by adding motivations found in literature on citizen science in environmental monitoring and volunteering. Furthermore the classification is changed and tailored to the source of a motivational factor, which could either be internal, external or impersonal (Ryan & Deci 2000). This was done, because the questions in this thesis focus on citizen science issued by water authorities and they have an influence on external motivational factors rather than internal motivation.

Self-determination Theory proposes a classification based on an interpretation of psychological needs in social contexts. In their model Ryan & Deci (2000) distinguish between intrinsic, extrinsic and a-motivation. Intrinsic motivation stimulates behaviour that is performed out of enjoyment or interest. Extrinsic motivation leads to behaviour because it is instrumental to some separable consequence. Processes of internalization and integration are used to make behaviour that is extrinsically motivated more self-determined. A-motivational factors discourage to perform certain behaviour.

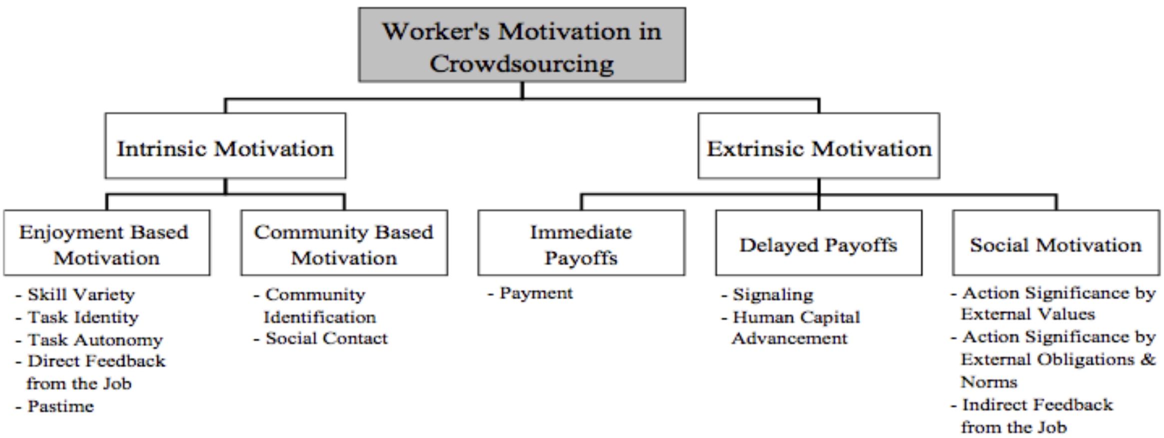


Figure 7.1 – Model on crowdsourcing worker's motivation (Kaufmann et al. 2011)

7.1.1 Intrinsic motivation

Intrinsic motivation is said to be the strongest (Ryan & Deci 2000), which will make that citizens put a greater effort in the activity considered (Chandler & Kapelner 2013). Intrinsic motivation is completely intrinsically regulated and means an activity is undertaken out of interest, enjoyment or inherent satisfaction (Ryan & Deci 2000).

A reason often mentioned to participate in citizen science is enjoyment (e.g. Raddick et al. 2010; Bramston et al. 2011; Roy et al. 2012). Whether an activity is 'fun' is personal, but Kaufmann et al. (2011) defined five factors that contribute to having fun. A variety in skills to be used, a tangible and complete task, autonomy in performing the task, receiving direct feedback from the job and using the task to kill time are mentioned (Kaufmann et al. 2011). Kaufmann et al. (2011) only distinguish between intrinsic and extrinsic motivation, thus some of these factors will be placed under integrated regulation in the SDT framework.

Besides enjoyment a personal interest in the topic (Raddick et al. 2010; Hobbs & White 2012; Rotman et al. 2012; Gharesifard & Wehn 2015) or in the particular project (Raddick et al. 2010; Roy et al. 2012) could motivate people to participate as well. Participants in environmental monitoring mention that they have an interest in nature or the in case of ecological monitoring in the species they monitor. Interest in wildlife is reported to be the main motivation of participants in bird counts in the UK (Hobbs & White 2012). Respectively 38% and 53% of the participants in the Leeds Garden Pond Survey and the BTO Garden Bird Watch reported an interest in wildlife as their main motivation to participate (Hobbs & White 2012). 46% of participants in Galaxy Zoo reported to participate out of interest in astronomy (Raddick et al. 2010).

Additionally people may be impressed by the topic or area of the tasks (Raddick et al. 2010; Hobbs & White 2012; Roy et al. 2012). For example 25% of participants in the GalaxyZoo project indicated that the beauty of the universe triggered participation (Raddick et al. 2010).

Citizens are also considered to be intrinsically motivated for a citizen science activity if it matches their hobbies (Rotman et al. 2012) or existing activities (Raddick et al. 2010). Examples can be nature photographers that combine photography with monitoring (Rotman et al. 2012). Equivalents for water monitoring could be sports fishermen that report on the fish population or water sports enthusiasts that measure water quality indicators while being out on the water.

7.1.2 Extrinsic motivation: integrated regulation

Integrated regulations internalise motivations to a great extent and these motivational factors are considered fully internal as well and are driven by a desire for congruence and synthesis with goals or the self (Ryan & Deci 2000).

Besides enjoyment or personal interest learning is considered a common motivation to participate as well (Bramston et al. 2011; Hobbs & White 2012; Rotman et al. 2012; Edwards 2014; Raddick et al. 2010; Buytaert et al. 2015; Gharesifard & Wehn 2015). Specifications of learning are discovery (Raddick et al. 2010), knowledge exchange (Gharesifard & Wehn 2015) and skill related learning (Roy et al. 2012). Such learning could focus on learning new skills (Edwards 2014) or combining several skills (Edwards 2014; Kaufmann et al. 2011; Gharesifard & Wehn 2015).

A high skill variety in the tasks to be performed has a positive influence on the quality of results in online crowdsourcing (Kaufmann et al. 2011). Whether this applies as well to citizen science in environmental monitoring is unknown.

Getting the chance to do scientific research can be a major motivation for citizens to participate as well (Raddick et al. 2010; Rotman et al. 2012). This may be related to the fact that many participants are higher educated and have experience in science or environmental monitoring (see section 7.2).

7.1.3 Extrinsic motivation: identified regulation

Motivational factors that have a personal importance or appeal to the conscious values of a person are considered to be extrinsic motivations of the identified regulation type (Ryan & Deci 2000).

Participants in citizen science indicate that they want to make a contribution. This contribution could be to a cause that is important to them (Bramston et al. 2011; Hobbs & White 2012; Edwards 2014; Buytaert et al. 2015). For example one in five participants in bird counting indicate to participate because they want to make a contribution to nature conservation (Hobbs & White 2012). Contribution could also be aimed at enhancing scientific research, such as 22% of participants in Galaxy Zoo indicated (Raddick et al. 2010).

This urge to make a contribution may originate from a moral obligation. Participants may feel responsible to make this contribution (Hobbs & White 2012; Rotman et al. 2012) or a need to help people or improve things (Bramston et al. 2011; Edwards 2014). 53% of British volunteers indicated to volunteer because they want to help (Edwards 2014).

This feeling of contribution is important and should not be neglected by organisers of citizen science. After a while, people will reconsider participation (Rotman et al. 2012). Feedback on the contribution of the group to the cause of the project and seeing the impact of citizen science efforts on communities were identified as important (Bramston et al. 2011; Rotman et al. 2012). In online crowdsourcing a test with equal tasks in three different level of meaning there were lower drop out rates in groups that were given a meaningful context while performing the tasks (Kaufmann et al. 2011).

Not only making a contribution on community level is important. Participants also indicated to participate in citizen science to do the activity together with friends (Bramston et al. 2011; Hobbs & White 2012) or use it to educate other people (Raddick et al. 2010).

7.1.4 Extrinsic motivation: introjected regulation

Motivational factors that focus on self-control and ego-involvement are of the introjected type of extrinsic motivation and are driven by internal rewards or punishments (Ryan & Deci 2000).

Participation in citizen science can influence the reputation or self-esteem of participants. Participants can have a feeling that they are needed (Bramston et al. 2010) or that their friends will think positively about them if they participate. Being part of a community when participating can be a motivation to join a program as well (Bramston et al. 2010). To continue participation it is important that participants have a feeling of control over the scientific process (Roy et al. 2012).

7.1.5 Extrinsic motivation: external regulation

Externally regulated motivation is triggered by compliance to (social) norms or by external rewards and punishments (Ryan & Deci 2000).

In most projects in citizen science there is some form of compensation. A financial reward though may work counterproductive. In online crowdsourcing financial compensation is more common than in citizen science in environmental monitoring. Studies on Mechanical Turk (MTurk, an online marketplace) reveal that financial compensation may increase speed of task performance, but decrease quality (Rogstadius et al. 2011; Chandler & Kapelner 2013).

A non-financial reward could be when citizens view participation as a career-building step (Rotman et al. 2012). Participation can be used to improve human capital by advancing one's skills (Kaufmann et al. 2011) or to increase one's visibility on the job market (Rotman et al. 2012; Kaufmann et al. 2011, Buytaert et al. 2015).

Participants may also be driven by external obligations or norms. Although they appear volunteers, external parties or social norms drive participation. Examples could be students who participate because their professor expects them to do so (Kaufmann et al. 2011).

Feedback on the recorded process can be considered a form of external reward as well (Kaufmann et al. 2011; Rotman et al. 2012). This feedback is of even greater importance when participants reconsider their participation. Rotman et al. (2012) found that citizens are more likely to continue participation if their individual contribution is valued throughout the project. Important motivational factors in on-going participation are further a deeper involvement, for example by taking part in data analysis (Roy et al. 2012), and having the opportunity to get advanced scientific training (Rotman et al. 2012).

In water resource management contexts citizens may participate to gain political leverage in the community (Buytaert et al. 2015). Rotman et al. (2012) describe this as self-efficacy, a desire to have scientific influence and to be known.

7.1.6 A-motivational factors

A-motivational factors are of the impersonal type. They originate from a lack of control or a feeling of incompetence or not being valued (Ryan & Deci 2000).

Not using the collected data is the most important a-motivational factor in citizen science. Citizens may decide not to participate if they see no personal application for the collected data (Gharesifard & Wehn 2015), but also if they feel there is no intention of the authority to use the data (Rotman et al. 2012).

More individual factors, such as a lack of confidence in one's ability to participate or a lack of resources (Gharesifard & Wehn 2015) may hamper participation as well.

In the phase of reconsidering participation, Hobbs & White (2012) reported that volunteers dropped out bird counting programs because the recording process did not appeal to them. If participants experience a power gap between the expert and themselves and if they feel undervalued they may drop out as well (Rotman et al. 2012).

Table 7.1 – Citizen motivations and barriers found in literature and categorised according to the Self-Determination Theory of Ryan & Deci (2000). Motivations in grey are applicable when participants re-consider their participation.

Motivation	A-motivation	Extrinsic motivation				Intrinsic motivation
Regulatory styles	Non-regulation	External regulation	Introjected regulation	Identified regulation	Integrated regulation	Intrinsic regulation
Source	Impersonal	External	Somewhat external	Somewhat internal	Internal	Internal
Mechanisms	Non-intentional; Non-valuing; Incompetence; Lack of control	Compliance; External rewards and punishments	Self-control; Ego-involvement; Internal rewards or punishments	Personal importance; conscious valuing	Congruence; Awareness; Synthesis with goals of self	Interest; Enjoyment; Inherent satisfaction
Motivations	*Data not being used [3]*	*Payment [6] [7]*	*Gaining reputation [6]*	*Feel responsible to do so [2] [3]*	*Learn new skills [4]*	*Enjoyment-based (fun) [1] [6] [9]*
	Not willing to collect for policy needs [5]	*Human capital advancement/ improve skills [6]*	*Community identification [1]*	*Contribute to important cause [1] [2] [4] [8] [10]*	*Use variety of skills [4] [6] [11]*	*Pastime [1] [4] [6]*
	Lack of confidence [11]	*Action significance (external obligations or norms) [6]*	*I feel needed [1]*	*Contribute to science [9]*	*Learning new things [1] [2] [3] [9] [10] [11]*	*It is beautiful/ Amazing [2] [5] [9]*
	Lack of resources [11]	*Direct feedback [6]*		*Willingness to help or improve things [1] [4]*	*Discover new things [9]*	*Was doing the activity already [2] [3]*
		Self-promotion/ signalling [3] [6] [10]		*Joining with friends [1] [2]*	*Do scientific research [3] [9]*	*Interest in topic [2] [3] [9] [11]*
		Gain political influence [3] [10]		*Use it to teach others [9]*	*Social contact (meet others) [1] [5] [9]*	*Interest in particular project [5] [9]*
	Recording process [2]	*Depth of involvement [5]*	*Complete work done by me [6]*	*Community impact involvement [1] [3]*	*Exchange knowledge [11]*	
	Power gap between scientist and volunteer [3]	*Recognition of contribution [3]*	*Feeling control over scientific process [5]*	*Feedback on group contribution [3]*	*Task autonomy [5]*	
		Scientific training [3]	*Trust [3]*			

[1] Bramston et al. 2011 [2] Hobbs & White 2012 [3] Rotman et al. 2012 [4] Edwards 2014
[5] Roy et al. 2012 [6] Kaufmann et al. 2011 [7] Rogstadius et al. 2011 [8] Chandler & Kapelner 2013
[9] Raddick et al. 2010 [10] Buytaert et al. 2015 [11] Gharesifard & Wehn 2015

7.2 Description of the survey on motivations and barriers

In the theoretical framework forty motivational factors and barriers to participate in citizen science were obtained from literature and mapped on the Theory of Self-Determination (Ryan & Deci 2000). To identify the most important motivations in citizen science in water quality monitoring a survey was issued among 13 000 members of a nature manager's newsletter.

7.2.1 Survey built-up for motivational factors and barriers

The survey is centred on a hypothetical citizen science project that is issued by nature manager Zuid-Hollands Landschap (ZHL), water authority Schieland & Krimpenerwaard (HHSK) and the Delft University of Technology (TU Delft). The survey built-up was discussed in Chapter 3 already. The survey on motivation was combined with the questions for the Technology Acceptance Model. The figure below shows the division of the two parts. In this chapter the black topics will be discussed.

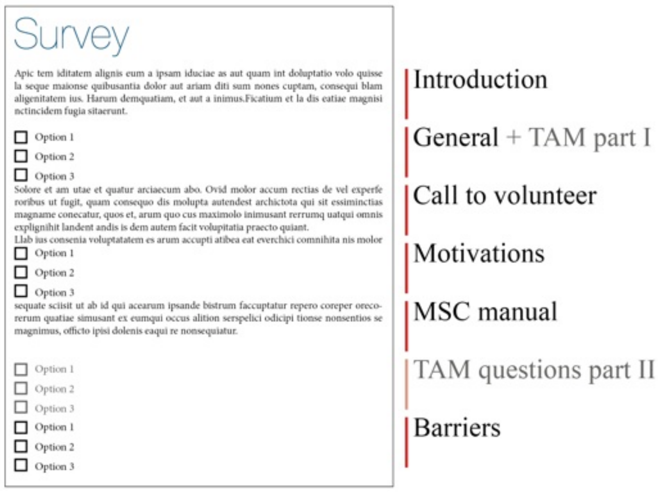


Figure 7.2 – Overview of the built-up of the survey. The questions related to the Technology Acceptance Model (TAM) are shaded in this overview; they will be discussed in the next chapter.

7.2.2 Project description

The full project description (in Dutch) can be found in the full survey that is attached as appendix A. The project is designed for the long term (Tulloch et al. 2013) and will be of a contributory nature (Bonney et al. 2009).

The section 'Call for volunteers' starts with a call for volunteers in general, which is partly copied from the Zuid-Hollands Landschap's (ZHL) web-page on the topic[5], and continues with introducing the specific citizen science project. In short this project citizens are asked to monitor three aspects of water quality, namely ecological indicators, chemical water quality indicators (chloride and phosphate) and turbidity.

7.2.3 Number of participants and drop out

A total of 160 respondents opened the questionnaire of which 143 actually started.

5 http://www.zuidhollandslandschap.nl/steun-het-landschap/vrijwilligers/

Figure 7.3 provides an overview of the number of participants after each step. It can be seen that around 100 people finished part I (general questions), around 75 did part II (about volunteering in general) and 60 completed the full questionnaire including part III (acceptance of technology).

25 of the participants that dropped out had no experience with smartphones or apps and quit at the drop-out option. Another 73 participants dropped out somewhere else in the process.

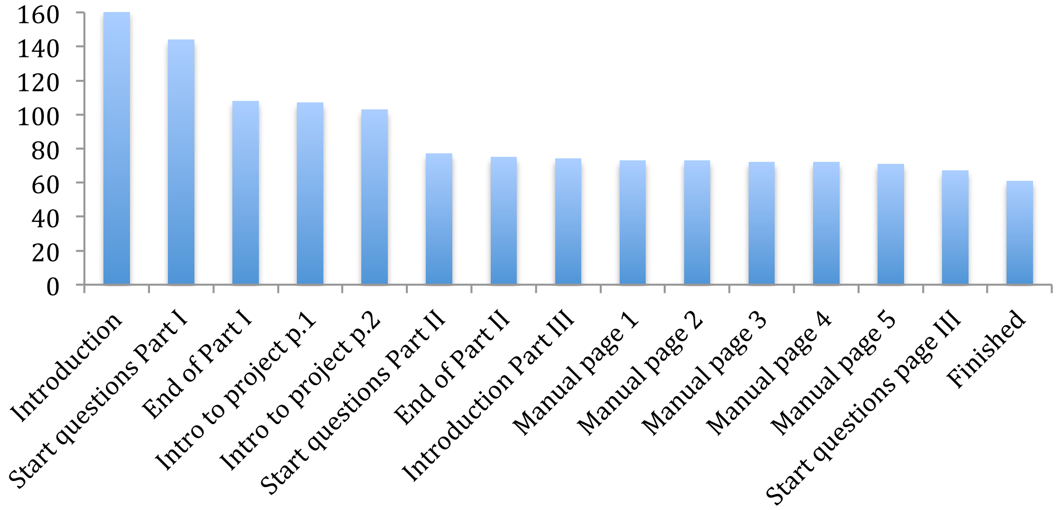


Figure 7.3 – Number of participants at each parts of the survey.

Smartphone & tablet experience
A total of 25 participants indicated that they have no access to a smartphone or tablet and no experience with apps. 11 people made use of the given option to quit, while 5 people without access or experience finished the questionnaire. 9 of them continued, but did not complete the questionnaire in the end.

18 participants did not have experience with smartphones, but they do know how to handle a tablet and how to use apps. 5 of them quit the questionnaire after the disclaimer that the questionnaire concerns smartphones instead of tablets.

One participant dropped out after reading the tablet disclaimer. The first part is not taken into account for this respondent either, since he answered he has the age of 6. This was probably a typing error, but still we removed him.

Location, age, gender and educational level
Based on GPS locations it seems that most participants originate from Zuid-Holland. It must be noted that this is based on IP addresses and there is thus a bias (i.e. three participants were located in Ghana according to their IP address GPS coordinates).

A majority of participants is higher educated and middle aged. The respondents are on average 59.8 years old and (standard deviation 13.0). 56.9% of the participants that started the questionnaire are male. It can be concluded there is no significant difference in drop out rate, since 55.6% of the completed questionnaires originates from male participants. There was a slight drop in the average age though, to 57.3 (Std. 10.4).

7.3 Results of motivational factors

In section 7.1 a theoretical framework was built that described motivational factors and barriers to participation in citizen science. The framework describes motivational factors from a-motivation (barriers) via externally regulated factors to internally regulated motivations. The survey inquired on these motivations in the context of a specific citizen science project. Descriptive statistics are presented and using one-way Anova it was investigated whether differences could be identified fro age, gender and educational level of respondents.

7.3.1 Intention to participate in this citizen science project

The intention to participate was measured using three questions. The correlation between the three questions was assessed using the Pearson correlation. Correlations were significant at the 0.01 level (2-tailed) and ranged from 0.726 to 0.941, which are considered good values (Sarstedt et al. 2014). Participation intention in the proposed citizen science project (before mobile crowd sensing is introduced) is 4.48 (std. 1.73). The distribution is displayed below.

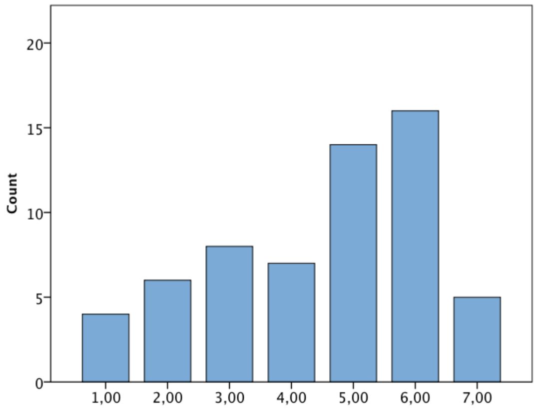


Figure 7.4 – Frequency distribution of the self-reported intention to participate (N=60).

Influence of age, gender and educational level
There were no significant differences found for smartphone experience (p =0.123, F=2445), age (p=0.381, F=0.983), gender (p=0.488, F=0.487) and educational level (p=0.673, F=0.180).

7.4 Results of targets to measure

Three topics of monitoring were introduced: ecological indicators (plant species), chemical indicators (chloride and phosphate) and turbidity. Respondents were asked to indicate to what extent they would like to monitor these topics and what the influence of the topics is on participation intention.

7.4.1 Intention to monitor ecology, chemical quality and turbidity

The respondents are most positive towards monitoring ecology in this particular project. For all three the average intention is positive though, with respectively 5.2 for ecology, 5.0 for chemical quality and 4.7 for turbidity on a scale of 1 to 7.

Table 7.2 – Intention to collect data of ecology, water quality and turbidity (scale 1-7). N=60

Monitoring target	Mean	Std. deviation	St. error
Ecology	5.2	1.78	0.23
Chemical quality	5.0	1.61	0.21
Turbidity (depth)	4.7	1.68	0.22

Influence of age, gender and educational level
No significant differences were found for age, gender and educational level.

7.4.2 Effect of topics on intention to participate

It can be noticed that most participants do not see a problem in carrying the box with strips, the Secchi Disc or other tools, as long as they fit within a backpack.

Influence of age, gender and educational level
No significant differences were found for age, gender and educational level.

Table 7.3 – Factors that influence the intention to participate negatively (scale 1-7). N=60

Influencing factors	Mean	Std. deviation	Std. error
Water quality affects intention negatively	2.6	1.70	0.22
Turbidity affects intention negatively	2.6	1.70	0.22
Having to bring the **box** *affects negatively*	2.1	1.67	0.22
Having to bring the **disc** *affects negatively*	2.4	1.83	0.24
As long as it fits in a backpack	5.8	1.86	0.24

Influence of age
Respondents of middle age (50-65) are most positive towards bringing the Secchi disc (p=0.030, F=3.733). They value the negative impact of brining the disc on average with 1.9 on a scale of 7 compared to the other age groups. The negative impact of the disc is respectively 3.3 and 3 for the age cluster below 50 and the cluster above 65.

Table 7.4 – The influence of the topics that have a significant difference (p<0.05) for respondents below the age of 50 (N=12), between 50 and 65 (N=37) and above 65 (N=11).

Motivational factor	Groups	Mean	F	p
Having to bring the disc affects my intention negatively.	<50	3.3	3.733	0.030
	50-65	1.9		
	>65	3.0		

Influence of gender and educational level
No significant differences were found for gender and educational level.

7.4.3 Relative importance of motivational factors to participate

Respondents were asked what their intention was to participate. Next they could indicate whether they considered a motivational factor important via the question "If I participate in a citizen science project, I find it important to…". Subsequently they could indicate a maximum of three factors they considered most and three that they considered least important. There are two missing values for each motivational factor.

Contributing to nature conservation is most often mentioned as an important factor (97%), followed by help others (86%), contribute to science (84%), discover things (83%) and learn new things (81%). Financial compensation (7%), improving one's reputation (7%) and improving one's chances on the job market (10%) are considered the least important factors.

Table 7.5 – Overview of motivations to participate. (N=60)

Reason to participate	N	Important		Unimportant		Most	Least
Financial compensation	58	5	7%	54	93%	2	32
Direct feedback	58	40	69%	18	31%	11	6
Increase of chance on a job	58	6	10%	52	90%	3	27
Increase my capacity	58	38	64%	20	36%	5	3
Teach others	58	38	64%	20	36%	6	3
Help others	58	50	86%	8	14%	12	0
Do something with friends	58	19	33%	39	67%	2	9
Contribute to science	58	49	84%	9	16%	20	2
Contribute to conservation	58	56	97%	2	3%	37	1
Learn new skills	58	41	71%	17	29%	1	2
Combine existing skills	58	21	36%	37	64%	2	3
Learn new things	58	47	81%	11	19%	11	1
Discover things	58	48	83%	10	17%	9	1
Do scientific research	58	36	62%	22	38%	5	4
Gain new social contacts	58	30	51%	28	49%	7	4
Being part of a community	58	18	31%	40	69%	3	8
Improve my reputation	58	4	7%	54	93%	1	28
Being able to act independent	58	35	60%	23	40%	10	4

Influence of participation intention

Significant differences were found for four motivations between respondents with a higher and lower intention (PI) to participate: 'financial compensation' (p=0.038, F=4.516) and 'increase my capacity' (p=0.058, F=3.735). 18% of the respondents with a low PI indicated to consider financial compensation important, compared to only 2% of the people with a high PI. The latter group does attain more importance to the opportunity to learn new skills and increase capacity (73%), compared to 47% of people with a low PI. Regarding the most important factors, 'discover new things' (p=0.036, F=4.616) is highlighted. None of the participants with a lower intention to participate designated this as most important, compared to 22% of the respondents with a higher intention.

Table 7.6 – Motivational factors with a significant (p<0.05) difference between participants with a low (N=17) and high (N=41) intention to participate.

Motivational factor	Groups	Proportion	F	p
Financial compensation	High	2%	4.516	0.038
	Low	18%		
Capacity	High	73%	3.735	0.058
	Low	47%		
Discover new things (most important)	High	22%	4.616	0.036
	Low	0%		

Influence of educational level

Significant differences were found between the motivational factors 'financial compensation' (p=0.020, F=5.761) and 'contribute to conservation' (p=0.014, F=6.387). Participants with a lower level of education indicated contribution to conservation and opportunities to increase their capacities less often as important, while they value financial compensation more than participants with a higher educational level. The difference between the two groups is small for contribute to conservation as all respondents with a high educational level (EL) consider this an important factor, compared to 87% of people with a low EL. For financial compensation the difference is larger, as one in five respondents with a low EL indicates financial compensation as important, compared to 2% of the people with a high EL.

Table 7.7 – Motivational factors with a significant (p<0.05) difference between participants with a low (N=15) and high (N=43) educational level.

Motivational factor	Groups	Proportion	F	p
Financial compensation	High	2%	5.761	0.020
	Low	20%		
Contribute to conservation	High	100%	6.387	0.014
	Low	87%		
Financial compensation (most important)	High	0%	6.387	0.014
	Low	13%		

Influence of age and gender

There were no significant differences found for age and gender.

7.5 Results of motivational factors for mobile crowd sensing

In the previous sections the characteristics of the respondents are presented and the factors that respondents perceive as motivational are listed. Influences of age, gender and educational level were taken into account. In this section presents the results of the remainder of the survey, where mobile crowd sensing (MCS) is added to the project description.

7.5.1 Description of the application

The design and functions of the application were based on meetings with nature manger Zuid-Hollands Landschap (ZHL), water authority Schieland & Krimpenerwaard (HHSK) and Mobile Water Management (MWM). The application is inspired on the existing mobile crowd sensing applications of the company Mobile Water Management (MWM) and the topics of monitoring were discussed with ZHL and HHSK to ensure a relevance to the context.

MWM's mission is to provide techniques to collect data in a water-rich environment, without having to rely on expensive equipment or risk electronic devises to be damaged by water, weather influences, animals or humans. MWM intends to monitor water quality with colorimetric analysis, a technique where a material changes colour at certain concentrations of a dissolved substance of interest. A picture should be taken of the coloured strip and uploaded to a server, where a software package performs the colour interpretation.

The author made the design of the application and composed a manual for the hypothetical application. Eleven people assessed clarity, language and lay-out of the images in the manual; where necessary adjustments were made to eliminate negative influences of lay-out and texts on the intention to use the application.

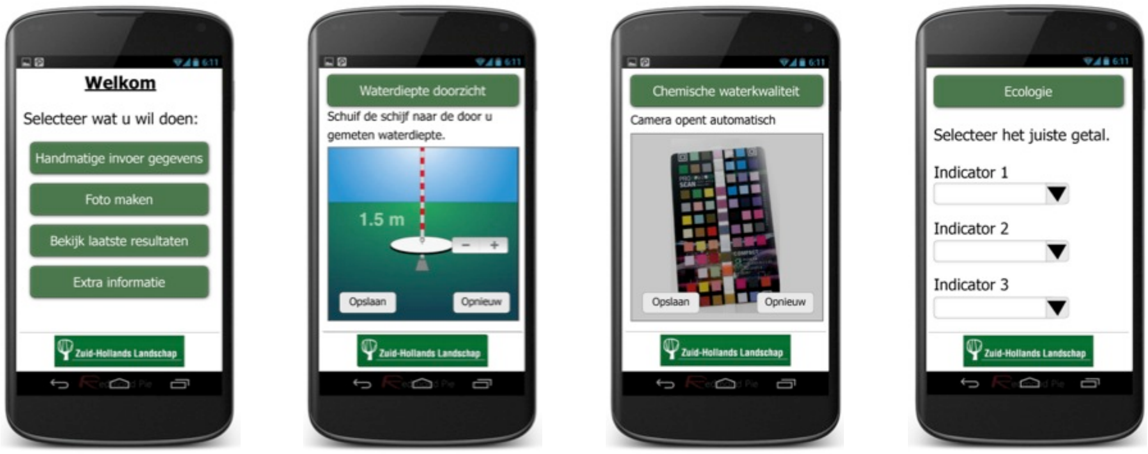
Five functions were included in the application, namely 1) data entry forms, 2) a map showing the spatial distribution of data entries, 3) a results section with times series per location, 4) the possibility to upload pictures of the monitoring context and 5) additional information on the monitoring topics and the facilitating organizations ZHL, HHSK and TU Delft. In general respondents valued these functions with scores around 6 on a scale of 7. Within this narrow range the data entry forms were most valued (6.4), while the additional information was least valued (5.9). See Table 7.8.

Table 7.8 – Appreciation of the functions in the mobile crowd sensing application. (N=60)

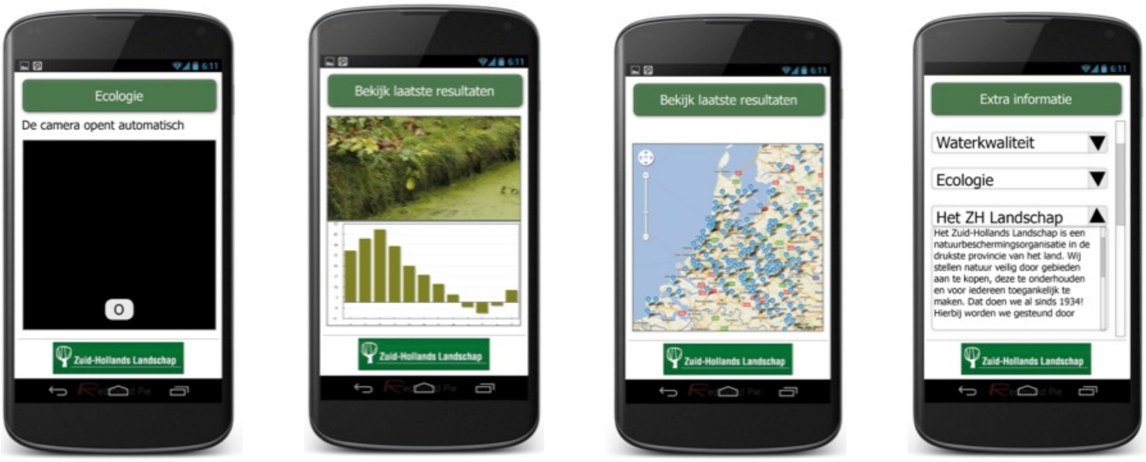
Functions in application	Mean	Std. Deviation	Std. Error of Mean
Data entry forms	6.4	1.25	.16
An interactive map with results	6.1	1.27	.16
Results, time series per location	6.0	1.80	.19
Photo upload section	6.1	1.36	.18
Additional information	5.9	1.33	.17

Influence of age
The functions 'data entry' (p=0.005, F=5.892), 'results' (p=0.025, F=3.931), 'photos' (p=0.002, F=7.045) and 'information' (p=0.029, F=3.763) showed significant differences between the age groups defined. In general it seems that the functions are least valued by the senior respondents (age above 65 years) and most valued by the middle-aged respondents (aged 50 to 65). It must be noted though that all age groups are positive towards the functions, with the lowest score being 5.0 on a scale of 7. See Table 7.9.

Influence of gender and educational level
There were no significant differences found for gender and educational level.



From left to right, top row:
Main menu; data entry for turbidity; data entry for chemical water quality using indicator test strips; data entry ecology.



From left to right, bottom row:
Data entry (adding a context picture); data viewer: time series at location; data viewer: entries on map; extra information.

Figure 7.5 – Images from the application manual presented to the respondents.

Table 7.9 – Features of the application with a significant (p<0.05) difference between participants for respondents below the age of 50 (N=12), between 50 and 65 (N=37) and above 65 (N=11).

Function	Groups	Proportion	F	p
Data entry forms	<50	6.3	5.892	0.005
	50-65	6.7		
	>65	5.4		
Results, time series per location	<50	5.9	3.931	0.025
	50-65	6.4		
	>65	5.0		
Photo upload section	<50	5.5	7.045	0.002
	50-65	6.6		
	>65	5.2		
Additional information	<50	5.7	3.763	0.029
	50-65	6.2		
	>65	5.1		

7.5.2 Intention to use the smartphone application

The intention to use the application was measured using three questions. The correlation between these questions was assessed using the Pearson correlation. Correlations were significant at the 0.01 level (2-tailed) and ranged from 0.915 to 0.969, which are considered good values.

There is a high intention to use the mobile crowd sensing (MCS) application (M=5.68, std=1.85). For an explanation of the drivers behind this behavioural intention the reader is redirected to the next chapter. In that chapter a Technology Acceptance Model will be introduced and used to identify such drivers.

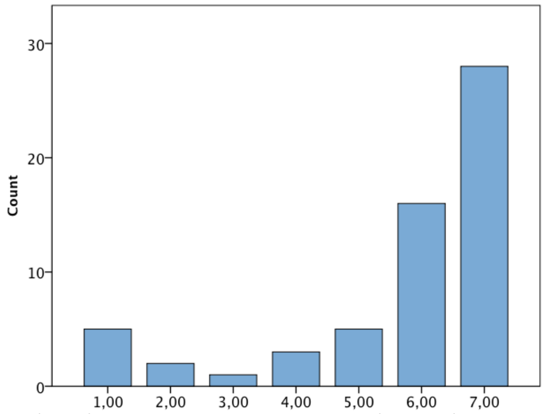


Figure 7.6 – Frequency distribution of the self-reported intention to use the application (N=60).

Influence of general citizen science participation intention

A significant difference (p=0.004, F=9.121) was found for the intention to use the mobile crowd sensing (MCS) application between people with a higher average intention and people with a lower average intention to participate in the citizen science project. The intention to use the application is still moderately positive to positive, with averages of respectively 4.7 and 6.1 for respondents with a lower and higher intention to participate in the citizen science project.

Table 7.10 – Intention to participate in MCS, comparison between higher and lower intention to participate as volunteer on a scale of 1 to 7. (F=9.121; Sig=0.004)

Participation intention in volunteering	Participation intention in MCS	N	Std. Deviation	Std. Error of Mean
higher	6.1	41	1.35	,21
lower	4.7	19	2.38	.55
Total	5.7	60	1.85	,24

Influence of age, gender and educational level

There were no significant differences found for gender and educational level.

Influence of smartphone experience

This difference increases and remains significant (p=0.000) when people with and without access to a mobile device are compared (see Table 7.11). The difference between smartphone and tablet users is present, but both are positive towards intention to use, with values of respectively 5.3 and 6.3, see

Table 7.12. The sample of tablet users is furthermore small compared to the combined group of smartphone users (47 people). Therefore the distinction between smartphones and tablets will not be made throughout the rest of this section, but the comparison between participants with and without experience with smartphone applications will be considered.

Table 7.11 – Intention to participate in MCS, comparison between with and without experience smartphones on a scale of 1 to 7. (F=34.121; sig=0.000)

Smartphone experience	Participation intention in MCS	N	Std. Deviation	Std. Error of Mean
Yes	6.2	48	1.10	,16
No	3.4	12	2.52	,73
Total	*5.7*	*60*	*1.85*	*,25*

Table 7.12 – Intention to participate in MCS, comparison between access to smartphones and/or tablets on a scale of 1 to 7. (F=13.566; sig=0.000)

Participation intention in volunteering	Participation intention in MCS	N	Std. Deviation	Std. Error of Mean
Both	6.1	39	1,21	.19
No	1.9	5	1.32	.59
Tablet	5.3	8	2.66	.94
Smartphone	6,3	8	0.82	.29
Total	*5,7*	*60*	*1.85*	*.24*

7.5.3 Drivers to participate in mobile crowd sensing

Respondents were asked to indicate what their reason would be to participate. They were given six options, which were based on the internally regulated motivations of the theoretical framework. 'I think the project is fun' stands out with 70% of the respondents indicating it as a reason to join and is followed, at a considerable distance, by 'I like this particular project' (38%) and 'The environment is beautiful' (28%). In Table 7.13 an overview is given.

Table 7.13 – Reasons to participate (N=60).

Reason to participate	All	%
It is fun.	42	70%
To kill time	0	0%
I like this project	23	38%
Beautiful environment	17	28%
It matches my hobbies	10	17%
I feel responsible to do so	14	23%

Influence of intention to participate

A significant difference was found for the drivers 'It is fun' (p=0.000, F=18.580), 'The environment is beautiful' (p=0.006, F=9.019) and 'I feel responsible to do so' (p=0.024, F=5.359), as can be seen in Table 7.13. For example, 85% of people with a high participation intention (PI) indicted to think the project is fun, compared to 37% of the people with a low PI. This is reflected in two other statements as well, namely 'Beautiful environment' and 'I feel responsible'. Respondents with a higher PI indicate more often than respondents with a low PI that they think the environment is beautiful, respectively 39% and 5%. Respondents with a high PI feel responsible to participate more often than respondents with a lower PI, respectively 32% and 5%.

Table 7.14 – Reasons to participate in the MCS project that have a significant difference (p<0.05) between participants with a lower (N=19) and higher (N=41) intention to participate in the citizen science project in general.

Motivational factor	Groups	Proportion	F	p
It is fun.	High	85%	18.580	0.000
	Low	37%		
Beautiful environment	High	39%	8.019	0.006
	Low	5%		
I feel responsible to do so.	High	32%	5.359	0.024
	Low	5%		

Influence of age and gender
There were no significant differences found for age and gender.

Influence of educational level
The reasons of "It matches my hobbies" (p=0.037, F=4.549) and "I feel responsible to do so" (p=0.061, F=3.658) have a significant difference between people with a high and low level of education (Table 7.15). None of the respondents with a lower educational level (EL) indicated that this project matches their hobbies, compared to almost one in four of the respondents with a higher EL. Respondents with a higher EL more often report to feel responsible to participate, 30% compared to 6% of the respondents with a lower EL.

Table 7.15 – Reasons to participate in the MCS project that have a significant difference (p<0.05) between participants with a lower (N=16) and higher (N=44) educational level.

Motivational factor	Groups	Proportion	F	p
It matches my hobbies.	High	23%	4,549	0.037
	Low	0%		
I feel responsible to do so.	High	30%	3.658	0.061
	Low	6%		

Influence of smartphone experience
The motivational factor 'It is fun' shows a significant difference (p=0.002, F=11.052) between respondents with and without experience with smartphone apps (see Table 7.16). 79% of the respondents with smartphone experience indicated to consider participation because the project seems fun to them, compared to 33% of the participants without smartphone experience.

Table 7.16 – Reasons to participate in the MCS project that have a significant difference (p<0.05) between participants with (N=16) and without (N=44) smartphone experience.

Motivational factor	Groups	Proportion	F	p
It is fun.	High	79%	11,052	0.002
	Low	33%		

7.5.4 Barriers to participate in mobile crowd sensing

In the final part of the survey respondents were asked what barriers they perceived in participating. A multiple choice list with seven barriers and participants was provide. Citizens could enter an alternative barrier using the option 'other'. A lack of time was the main barrier to participate, with 45% of the respondents marking it as a barrier perceived. Other barriers were reported by one in five respondents, as can be seen in Table 7.17.

Three respondents that reported other barriers indicated that the location was too far from their home and three named time-related barriers. One participant mentioned that the topic did not appeal to him as the topic is "too narrow" and one indicated that the project is "not applicable". One participant indicated that he does not want to use an app, while the other one mentioned personal reasons.

Table 7.17 – Overview of reasons not to participate.

Reason to not participate	All	%
I do not believe that the data I collected will actually be used.	1	2%
I am not willing to collect data for management purposes.	0	0%
I experience a negative power relation between myself and the ZHL	1	2%
I have insufficient time.	27	45%
I do not have faith that I can perform these measurements.	2	3%
The monitoring process does not appeal to me.	2	3%
I am physically unable to participate.	4	7%
Other	13	22%

Influence of intention to participate

The barriers insufficient time (p=0.056, F=3.816) and physical constraints (p=0.055, F=3.833) showed significant differences between the respondents with a higher and a lower intention to participate (PI). Respondents with a low PI mentioned a lack of time (63%) and physical inability to participate (16%) more often than people with a high PI (respectively 37% and 2%). See Table 7.18.

Table 7.18 – Barriers to participation in the MCS project that have a significant difference (p<0.05) between participants with a lower (N=19) and higher (N=41) intention to participate.

Motivational factor	Groups	Proportion	F	p
I have insufficient time.	High	37%	3.816	0.056
	Low	63%		
I am physically unable to participate.	High	2%	3.833	0.055
	Low	16%		

Influence of age

The age of the respondent makes a difference when it comes to the barriers of sufficient time (p=0.004, F=6.128) and physical ability (p=0.005, F=5.839). For participants below the age of 50, the lack of time is most important (83%) when it comes to participation, while there are not many instance of physical inability (8%). The middle aged people between 50 and 65 years old reported no instances of physical barriers, but still report a lack of time (41%). The oldest age group, with an age above 65, reported a lack of time the least often (18%), but do face more often physical barriers to participate (27%). See Table 7.19.

Table 7.19 – Barriers to participation in the MCS project that have a significant difference ($p<0.05$) for respondents below the age of 50 (N=12), between 50 and 65 (N=37) and above 65 (N=11).

Motivational factor	Groups	Proportion	F	p
I have insufficient time.	<50	83%	6.128	0.004
	50-65	41%		
	>65	18%		
I am physically unable to participate.	<50	8%	5.839	0.005
	50-65	0%		
	>65	27%		

Influence of smartphone experience

A significant difference in the barrier of disliking the monitoring method was found between respondents with and without experience with smartphones (p=0.003, F=9.280). None of the respondents with experience in the use of smartphone applications report the monitoring process as a reason no to participate, compared to 17% of the people without smartphone experience. See Table 7.20.

Influence of gender and educational level

There were no significant differences found for gender and educational level.

Table 7.20 – Barriers to participation in the MCS project that have a significant difference ($p<0.05$) between participants with (N=16) and without (N=44) smartphone experience.

Motivational factor	Groups	Proportion	F	p
The monitoring process does not appeal to me.	High	0%	9.280	0.003
	Low	17%		

7.6 Chapter summary

The survey was completed by 60 respondents, of which a majority is higher educated and middle aged. 57% of the respondents are male. The respondents have an overall positive behavioural intention to participate in this citizen science project, with a mean of 4.48 on a scale of 1 to 7.

It was expected that respondents would favour ecological monitoring over chemical quality and turbidity monitoring. There was a preference for ecology, but for all three topics the mean was around 5 on a scale of 7. Participation intention was unaffected by the extension of the volunteer monitoring activities of the Zuid-Hollands Landschap to water quality and turbidity. A majority of respondents, and especially the middle-aged, is positive to bringing monitoring equipment that fits into a backpack.

The most important aspects of a project that motivates to participate are contribution to conservation, contribution to science and the opportunity to discover new things and learn new things. All respondents with a high education consider a contribution to conservation important. Especially respondents with a high intention to participate value the discovery of new things and the development of skills to increase one's capacity. Financial compensation is the most appealing to respondents with a lower educational level and respondents with a low intention to participate.

The mobile crowd sensing (MCS) application was introduced halfway the survey. The intention to use the application was high, with a mean of 5.68 on a scale of 1 to 7. Respondents without access to smartphones or tablets and respondents without experience had a much lower intention to use the application, with averages of 1.9 and 3.4 respectively.

The most important driver to participate in this MCS project is fun, followed by enjoyment of this particular project itself and the beautiful environment where it takes place. Especially people with a high general intention to participate mentioned these reasons. Respondents with a higher educational level more often feel responsible to participate, or that the activities in the project match their hobbies. One third of the participants with smartphone experience considered the project fun, compared to almost 80% of the experienced respondents.

The main barriers to participation are a lack of time and other, individual reasons. People with a low general participation intention reported time and physical inability more often that people with a high participation intention. Senior respondents perceived time as less of a barrier than younger respondents, but more than one in four reported to be physically unable to perform the tasks. The monitoring method is overall not perceived a barrier, but this increases when zooming in to participants with a lack of experience in smartphone use.

The next chapter focuses on the intention of citizens to use an MCS application and in particular what drivers can predict this behavioural intention to use the application.

Chapter 8 Acceptance of mobile crowd sensing technology in a Dutch case study

In the previous chapter the survey motivational factors and barriers to participate in a citizen science project was introduced. Mobile crowd sensing was discussed as well, but the drivers to use the application remained unexposed so far. In this chapter an adapted Technology Acceptance Model will be introduced (8.1.1) and the results will be discussed (8.2).

8.1.1 Full methodology for the acceptance of smartphone technology

A summary of the method used to assess intention to use a smartphone application (in the context of mobile crowd sensing) was given in chapter 3. In this section the full method description is presented.

8.1.2 Theoretical framework: an adapted Technology Acceptance Model

An introduction to the Technology Acceptance Model 3

The Technology Acceptance Model originates from Information System theories and describes the intention to adopt IT by individuals. Davis et al. first defined it in 1989. Five constructs form the core of the model: the actual *Use* of the technology, which is directly influenced by the intention to use the technology. This *Behavioural Intention* is based on the *Attitude Towards* and *Perceived Usefulness.* The *Attitude Towards* is driven *Perceived Usefulness* of the technology and *Perceived Ease of Use* (see Figure 8.1). *Perceived Ease of Use* is defined "as the degree to which a person believes using an IT will be free of effort" (Davis 1989, p. 320). *Perceived Usefulness* is defined as "the extent to which a person believes that using an IT will enhance his or her job performance" (Davis 1989, p. 320).

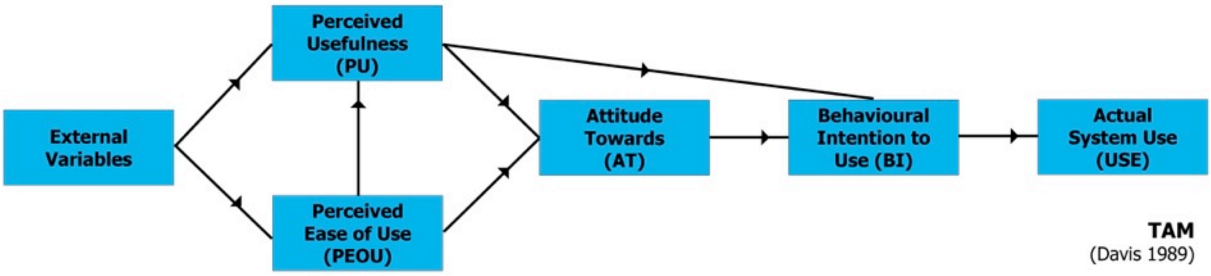


Figure 8.1 – The original technology acceptance model (TAM) (adopted from Davis 1989).

Several adjustments to the original TAM have been proposed over time, including two by the authors that defined earlier versions of the model. This resulted in TAM2 (Venkatesh & Davis 2003) and TAM3 (Venkatesh & Bala 2008).

The construct *Attitude Towards* is omitted in TAM3 and as a consequence PU and PEOU directly relate to *Behavioural Intention*. TAM3 puts an emphasis on individual differences, system characteristics, social influence and facilitating conditions. This third version of TAM furthermore adopted anchors and adjustments. The anchors are *Computer Self-Efficacy, Perceptions of External Control, Computer Anxiety* and *Computer Playfulness* and are initial judgements of *Perceived Ease of Use*. The influence of the anchors on *Perceived Ease of Use* will decrease with increasing experience with the system, while the influence of the two adjustments (*Perceived Enjoyment* and *Objective Usability*) grows stronger over time.

The third Technology Acceptance Model (TAM3) was chosen as a basis for the model to assess drivers to using a mobile crowd sensing (MCS) application. The TAM was preferred, because it is most often used in previous research on adaptation of mobile phone technologies or services (Sanakulov & Karjaluoto 2015). TAM3, shown in Figure 8.2, furthermore discusses potential pre-implementation interventions (Venkatesh & Bala 2008) that can enhance the intention to use the technology under review, which makes it most suitable for this design-oriented thesis research. Despite this suitability of TAM3 to this study, several adjustments had to be made. The constructs related to *Use* were excluded and constructs related to *Trust* were added. The questions used to assess the TAM constructs were combined with the survey on motivation and barriers (see the previous chapter). A balance between validity and feasibility leaded to was a reduction of the number of items used.

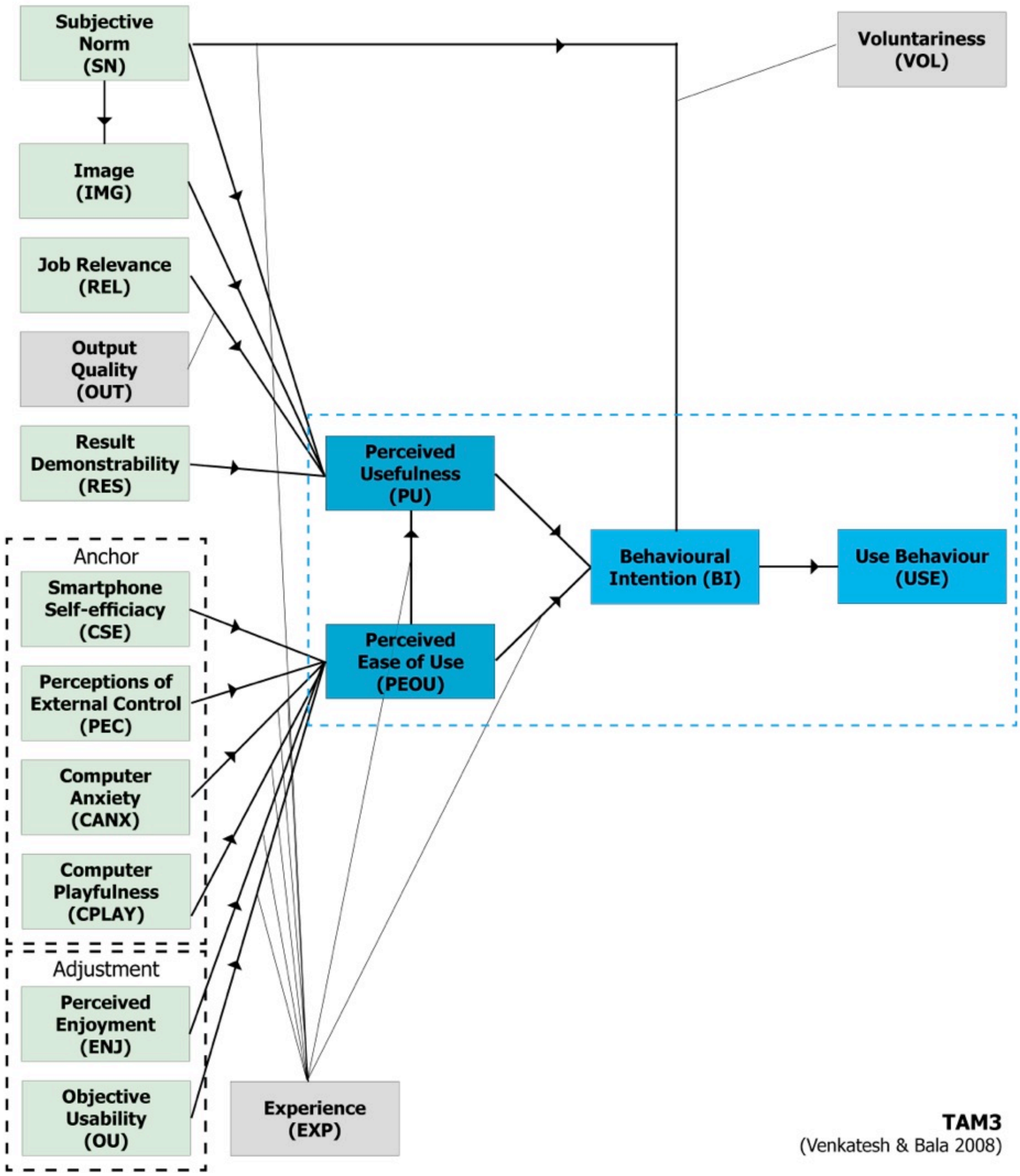


Figure 8.2 – Technology Acceptance Model 3 as proposed by Venkatesh & Bala (2008).

Adjustments to the Technology Acceptance Model: exclusion of use

The constructs *Use*, *Output Quality*, *Perceived Enjoyment* and *Objective Usability* are excluded, because the technology under review is a hypothetical MCS smartphone application. The construct *Use* measures the actual use of a system. In this study there is no actual application and no prototype available. Actual use cannot be measured therefore, although behavioural intention can be. Respondents were provided with a prototype manual (see Appendix B for the full survey), but could not try out the application itself, neither physically nor virtually. As a consequence the mentioned constructs, that involve the actual use of a product or prototype, were excluded. *Objective Usability* and *Perceived Enjoyment* are adjustment constructs, meaning their influence on *Perceived Ease of Use* will increase with experience (Venkatesh & Bala 2008). Common sense leads to the conclusion that it will be difficult to report perceived enjoyment if one did not actually use the item. The same goes for *Output Quality*, which is defined as "the degree to which an individual believes that the system performs his or her job well." (Venkatesh & Bala 2008, p. 277). *Objective Usability* is based on "the actual level rather than perceptions of effort required" (Venkatesh & Bala 2008, p. 279) and thus requires hands-on experience. Use-related constructs *Output Quality*, *Perceived Enjoyment* and *Objective Usability* were excluded for this reason.

It is hypothesised that the original TAM will be applicable in a hypothetical technology as well.

H1a: Perceived Usefulness (PU) is positively related to Behavioural Intention (BI).
H1b: Perceived Ease of Use (PEOU) is positively related to Behavioural Intention (BI).
H1c: Subjective Norm (SN) is positively related to Behavioural Intention (BI).

H2a: Subjective Norm (SN) is positively related to Perceived Usefulness (PU).
H2b: Subjective Norm (SN) is positively related to Image (IMG).
H2c: Job Relevance (REL) is positively related to Perceived Usefulness (PU).
H2d: Result Demonstrability (RES) is positively related to Perceived Usefulness (PU).
H2e: Perceived Ease of Use (PEOU) is positively related to Perceived Usefulness (PU).

H3a: Smartphone Self-efficacy (SSE) is positively related to Perceived Ease of Use (PEOU).
H3b: Perception of External Control (PEC) is positively related to Perceived Ease of Use (PEOU).
H3c: Smartphone Anxiety (SA) is positively related to Perceived Ease of Use (PEOU).
H3d: Smartphone Playfulness (SPLAY) is positively related to Perceived Ease of Use (PEOU).

Adjustments to the Technology Acceptance Model: inclusion of trust

Trust is an important factor in citizen science projects and was therefore introduced. Six hypotheses were formulated based on four new constructs and the model was complemented with the constructs *Reputation*, *Trust in Mobile Communications* and *Satisfaction of Past Interactions*. See Figure 8.3 for the final model.

Trust was added as a construct that relates to *Behavioural Intention* (BI), as well to *Perceived Usefulness* (PU) and *Perceived Ease of Use* (PEOU). Rotman et al. (2012) stress the importance of trust in citizen science projects, especially in a situation where there is a power relation between the collaborating parties. Such power relations are particularly present in water quality monitoring as water authorities are not only experts, but also have a status equal to local governments. In MCS water authorities have access to potentially privacy sensitive information, especially when citizen scientists information is coupled to the database of the water authority. Citizens need to trust water authorities have taken measures to deal with their data responsibly and prevent violation of privacy (He et al. 2015), because mistrust in the intentions of the initiating party might be a barrier in participation (Gharesifard & Wehn 2015, unpublished). It is assumed that the trust an individual has in the initiating party will influence his or her intention to participate. Question items used for the construct *Trust* are based on Carter & Belanger (2005) and can be found in Appendix G.

H4a: Trust (TRU) is positively related to Perceived Usefulness (PU).
H4b: Trust (TRU) is positively related to Behavioural Intention (BI).
H4c: Trust (TRU) is positively related to Perceived Ease of Use (PEOU).

The degree to which one trusts others is directly related to the *Reputation* of the initiating party (Pavlou 2003). It was assumed that there is a positive influence of reputation on trust. Second it was assumed that *Past Interactions* of an individual with an organisation would influence the degree of trust in that organisation. Question items used for this construct are based on Pavlou (2003) and Carter & Belanger (20015) and can be found in Appendix A. Finally, trust does not only play a role in the sense that users should be able to trust the party that offers MCS, but also in trusting the use of mobile internet via the mobile technology (Carter & Belanger 2005). Smartphones use the mobile Internet network. It was therefore hypothesised that *Trust in Mobile Communications* (TMC) would positively contribute to trust in the project as well. Trust in using the mobile service of an MCS application is defined as "a user's believe or faith in the degree to which a specific service can be regarded to have no security and privacy threats." (Gao et al. 2014).

H5a: Trust in Mobile Communications (TMC) is positively related to Trust (TRU).
H5b: Reputation (REP) is positively related to Trust (TRU).
H5c: Satisfaction of Past Interactions (SPI) is positively related to Trust (TRU).

Reframing the questions
The number of items was reduced, because a long survey may demotivate people to finish it. Constructs of the adjusted Technology Acceptance Model 3 (TAM3) are challenging to measure directly and are therefore measured via multiple, associated topics. Multiple items are used to check for internal consistency. For example *Perceived Usefulness* is measured using items that measure the perception that the system improves job performance, productivity and effectiveness when using the technology under review. Again a trade-off with feasibility had to be made, as a maximum of 20 minutes to complete the questionnaire was assumed. The questionnaire became too lengthy, as the model hosted 15 constructs with three to four items per construct and because it was combined with the survey as described in the previous chapter. A minimum of two items per construct was remained though to allow for internal consistency assessment. See the appendix for an overview of the constructs, the items and their sources.

Pretesting the questionnaire
The questionnaire was pre-tested, because the questions used to assess the proposed model were modified as described above and translated to Dutch. Two small scale evaluations were done, as it was not feasible to do a full pilot to validate the item questions.

First the nature of the questions was discussed in a group of 28 bachelor students in Civil Engineering, following an elective course on research methodologies. The two main points of criticism focussed on the stiff and old-fashioned formulation of the questions and the perceived duplication of questions. This demotivated the students to finish the questionnaire, thus adjustments were made. Adjustments were made in the framing of the questions, but no items were omitted, as the number of items per construct was reduced already compared to the original Technology Acceptance Model 3 (TAM3).

Second, a group of sixteen acquaintances was recruited via social media to assess the clarity, ability to enthuse and readability of the introductory texts used in the survey and the manual presented. The layout of the manual was evaluated as well, to prevent obnoxious illustrations to cause a negative bias of respondents. The texts and manual were evaluated moderately to good and changes were at the level of formulation and spelling and based on suggestions of the respondents.

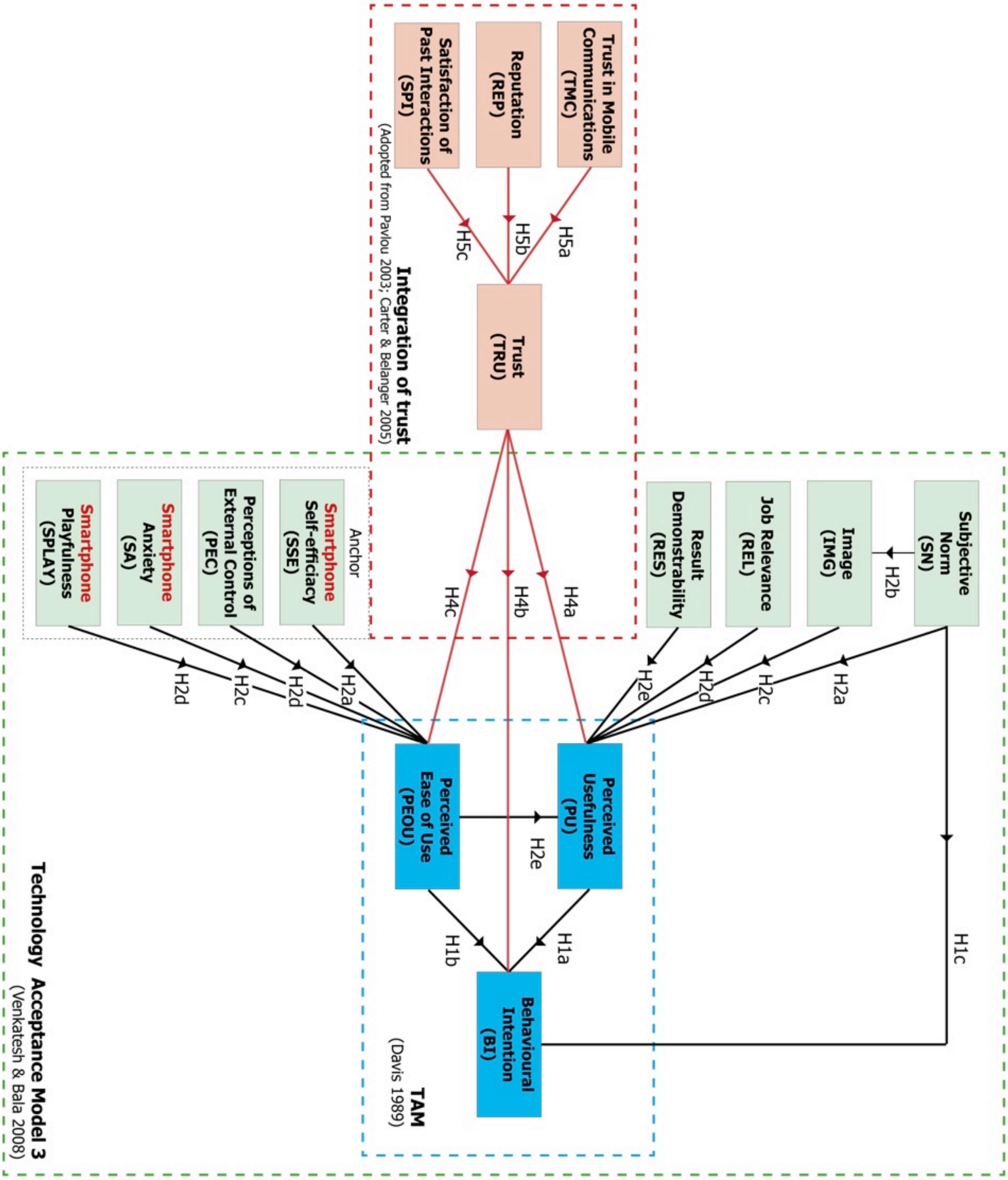


Figure 8.3 – The proposed model for technology acceptance. The blue represents the original Technology Acceptance Model (Davis et al. 1989), the green area the (adjusted) TAM3 and the red area shows the added constructs in this thesis (Pavlou 2003; Carter & Belanger 2005).

Table 8.1 – Constructs used in the adjusted Technology Acceptance Model. Excluded constructs are included as well. Definitions are adopted from Venkatesh & Bala (2008), unless stated otherwise.

Constructs	Definition
	INCLUDED CONSTRUCTS
Behavioural Intention	The degree to which an individual has the intention to use an IT.
Perceived Usefulness	"The extent to which a person believes that using an IT will enhance his or her job performance."
Subjective Norm	"The degree to which an individual perceives that most people who are important to him think he should or should not use the system."
Image	"The degree to which an individual perceives that the use of an innovation will enhance his or her status in his or her social system."
Job Relevance	"The degree to which an individual believes the target system is applicable to his or her job."
Result Demonstrability	"The degree to which an individual believes that the results of using a system are tangible, observable and communicable."
Perceived Ease of Use	"The degree to which a person believes that using an IT will be free of effort."
Smartphone Self-Efficacy	"The degree to which an individual believes that he or she has the ability to perform a specific task/job using the *smartphone*." [computer has been replaced by smartphone]
Perceptions of External Control	"The degree to which an individual believes that organizational and technical resources exist to support the use of the system."
Smartphone Anxiety	"The degree of an individual's apprehension, or even fear, when he/she is faced with the possibility of using *smartphones*." [computer has been replaced by smartphone]
	ADDED CONSTRUCTS
Trust	The degree to which a person believes that "a specific service can be regarded to have no security and privacy threats." (Gao et al. 2014).
Trust in *Mobile* Communications	The user's beliefs or faith in the degree to which a specific service can be regarded to have no security and privacy threats. (Gao et al. 2011)
Reputation	The degree to which an individual believes that the party offering the IT service has a good reputation. (freely adopted from Pavlou 2003)
Satisfaction of Past Interactions	The degree to which an individual has positive associations with past interactions with the party offering the IT service. (freely adopted from Pavlou 2003)
	EXCLUDED CONSTRUCTS
Output Quality	"The degree to which an individual believes that the system performs his or her job well."
Perceived Enjoyment	"The degree to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use."
Objective Usability	"A comparison of systems based on the actual level (rather than perceptions) of effort required to completing specific tasks."
Use	The actual use of the system, expressed in time used per time unit.

8.1.3 Data acquisition

The questions of the adjusted Technology Acceptance Model (TAM) were incorporated in a survey that also inquired about perceived motivations and barriers to participate in citizen science. A description of the survey built-up can be found in Chapter 3 (Methodology) and characteristics of the respondents can be found in the previous chapter. In short 60 respondents completed the full questionnaire. The constructs *Smartphone Anxiety*, *Smartphone Playfulness*, *Trust in Mobile Communications*, *Satisfaction of Past Interactions* and *Reputation* (in order of appearance) were inquired in the first part of the survey (see Figure 8.4) and the remainder of the constructs in part II. The questions could be spread, because the mentioned constructs are independent of the technology under review. This spreading was beneficial, since it allowed a more balanced mix between text and question sections.

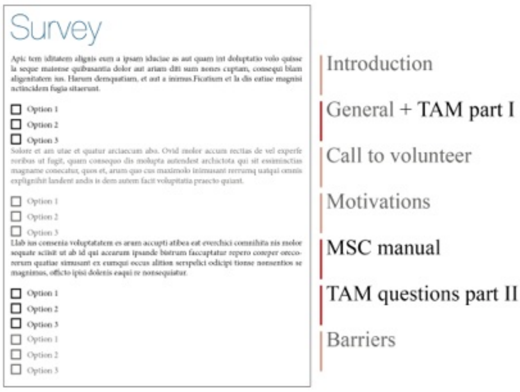


Figure 8.4 – Overview of the incorporation of the TAM questions in the survey.

8.1.4 Method of analysis of the Technology Acceptance Model

An adjusted Technology Acceptance Model (TAM) was proposed and a survey was used to collect the required input data. The model's performance and the hypotheses were tested using Partial Least Squares Structural Equation Modelling (PLS-SEM). Software package Smart-PLS (version 3.2.1) is used to assess the structural equation model and the evaluation stages of Sarstedt et al. (2014) are followed to assess the PLS-SEM results.

Choice of Partial Least Squares Structural Equations Modelling

Structural Equations Modelling (SEM) can be used to assess models like the Technology Acceptance Model. SEM is a second-generation multivariate method, in contrast to for example exploratory factor analysis or multiple regression, which are first generation multivariate methods. SEM can incorporate un-observable variables, which are measured by indicator variables, and it can either be exploratory or confirmatory in nature. The model used (TAM3) is rather complex and the study purpose is of an exploratory nature, with identifying key driver constructs as a major goal. Partial Least Squares Structural Equation Modelling (PLS-SEM) method is therefore preferred above a Co-variance SEM (CB-SEM) (Hair et al. 2013), which corresponds to the method chosen by previous authors (e.g. Venkatesh & Bala 2003; Venkatesh & Bala 2008).

PLS-SEM has three advantages when it comes to analysing the data and model under review. First, it is a variance based approach that is mainly used to develop theories and focuses on explaining variance in the dependent variables when examining the model. Second, PLS-SEM has proven to reach a high statistical power levels for models with complex structures and small sample sizes. (Hair et al. 2013) A high statistical power means the method has a high likelihood of detecting an effect if there is any, with lower probabilities for false negatives. Third, PLS is based on Ordinary Least Squares (OLS) regressions, which means it is suitable for non-normalised datasets with minimised error terms and maximised R^2-values (Hair et al. 2013).

Smart PLS
The model is created in software package Smart-PLS using reflective measurements only and running it with a path-weighing algorithm. Reflective measurements are used in the model, since constructs cause the co-variation of items and no causal relationships are identified between items and constructs (Hair et al. 2013). A path-weighing algorithm is the standard running procedure. Path weighing yields well-predicted variable scores, which maximises the R^2-values, and can be applied to all kinds of PLS modelling, including PLS-SEM (Sarstedt et al. 2014).

SmartPLS was preferred above other packages such as LVPLS, PLS-GUI, VisualPLS, PLS-Graph and PSAD0-PLS for two reasons: it is platform independent and it is highly user friendly (Temme et al. 2006). The data collected in the survey is ordinal in nature. PLS usually works with metric data, although ordinal data can be used as well (Henseler et al. 2012).

1.1.1. Results: evaluation stages of the model assessment

The model has to be assessed on validity and reliability after the data is loaded into SmartPLS. To structure this evaluation the evaluation criteria as described by Sarstedt et al. (2014) were followed (see Figure 8.5). All constructs are modelled reflective, which means the evaluation criteria for formative models were omitted from the assessment.

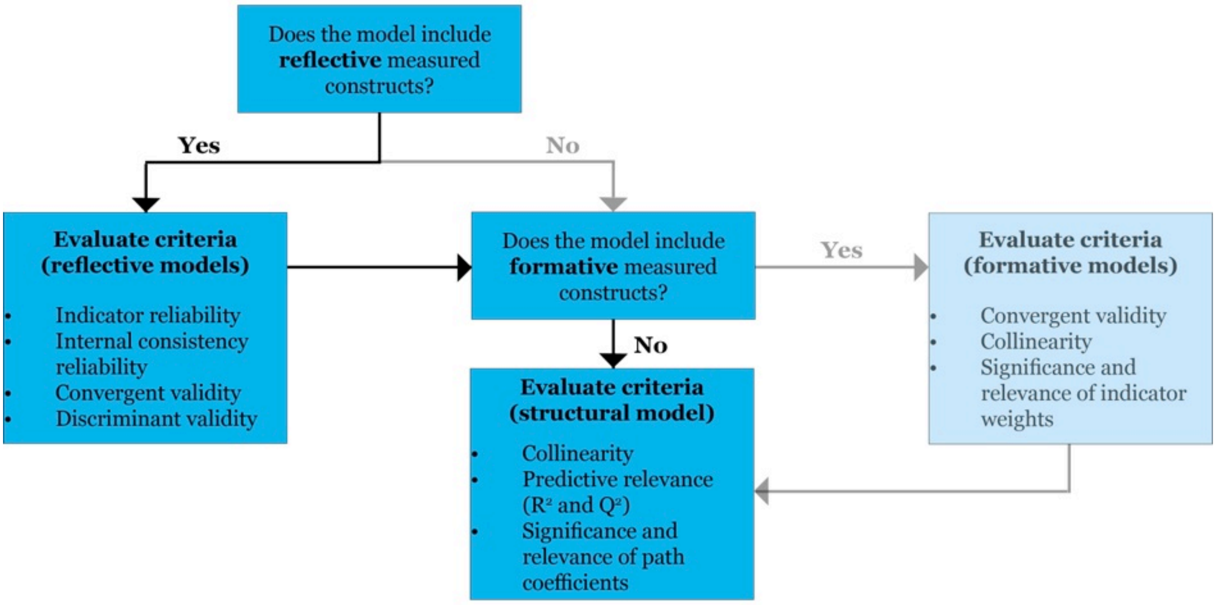


Figure 8.5 – PLS-SEM evaluation stages, the evaluation criteria for the reflective and structural model are incorporated in the assessment (adopted from Sarstedt et al. 2014)

8.2 Results of smartphone acceptance

In the previous section the theoretical framework of an adapted Technology Acceptance Model (TAM) was presented. Methods for data collection and data analysis were discussed as well. In this section the assessment of the model quality is assessed for both the reflective measurement model and the structural model.

8.2.1 Stage 1 analysis: reflective measurement model assessment

The reflective measurement model is assessed first, following the evaluation steps as described by Sarstedt et al. (2014). The convergent validity, internal consistency reliability, convergent validity and discriminant validity are discussed in the following paragraphs.

Step 1.1: convergent validity
The dataset was assessed on convergent validity by calculating the correlation between each individual construct and its global measure. Following Venkatesh & Bala (2008) item loadings above

0.70 were accepted, which means the construct explains over 50% of the variance of the indicator (Sarstedt et al. 2014).
Several items had an item loading below 0.70. After an assessment of potential explanations IMG3, IMG4, IMG5 were excluded, since they were added constructs that apparently measure something else than IMG1 and IMG2. Items PEC4, REL3 and RES4 were excluded, since there was reason to maintain them. TRU2 were moved to Reputation, since it rather describes reputation than trust in the Dutch translation. TMC1 was remained, because the value is just below 0.70 and to maintain multiple items for TMC. The new loadings are displayed and as can be seen in Table 8.2 all loadings (except TMC1) are above 0.70.

Step 1.2: internal consistency reliability
Composite reliability (ρ_c) is higher if values increase. Cronbach's alpha measures more or less the same. Values below 0.60 imply unreliable responses, while values from 0.60 to 0.70 and are considered 'acceptable in exploratory research'. A value above 0.70 indicates that there internal consistency. SSE and TMC provide a poor internal consistency and are excluded.

Step 1.3: convergent validity
Average Variance Extracted (AVE), should be over 0.50: 50% of indicator variance explained by the construct. AVE is above 0.50 for all constructs.

Step 1.4: Discriminant validity
Construct indicators should have a higher loading on its own construct than other indicators have on this construct (Fornell & Larcker criterion). A less strict criterion would be to assess cross loadings. If a construct's indicators have a higher correlation to that construct than other indicators, the construct will exhibit discriminant validity (Sarstedt et al. 2014). All constructs meet both criteria and thus discriminant validity is positively assessed.

8.2.2 Stage 2 analysis: structural model assessment

The measurement model (stage 1) was assessed in the previous section and is considered acceptable after removing items where convergent validity was rejected. The structural model assessment is the next step, as there are no formative measurements in the model.

PLS-SEM has no goodness-of-fit parameter to assess the predictive capacity of the proposed model, in contrast to CB-SEM (Hair et al. 2013). The 'goodness-of'-fit' for PLS-SEM is based on its capability to predict the endogenous constructs. Four assessments steps are made: R^2, Q^2, path coefficients of the regression analysis and prior to this a collinearity check.

Step 2.1: collinearity
The inner model is considered. Construct Variance Inflation Factor (VIF) are calculated. VIFs above 5.0 indicate there is collinearity and may be problematic, values above 10 are considered problematic in general (Sarstedt et al. 2014). Three VIF values are above 5.0, but none of them is considered problematic.

Step 2.2: Model prediction's accuracy, coefficient determination (R^2)
R^2 is the measure of the variance explained and is therefore a measure of the predictive accuracy of the model (Sarstedt et al. 2014). R^2 above 0.75 are considered strong, above 0.50 moderate and above 0.25 weak. As can be seen in Table 8.5 R^2 coefficients are strong for PEOU and PU. For BI it is moderate, while TRU and IMG are fairly poor. The predictive capacity for these two construct is low.

Step 2.3: Model prediction's relevance, cross-validated redundancy (Q^2)
The model predictive relevance is measured using Q^2, whose value should be above zero. This is the case for all constructs. Alternatively the standardized root means square residual (SRMR) could be used, which would require a value of the composite model below 0.10. In this model the SRMR is 0.069 and thus sufficient.

Table 8.2 - Item loadings for PLS (N=60) after changes were made.

Construct	Item	Loading	Construct	Item	Loading
Behavioural Intention (BI)	BI1	0,983	Result Demonstrability (RES)	RES2	0,926
	BI2	0,986		RES3 (R)	0,94
	BI3	0,966		RES4	-
Image (IMG)	IMG1	0,92	Smartphone Anxiety (SA)	SA1 (R)	0,902
	IMG2	0,931		SA3	0,887
	IMG3	-		SA4	0,877
	IMG4	-	Subjective Norm (SN)	SN1	0,919
	IMG5	-		SN2	0,946
Perceived External Control (PEC)	PEC1		Satisfaction of Past Interactions (SPI)	SPI1	0,939
	PEC2			SPI2	0,97
	PEC3 (R)	0,114	Smartphone Playfulness (SPLAY)	SPLAY1-1	0,907
Perceived Ease of Use (PEOU)	PEOU1	0,990		SPLAY1-2	0,908
	PEOU2	0,988		SPLAY1-3	0,925
	PEOU3	0,986		SPLAY2	0,823
Perceived Usefulness (PU)	PU1	0,872	Smartphone Self-Efficacy (SSE)	SSE1	-
	PU2	0,788		SSE2	0,799
	PU3	0,932		SSE3	-
Relative advantage (REL)	REL1	0,965		SSE4	0,804
	REL2	0,926	Trust in Mobile Communications (TMC)	TMC1	1,000
	REL3 (R)	-		TMC2	-
Reputation (REP)	REP1	0,931	Trust (TRU)	REP1	0,931
	REP2(R)	0,721		TRU3	0,721
	REP3	0,943		TRUS5	0,943

Table 8.3 – Overview of the constructs' Composite Reliability and Cronbach's alpha, Average Variance Extracted (AVE) and an assessment for discriminant validity via cross loadings and the Fornell & Larcker criterion.

Construct	Composite reliability (ρ_c)	Cronbach's alpha	AVE	Cross loadings	Fornell & Larcker
BI	0.985	0.978	0.958	Yes	Yes
IMG	0.889	0.758	0.801	Yes	Yes
REL	0.963	0.923	0.929	Yes	Yes
PEOU	0.992	0.988	0.976	Yes	Yes
PU	0.899	0.833	0.750	Yes	Yes
PEC	0.968	0.934	0.937	Yes	Yes
REP	0.903	0.860	0.759	Yes	Yes
RES	0.931	0.851	0.870	Yes	Yes
SPI	0.954	0.905	0.910	Yes	Yes
SA	0.919	0.867	0.790	Yes	Yes
SPLAY	0.939	0.913	0.795	Yes	Yes
~~SSE~~	~~0.782~~	~~0.444~~	~~0.643~~	~~Yes~~	~~Yes~~
SN	0.930	0.852	0.870	Yes	Yes
TRU	0.963	0.922	0.928	Yes	Yes
TMC	1,000	1,000	1.000	Yes	Yes

Step 2.4: path coefficients
The strength and level of significance of the paths is important. Coefficients close to +1 or -1 represent are indicators of respectively strong positive and strong negative relations. Paths are considered significant when the relation is significant with p<0.10. The output of the bootstrapping with 5000 iterations is presented in Figure 8.6 and includes path strengths, the accompanying standard error and the statistical T and p values. Five significant paths are identified that have moderate to convincing positive relations.

Five significant relations are found and the final model is presented in Figure 8.6. Drivers *Job Relevance* and *Result Demonstrability* have a moderately strong positive relation to *Perceive Usefulness*, which is highly significant for the first construct as well. *Perceived Usefulness* has a strong, highly significant relation to *Behavioural Intention. Perceived Ease of* Use has a moderately strong positive relation to *Perceived Usefulness*, but its relation to *Behavioural intention* could not be confirmed. The relation between *Satisfaction of Past Interactions* and *Trust* could not be incorporated in the final model though, as *Trust* does not relate directly to one of the other constructs in the final model.

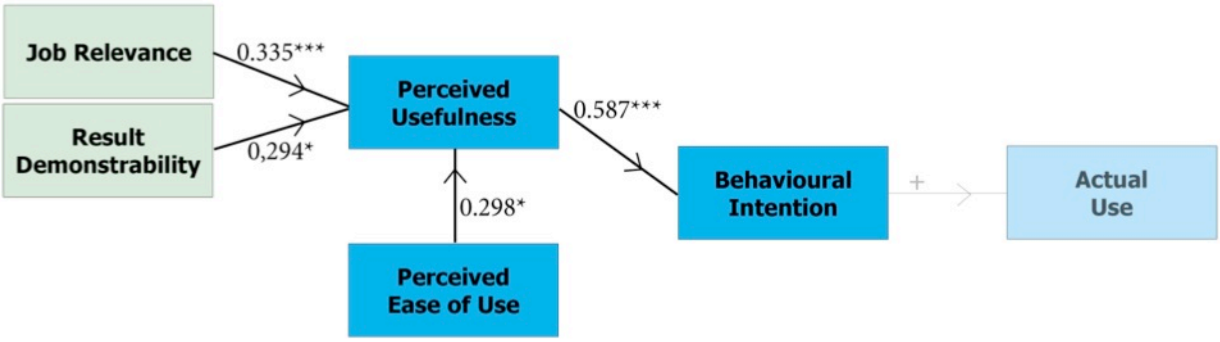


Figure 8.6 – Final model with the significant paths. The relation between BI and USE is faded, as it is an assumed relation that was not tested in the model. *** p< 0.01 ** p<0.05 *p < 0.1

8.3 Chapter summary: a Technology Acceptance Model

This chapter provides the results that help answering the question what drivers influence citizens' intention to use a mobile crowd sensing application (MCS). An adapted version of the Technology Acceptance Model 3 (TAM3) was formulated and used as theoretical framework to assess citizen's intention to use a hypothetical MCS application. The measurement and structural model were evaluated in the previous sections and five significant paths were found. *Job Relevance*, *Result Demonstrability* and *Perceived Ease of Use* are positive predictors of *Perceived Usefulness*, while *Perceived Usefulness* itself is a strong positive predictor of *Behavioural Intention.*

Table 8.4 –Variance Inflation Factors (VIFs) of the inner model. Values between 5.0 and 10.0 are potentially problematic, but not necessarily.

Construct	BI	PU	PEOU	TRU	IMG
PU	4.400				
PEOU	3.448	6,493			
TRU	2.349	2,551	1.787		
SN	1.182	1.322			1.000
RES		6.798			
REL		2.643			
IMG		1.173			
SPI				1.986	
REP				1.892	
TMC				1.122	
BI					
PEC			4.560		
SA			6.704		
SPLAY			3.894		
SSE			1.650		

Table 8.5 – R^2 values

Construct	R^2
BI	0.572
IMG	0.037
PEOU	0.642
PU	0.838
TRU	0.134

Table 8.6 – Path coefficients for the adapted Technology Acceptance Model (TAM). Significant paths (p<0.10) are in the top five rows of the table, indicated with a dashed line.

Path	Strength	Std. error	T-statistics	p-value
REL → PU	.342	.114	3.038	.002
PU → BI	.583	.207	2.785	.005
SPI → TRU	.395	.166	2.378	.017
RES → PU	.292	.150	1.933	.053
PEOU → PU	.293	.163	1.778	.076
SSE → PEOU	.199	.129	1.518	.129
PEOU → BI	.237	.159	1.505	.132
TRU → PEOU	.311	.225	1.382	.167
SN → IMG	.194	.146	1.318	.187
TRU → PU	.132	.102	1.279	.201
PEC → PEOU	.214	.168	1.275	.202
SN → PUOU	-.063	.059	1.106	.269
SA → PEOU	-.156	.174	.909	.364
IMG → PU	.098	.112	.847	.397
SPLAY → PEOU	.030	.047	.639	.523
TRU → BI	-.057	.099	.510	.610
REP → TRU	-.049	.115	.485	.628
TMC → TRU	.020	.089	.231	.817
SN → BI	-.004	.062	.065	.948

Chapter 9
Conclusion and discussion of Part II

The previous two chapters presented the results of technology acceptance in the form of a technology acceptance model. Before significant differences were revealed in terms of motivations and barriers between participants with a high and low intention to participate.
For both the chapter concerning motivations and barriers and the chapter concerning the Technology Acceptance Model it must be noted that the survey was issued in name of nature manager and not by a water authority. The desired target audience (people that are interested in their environment) could only be accessed via this nature manager. A water authority was mentioned as partner in the hypothetical project, to make the link to water authorities. However, this does imply that the results may be different if a water authority was used, because of differences in context and in audience reached (different people being reached via different channels).

9.1 Conclusion of Part II

In this part of the thesis motivational factors and barriers that citizens perceive were investigated. Additionally drivers were identified for the acceptance of a smartphone application to aid water quality monitoring.

9.1.1 Conclusions regarding citizen motivations and barriers to participate

In Chapter 7 motivations and barriers were identified that influence citizen intention to participate in citizen science or mobile crowd sensing (MCS). A theoretical framework was composed following the Self-Determination Theory (Ryan & Deci 2000), based on motivational factors and barriers identified in literature.

The citizen motivation and barriers model contains motivations that were found in literature on various types of citizen science. Context and project define what motivations are important, although there is overlap to a large extent. In the survey a citizen science project in water quality monitoring was introduced to assess what motivations are important to Dutch citizens when it concerns water quality monitoring. This will be administered in the survey part. It was further discovered that different motivations play a role at different periods of the project.

The most important motivational factors to participate in citizen science in general are to contribute to conservation (97%), to help others (86%), to contribute to science (84%), to discover new things (83%) and to learn new things (81%). Least important are improve one's reputation (7%) financial compensation (9%) and increase the chance of a job via participation (10%). This study confirmed literature findings that extrinsic, external regulated motivational factors are less important than intrinsic and fully internal regulated motivations. Insight is given into the difference between non-participants and participants and between higher and lower educated people. Respondents with a lower educational level or with a lower intention to participate value externally regulated motivations, such as financial compensation, more often than respondents with a high intention to participate or with a higher educational level.

The functions of the introduced MCS application are appreciated, although a lack of smartphone experience discourages the intention to use the application. Fun (70%) was mentioned as the most important driver to participate in the MCS project.

In particular middle-aged and higher educated people responded and these people are more likely to participate on average. This project is likely to attract mainly higher educated respondents as they feel responsible to do so and as their hobbies match the project nature. Time is mentioned as the most important barrier (45%), but the influence of this barrier decreases with age, suggesting that the younger generations do not have the time to participate in MCS.

To attract a different target audience than the higher educated middle aged person, designers of citizen science projects should pay attention to what they would value in citizen science.

9.1.2 Conclusions regarding Technology acceptance

In Chapter 8 a Technology Acceptance Model (TAM) was used to identify drivers for the intention to use the application. This study had three objectives namely 1) to explore whether an adjusted TAM3 could be used for an hypothetical technology as well, 2) to assess the influence of trust on *Behavioural Intention*, *Perceived Usefulness* and *Perceived Ease of Use* and 3) to link the identified drivers to possible interventions to enhance the intention to use the application.

Objective 1: application of TAM3 to a hypothetical technology
The initial goal was to test whether TAM3 could be used as a predictor for behavioural intention. The final Technology Acceptance Model explains a good amount of variance (57.2%) in the behavioural intention of respondents to use the presented smartphone application for citizen science activities in water quality monitoring. The measurement (outer) model was successfully evaluated no indicator and internal consistency reliability and convergent and discriminant validity. In the structural (inner) model significant path coefficients were found and the predictive relevance of the model is evaluated as good. Hypotheses, 1a, 1c, 2c and 2d could be accepted based on the results, providing insufficient backing of TAM3.

H1a: Perceived Usefulness (PU) is positively related to Behavioural Intention (BI).	**Accepted**
H1b: Perceived Ease of Use (PEOU) is positively related to Behavioural Intention (BI).	Rejected
H1c: Perceived Ease of Use (PEOU) is positively related to Perceived Usefulness (PU).	**Accepted**
H2a: Subjective Norm (SN) is positively related to Perceived Usefulness (PU).	Rejected
H2b: Subjective Norm (SN) is positively related to Image (IMG).	Rejected
H2c: Job Relevance (REL) is positively related to Perceived Usefulness (PU).	**Accepted**
H2d: Result Demonstrability (RES) is positively related to Perceived Usefulness (PU).	**Accepted**
H3a: Smartphone Self-efficacy (SSE) is positively related to Perceived Ease of Use (PEOU).	Rejected
H3b: Perception of External Control (PEC) is positively related to Perceived Ease of Use (PEOU).	Rejected
H3c: Smartphone Anxiety (SA) is positively related to Perceived Ease of Use (PEOU).	Rejected
H3d: Smartphone Playfulness (SPLAY) is positively related to Perceived Ease of Use (PEOU).	Rejected

The first objective of this study was to identify whether the Technology Acceptance Model 3 (TAM3) could be applied to a mock-up mobile crowd sensing application. The original TAM (H1a, H1b, H1c) is more or less confirmed, as only hypothesis 1b had to be rejected. The hypotheses concerning constructs that support *Perceived Usefulness* (PU) are rejected in case of *Subjective Norm* and accepted in case of *Job Relevance* and *Result Demonstrability*. The hypotheses regarding constructs that determine *Perceived Ease of Use* (PEOU) are all rejected. It was therefore concluded that the TAM can was successfully applied to the case, but that TAM3 is an insufficient predictor for *Perceived Ease of Use*. The remaining model describes a healthy 57.2% of the variance in *Behavioural Intention* and is therewith a good predictor for *Behavioural Intention* in this case.

Objective 2: Trust as a driver
The second goal was to test the hypothesis that *Trust* is an important predictor for *Behavioural Intention* and *Perceived Usefulness* and *Perceived Ease of Use.* There were no significant relations found between *Trust* and the mentioned constructs, thus H41, H4b and H4c had to be rejected. There were strong and significant indirect effects of *Trust* on *Behavioural Intention* though. *Satisfaction of Past Interactions* was identified as driver for Trust as hypothesis 5c was accepted.

H4a: Trust (TRU) is positively related to Behavioural Intention (BI).	Rejected
H4b: Trust (TRU) is positively related to Perceived Usefulness (PU).	Rejected
H4c: Trust (TRU) is positively related to Perceived Ease of Use (PEOU).	Rejected
H5a: Trust in Mobile Communications (TMC) is positively related to Trust (TRU).	Rejected
H5b: Reputation (REP) is positively related to Trust (TRU).	Rejected
H5c: Satisfaction of Past Interactions (SPI) is positively related to Trust (TRU).	**Accepted**

As a conclusion *Trust* cannot be confirmed to be a driver for the intention to use the smartphone application.

Goal 3: interventions
The third goal of this part was to identify possible pre-implementation interventions. Interventions in user participation, management support and incentive alignment are preferred above changing design characteristics. Additionally post-implementation interventions, such as management support, peer support and training might enhance Subjective Norm, Image, Smartphone Self-Efficacy, Smartphone Playfulness and Perceptions of External Control and reduce Smartphone Anxiety.

Table 9.1 – Summary of Interventions (adopted from Venkatesh & Bala 2008).

	Pre-implementation Interventions				Post-implementation Interventions		
	Design Characteristics	User Participation	Management Support	Incentive Alignment	Training	Organisational Support	Peer Support
Perceived Usefulness							
Subjective Norm		X	X	X			X
Image			X	X			X
Job Relevance	X	X	X	X	X	X	X
Output Quality	X	X	X	X	X	X	X
Result Demonstrability	X	X	X	X	X	X	X
Perceived Ease of Use							
Smartphone Self-Efficacy					X		
Perceptions of External Control		X	X			X	X
Smartphone Anxiety		X			X	X	
Smartphone Playfulness		X			X		
Perceived Enjoyment	X	X		X	X		X
Objective Usability	X	X			X		

9.2 Discussion of Part II

In this discussion section the survey will be discussed. Regarding the model outcomes the significant relationships and possible interventions are discussed. The assessment discussion focuses on criteria that were met with the narrowest margins and addresses potential causes and consequences. In the discussion I may switch to active voice, particularly when I discuss my beliefs or behaviour.

9.2.1 Discussing and interpreting the motivation and barriers of citizens

A framework of motivations was developed and using a survey these were quantitatively assessed. For several motivational factors a significant difference was found. The sample size of the survey on motivational factors was small though (70), thus it will not be possible to make any statements or generalise the findings. However, the results are an interesting confirmation of previous studies that suggest that non-participants are driven by different motivational factors and barriers (Gharesifard & When 2015). An important difference with the study by Gharesifard & Wehn (2015) is that their study involved participants and non-participants, while the distinction in this study is based on intentions. There is a strong positive correlation between intention and actual behaviour (e.g. Davis 1989), but it is not a causal one-to-one relation.

There is a threefold bias in participants identified. First, the average participant in this study is middle aged and higher educated. These respondents are no fair representation of the population in this region (Zuid-Holland) and the Netherlands as a whole. Unfortunately there are no statistics available about the members of the newsletter, thus is not possible to say whether this is caused by a bias in the study population (i.e. the members of the newsletter) or a bias in who filled out the questionnaire. The respondents match volunteer profiles sketched in literature (e.g. Edwards 2014),. Higher educated, native, middle aged men living in a rural environment are earlier identified as a 'high potential' target audience for water quality monitoring (Overdevest et al. 2004). This suggests that this bias is a general problem rather than a case-specific issue

Second, it is conceivable that people who filled out the survey already had a strong affinity with natural resource management. The survey was spread via nature manager Zuid-Hollands Landschap and this poses an additional bias on the study sample.

Third, there are significant differences identified between citizens with a low and high intention to participate. The difference is lower than expected. This could be caused by a bias in respondents, caused by the non-committal method of data collection. Participants could drop out any time and it is very well possible that the people with no interest did not finish the survey. On top of this the low intention of respondents may be caused by constraints, such as lack of time, rather than a lack of interest. This is supported by the results for lack of time and physical inability, these were perceived as barriers by a majority of people with a low intention. This suggests that indeed all participants like the project, but people with a low participation intention experience limitations to participate. It supports the expectation that people only completed the survey when they have a positive attitude towards participation. It must be stated thought that, as far as I am aware, this is one of the few studies that captures the motivations of people with a low intention to participate.

9.2.2 Discussing and interpreting the Technology Acceptance Model

A majority of the original Technology Acceptance Model 3 (TAM3) proved to be not applicable on this case. However, the model has a relatively high R^2 and can describe 57.2% of the variance in Behavioural Intention.

The original TAM was found to be applicable in this study as well, even though there was no significant relationship found between *Perceived Ease of Use* and *Behavioural Intention* (0.298; p=0.073). The relationship between *Perceived Usefulness* and *Behavioural Intention* is significant at p<0.01 and the relation found is strong (0.587). In the early versions of TAM, Davis (1989) already described that the relationship between usefulness and use is relatively strong when compared to ease of use and use. This is an indication of a preference of users that the IT in question should be useful and that users are willing to overcome challenges in ease of use (Davis 1989). It is suggested that *Perceived Ease of Use* may play a more substantial role in early stages of technology acceptance and that its effect on behavioural intention diminishes over time (Venkatesh & Bala 2008). Although the respondents in this study were not experienced in using this application, 55 out of 60 poses a smartphone and/or tablet and 48 participants have experience with applications. This was reflected in *Smartphone Self-Efficacy*, where only five participants reported low self efficacy (i.e. ranked all SSE items below 4). Therefore the study sample can be considered rather experienced using applications. The features of the application in question are registration, taking pictures and entering values and are not considered to be complex or unusual, which may explain why the results of *Ease of Use* match that of an experienced sample.

The focus on suitability for the task is strengthened further by the constructs contributing to usefulness. The significant, positive paths of job relevance and result demonstrability suggest that participants value task-related constructs of PU, while there is no influence of social factors such as subjective norm and image. None of the constructs had a significant relation to Perceived Ease of Use.

It can be doubted whether TAM is the appropriate model for this phase of design process. The TAM is usually applied in a work environment where people are confronted with a functional technology, although this could be in a prototype phase as well. The core of the model, the original TAM, was confirmed, but the drivers for which TAM3 was chosen were hardly confirmed. This may have been caused by the fact that respondents were confronted with a paper model, causing them to struggle with emphasizing the situation. Design methods, such as user tests, may be more appropriate.

9.2.3 Discussing the Technology Acceptance Model assessment

The model structure of the Technology Acceptance Model (TAM) was assessed. Most constructs revealed a strong internal consistency. Several constructs have an internal consistency (Composite Reliability) above 0.95. Such high values are more suspicious than values between 0.70 and 0.95 (Staub et al. 2004), because it may indicate that participants did not answer each item as a different one, but rather repeated their answer of the previous item.

Job Relevance has a composite reliability above 0.95, caused by a translation error. The questionnaire was in Dutch, as it is the mother tongue of participants and no evidence was in general did not affect the results, with one exception. In the pre-test bachelor students indicated that they found the items "Using this application is relevant" synonym to "Using this application is important". During the pre-test bachelor students indicated that there were many questions alike and respondents complaint about 'repeated questions'. During the discussion they acknowledged that something that is relevant does not need to be important, but also admitted that they did not think of it while filling out the questionnaire. The meaning of this remark was overlooked and the original translated item was maintained. The dictionary designates 'important' is a synonym of 'relevant' in Dutch, while it is not in English. Therefore respondents seemingly considered both items identical. It would have been more appropriate to choose "toepasselijk" as translation of relevant.

Behavioural Intention could be explained by a similar meaning of questions. Questions BI1 ("I have the intention to download this application") and BI1 ("I have the intention to use this application to collect data") correlated with a value above 0.950 and are considered 'too good to be true' (Sarstedt 2014). The relation between downloading the application and using it may be more apparent than expected. A sensible explanation is lacking for the other constructs with suspicious internal consistency.

A disadvantage of the model set up is that there are few indicators available for some latent variables, which is likely to increase PLS bias (Henseler et al. 2013). A larger number of indicators on the other hand may increase error term correlations (Henseler et al. 2013). Indirect effects were found of Trust (being trust in the organisation that initiates the citizen science), Job Relevance and Result Demonstrability on Behavioural Intention.

PLS-SEM assumes a homogeneous set of respondents, while this is often not the case in practice (Sarstedt et al. 2014). FIMIX (finite mixture) segmentation was applied and two segments were found. This indicates that the sample shows heterogeneity and in fact consists of two groups. 41 people are in segment 1, with an R^2 of 0.914, while 19 people form segment 2 with R^2 being 0.471. A preliminary analysis was performed, but it could not be distinguished what differentiated the two segments. In a next research step the characteristics and implications of these segments need to be studied.

Finally, it cannot be ruled out that the excluded constructs Output Quality, Result Demonstrability, Perceived Enjoyment and Objective Usability will have an influence as well on the acceptance of such an application. Since this was not tested in this study, it will be recommended to repeat this study with an application. The proposed model shall be tested before the application is used, shortly after respondents start using the application and after a period of using. The final model should be extended with the excluded constructs. More case studies in different contexts using different applications will be essential to be able to generalise conclusions about the hypotheses and the TAM3 model.

9.2.4 Generalizability of Part II

The study took place in a very specific case study. The sample size was small, consisted primarily of elderly, higher educated people and geographic distribution was limited. There was one organisation introduced as organising party of citizen science and topics of sensing, being chloride, phosphate, turbidity and ecology, were pre-defined. The context was rather specific and the design of the application was tailored to this context and organisation. The results cannot be translated into general recommendations to set up citizen science in water quality monitoring. However, the sample matched the general participating audience of citizen science and therefore the final model provides a first insight of acceptance of such applications.

Respondents match the general profile that is seen in volunteering and citizen science (Koehler & Koontz 2008; Hobbs & White 2012; Edwards 2014) that describe the average citizen scientist as middle aged and higher educated. It can therefore be assumed that respondents that filled out the survey have a positive attitude towards volunteering.

Further research will be needed to determine whether these findings can be confirmed in a larger sample size. A repetition of this survey in different contexts could be used to confirm whether the findings in this study hold in different contexts. Future studies should aim to have a more representative sample of the target audience (in this case the general public) and consider different data collection methods.

Water authorities could alternatively aim to involve other target audiences, but previous studies have shown that these groups are hard to involve though. An interesting trend observed in the Netherlands (Van Houwelingen et al. 2014) is an increase of volunteer effort for local issues. Water authorities could link up with this trend, as water quality monitoring concerns local issues as well.

Part III – Water authority viewpoints

In previous parts of this thesis key success factors were introduced and motivations and barriers of citizens were investigated, answering sub-questions 1, 2 and 4. This third part corresponds to sub-question 3 ("*What are different viewpoints of Dutch water authorities regarding the application of a citizen science in water quality monitoring?"*). A Q methodological approach is used and will be explained first. Next the results are presented in the form of the final factor arrays and narratives of the identified viewpoints. Finally a conclusion is drawn for this sub-question and the outcomes are discussed.

Chapter 10 The Q methodological approach to identify viewpoints on citizen science at water authorities

In this chapter the Q methodological approach will be discussed, this method was used to identify different viewpoints on citizen science in water quality at water authorities. A summary of the method has been given in chapter 3. An extensive version is given in 10.1. Next the results are discussed, which consist of the final factor arrays (1.2), a narrative is created for each of the three viewpoints (10.2) and a deeper examination of the viewpoints using the post-sort interviews (10.3).

10.1 Extensive method description for Q methodology

Q methodology is used to describe a population of viewpoints (Van Exel 2005; Watts & Stenner 2012). In contrast to R methodology, where traits are variables and persons form the sample, in Q methodology persons are the variables and their traits and abilities or viewpoints are the sample (Van Exel 2005). Q methodology was first introduced in 1935 by Stephenson (Watts & Stenner 2012) and gained popularity in psychological research thanks to Brown's paper on political subjectivity (Brown 1980).

The strength of this method is that it combines qualitative and quantitative aspects, since a small sample size is statistically analysed using a factor analysis. Additionally, Q methodological approaches are neither inductive nor deductive. The approach is abductive in nature (Watts & Stenner 2012). Where an inductive approach describes empirical observations, Q methodology aims to explain them to develop theory (Watts & Stenner 2012). This explanatory nature is expressed in the factor rotations and in the interpretation of the final factor arrays. The additional use of interviews and demographic information can be used to enhance the explanation that leads to new theoretical insights.

The research steps are summarised in Figure 10.1. Each step will be described and the corresponding part of the process will be highlighted in the flowchart below. The next sections discuss the data collection (10.1.1), data manipulation (10.1.2) and data analysis (1.1.1).

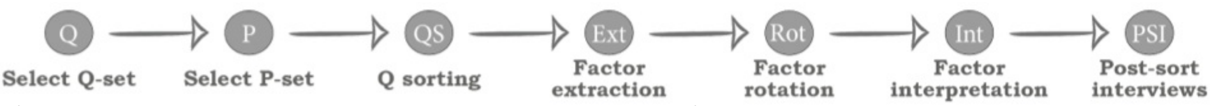


Figure 10.1 – Flowchart of the steps of the Q methodological approach.

10.1.1 Q methodological data collection

A Q methodological approach is composed of a Q-set (the statements or items) and a P-set (the participants). Each participant is handed the Q-set and asked to order the statements in the so-called Q sorting process.

Sampling the Q-set

An initial list of statements was composed based on interviews, a focus group meeting, a workshop and literature. These statements were reformulated using creativity to align the language used and to frame them from the perspective of a water authority employee.

Ten semi-structured interviews were conducted with individuals or small groups of three to four people. Four water authorities, two nature managers, a drinking water company and three citizen associations were interviewed. Topics included current water quality monitoring practice, experience with citizen science and future intentions regarding citizen participation in monitoring. An informal walking club in the central Netherlands was approached for a focus group meeting. Six members out of approximately fifteen participated. The six women were between the age of 47 and 62. They have a shared interest in walking in nature, but they had different socio-economic backgrounds and resided in different municipalities. A workshop on citizen science was used as input for the statements as well. The workshop was organised by water authority Delfland and it was part of the symposium on the physical digital delta Physical Digital Delta[6] in November 2014.

The initial list consisted of 229 statements. Statements that were similar were merged and statements out of scope were excluded. This resulted in an second list of 65 statements. These were pre-tested with six master students from different backgrounds and different levels of knowledge on water quality monitoring and citizen science. A final set of 46 statements was used for the Q sorts. The statements were formulated in Dutch, as this is the mother tongue of all participants.

Selecting the P-set

The P-set is selected using a strategic sampling approach. The aim of the selection strategy for the P-set is to collect a range of opinions that represents as much of the variance as possible. Two sampling strategies were applied to maximise the diversity of opinions. A more detailed description can be found in the Appendix.

First people were selected based on their water authority and field of expertise. Three criteria were used to select eight different water authorities: flooding risk, age (expressed in years since the last reform or merge with another water authority) and location (within or without the urban conglomerate Randstad). Two to six people were interviewed per water authority. All participants were politicians, policy advisors or people that actually work with the data. This last category consisted of field staff collecting the data and of hydrologists and ecologists that use the data.

The second strategy consisted of asking people to put colleagues forward with a different viewpoint. Five participants were recruited via the latter strategy. A list of participants characteristics can be found in Appendix H.

Sorting procedure

Each sort consists of four phases in a total time of 45-60 minutes. The four stages are described below.

1) The procedure starts with an introduction where participants are informed about the procedure. They were also provided with three examples of citizen science (the three Dutch cases as described in part I) in order to ensure a basic level of knowledge on the topic.
2) Secondly the initial sorting takes place where participants classify each statement as agree, disagree or neutral.
3) In the third phase participants distribute the statements as shown in Figure 3.4. They are guided in doing so. Participants are first asked to select the two statements they most agreed with. These are taken from the agree pile and placed in column +4. Subsequently columns +3, +2 and +1 were filled. This is repeated for the statements on the disagree pile.
4) At last a short post-sort interview is held. Participants were asked about their motivations for the statements in category -4 and +4 and whether they would like to add a statement to the P-set.

[6] The Digital Delta is an initiative of private-public participation, among others TU Delft and the Union of Water Authorities. The Digital Delta aims to account for fragmentation, incompatibility and lack of transparency in a growing amount of data. It "is the open platform that contains and provides access to as much information as possible relating to water management (in the broadest sense of the word)". Data will be made available for professional and non-professional use. See www.digitaledelta.nl/en.

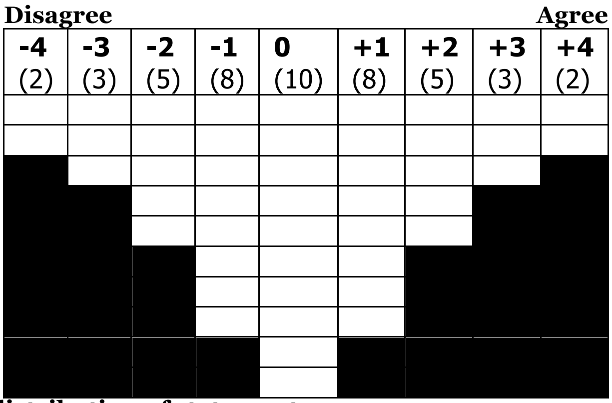


Figure 10.2 – The fixed distribution of statements.

10.1.2 Data analysis

A factor analysis as described by Brown (1980) is applied to extract initial factors. Factors are checked for their compliance with the Kaiser-Gutmann Criterion, significant factor loadings and Humphrey's rule. Details of these criteria are given in Brown (1980) and Appendix F. Factors are extracted in the PQMethod software package (version 2.3.5) that follows the factor extraction of Brown (1980).

1.1.1. Data manipulation: factor rotation and final factor arrays

Factor rotations

After extraction of the initial factors a factor rotation is performed to optimise the factors. Factors itself are not affected, but the positioning of the factors in a two-dimensional space is. Rotation allows for maximising the loading on one factor, while decreasing the loading on the other factor. An illustrative example is given in Figure 10.3. Manual and Varimax rotations are applied to obtain the final factors.

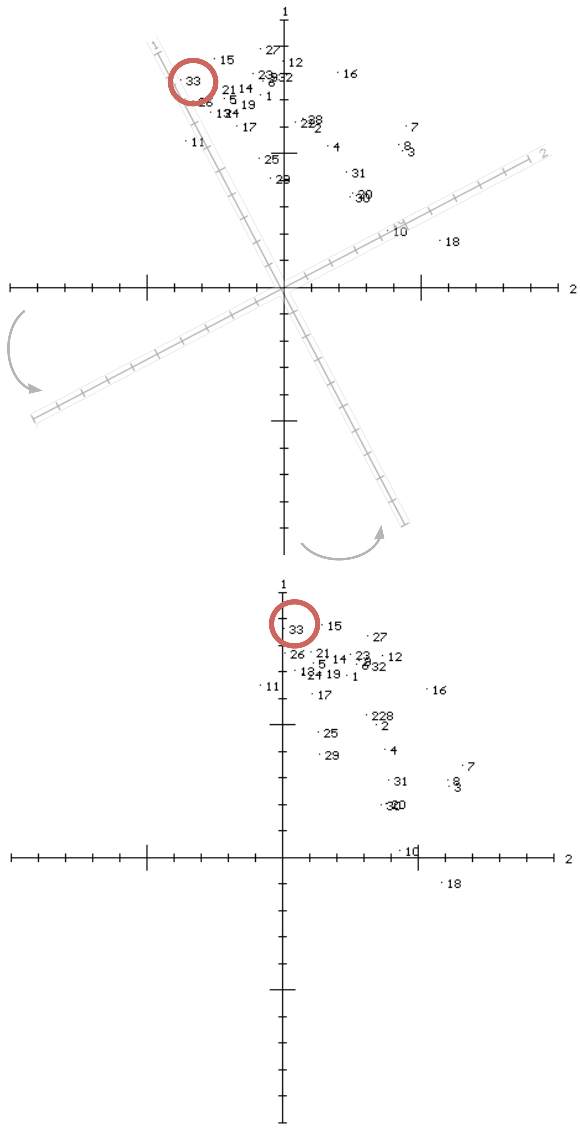
Varimax rotations are performed automatically and lead to a solution that is mathematically optimised for all factors as a whole. The software package PQMethod is used to this end. Varimax can be considered 'objective', but it may cause Q sorts that have a high weight in reality to end up suboptimal in a Varimax rotation (Watts & Stenner 2012). Manual rotations can address this, but are more subjective. Manual rotations are preferred if the researcher knows what to look for in the data (Watts & Stenner 2012). Since the author of this study is inexperienced in Q methodology, both rotations will be tried out.

In total four different rotations were performed, being:

I. Varimax (using PQMethod software);
II. A 'best fit' manual rotation;
III. A 'tailored' manual rotation;
IV. A manual re-rotation of the Varimax rotation.

Factor correlations were used to evaluate the alternatives and choose the final solution. The lower the correlations between the factors are, the better the final solution is considered to be.

The factor loadings are used to calculate a weighted average of the 'ideal viewpoint' of a person that would load 100% on this factor. This 100%-viewpoint is presented in the form of a factor array, i.e. the way such a person would have ranked each statement. In Appendix F the details of the rotations and the corresponding factor arrays are presented.



Situation 1

In the initial situation sort 33 is located around 0.8 on factor 1 (factor A) and -0.4 on factor 2 (factor B).

This significant loading on two factors makes it harder to interpret the results.

Basically the researcher is viewing the factors from the centre of the axes. When rotating the axes, the viewpoint will change.

Situation 2

The axes have been rotated -26°. Sort 33 is now purely loading on factor 1 with a value of above 0.85 and does not load on factor 2 any more. The ranking of the statements of person 33 resembles that of the hypothetical factor 1 to a great extent.

It must be noted that this rotation is not yet ideal: there are many sorts that have high loadings on factor 1, but also load on factor 2 in the new situations. Hence the difficulty of manual factor rotations.

Figure 10.3 – Example of a rotation. In this example sort 33 is optimised for factor 1.

10.1.3 Obtaining the viewpoints: factor interpretation

Initial factor interpretation

The factor array describes the score of a person with a 100% loading on each factor. These scores are compared between the factors. A crib sheet as developed by Watts and described by Watts & Stenner (2012, p. 150) was used to identify distinguishing items for each factor.

Distinguishing scores are collected on a 'crib sheet' per factor. This crib sheet contains the items ranked +4 and -4 and items for which the factor has a higher or lower score than any other factor (Watts & Stenner 2012). For example item 1 is distinguishing for factor A if factor A gives a score of +3 to item 1, while other factors have a score of -1.

Integration of post-sort interviews in viewpoints

In the second round of interpretation the post-sort interviews as described in 10.1.1 were taken into account. Post-sorting interviews were included in this study, because they can provide in-depth insight in beliefs and values underlying the sorts and allow for analysis in the context of participants rationale rather than literature or the researcher's bias (Gallagher & Porock 2010).

A trade-off between validity and feasibility had to be made, because an important disadvantage of post-sorting interviews is that is it time consuming (Gallagher & Porock 2010). It would be too time-intensive for both researcher and participant to discuss all statements after sorting. An option would be to return after the initial analysis and discuss distinguishing statements only. However, this was infeasible too, due to geographic spreading of participants. The interviews were therefore held immediately post sorting and participants were encouraged to elaborate on statements they most agree and disagree with, but also on statements of their choice.

Tow post-sort interview analysis approaches as suggested by Gallagher & Porock (2010) were followed, to use as many parts of the post-sort interviews as possible. The two approaches are consensus card content analysis (C-CCA) and distinguishing card content analysis (D-CCA). C-CCA uses the statements that all participants ranked more or less equal, while D-CCA searches for statements that define the viewpoint of a particular group.

To increase the reliability and generalizability of the results, only statements with two or more post-sort interview fragments from persons with significant loadings on one factor were included in the C-CCA. This was done to increase validity of the results, as one persons' commentary could equally well reflect a personal opinion rather than the common factor. For the same reason people with a significant loading on two factors were also excluded from this analysis. People with an opposite ranking for a card compared to their viewpoint were kept, although a disadvantage is that the underlying values represent personal opinions rather than those of the common viewpoint.

An overview of the underlying values regarding data trustworthiness and the applicability of citizen data is additionally presented. This part is included since it is considered one of the main (perceived) challenges of citizen science.

10.1.4 Validation of the results with participants

Narratives were formulated based on the factor arrays and were studied in depth using the post-sort interviews. Since this procedure is subjective to the subjectivity of the researcher, the viewpoint narratives and the post-sort interview results were submitted to all participants. Participants received their factor loadings, the viewpoint narratives (in Dutch) and the interview results (in English) via individual emails. They were asked to indicate whether they identified themselves with the viewpoint where they had the highest loading and whether they agreed with the post-sort interview results.

Table 10.1 Overview of all available interview fragments on statements 1 to 46.

Items				Q sorts																																
A	B	C		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33
			1			-4/-4	-4/-3		-4/-3		-4	-2/-3			-4	-3/-3								-4/-3	-4/-3											
-	-	-	2					+4/+4		+4	+4	+4/+4			+4		+4	+4/+4								+4/+4				+4/+4	+4/+4					+3/+4
x			3																																	
			4			-4/-3							-4/-3												-3/-1	-2/-1										
			5																																	
		x	6													-2/-1									-4/-1	-1/-1		+4				+4				
			7																															-4/-1		
		x	8																															-4/1		
x		x	9	+4/+4			+4/+4		+4/+4			+4/+4										+4/+4				+4/+4			+4/+4	+4/+4			+4/+2			
x			10	-4/-4							+4												-3			-3/-4	-4/-4	+4/+3		-4/-4					-4/-4	-4/-4
			11		+4/0		-4/0													+4/0	+4/+1															
			12																																	
			13																						+3/0								+4/0			
		x	14										+3/+2				+4				+2/0			+3/0			+1/0	0/0								0/0
			15																																	
		x	16					-4/-2								-4/-2						-4/-2				-3/-2			-4/-2							
			17													+4/+1								-1/+1	+4/+1											
			18									+3/+2							+2																	
			19									-4/-3	+4/-1			-4/-3	-4		-3			-4/-3				-4/-3			-2/-3							
		x	20			+4/+2							-4/-2								+3/+2		+4/+2													
			21				+1/-1																													
			22									+3/+2										+3/+2							+4/+2			+4				
			23												+4			+4/+3				+4/+3		+4/+3										+4/+3	+4/+3	
	x		24	+4/+2			+4/+2							+4/+2									-4	+4/+2												
x	x		25									0/+1						+1/+1			-3/-1															
			26		-4/0												0									-1/0										
			27		+2/+2				+4/+2										+4																	
			28									-3/-3						-4/-3														-4	-4/-3			
	x		29										-1/-1																							
			30																	+4/0		+3/0				-1/0					-4/0				+4/0	+4/0
			31					-4/-1				+1/-1				+4/-1								-4/-1		+3/0										
	x		32									-1/-1														+2/0										
			33									-2/0					-1					-3/-2														
	x		34																																	
-	-	-	35									+3/0																								
			36							-4	-4	-4/-2							-4	-4/-4	-4/-4	-4/-2							+1/-2				-4/-4			
			37					+4/+3											+4				+4/+4			+2/+3	+4/+3				+4/+3					
			38																		-4/0						+4/+1									
			39										+3/+2										-4/+1													
x			40							-4				+4/0							-3/-3															
	x		41		-4/-4							-2/-4		-4/-4	-4		-4	-4/-4	-4	-4/-4						-4/-4				-4/-4	-4/-4				-4/-4	-4/-4
x			42			+4/+2				+4			+4/+2	-4/-2														-4/-2	-3/-2							
			43						-4/-2			-2/-2														-3/-2						-4				
			44									+1/-1							-1			-3/-1			+4/-1	-1/-1		-4/+1	-4/-1							
			45																															+4/+1		
	x		46				0/-1											-2/-1			+4/+2															

For participants with a high (>0.50) loading and no significant (<0.38) loading on the other factors their factor is indicated. For the items they discussed their personal score and the item score is presented. Participants with no significant loadings or multiple significant loadings only their personal item score is displayed. Distinguishing items are marked x in the first three columns.

1.2. Results: from initial factor to final factor arrays

In the previous section the methodology has been introduced. In this section the initial factors will be extracted and subsequently manipulated using factor rotation to obtain the final factor arrays.

10.1.5 Initial factor extraction

A factor analysis was performed using PQMethod software package (version 3.2.1). Based on several statistical criteria (Watts & Stenner 2012; see appendix J) it was decided to keep three factors. These factors were rotated and subsequently the factor array was determined.

There are several criteria to assess whether a factor should be included or not. Several criteria suggest that three factors should be taken into account (e.g. Humphrey's Rule), while others (e.g. the Kaiser-Gutmann Criterion) suggest that there are only two factors. Since these criteria are rather mathematical guidelines than fixed boundaries, three factors will be incorporated in the next step: the factor rotation.

In total four rotations were performed for two types of rotation (Varimax and manual). The automatic Varimax rotation performed by PQMethod (1) is compared to the manual re-rotation of this Varimax (2) and two manual rotations: a 'best fit' rotation (3) and a rotation with a focus on distinguishing sorts (4). Each manual rotation aimed to optimise the factor loadings, based on the judgment of the researcher. Rotation 4 was preferred, since it has the lowest factor correlations, meaning less influence the factors have on each other (Watts & Stenner 2012). Below the factor loadings are shown in Table 10.3 and a more detailed description of the factor correlations can be found in Appendix K.

10.1.6 Final factor array

The final factor arrays are obtained by normalising the factor loadings to the highest loading and including all factors with a significant loading (SFL>0.38). Some authors prefer to use 0.60 or even stricter requirements (Stenner & Watts 2012). Participants with a loading higher or equal to the Significant Factor Loading (SFL) of 0.38 were included in this study, because the factor array is an average that becomes more stable if more sorts contribute (Watts & Stenner 2012, p.131). In Table 10.2 the final factor arrays are presented.

Table 10.2 – Final factor arrays, the numbers in columns A, B and C are the theoretical item score for a person whose viewpoint is 100% that factor.

	Item	A	B	C
1	Providing citizens with insight in water quality will only lead to unnecessary panic and questions.	-3	-4	-4
2	Citizen Science is important, since it contributes to increasing water awareness.	4	4	4
3	Citizen Science is a resolution to explain why you take certain measures as a water authority.	1	-1	-1
4	Water quality is an abstract concept, citizens will not understand what they measure.	-1	-2	-3
5	It is important to have proper communications to citizens about why values deviate from the norm and what the uncertainty in the measured value is.	1	0	1
6	I would not know why citizens would not be interested in monitoring water quality.	-1	-2	0
7	Citizen Science is an economic way to collect (extra) measurements.	1	1	-1
8	Citizen Science enables the collection of more measurements by doing them more frequent.	3	3	1
9	Citizen Science enables the collection of large amounts of measurements.	4	2	0
10	Measurements and observations by citizens are no valuable addition to the official monitoring network.	-4	-2	-1
11	The most important goal is that the measurement data is valuable for the water authority because time and energy is invested by the organisation.	0	1	1
12	I would rather make (smart) use of existing measurements than letting citizens do more measurements.	-1	0	0
13	The greatest challenge is how to teach people something, if they can or want to spend little time on it.	0	0	-1
14	Especially schools are suitable target groups to do these measurements, for example during a 'water lesson'.	0	0	2
15	The most important goal of citizen science is to learn people something about the environment they live in.	1	2	3
16	Citizen Science is an interesting social innovation, but not suitable to actual collect useful data.	-2	-2	0
17	Citizens are often underestimated, they are better educated and smarter than we think.	1	1	0
18	As a water authority we need to learn how to handle the uncertainty of alternative (cheap) measurements that originate from Citizen Science.	2	1	1
19	Data collection by citizens is unreliable and should not be accepted by the water authority.	-3	-2	-1
20	Citizens will only participate in Citizen Science, if participation is in their own interest.	0	2	-2
21	Not all citizens can be trusted to do these measurements.	-1	1	0
22	With a short training, citizens will be able to do measurements for the water authority.	2	1	2
23	Citizen Science is an interesting way to give meaning to the concept of citizen participation.	3	1	3

Continuation of the table of previous page.

	Item	A	B	C
24	Citizen Science is necessary, because it helps to decrease the gap between citizens and the water authority.	2	-3	2
25	By using Citizen Science, the water authority shows that it is keeping pace with the time.	1	-1	0
26	An important advantage of Citizen Science is that it reduces the resistance of citizens against projects.	0	0	1
27	With Citizen Science one can bind and involve another part of the audience.	2	0	3
28	As long as Citizen Science is not included in the policy at the top levels, the water authority should not invest in it.	-3	-3	-2
29	It is a major bottleneck to create support within the water authority for the deployment of Citizen Science.	-1	0	-1
30	The water authority will benefit from using Citizen Science in conducting its tasks, because less (financial) resources are available.	0	-1	0
31	The conservative character of my organisation is a major bottleneck for Citizen Science.	-1	-1	-2
32	The organisation is not equipped to work with large groups of citizen scientists.	0	3	0
33	My organisation has no capacity to work with all these data.	-2	-1	-2
34	The water authority should incorporate in its policy how to deploy and stimulate Citizen Science more.	2	-1	1
35	If citizens are structurally contributing, they shall be compensated for that.	0	0	0
36	If citizens collect data for the water authority, they should have a say in the measures taken afterwards.	-2	-4	-3
37	Citizens often have local knowledge, the water authority should use this knowledge.	3	4	4
38	Citizen Science is important, because it gives insight into the problems that citizens are concerned with.	1	0	1
39	Citizen should have insight in the most recent information of the water quality that is available with the water authority.	1	1	2
40	If you provide citizens with a reference framework, they themselves can validate their data.	0	-3	-3
41	I do not want citizens to interfere with our work.	-4	-1	-4
42	The water authority should stay in control of doing the measurements, since the water authority is indeed responsible.	-2	3	2
43	I think the creation of Citizen Science does not fall within the tasks of the water authority.	-2	-1	-2
44	I do not have a full image of what is possible with Citizen Science.	-1	0	-1
45	An important caveat is that citizens will expect that their measurement have a direct influence on policy.	0	2	1
46	Citizens cannot be motivated to participate in such projects for a longer period.	-1	2	-1

Table 10.3 – Final factor loadings after rotation. Bold sorts load significantly on that factor.

Q sort	A	B	C
1	**0,74**	0,18	-0,01
2	**0,49**	0,18	0,35
3	0,35	**0,55**	0,18
4	**0,49**	0,36	-0,03
5	**0,69**	-0,07	0,29
6	**0,71**	0,09	0,32
7	**0,45**	**0,62**	0,12
8	0,31	**0,46**	**0,43**
9	**0,79**	0,19	0,06
10	-0,05	0,22	**0,66**
11	**0,64**	-0,17	0,03
12	**0,72**	0,12	**0,49**
13	**0,75**	0,01	-0,12
14	**0,69**	-0,06	**0,41**
15	**0,84**	-0,06	0,30
16	**0,64**	0,33	**0,42**
17	**0,58**	-0,05	0,25
18	-0,04	**0,55**	0,24
19	**0,69**	0,01	0,17
20	0,32	**0,43**	-0,13
21	**0,73**	-0,09	0,32
22	**0,59**	0,25	0,04
23	**0,82**	0,17	0,01
24	**0,74**	0,04	-0,12
25	**0,45**	0,00	0,23
26	**0,80**	-0,06	-0,07
27	**0,85**	0,15	0,23
28	**0,54**	0,20	0,27
29	0,34	-0,03	0,34
30	0,30	**0,39**	-0,09
31	0,27	0,23	**0,43**
32	**0,77**	0,21	0,10
33	**0,79**	-0,22	0,34
Eigenvalue	12.55	2.29	2.58
Variance explained	38%	7%	8%

10.2 Results: factor interpretation to obtain viewpoints

In the previous sections three factors were extracted using the method of Brown (1980). These factors were manipulated using factor rotations. Eventually the final factor array was given in Table 10.2. Next these factors A, B and C will be transformed into viewpoints in the interpretation step. This will be done using so-called crib sheets. The distinguishing statements are put together per factor and translated into a narrative by the researcher. This narrative would be the viewpoint of a person with a 100% loading on (agreement with) this factor.

Defining distinguishing factors using crib sheets

The distinguishing items were defined for each factor. A crib sheet as developed by Watts and described by Watts & Stenner (2012, p. 150) was used for this purpose. The crib sheets are used to structure the collection of distinguishing items for each factor. The full sheets are in Appendix L.

To give an example: statement 20 ("Citizens will only participate in citizen science, if participation is in their own interest.") is distinguishing for both factor B and factor C. Factor B has a factor score of +2 for this item, confirming the statement, while factor C has a score of -2, rejecting the statement.

In Table 10.4 the number of distinguishing items can be found per factor. For example in six items where C has the highest score, these items scored equally high in A. The numbers in the diagonals (e.g. A-A) represent the number of unique distinguishing items for factors A, B or C.

Table 10.4 – Distinguishing items per factor.

	Highest			**Lowest**		
	A	**B**	**C**	**A**	**B**	**C**
A	7	-	-	9	-	-
B	5	10	-	5	11	-
C	6	3	10	7	4	7

Viewpoint narrative as outcome of factor interpretation

The final factor description contains three elements: factor characteristics, factor demographics and the viewpoint narrative. In Figure 10.4 the building of the sections 10.2.1 to 10.2.3 is presented.

The factor characteristics describe the statistical characteristics of that factor, being the eigenvalue, the variance explained by this factor and the number of people that load significantly on this factor. These numbers give insight in the strength of the factor and its contribution to the study as a whole. High eigenvalues and high variance levels are associated with solid foundations for the study (Watts & Stenner 2012). An eigenvalue above 1.00 is considered sufficient, as it indicates the factor has enough in common with the other factors. The variance refers to the variance explained by this factor. The total variance explained by the sum of all factors should be above 35% (Watts & Stenner 2012), which is the case in this study with 53%.

The number of people loading on a factor gives an indication what share of the participants share this viewpoint. This number does not say anything though about the distribution in the total population (i.e. the distribution in the whole water authority); additional research would be needed for that.

The narrative is composed of the distinguishing statements per factor. References to statements are placed between brackets and consist of [item number]:[item score for this factor array]. For example statement 2 with a score of +4 would be presented as: *(…) citizen science is important for water authorities to increase water awareness (2: +4).*

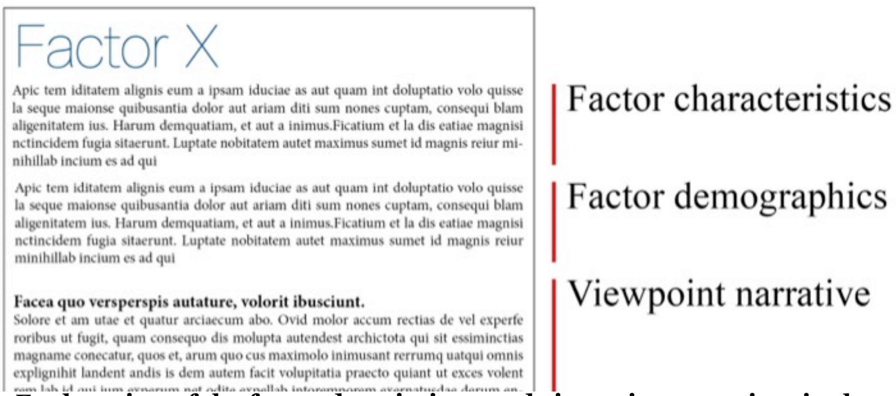


Figure 10.4 – Explanation of the factor descriptions and viewpoint narratives in the next section.

10.2.1 Factor A

Factor A has an eigenvalue of 12.55 and explains 38% of the total study variance. 25 participants load significantly on this factor. Among them are two people who load significantly on factor B as well and three that also load on factor C.

The people with viewpoint A are a mixture of hydrologists, advisors, policy advisors, field staff and a politician. In this group are fourteen men and eleven women. Fifteen people are middle aged. They are distributed over all eight incorporated water authorities, which are located within and outside the Randstad and with a mixture of higher and lower flood risk. Six people work at a water authority that is recently reformed.

Viewpoint A: "Citizen participation for data application"
Citizen science is important for water authorities to increase water awareness (2: +4), but also for the collection of large amounts of measurements (9: +4) and for conducting measurements more frequent (8: +3). The organisation is expected to have sufficient capacity to analyse all the data (33: -2) at the moment, but the water authority has to learn how to handle the uncertainty of these alternative (often cheap) measurements (18: +2).

Employees believe that their water authority should actively incorporate citizen science in its policy (34: +2) and the water authority should not wait with investing in citizen science until it is included in top level policies (28: -3).

They do not think that the water authority should stay in control of monitoring, although water authorities are in the end responsible for monitoring (42: -2). Employees do not fear citizen interference with their work (41: -4). They further believe that citizens, if provided with a reference framework, can validate their own data (40: 0). Citizens can be trusted to do these measurements (21: -1). Although citizen data is less accurate, it should be accepted by the water authority (19: -3) and is a valuable addition to the official monitoring network (10: -4). These people do not prefer smart use of existing data to citizen science data (12: -1).

These people consider citizen science to be a solution when it comes to explain why you undertake certain measures (3: +1). Also this group feels that citizen science will show that the water authority is keeping pace of time (25: +1). Also, citizen science is an interesting way to give meaning to the concept of citizen participation (23: +3) and decrease the gap between the water authority and citizens (24: +2). They are not afraid that citizens will expect their contribution to have a direct impact on policy (45: 0) and they do not think that giving citizens insight in water quality will lead to unnecessary questions and panic (1: -3).

10.2.2 Factor B

Factor B has an eigenvalue of 2.29 and explains 7% of the total study variance. Six participants load significantly on this factor. Among them are two people who load significantly on factor A as well and one that also loads on factor C.

The people with viewpoint B form a mixture of advisors, policy advisors and field staff. Five out of six are male and four of them are middle aged. They work at three different water authorities, three people work outside the Randstad. Four people work at water authorities that are recently (after 2005) reformed. Four work in an area with a high flood risk.

Viewpoint B: "The water authority in control"
People with viewpoint B consider citizen science to be important to increase water awareness (2: +4). Although they believe that local knowledge will be valuable for the water authority (37: +4), people with this viewpoint strongly advice the water authority to stay in control of monitoring, because they have the final responsibility for it (42: +3). Citizen Science enables the collection of more measurements by doing them more frequent (8: +3), but this group does not believe the water authority needs citizen science in conducting its tasks to compensate for less financial resources (30: -1). It can also be noted that these people do not have a full image (yet) of what is possible with citizen science (44: 0).

The water authority should not incorporate stimulation of citizen science in its policy (34: -1), but on the other hand: they do think the water authority should invest in citizen science, even if it is not included in top level policies yet (28: -3). This group believes that a major bottleneck will be to create a support base within the organisation (29: 0).

They do fear that citizens cannot be motivated for a long-term participation (46: +2) and will not participate unless participation is in their own interest (20: +2). They further doubt whether all citizens can be trusted in doing these measurements (21: +1). This is reflected in the fact that they can think of reasons why citizens would not be interested to participate (6: -2). People in this group do not fear questions or panic from citizens (1: -4).

They think citizens will be able to do measurements after a short training (22: +1), but they do not expect that citizens will be able to validate their own data if provided with a reference framework (40: -3). If citizens would be collecting data for the water authority, this group strongly feels that they should not be given more influence on measures taken (36: -4), but does fear that citizens will think that their work will influence policy directly (45: +2). Also, they are convinced that their organisation is not equipped to work with large groups of citizen scientists (yet) (32: +3).

People with this viewpoint further believe that citizen science should not be used to decrease the gap between citizens and water authorities (24: -3) or to show that the water authority is keeping pace with time (25: -1). They further are not convinced that citizen science will involve another part of the public (27: 0) or that it is an interesting way to give meaning to citizen participation (23: 1).

10.2.3 Factor C

Factor C has an eigenvalue of 2.58 and explains 8% of the total study variance. Six participants load significantly on this factor. Among them are three people who load significantly on factor A as well and one that also loads on factor B.

The people with viewpoint C are a mixture of advisors, policy advisors and field staff. Four people are middle aged and three of them are male. They work at different water authorities, three within and three outside the Randstad. Three people work at a water authority recently (after 2005) reformed. Five out of six people with viewpoint C works in an area with a lower flood risk.

Viewpoint C: "Education and sharing local knowledge"

People in factor C think that citizen science is important, because it contributes to the increase of water awareness (2: +4). They also feel that the water authority should use the local knowledge that citizens have (37: +4).

Citizen should have insight in the most recent information of the water quality that is available with the water authority (39: +2). These people strongly disagree that providing citizens with insight in water quality will not lead to unnecessary panic and questions (1: -4). They strongly disagree that citizens should not interfere with their work (41: -4).

The conservative character of water authorities is not considered a major bottleneck (31: -2). People with this viewpoint consider citizen science to be a good way to bind and involve another part of the audience (27: +3), to decrease the gap between citizens and water authorities (24: +2) and in a lesser extent to reduce resistance of citizens against projects (26: +1). They consider citizen science to be merely a social innovation, rather than a way to collect useful data (16: 0). This is also reflected in the relatively small support that citizen science enables the collection of large amounts of data (9: 0) and the possibility to conduct measurements more frequently (8: +1). People in this group further believe that citizens will not be able to validate their own data (40: -3).

The most important goal will be to teach people something about their environment (15: +3) and especially schools will be a good target audience (14: +2). They further think that citizens will understand what they measure, even though water quality is an abstract concept (4: -3). To teach people something within little time should be possible (13: -1) and they find it difficult to think of reasons why people would not be interested in water quality (6: 0). They do think that citizens will participate, also when participation does not directly serve their own interest (20: -2).

10.3 Deepening factor interpretations with interviews

In the previous section the factors were translated into viewpoints, using a crib sheet to interpret factor arrays. Post-sort interview data is available as second source of data on top of the ranking of the statements. After sorting the participant was interviewed on his motivation for the +4 and -4 categories. If time allowed participants were invited to share their motivation for any other statement. This resulted in several post-sort interview fragments per item, although there also are items that were not explained by any participant.

Two types of statements were analysed using the post-sort interviews: the statements all participants agreed on (consensus card content analysis, C-CCA), in order to see whether the underlying values differ between factors, and the statements that differ between the factors (distinguishing card content analysis, D-CCA). The items that were identified as highly distinguishing in the crib sheets are marked with an X in Table 10.1.

In the following sections an interpretation of the interview fragments is presented. The subheadings (i.e. 1.1.1) reflect the topic of that section. The corresponding statements are given in between brackets. Participants are indicated with a #; and incidentally an S followed by a number (e.g. S1) is used to refer to a statement. All participants are referred to as male.

10.3.1 Consensus card content analysis

In the consensus card content analysis (C-CCA) items with equal scores in all viewpoints are compared. The items 2 and 35 were ranked equally high by all three factors. In this section a narrative based on the post-sort interview fragments with viewpoint A on statement 2 are presented. Unfortunately there were no interview fragments available for viewpoints B and C.

> *Citizen science is important, since it contributes to increasing water awareness.*
> *Statement 2 (all: +4)*

Viewpoint A
There is a lack of risk awareness, because the water authority is managing so well (#23, #28). Participant #23 referred to the OECD (2014) report, where water awareness is marked as one of the prime topics that need improvement.

There are three underlying motivations why water awareness should be increased. First of all, water awareness can increase citizen understanding of what the water authority is doing (#05) and why (#05, #23, #24, #28). Citizen science is a positive way to involve citizens (#08, #09), at least more positive than the current ways (e.g. taxes and construction works). Citizen science may increase this awareness so that people understand why they pay taxes (#05) or why measures are taken (#09, #12). A positive side effect is that citizens will talk about it to other people, increasing outreach via mouth-to-mouth spreading (#09).

Second, water awareness can create a support base for measures taken (#09). Participants from viewpoint A do not feel that it should be used to justify measures taken, as the fragments of statement 26 (resistance) suggest. If citizen science is needed to reduce resistance, there has been ill-communication in early stages of the process (#20). Citizen science should not be used to reduce resistance, but can be used in early stages to clarify why a certain measure is chosen and improve communications. Participant #02 suggests that there is no link between participation and a reduction of resistance, because participants are already motivated and positive. Resistance towards measures comes from personal interest and does not play a role in citizen science (#23).

Finally, water awareness can encourage people to change their behaviour (#15, #27). Water authorities are not able to manage water quality alone; citizen science provides citizens with insight in how the water system works and how they can contribute to improve water quality (#15, #27). If citizens, for example (#15), understand the influence of pesticides on water quality, they may use them less frequently. If the water quality increases afterwards, this may encourage people to continue monitoring (#27).

Challenges where identified as well: to encourage citizens to monitor, the data should be used (#27) and not just collected to raise awareness. Participant #28 adds that he thinks that the monitoring topic should be fun and important to citizen scientists.

Viewpoint B & **Viewpoint C**
There are no post-sort interview fragments available.

> *If citizens are structurally contributing, they shall be compensated for that.*
> *Statement 35 (all: 0)*

Viewpoint A
Participant #09 mentions that compensation should be well thought out. He considers this as a discussion that should be held when applicable: how and to what extent should citizens be compensated?

Viewpoint B & **Viewpoint C**
There are no post-sort interview fragments available.

10.3.2 Disconsensus card content analysis

As described above there were several statements with distinguishing scores in one of the factors. The statements 3, 6, 8, 9, 10, 14, 16, 20, 24, 25, 29, 32, 34, 40, 41, 42 and 46 were distinguishing for one or multiple factors and will be discussed in this section. Sometimes other statements are involved as well, because they were often discussed together as their topic was closely related to the distinguishing statement. All distinguishing statements are listed here, even if there are no post-sort interviews available for these statements.

> *Citizen science is a resolution to explain why you take certain measures as water authority.*
> *Statement 3 (A: +1, B: -1, C: -1)*

Viewpoint A, **viewpoint B** & **Viewpoint C**
There are no post-sort interview fragments available.

> *I would not know why citizens would not be interested in monitoring water quality.*
> *Statement 6 (A: -1, B: -2, C: 0)*

Viewpoint A
A person with viewpoint A can think of reasons why people would not be interested in monitoring water quality.

Participants #13, #22 and #23 can think of various reasons why citizens are not interested to participate. Participant #13 indicates that he believes that there are many people who are not interested in their environment and what happens there. He adds that this is a pity, because it reduces the applicability of citizen science, if there happen to be areas where there is no one interested in participation.

Participant #22 feels that it is a prejudice of the water authority that people would not be interested. He believes there are people who are interested, but indeed also people who are not interested and he knows why: they are just not interested.

Participant #23 can think of several reasons, but mentioned that citizens consider water quality monitoring the task of the water authority and that the water authority should thus do this.

Participant #25 believes that there are more people who think water quality is interesting. As he put it: "As long as I see people buy test kits at the gardening centre to check their fish ponds, I think there is enthusiasm for it."

Viewpoint B & **Viewpoint C**
There are no post-sort interview fragments available.

> *Citizen science is an economic way to collect extra data.*
> *Statement 7 (A: +1, B: +1, C: -1)*
>
> *Citizen science enables the collection of more measurements by doing them more frequent.*
> *Statement 8 (A: +3, B: +3, C: 1)*
>
> *Citizen science enables the collection of large amounts of data.*
> *Statement 9 (A: 4, B: 2, C: 0)*

Viewpoint A
A person with viewpoint A considers citizen science a suitable way to collect extra data, to collect them more frequent and in an economic way.

Participant #01 explains that measurements are expensive in time and money. If a citizen can do these measurements in little time in their backyard, they can be part of the water authority system. Compensation is unnecessary, as it takes them little time.

The water authority cannot monitor everything ideally aspired because of budget constraints (#06). More data than can be organised by the water authority alone with samples and analysis, could be collected by citizens if they monitor something simple, but regularly and with a large group (#04, #06).

Participants #19 and #27 stress the added value of frequent measurements by citizens. Participant #19 explains that it happens often that the water authority has a lack of data when creating or validating hydrological models. Structures are usually measured frequently (every 15 minutes), but other locations are often measured once a month (#19). If it has been raining for two days, it means the water authority basically samples rainwater (#27). More measurements, collected by citizens, will increase insight in the water quality (#26, #27), ecology (#26) and fluctuations over time (#19, #27). Trustworthiness is not really an issue, as the large number of measurements allows to filter out (#23, #27) or average out (#09, #19) erroneous entries.

Participant #26 notes that citizen science is one of the ways to collect more data and more frequently. Participant 23 adds that maybe in a few years there will be much more possible regarding data collection and that citizen science may become common practice.

Viewpoint B
A person with viewpoint B considers citizen science as particularly suitable to collect extra data and to collect it more frequent.

Participant #30 sees potential in the large numbers. "There are 800 000 people the water authority's control area, if they all look at something for once, that will be unequalled by our own measurements.

Viewpoint C
A person with viewpoint C sees potential in citizen science to collect extra data and more frequent, but not in an economic way.

Participant #31 does not consider citizen science an economic way to collect data, because the uncertified, invalidated measurements cannot replace the standard monitoring network. Citizen science has mainly potential as illustrative data or as a way to involve citizens.

> *Measurements and observations by citizens are no valuable addition to the official monitoring network.*
> *Statement 10 (A: -4, B: -2, C: -1)*
>
> *The most important goal is that the measurement data is valuable for the water authority, because time and energy has been invested by the organization.*
> *Statement 11 (A: 0, B: +1, C: +1)*

Viewpoint A
A person with viewpoint A strongly believes that citizen measurements and observations are a valuable addition to the official monitoring network and considers value of the data little importance.

Participant #01 thinks that there are measurements that everybody could do for the water authority, for example with new devices that are easy-to-use. However, one should think of how to do the measurements, in the end measurements need to be valuable (#01). Or, as participant #17 puts it: "you measure to know something."

Participants #02 and #04 state that data should be valuable, but that valuable does necessarily mean 'directly contributes to the tasks of water authority' (#02) or filling your database with high quality data (#04). The data should be used though according to participant #04, even if it is superficial use. Participant #32 thinks that the accuracy of the data should be labelled, in order to make them valuable. Data could already be useful though if it is known when, where and how citizens measured something. Participant #01 adds that errors in data are always possible, and thus the existing network should be used to validate the data.

Participants #23, #24 and #27 consider citizen science to be valuable, because they can fill gaps in the official monitoring network first of all. For example, now it takes one or two years to have a time series with twenty data points (#27). Citizen science can result in daily measurements, although the water authority is turning to online monitoring as well. Second, citizen Science will allow monitoring on places where we cannot monitor now, according to participant #33. Third, participant #23 sees added value in speed, as citizens are really fast in reporting via social media in case of calamities.

Viewpoint B
A person with viewpoint B believes that citizen measurements and observations are a valuable addition to the official monitoring network and think that it is important that data is valuable for the water authority.

Participant #18 believes that data collection should be well done, as the data should be useful, although citizen data do not have to match the quality of a laboratory. This usefulness is also fair to citizens; it would be unfair to have citizens monitor without using the data. Participant #20 believes that citizen science data can be a valuable addition to the existing network, although citizens cannot replace the standard measurements.

Viewpoint C
There are no post-sort interview fragments available.

Especially schools are a suitable target group to do these measurements, for example during a 'water lesson'.
Statement 14 (A: 0, B: 0, C: +2)

Viewpoint A
A person with viewpoint A sees schools as a possible target group to do these measurements.

Participant #25 sees schools as a temporary solution only; at some point they lose their interest and it does not work anymore. Participant #24 rather sees schools as an ideal test environment and pupils as a very interesting group of first users. It will be easier to reach other participants afterwards.

Participant #21 has another interest in schools: by involving them in citizen science the water authority can invest in the youth. He believes that pupils will develop an interest in water management if they receive guest lessons, because it leaves an impression.

Viewpoint B
A person with viewpoint B sees schools as a possible target group to do these measurements.

Participant #18 mentions that schools are already involved in shorter projects, with a focus on education. In that respect he does not see potential for schools as a target audience to monitor, especially for long-term projects.

Viewpoint C
A person with viewpoint C sees schools as an especially suitable target group to do these measurements.

Cooperation with schools is enjoyable, according to participant #10. He has experience with involving schools: high school students developed new concepts for fish ways. The project was successful, although there were no new and useful ideas.

Citizen science is an interesting social innovation, but not suitable to actually collect useful data.
Statement 16 (A: -2, B: -2, C: 0)

Viewpoint A
A person with viewpoint A considers citizen science an interesting social innovation and suitable to collect useful data.

The interviewees (#05, #13, #19, #23 and #26) agree that citizen science is a social innovation, but they disagree that it is not suitable to collect valuable data (#05, #23) and participant #26 calls it a technological innovation. He poses the question whether you "want high quality data with two decimals or do you want a more global measurement with a higher frequency?"

Participant #26 further thinks that the water authority can learn from it, but has to look different at the data. Participant #19 believes that the data can be valuable, but the water authority needs to be aware of a difference in data accuracy. Participant #13 thinks the water authority is not equipped yet to deal with such data, as "we do not have the right people and the right analysis methods". Participant #26 believes that the water authorities have to look different to these data and have to think of what they can learn from it. How to validate the data and guide citizens, who are different from trained experts, is a question raised by participant #05.

Viewpoint B
There are no post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

Citizens will only participate in citizen science if participation is in their own interest.
Statement 20 (A: 0, B: 2, C: -2)

Citizens cannot be motivated to participate in such projects for a longer period.
Statement 46 (A: -1, B: +2, C: +1)

Viewpoint A
A person with viewpoint A thinks that participants do not necessarily need personal interest to participate and that they can be motivated to participate for longer periods.

Is positive and believes that it is possible to motivate people for a longer period, although they are not sure how (#15). Explaining participants why it takes long to see the change (#4) and linking the project time span to the European policy cycle of six years or two times three years (#15) would be options.

Viewpoint B
A person with viewpoint B thinks that participants will participate only if they have a personal interest to participate and that they cannot be motivated to participate for longer periods.

Agrees that citizens cannot be motivated to participate in a project for a longer time. #18 sees possibilities in short term projects, but is convinced that citizens drop out if it becomes a routine and if no direct changes are visible. Besides a few idealistic people, people will not participate, unless participation is in their personal interest (#03) or fun (#03). Such interests could be a local issue where the water authority takes action (#18). Personal interest could also increase how serious people take the measurements and whether they do them regularly (#20).

Viewpoint C
A person with viewpoint C thinks that participants will participate even if they have no personal interest and that they are difficultly motivated to participate for longer periods.

Participant #10 partakes in citizen science projects and indicates that making a contribution and having fun are the main motivations to participate and believes that there are more people out there that are willing to contribute.

Citizen science is necessary because it helps decrease the gap between citizens and the water authority.
Statement 24 (A: +2, B: -3, C: +2)

Viewpoint A
A person with viewpoint A believes that citizen science can help decrease the gap.

Participants #04, #11 and #21 all indicate that they experience a lack of knowledge or understanding among citizens about what a water authority does and what they pay taxes for. Participant #11 summarises the situation as "much misunderstanding about what a water authority does, why people pay us and what we do for that, but also what they could do for us. (…) I mean, now it is a situation of us versus them, we should get rid of that".

Participant #04 noticed that citizens lack knowledge compared to or possess different knowledge than the water authority and they have a different view on situations. The water authority will have more direct contact with citizens when involving them via citizen science. Participant #10 expects that this will lead to more opportunities "to explain clearly why you do things", which will close the gap. Participant #11 also mentions the importance of explaining and making clear what the water authority expects from citizens, for example explaining their environment to each other. The ultimate goal will be to involve the mass and offer them a collaboration where they want to be part off (#11).

Participant #21 mentioned a difference between farmers and urban citizens; the first has a business interest in water quality, while the latter has little knowledge about it, perhaps because it was added relatively recent to the tasks of the water authority.

Viewpoint B
There are no post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

> *By using citizen science, the water authority is showing that it is keeping pace of time.*
> *Statement 25 (A: +1, B: -1, C: 0)*

Viewpoint A
A person with viewpoint A thinks that the water authority can show to be keeping pace of time with citizen science.

Citizen science suits modern time. The water authority should be up to date of what is going on outside, if citizens could contribute information via their smartphone that would be an example of showing that the water authority has an innovative vision (#15). Participant #09 thinks that especially politicians in the water authority would like to use citizen science to show that the water authority is keeping pace of time.

Viewpoint B
A person with viewpoint B thinks that the water authority should not use citizen science to show that it is keeping pace of time.

Participant #18 indicates that he thinks that keeping pace in time is a wrong reason to initiate citizen science.

Viewpoint C
There are no post-sort interview fragments available.

> *To create internal support within the water authority for the deployment of citizen science is a major bottleneck.*
> *Statement 29 (A: -1, B: 0, C: -1)*

Viewpoint A
There are no post-sort interview fragments available.

Viewpoint B
There are insufficient post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

The organisation is not equipped to work with large groups of citizen scientists.
Statement 32 (A: 0, B: +3, C: 0)

My organisation has no capacity to work with all these data.
Statement 337 (A: -2, B: -1, C: -2)

Viewpoint A
A person with viewpoint A believes that the organisation has sufficient capacity to work with the data, but is not convinced if it is equipped to work with large groups of citizens.

Participants #09 and #32 do not think the water authority is equipped at the moment to deal with the data or a large group of citizens, although participant #09 believes this is surmountable and should not be a limitation to deploy citizen science. According to participants #19, #20 and #32, there will be no capacity issues as long as citizen science data has the same format, e.g. accuracy, locations and methods used, as the existing data. Enlarging the database will not be a problem (#20), but participants #19 and #20 stress that new processing will be problematic. Participant #20 expects that new data sources will require other software and a change in organisation; at the moment the organisation is not capable to handle this data.

Viewpoint B
There are no post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

The water authority should incorporate in its policy how to deploy and stimulate citizen science.
Statement 34 (A: +2; B: -1; C: +1)

Viewpoint A
There are no post-sort interview fragments available.

Viewpoint B
There are no post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

If you provide citizens with a reference framework, they themselves can validate their own data. Statement 40 (A: 0, B: -3, C: -3)

Viewpoint A
There are insufficient post-sort interview fragments available.

Viewpoint B
There are insufficient post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

[7] Statement 33 is not a distinguishing item, but is included because it is closely related to statement 32.

I do not want citizens to interfere with our work.
Statement 41 (A: -4, B: -1, C: -4)

Viewpoint A
A person with viewpoint A strongly feels that citizens should be involved in his work.

Participants #02, #17 and #23 believe that the water authority will benefit from citizen input, both positive and negative. Participant #28 even states that it should be that way. Participant #17 thinks the water authority should organise its own resistance: both positive critical and plain criticism are welcome. He further thinks the lack of positive criticism is caused by the decrease of local, critical press.

Participants #11, #15, #27, #32 and #33 mention that the water authority should serve the public and needs input, even if this is something that people dislike and want to see it change (#02). As participant #32 puts it: "I would rather have them call me when there is something going on, than that they stay silent."

Participant #15 is hesitating, because he thinks that it is a good thing if citizens, "who pay, they are our client" engage more, but he suspects that the water authority in general considers citizen interference as inconvenient. Participant #33 mentions a transition, towards a situation where citizens participate and bring in knowledge. Participant #27 believes that the water authority is malfunctioning if they adopt an attitude like "let us do our job, we know about the water quality and you [citizens] should not interfere". The water authority needs citizens in their task, as their behaviour is crucial for good water quality too. He gives the example of feeding ducks: if citizens are aware of the situation, they may stop feeding the ducks.

Participant #11 believes that citizens interference means that the water authority did not explain well enough what they are doing and why. Participant #41 thinks that the water authority should always explain what We have to set boundaries though, until where interference is desirable, other communication should be done via the board.

Participant #28 believes there will be friction between citizens and water authorities in the beginning, which will evolve to a 'Wikipedia effect' where water authorities and citizens learn together. He thinks that the support for this social learning is increasingly growing among water authority employees.

Viewpoint B
There are no post-sort interview fragments available.

Viewpoint C
There are no post-sort interview fragments available.

The water authority should stay in control of doing the measurements, since the water authority is indeed responsible.
Statement 42 (A: -2, B: +3, C: +2)

Viewpoint A
A person with viewpoint A believes that the water authority does not need to stay in control.

The water authority has to collect certain data in a certain way according to law, but according to factor A citizens can collect other and extra data (#11). The water authority already uses data collected by others, such as meteorological data, (#26) and could make use of citizen data, such as fish population data of sports fishermen (#25).

Viewpoint B
A person with viewpoint B strongly thinks that the water authority should stay in control.
People with viewpoint B are convinced that the water authority should stay in control of the monitoring. The data collection is uncertain (#03), because you don't know whether they will come on time or what the outcomes will be.

Viewpoint C
A person with viewpoint C thinks that the water authority should stay in control.

Participant #10 agrees, but adds a nuance as well. The water authority should collect essential data if it is to be used for policy, because one cannot see whether the volunteer is semi-professional or experienced, but citizen science data can be used illustrative or anecdotic.

10.3.3 Interpretation of statements regarding goals and citizen science typology

In the previous sections the narratives of the viewpoints A, B and C were given and interview fragments were used to deepen these narratives. In this section these results will be linked to the goals as defined in Part I (see Table 10.5) and the activities of the research process where citizens could be involved in (see Table 10.6). The researcher makes the link between the statements and post-sort interviews afterwards, as the goals were not directly inquired in the statements.

Goals of citizen science
All viewpoints, but especially viewpoints A and B, reveal support for the goal Increase knowledge. This is based on the factor scores of statements 8 and 9, which state that citizen science can be used to collect more measurements and to collect data more frequent. This is related to the goal 'Increase knowledge' by its definition to know more about a system, species or a theory (Tulloch et al. 2013, p. 130).

The goal of improving methods was mainly supported by viewpoint A. This is based on the post-sort interview results for statements 32 and 33, where participants with viewpoint A explained that citizen science data could be obtained with different methods, as long as it is clear how it is done and how data is validated. For the other viewpoints there were no interview fragments available for statements 32 and 33.

Raise awareness was mentioned in all three viewpoints as an important goal of citizen science (statement 2). The post-sort interviews of viewpoint A further clarified that this awareness should contribute to a change in behaviour of citizens, such that it contributes to water quality management. For the other viewpoints there were no post-sort interview fragments available for statement 2.

Concerning management support was found in viewpoint A. In the post-sort interviews of statement 10 and 11, where participants for example indicated that citizen science allows monitoring on places where there is currently no monitoring. Viewpoints B and C do mention that citizen science data can be used illustrative, but they do not refer to management related themes.

Public education was a central theme in viewpoint C, which considers schools a fundamental target group for citizen science (statement 14) and which considers teaching about one's environment important (15). The other viewpoints do support learning-related statements, but rather in the context of increasing understanding or explaining what a water authority does.

Social research, recreation and serendipity were not inquired and were not mentioned in the post-sort interviews.

Regarding policy support, the main goal seems to be to create a support base for the water authority's decisions. Participants with viewpoint A mentioned that citizens have to understand the water quality issues at hand and that taking decisions is always a compromise after balancing interests.

Table 10.5 – Overview of possible goals (adopted from Tulloch et al. (2011) and Hollow et al. (2013)) and goals supported in the viewpoints A, B and C.

	Monitoring in general	Viewpoint A	Viewpoint B	Viewpoint C
Increasing knowledge	x	x	x	x
Improving methods	x	x		
Raising awareness	x	x	x	x
Change behaviour		x		(x)
Create support base		x		x
Management	x	x	(x)	
Public education	x			x
Social research	x			
Recreation	x			
Serendipity	x			
Policy development	*x*			
(I) discover alternatives	x			
(II) educate about situation	x			
(III) measure public opinions	x			
(IV) persuasion/support base	x	x		(x)
(V) legal justification				

Table 10.6 – Overview of all activities citizens can be involved in (adopted from Cooper et al. 2009) and tasks supported in the viewpoints A, B and C.

	Contributory projects	Collaborative projects	Co-created projects	Viewpoint A	Viewpoint B	Viewpoint C
Choose or define question(s) for study			x			
Gather information and resources			x			
Develop explanations (hypotheses)			x			
Design data collection methodologies		(x)	x			
Collect samples and/or record data	x	x	x	x	x	x
Analyse samples		x	x	x		
Analyse data	(x)	x	x	x		
Interpret data and raw conclusions		(x)	x			
Disseminate conclusions/translate results to action	(x)	(x)	x			
Discuss results and ask new questions			x			

Steps in the research process
Several items contained statements related to the steps in the research (or monitoring) process identified in Chapter 4 (Bonney et al. 2012). In all viewpoints support was found for the collection of data by citizens (statements 7, 8, 9 and 10). Support for the remainder of the steps is absent or identified in Factor A solely.

In viewpoint A it is believed that citizens can validate their own data, if provided with a reference framework (statement 40). This shows that there is support for the involvement of citizens in the analysis of data and the analysis of samples.

There was no support found for citizen involvement in the problem formulation phase (statement 38) translating the results to action (statement 36). All viewpoints disagreed with the statement that citizens should be involved in the decision of the measures that have to be taken based on the conclusions of the monitoring.

10.4 Chapter summary: three viewpoints

A Q methodological approach was used to identify viewpoints of water authority employees on citizen science. 46 statements on citizen science in water quality monitoring were formulated, forming the Q set. 33 people from eight different water authorities were asked to sort the statements. Using factor analysis three factors were identified. Using factor rotation and factor interpretation these factors were formulated to three viewpoints.

The first viewpoint is called 'Citizen participation for data application'. People with this viewpoint consider citizen science suitable to raise awareness and to collect valuable data that can be used for water management. The practical constraints are surmountable.

The second viewpoint is called 'Water authority in control'. People with this viewpoint see added value of citizen science in raising awareness. They feel the water authority should stay in control of measurements, as they doubt whether the data can be of much added value except from illustrative use.

The third viewpoint is called 'Education and local knowledge'. People with this viewpoint see raising awareness and education as the most valuable functions of citizen science. Although data can be used illustrative, this is not considered most important. Citizen science is an interesting way to create outreach.

Participants were given the opportunity to explain their statement ranking in post-sort interviews. These interviews indicated that there is little support for involving citizens in other steps of the monitoring process than data collection. They further revealed that there are two sub-goals of raising awareness in viewpoint A: change citizen behaviour, such that they contribute to a good water quality, and create a support base for the work of the water authority.

In the next chapter the conclusion and discussion are presented for Part III.

Chapter 11
Conclusion and discussion for Part III

In Chapter 10 an introduction to Q methodology was given and a Q methodological approach was applied to identify viewpoints on citizen science in water quality monitoring at water authorities. The Q methodological approach was supplemented with a post-sort interview analysis. This chapter hosts the conclusion (section 11.1) and the discussion (section 11.2) of the methodology and results.

11.1 Conclusion for Part III

In the previous sections of this chapter Q methodology was introduced, the results of the Q methodological approach were presented.

A Q methodological approach was applied among 33 water authority employees using a set of 46 statements related to citizen science in water quality. Three differing factors were identified and narratives were formulated to obtain the corresponding viewpoints.

The first viewpoint, viewpoint A, is named 'Citizen participation for data application'. People with viewpoint A see more opportunities than challenges when it comes to citizen science. They see applications in physical application of the data, but also for active engagement of people.

The second viewpoint, viewpoint B, is named 'Water authority in control'. People with this viewpoint see potential for data contributions by citizens in an illustrative way, but state challenges in organisational capacity, expectation management and motivating citizens as well.

The third viewpoint, viewpoint C, is named 'Education and local knowledge'. People with this viewpoint focus on educational goals, such as teaching people about their environment and involving schools. They considers data applicability of secondary importance and mainly illustrative in nature.

The viewpoints identified a support base for seven goals of citizen science, as were described by Tulloch et al. (2011) and Hollow et al. (2013). The goals supported are: Increasing knowledge, Improving methods, Raising awareness, Changing behaviour, Management, Public education and Policy development for persuasion.

The results of the Q methodological approach indicate that there is a broad support base for contributory citizen science projects, but no support was found for collaborative or co-created projects. These higher levels of participation are not supported, probably because of current external (e.g. the legal obligations regarding water quality monitoring of the water authority) and internal (e.g. procedures for citizens to influence decision making) conditions.

11.2 Discussion for Part IIII

In the previous section conclusions were drawn based on the results of the Q methodological approach at water authorities. In this chapter the results and methods will be discussed. In the discussion I may switch to active voice, particularly when I discuss my beliefs or behaviour.

11.2.1 Methodological discussion for Q methodology

Three viewpoints were identified in the Q methodological approach, although a vast majority (25 out of 33) of participants loads on the first factor. Up to a certain extent that is inherent to factor extraction, which extracts the largest common factor first (Watts & Stenner 2012). In this study however, there are more people in the first factor than expected. This is probably caused by the strategy to recruit participants. This was initially done via a list of ecologists at all water authorities. These people, one person per water authority, were approached and asked to recruit colleagues to participate with different backgrounds. It then seemed to be that only people with a (positive) interest in citizen science participated, so a second strategy was initiated to reduce this bias. In this second strategy people were asked to recommend colleagues with an opposite opinion (e.g. participants #30 and #31) and people with a known different opinion than the majority of previously interviewed participants (e.g. participant #20) were approached as well. In Q methodology it is acceptable to have participants contribute to formulation of the Q-set and be part of the P-set at the same time.

People with different function profiles, different educational backgrounds and different levels of experience with citizen science participated, to increase the diversity of viewpoints. Participants were all provided with three diverse examples of citizen science (the annual bird count, iSPEX and groundwater monitoring) in order to ensure a basic level of knowledge on the topic. It cannot be denied though, that there are large differences among participants regarding their level of experience with and knowledge on citizen science. This does make it harder to translate the results to design principles, which is further impeded by the fact that not all participants have an equal role in data collection or data processing and they have different levels of influence on policy.

The final P-set consisted of 33 people, which is in line wit recommendations to use 30 to 40 participants (Van Exel 2005; Watts & Stenner 2012). There are studies with more than 40 participants though, for example Wolf et al. (2009) who used nearly ninety participants. It may have been beneficial to use a larger P-set, because there are only six sorts contributing to both viewpoints B and C. A larger sample increases the chance of including more of the existing viewpoints. On the other hand, more participants is more time consuming and due to the nature of the factor analysis it may be more difficult to distinguish between shared and individual opinions with an increasing sample. In future studies aiming at a sample of 30 to 40 participants it would be beneficial to use snowball-sampling (where participants are asked to recommend a colleague with a different opinion) as it increases diversity in the sample.

11.2.2 Researcher bias in Q methodology as an abductive approach

Q methodology is an abductive research approach (Watts & Stenner 2012), which means that I tried to understand and explain the data rather then describe it or test a hypothesis. The viewpoint narratives and the interview results were based on interpretations by one researcher. This approach is subjective in nature

In general I am positive towards using citizen science in water management, which may have led to a bias on the selection of statements. Selection and framing of statements and interpretation could have be done by multiple researchers to reduce this bias, but this was not feasible, as it would be too time consuming for the other person. This subjectivity is guided by the rigid nature of the Q methodological approach, with predefined steps and a pre-described statistical analysis method. I further applied two measures to reduce bias.

First, a pilot was organised with the pre-set of 65 statements instead, 6 people judged the pre-set of statements and their ideas were taken into account. For example, they commented that some of the statements that oppose citizen science were formulated to strict and thus discourage participants to choose this statement. The formulation was adjusted based on their recommendations. Peers further indicated that they considered some statements similar, for example A4 *("Data verzameling door burgers is niet nauwkeurig genoeg, dat moet je overlaten aan veldmedewerkers van het waterschap of andere specialisten.")* was comparable to H7 *("(Nieuwe) databronnen waarvan de nauwkeurigheid lager ligt dan die van laboratoriametingen moet het waterschap niet accepteren.").* The two were merged into statement 19 *("Data verzameling door burgers is onnauwkeurig en moet dus niet geaccepteerd worden door het waterschap.").*

Second, I validated the results with participants. Initially I planned to organise a workshop to discuss and deepen the results, but this was not feasible due to the summer holidays. I asked participants whether they recognised themselves in the viewpoint(s) instead. Asking feedback from the participants was used to assess the validity of the results. All 33 participants received an email with their factor loadings, the viewpoints (in Dutch) and the interview results. Thirteen out of this 33 participants (#01, #02, #04, #05, #09, #12, #14, #21, #22, #25, #26, #26, #27, #28) responded and unfortunately participants #05, #07, #15 and #18 were unavailable until after the finalisation of the research. Two participants placed a remark on their loadings on the viewpoints. Participant #28 indicated to see many parallels between viewpoint A and C, with a difference in an emphasis on social use (viewpoint C) or on technological use (viewpoint A). Participant #22 indicated that she had expected to load higher on B (now 0.25), because she sees viewpoint A as her ideal, but fears that accomplishing viewpoint B with her colleagues will be challenging already. Eleven respondents indicated to recognise themselves in the viewpoint where they had the highest loading. For example participant #06 indicated to look for participation with citizens and to have a 'why not?'-mentality and to recognise this in viewpoint A. This confirmation of the results strengthens me in the feeling that I followed the research steps thoroughly and with integrity.

Confusing and missing statements in the Q-set

Even though effort was made to align the formulation of similar statements, there were nuances such as 'important to' in item 5 versus 'necessary' in item 24. Some participants focussed on formulation and excluded statements that had a different nuance than they would prefer, while others did not seem to take formulation into account and seemed to focus on agreement with the underlying idea. Although these statements could have been aligned better, these nuances match the type of the statement, for example 'necessary' in item 24 refers to a logical action following a situation, while 'important' in item 5 relates to an ambition. It is therefore unlikely that the nuances in the statements negatively affected the results.

A majority of participants struggled with statements 6 and 16. The double deny made item 6 confusing, especially for participants disagreeing with it. However, there is no reason to suspect participants to have misinterpreted this statement, since virtually all participants made a joke or asked a question about this item. It would be advisable though, to avoid such double-deny sentences. Statement 16 was intentionally formulated containing two sentences: "Citizen Science is an interesting social innovation, but not suitable to actual collect useful data". As a consequence there are two parts to disagree or agree. Comments by several participants on item 16, even from people who did not discuss this item in the post-sorting interview, indicate that most participants who disagreed, disagreed with the second part of the sentence.

Influence of rotation on factor arrays

The final factor composed by the weighted average of participants with a high loading on this factor. Decisions leading to the selection of contribution sorts influence the final factor array and their consequences need to be discussed.

As described in Appendix J Humphrey's rule accepts factor loadings above 0.295, while the Significant Factor Loading (SFL) is 0.38. Using Humphrey's rule would result in more Q sorts contributing to the final factor arrays, although they would have a lower factor contribution and would have significant loadings on multiple factors more often. This may lead to a higher correlation between the factors and thus a less clear image of the different viewpoints. Therefore SFL will be used, meaning only factor loadings above 0.38 are used to construct to the final factor arrays.

It was also considered to leave out sorts that load significantly on multiple factors (Watts & Stenner 2012). However, in this case that would mean leaving out more than five sorts. That is considered too many on a total of 33, therefore this has not been applied.

I tried several rotations, ranging from an objective Varimax rotation (rotation I) to a rotation where I tried to maximise bias by selecting certain sorts (rotation IV). There were small differences between the factor arrays and factor correlations (see Appendix K), but I believe that in the end the influence of factor rotation is considered to be minimal.

11.2.3 Integration of post-sort interviews

Interviews after the sorting are mentioned in some articles (e.g. Van Exel 2005) and books (e.g. Stenner & Watts 2012) mention, but these are insubstantial on *how* to do this. Van Excel (2005), often cited as an important guideline, simply mentions: "Finally, the explanations Q sorters gave during the follow-up interview can be helpful in interpretation of the factors, in ex-post verification of the interpretation, and as illustration material (sometimes a single quote says it all)." (Van Exel, 2005

p. 10). This study demonstrated that post-sorting interviews strengthen findings and provide a deeper layer of understanding to the underlying values of the participants and thus enhance the aims of Q methodology as was claimed by Gallagher & Porock (2010). For example in the case of awareness the interviews led to the identification of underlying goals of behavioural change, outreach and create a support base.

The interviews represent just a subset of the whole sample, but they provided an important second layer of understanding in this thesis. It would have been advantageous to conduct the interviews after factor arrays were known, because that allows the researcher to ask all participants about all statements of interest (Gallagher & Porock 2010). The geographic spreading of participants prevented this. In this study therefore not all distinguishing, relevant statements were discussed with each participant, but it proved to be beneficial to analyse the fragments. An analysis with both the D-CCA and C-CCA approach as described by Gallagher & Porock (2010) has proven its strength as well in this situation where it is unknown which items will be distinguishing at the time of interviewing. If C-CCA was not taken into account the deeper level of understanding of awareness would not have been found. Excluding D-CCA would mean that there would have been no foundation for the difference found between factors A and B regarding motivation to participate for longer periods. I would therefore advise to integrate post-sorting statements in the methodology, even if practical constraints reduce the number of statements discussed.

11.2.4 Result discussion for Q methodology

Three viewpoints were developed as result of the Q methodological approach. Factors A and B were convincingly included as distinguishing viewpoints. The third factor (factor C) was included in analysis, despite its eigenvalue below 1.00. During factor rotation it further seemed that factor C was a mixture of factors A and B, rather than a viewpoint on its own. The crib sheets however further confirm that factor C is indeed a third factor. Factor C is not sharing more distinguishing items with factor A or factor B than the other two factors among themselves, as can be seen in Table 11.1. It can thus be concluded that inclusion of factor C as a third factor was the right decision.

It must be noted that there is a rather high correlation between the factors, which indicates that they are interrelated and have substantial overlap. This is not considered problematic, but it indicates that the three factors have a large common ground. Explanations might be found in the low diversity of the P-set, as discussed above, and in the fact that all participants worked at Dutch water authorities, with more or less similar policies and regulations. This may have influenced the result.

Factor A and C have the highest correlation, which was noted by the participants as well. Participants were sent the result analysis. Participant #30 noted that he considered viewpoints A and C similar, with a focus on data collection and education in both, although A emphasises the first and C the latter. The third viewpoint C reflects the social objectives that are typical for developed countries in citizen science: to increase awareness and scientific literacy (Gura 2013).

Viewpoint B reflects a lesser understanding of what is possible with citizen science. This may increase the critical attitude and may lead to problems in project set-up, as it will be difficult to design an adequate citizen science project if there is insufficient knowledge on possibilities.

Table 11.1 – Correlations between the final factor arrays A, B and C.

	A	B	C
A	1.00	0.26	0.43
B	0.26	1.00	0.35
C	0.43	0.35	1.00

Awareness: goals and a step towards support base and behavioural change

Support was found for several of the citizen science goals (as defined in Chapter 4). Raising awareness was high-ranked in all three viewpoints. Using the post-sort interviews three underlying aims raising awareness were identified: changing citizens' behaviour, communicate to citizens in a positive way and create a support base for measures taken.

The first sub-goal of hanging citizen behaviour can be considered a sub-goal of raising awareness. This sub-goal already emerged in Chapter 5 (case comparison) and can thus be confirmed as sub-goal. Research in conservation biology suggest that raising awareness alone is not likely to induce a change in behaviour (Schultz 2011; Cosquer et al. 2012), a motivational element, preferably by suggesting a positive, single and achievable action (Schultz 2011).

An example in the case of water quality monitoring could be:
A citizen is monitoring phosphate and discovers that levels are high in the local pond and is now aware of this local water quality issue. The water authority could encourage the citizen to contribute to management by stopping to feed the ducks, because their excreta may increase phosphate levels.

Create support for measures is similar to the goal 'policy, create support base' as defined by Tulloch et al. (2011). The participants (#9 and #12) who indicated that awareness could ultimately lead to increase the support base for measures have ranked statement 26 (reduce resistance) as moderately agreed and neutral. This suggests that they aim for a higher support base via raising awareness, without expecting a direct reduction in resistance. It could also be, as participant #14 stressed, citizen science can be used to increase understanding before you execute the measure ('persuasion') and should not be used to defend it afterwards ('justification'). The results of the interviews suggest that factor A (and likely, but untested factor C) considers the creation of support base for decisions to be a suitable application for citizen science as well. Hollow et al. (2015) based the conclusion that citizen science can be used in environmental monitoring to create a support base on a case study in koala management. The results suggest that their conclusions remain valid when the field of water quality management is considered.

Added value of post-sort interviews
The post-sort interviews included only responses from participants that load on factor A. Therefore, it will be impossible to draw conclusions for viewpoint B and C. Given the narrative of viewpoint C, it is expected though that factor C will include outreach as well as sub-goal of awareness. The eight participants, who all significantly load on factor A, gave the same score (+4) to statement 2. This example does show that post-sort interviews can indeed reveal underlying values or assumptions (Gallagher & Porock 2010) that remained uncovered with the factor arrays only.

Some participants mentioned that they have the feeling that the attitude of citizens towards the water authority is more positive in rural areas, also do rural communities know more about the water authorities activities and they collaborate active with farmers. They indicate that citizen science is a way to reach a new, urban audience. In community based monitoring programs in the USA rural participants were actively participating more often than urban participants (Overdevest et al. 2004).

11.2.5 Application in and generalisation to water resource management

The support for contributory projects is evident from the results; even the most sceptical factor B sees opportunities for data collection by citizens. There was no evidence found that one of the factors supports citizen science other than contributory projects. Statements 36 (say in measures taken), 38 (concerns of citizens), 40 (validation by citizens), 42 (water authority in control) and 45 (citizen influence on policy) contained element of collaborative and co-created projects and are hardly supported. This conclusion matches literature findings (e.g. Roy et al. 2012) and the findings of previous chapters (e.g. the case study in Chapter 5). If citizen science is to be used in more flexible governance structures, it will be essential for water authorities to move towards these higher levels of citizen involvement.

The viewpoints are expected to be representative to water authorities in the Netherlands, but only when it comes to citizen science in water quality monitoring as water quantity management and other tasks of the water authority were omitted and all participants were working in the field of water quality. Since only a subset of employees and of water authorities was involved it might be that there are other viewpoints that did not stand out in this study. Repeating the study on a national scale, followed by an R methodological study to evaluate distributions would justify generalisation of the results to the Dutch water authorities as a whole.

Part IV – Synthesis

In the previous parts of this thesis a research was proposed (Part 0) and several research steps took place. In Part I a literature review and a case study comparison took place to answer research sub-questions 1 and 4. In Part II reasons to engage in citizen science were investigated from a citizen perspective. In Part III the attitude towards citizen science was perceived from the viewpoints of water authorities. In this final part of the thesis, the findings of parts I, II and III are combined in a synthesis towards the composition of guidelines to implement citizen science for water authorities.

The synthesis provides a preliminary answer to the main research question ("*How can a citizen science project be designed for water quality monitoring initiated by Dutch regional water authorities, with special attention to the potential role of mobile crowd sensing?").* A design step has to be made from research findings to guidelines. This process is guided by a design pattern, the Seven-Layer Model of Collaboration (SLMC, Briggs et al. 2009). The process description is used to rationalise the synthesis step, although it must be kept in mind that this step is an abductive approach and thus based on the interpretation of the author. An elaborated description of the synthesis process is incorporated in Chapter 12. The tangible outcome of this process is a guideline written for water managers, which can be found in Chapter 13.

Chapter 12
Synthesis: process description

In the synthesis the results of the previous parts of the thesis (literature, survey and Q methodology) are integrated. The synthesis aims to answer the questions that arose during the workshop at Delfland in November 2014: how to implement citizen science. Insights from previous chapters with different levels of scientific validity were translated into guidelines for water authorities. The guidelines are written with a water authority in mind that has heard of citizen science and wonders how they could deploy citizen in their activities. This chapter is written in the active voice, as it is based on my interpretation and combination of the results.

Summarising the previous chapters initially an extensive literature review was carried out that, among others, identified key success factors in the project design phase, at the project start and while the project is running. These literature findings were compared to four case studies in citizen science and mobile crowd sensing. Additionally three different viewpoints of water authorities regarding citizen science were identified using Q methodology. These viewpoints were showed parallels to the goals and typology of citizen science that was identified in literature. Citizen intention to participate and their motivations were mapped in a survey. Finally the Technology Acceptance Model was used to identify relevant aspects of the application of a mobile crowd sensing application for water quality monitoring.

The Seven-Layer Model of Collaboration (SLMC, Briggs et al. 2009) was used as a design pattern to structure the synthesis process. In the following sections I will outline how I combined the findings of the previous parts of the thesis (literature, case studies, survey, Technology Acceptance Model and Q methodology) into these guidelines.

12.1 Integrating the research into the Seven-Layer Model of Collaboration

Five research parts are integrated into the Seven-Layer Model of Collaboration (SLMC) to develop guidelines: 1) the survey on citizen motivations and barriers (‘survey’); 2) the case studies (‘cases’); 3) the Technology Acceptance Model (TAM); 4) the characteristics of mobile crowd sensing found in literature (‘MCS’); 5) the viewpoints emerging from the Q methodological approach (‘Q method’) and 6) the final key success factors (‘KSF’). The figure below illustrates how this integration of research findings in the SLMC is done and the following sections elaborate on each step.

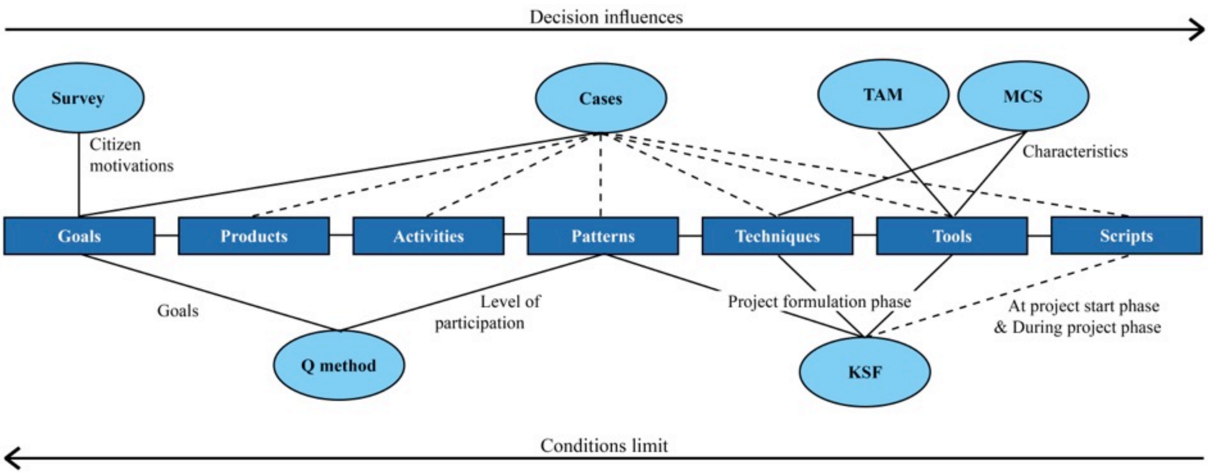


Figure 12.1 – Overview of how I integrated the research findings with the Seven-Layer Model of Collaboration. Dashed lines (- -) indicate an illustrative use of the study’s findings as examples.

12.2 Contribution of findings per layer

12.2.1 Goals layer: integrating Q method, the cases and the survey

The first step will be to integrate the information available for the goals layer. As illustrated below I used the cases and the Q method for this purpose.

Goals are desired states or outcomes (Briggs et al. 2009). Goals are positions as a starting point of the SLMC design pattern decision process, because "without a group goal, collaboration does not exist." (Briggs et al. 2009, p. 8).

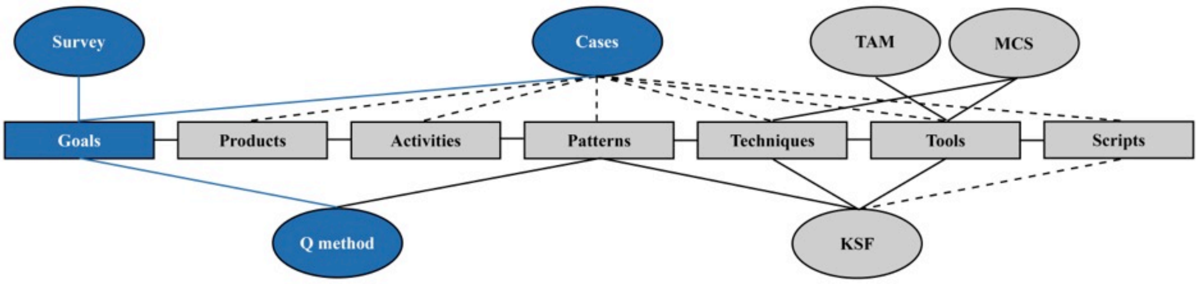


Figure 12.2 – Integration of findings of the cases and Q method in the Goals layer.

As mentioned before, citizen science is a means rather than a goal in itself, which implies that there are overarching goals. During the research, nine different, but non-exclusive goals were identified in the literature review and the cases. The Q method suggested which goals identified in literature (Tulloch et al. 2013; Hollow et al. 2015) can be applied in water quality monitoring. These goals are for citizen science as means to increase knowledge, improve methods, raise awareness, change behaviour, management and create a support base for policy. In the first layer of goals, the water authority should decide on the goals it wants to achieve. In the guidelines I enumerate the six abovementioned goals and give an example for each of them.

These goals are non-exclusive, as was demonstrated in both the cases and the Q method. The four citizen science cases studied had multiple goals and all three viewpoints of the Q method include at least two goals. A combination of goals is therefore possible and I suggest it may even be favoured if citizen science contributes to multiple goals. If a project supports multiple goals, there are more points of engagement for both citizens and water authorities, which can enhance both citizen motivation to participate and the water authority's internal support.

The goals probably already indicate that there are stakeholders involved: citizens. Additionally the cases prove that having strategic partners is beneficial as well. Here stakeholder's motivations have to be aligned to define a group goal. The project will not be successful "Unless the private goals of individuals are congruent with the group goal (...)" (Briggs et al. 2009, p. 8). In this case that means that I have to integrate citizen's motivations and partner's goals with the goals of the water authority. Given the rather generic nature of the guidelines, and thus the absence of specific case with specific actors, I will just mention the citizen motivations and barriers that I found in the survey. I will further provide an example from the cases of how motivations were integrated in that situation.

The results of the case study are described in Chapter 5, section 5.2. Results of the survey on citizen's motivations and barriers can be found in sections 7.2 to 7.5. The results of the Q methodological approach can be found in 10.2.

12.2.2 Product and Activities layers: discussing possibilities

The next step will be to translate the goals to tangible or intangible products. The decision on products results in a relevant set of possible activities.

Products are "artefacts and outcomes that constitute goal attainment." (Briggs et al. 2009 p. 8). In the Products layer it is decided what the sub-goals of the project are and what outcomes contribute to this goal.

Activities are defined as "…subtasks that, when completed, yield the products (…)" (Briggs et al. 2009 p. 3).

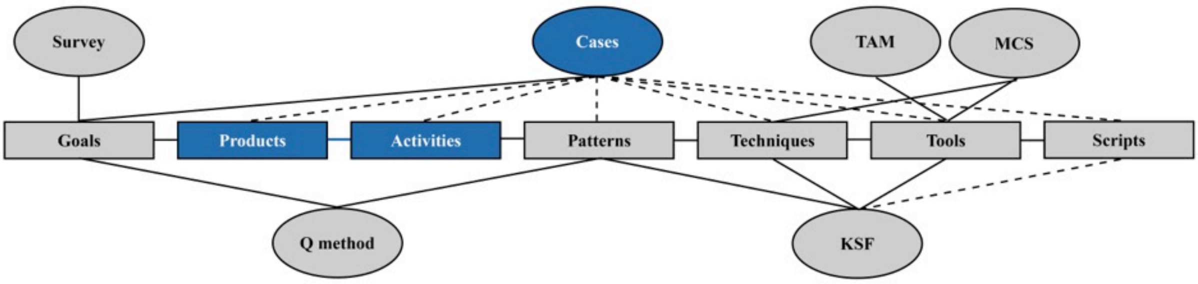


Figure 12.3 – Discussing the Products and Activities layer.

In the Activity layer is it decided whether citizen science is the right activity or means to use for the defined goals and products. The filling of the model resembles a fan or a tree diagram: one goal can have multiple sub-goals and related products; there are several possible activities per product; each activity can be shaped by various patterns; etc. I will not name all possible routes, since this is neither aimed for nor feasible. Constraints put by one layer on the other will be mentioned where applicable and examples will be provided where possible.

Sub-goals and various products for each goal were identified, primarily inspired by the case studies and the Q methodological post-sort interviews. An important point in this section is that citizen science should never be a goal, but always an activity to achieve goals via tangible or intangible products. In the guidelines one example is given to illustrate the link between goals-products-activities and to demonstrate the line of thoughts that should be followed in these three layers.

The results of the case study are described in Chapter 5, section 5.2.

12.2.3 Patterns layer: integrating the Q methods, cases and key success factors

Patterns of collaboration are "observable regularities of behaviour and outcome that emerge over time in teamwork." (Briggs et al. 2009, p. 3).

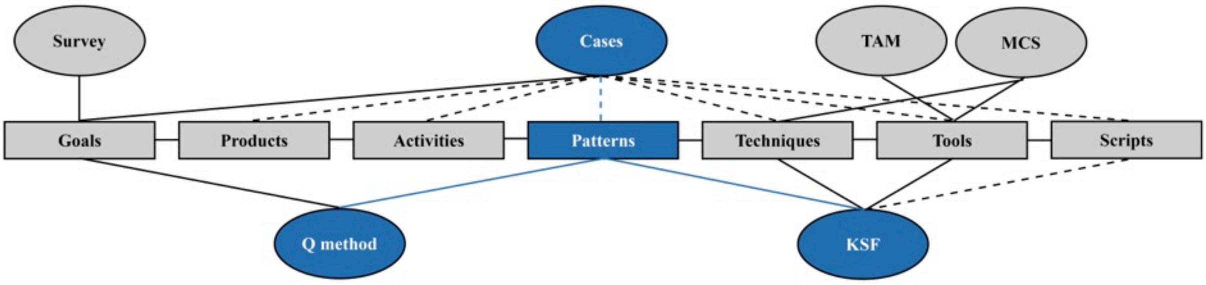


Figure 12.4 – The Patterns of collaboration in the guidelines focus on the level of citizen participation, which originates from the Q methodology and the key success factors. It is illustrated by examples from the cases.

This set-up (or design) of a citizen science project takes place in the 'project formulation' phase and consists of the remainder of the layers (Patterns, Techniques, Tools and Scripts). In these layers it is determined what the project will look like in terms of interaction, technology used and the organisation of the whole.

This implies that the identified key success factors (KSF) play a role only after this 'phase zero', where the decision to use citizen science is made. The KSF concern the practical features of the citizen science project, such as techniques, patterns and tools. Therefore the KSF become relevant only after the decision has been made to use citizen science.

The results of the Q methodological suggest that there is no support base for other types of citizen science than the contributory model. This will be incorporated in the guidelines of the Patterns layer together with a part of the key success factors.

The framework of KSF can be found in Table 4.1 The results of the case study are described in Chapter 5, section 5.2. The results of the Q methodological approach can be found in 10.2.

12.2.4 Technique layer

Techniques are "reusable procedure[s] for invoking useful interactions among people working towards a group goal." (Briggs et al. 2009, p. 3).

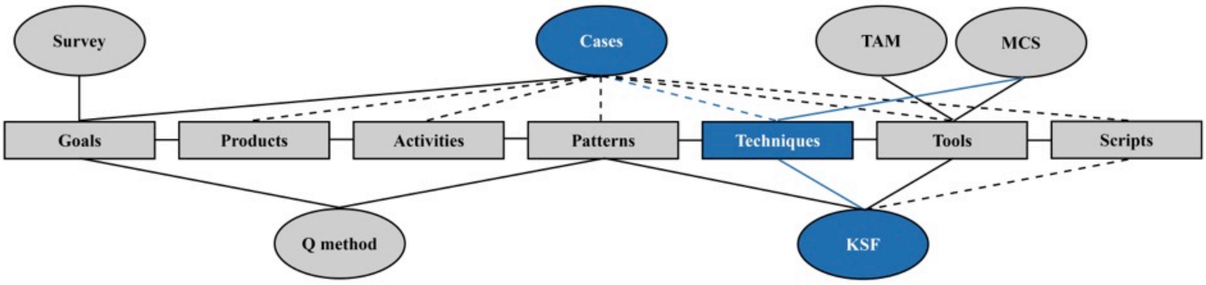


Figure 12.5 – The Techniques used are given shape by the key success factors and are illustrated with examples from the case study.

The techniques describe the way actors in the citizen science project work together. Such techniques may include feedback sessions or meetings. Mobile crowd sensing (MCS) is incorporated as a specific technique.

The framework of KSF can be found in Table 4.1 The results of the case study are described in Chapter 5, section 5.2.

12.2.5 Tools layer

Tools are "artefacts or apparatus used in performing an operation (…)" (Briggs et al. 2009, p. 3).

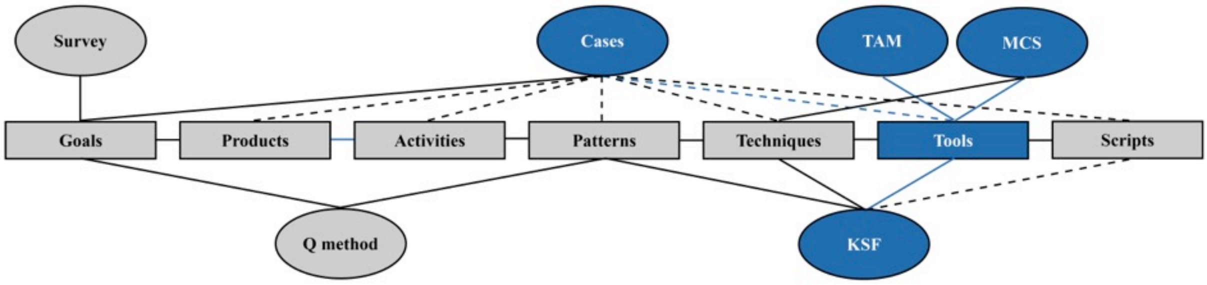


Figure 12.6 – The Tools layer concentrates on Mobile Crowd Sensing (MCS) as specific tool, with the cases, key success factors and MCS characteristics as input. The Technology Acceptance model serves as example for the integration of models in the tool design phase.

In the Tools layer I zoom in to one tool in particular: mobile crowd sensing (MCS). Characteristics of MCS, the cases and the use of the Technology Acceptance Model (TAM) in my thesis illustrate how important it is to match the tools with the goals, level of interaction and citizen audience. The characteristics of MCS mainly provide limitations (e.g. because of privacy issues) and opportunities (e.g. because it allows large scale projects) to the other layers, while the key success factors (KSF) provides practical advices. The TAM is used as example of how such models can support decision-making, because it highlights the importance of relevance of the tool (an application).

The framework of KSF can be found in Table 4.1 and the characteristics of MCS in section 4.4. The results of the case study are described in Chapter 5, section 5.2. The TAM is described in Chapter 8.

12.2.6 The script layer

Scripts "provide guidance about the things people in various roles should do and say (…)")Briggs et al. 2009, p. 9).

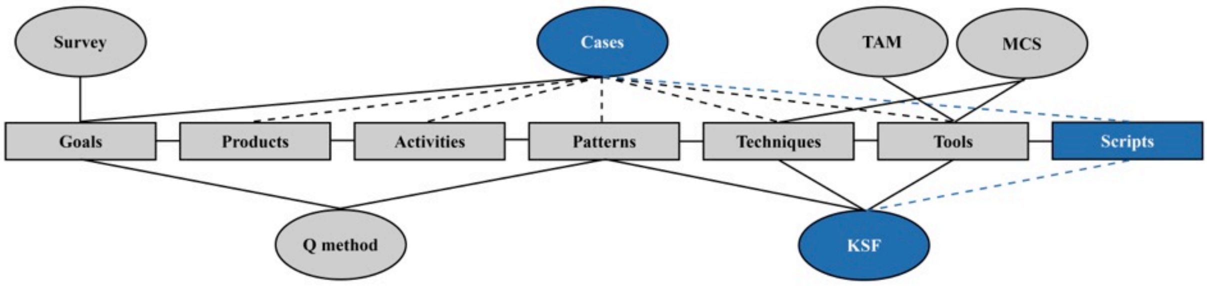


Figure 12.7 –Examples from the key success factors and the case studies will be given to illustrate the Scripts layer.

The script step gets the least attention in this guideline, since this is highly case specific and focuses on the level of protocols and planning. An example will be given though, to illustrate the importance of this step. This example is based on the key success factors (KSF) and the cases.

The framework of KSF can be found in Table 4.1 The results of the case study are described in Chapter 5, section 5.2. The results of the Q methodological approach can be found in 10.2.

12.3 Formulation of the guidelines

In the previous sections the Seven-Layer Model of Collaboration (SLMC, Briggs et al. 2009) is outlined. Per layer the scientific results contributing to the guidelines are mentioned. This description aimed to inform scientists and others interested about the procedure used to develop the guidelines.

The guidelines itself are targeted at practitioners and concentrates on five questions that practitioners at water authorities frequently asked me during the research:

- What is citizen science?
- How can citizen science add value to the water authority?
- How to decide whether citizen science an appropriate means for the water authority?
- How to set up a citizen science project?
- How can citizens be motivated to participate for longer time periods?

I choose these five questions as people at water authorities frequently asked them to me, both during the explorative interviews to collect statements and during the post-sort interviews. I imagined myself that a water authority would ask me these questions. The answer I would give, based on the research findings, was written down in a structured way, following these five questions. As a consequence, in the next chapter the SLMC is not explicitly followed, but the guidelines are formulated along the line of the five questions.

Chapter 13 Synthesis – product

This document is written for water authorities that consider using citizens for monitoring, often referred to as 'citizen science'. The document will answer five common questions about citizen: What is citizen science? How can citizen science add value to the water authority? How to decide whether citizen science an appropriate means for the water authority? How to set up a citizen science project? and How can citizens be motivated to participate for longer time periods?

13.1 What is citizen science?

Citizen science is a type of citizen participation. In water authorities it is often referred to as identical to 'participatory monitoring'. Citizen science is defined as: a scientific research project, whereby citizens (non-professionals) conduct one or more parts of the process. Often this will be data analysis, data collection and/or data interpretation. However, citizens could as well be involved in the framing of questions or translating the results into action.

The most famous example of citizen science is the annual bird count, where large group of volunteers record the presence of bird species in their surroundings. Combining all the contributions of individual citizens increases insight in the distribution of species. By conducting the bird count over multiple years, it will also be possible to analyse a trend.

Another example of citizen science is iSPEX. This was a single-event project, where a large group of citizens collected data on particulate matter (fijnstof) using a smartphone plug-in device.

Citizen science is often mentioned to be useful in data collection. It offers the opportunity to collect data on a higher spatial and temporal resolution. Additionally citizen science is said to be useful in raising awareness and to educate people.

For example in the bird count project, people increase their knowledge on bird species and their behaviour.

In the following guideline we will show more goals where citizen science could be applicable. Additionally we provide advice on how to set up the project.

Interested in reading more about citizen science in general?
Jonathan Silvertown has written a comprehensible article that describes the origin of citizen science, that provides several examples and discusses application of citizen science.
→ "A New Dawn for Citizen Science" as published by J. Silvertown in 2009.

13.2 How can citizen science add value to the water authority?

Three main benefits of citizen science are identified:

- **Low cost data collection method**
  Collecting data with citizen science can be, if well designed, an economic way to collect additional data. This data could serve to improve the understanding of how a system works, but could also serve to identify which areas require more thorough monitoring. Citizen science could also be a way to monitor areas that otherwise would not have been monitored.
- **Flexible monitoring scheme**
  Citizen science can be used for temporary monitoring or for monitoring at different locations.
- **Involves citizens**
  Citizen science offers a new, positive way to engage citizens.

13.3 How to decide whether citizen science is an appropriate means?

To answer how a citizen science project is set up we need to go beyond knowing what citizen science is and what associated benefits there are. Citizen science serves a higher end, just like communication campaigns, monitoring programs and physical measures are ways to achieve goals. It is therefore important to realise that citizen science is a means, not a goal in itself. What makes citizen science interesting is that it is a means that can serve many purposes. It can be, for example, used to increase knowledge or to educate people.

Education and knowledge generation are not the only goals of citizen science. Several studies have been conducted on the goals that citizen science could serve. In total nine goals for citizen science were identified in such literature. These goals were confirmed to be suitable in the Dutch context. With a subset of the Dutch water authorities we identified three different ways to view citizen science. These three ways provide support for six of the identified goals as suitable for water quality monitoring.

These six goals are listed below and labelled A to F. Each goal is illustrated with at least one example from one of the three cases. It can be noted that each project serves several goals, as each project occurs several times in the list. The number behind each example refers to project information at the end of the document. Examples without a number

A. Increase knowledge
Citizen science used to increase knowledge focuses on collecting data to create a deeper understanding of the water system or of certain species. This knowledge is collected for the sake of knowing, without a direct application.

Example – The Tuintelling (Garden Count) was initially started to increase knowledge about city wildlife. There is little knowledge about birds in cities and for other specie classes (e.g. amphibians) cities are blank spots. Increased understanding on the species occurring in cities and seasonal patterns is therefore the main goal of the project. [1]

B. Improve methods
Citizen science could also be used to improve monitoring methods. Alternatively, it could be used to test and evaluate several methods to identify which one is best.

Example – The iSPEX project used a new measuring method to measure the polarisation (scattering) of sunlight. The size and composition of particulate matter in the sky determines this polarisation. The SPEX (Spectropolarimeter for Planetary Explorations) is "designed to measure aerosol and cloud particles in atmospheres of planets within our solar system."[8] and the iSPEX is a simplified version to be used with an iPhone app. With iSPEX the RIVM aimed to put a new method to proof using citizen science and the iSPEX device. [2]

C. Management
The collected citizen science data will be used to inform decision-making to improve resource management. This data could serve to improve the understanding of how a system works, but could also serve to identify which areas require more thorough monitoring. Citizen science could also be a way to monitor areas that otherwise would not have been monitored.

Example – The Tuintelling (Garden Count) used citizen science to gain insight in the seasonal and migratory patterns of city birds. This insight will be used to sharpen the conservation management in urban environments. If it for instance turns out that a certain species prospers in arboreal areas, bird protection programs can make a case for increasing the number of trees in urban areas. [1]

[8] Quoted from http://ispex.nl/en/techniek/spex.

D. Public education

Citizen science that has education as a goal aims to increase public knowledge on a certain topic (the topic of monitoring).

> *Example – The iSPEX project was created to educate people about the work of the RIVM (Rijksinstituut voor Volksgezondheid en Milieu, National Institute for Public Health and the Environment). The project is named after the iSPEX, a smartphone accessory to be attached in front of an iPhone's camera, and aimed to teach people about particulate matter, about the technology used and the (new) measuring method spectropolarimetry. [2]*

E. Awareness

Citizen science could also serve to increase information availability on long-term or short-term effect or processes. This goals is closely related to the next.

> *Example – The Tuintelling' (Year Round Garden Count) asks citizens to monitor wildlife in their garden throughout the year. Every week they report on the species they have seen and/or on the number of animals of one species in a certain time frame. By doing so, citizens will realise how important for example their garden tree is; because a certain bird returns to it every day. The organising parties (nature associations) wish to raise awareness about the importance of gardens for city wildlife. [1]*

Using citizen science to create awareness could ultimately lead to a behavioural change of these citizens.

> *Example – The Tuintelling' (Year Round Garden Count) aims to increase awareness about the importance of gardens, but ultimately hopes to encourage citizens to adjust their garden so that it will be more attractive to wildlife. [1]*

F. Policy development

Citizen science can be used to aid decision making. A distinction is made between five sub-goals.

In early stages of the policy making process, when there is no desired alternative yet, citizen science can be used to explore alternatives. The water authority can formulate issues together with citizens and to develop alternative scenarios (1^{st} sub-goal). Alternatively citizen science could be used to measure (2^{nd}) the public opinion, as citizen science brings concerns of citizens to the surface, or to educate (3^{rd}) people about the issues at hand in the area and about the identified policy alternatives.

In a later stadium, when there is a desired alternative, citizen science can be used to persuade (4^{th}) public opinion to this preferred alternative. Citizens may change their opinion on a proposed policy with increasing insight in the situation.

> *Example – The 'crowdsourcing in Reeuwijkse Plassen' (CiRP) emerged out of a feedback group on plans of the water authority to install a flexible water level in the area, assuming this would not affect groundwater levels. Residents were afraid of negative consequences of this water level. The water authority suggested a contributory citizen science experiment, where citizens collect groundwater and surface water levels. By doing so citizens gain insight in the relation between these two. The project aims to increase citizens' understanding of the water system and therewith persuade them towards the preferred policy of flexible water levels. [3]*

In a final stage of the decision process, when a preliminary decision is made, citizen science can be used to legitimise (5^{th}) this decision.

Interested in reading more about citizen science goals related to policy development?
This scientific article provides deeper insight in the application of the five sub-goals in an example of koala management in South Australia.
→ "Citizen Science for Policy Development: The Case for Koala Management in South Australia" as published by Hollow et al. in 2015.

Recreation, serendipity, social research
For three other goals no support base was found, although water authorities should beware overlooking them. These goals are recreation, serendipity and social research.

Citizen science is used increase the well being of people when **recreation** is the goal of citizen science. Citizens could be involved in activities that match the hobbies of citizens or that contribute to recreation.

Example – Zwemmen in Brabant aimed to provide up to date information on water quality in a swimming lake in Brabant. Water authorities in Brabant shared up to date water quality information with citizens via a website and a mobile application. Via the application citizens could share feedback on the swimming location, therewith enhancing recreation of other citizens. [4]

Citizen science could also be used to discover unexpected things (**serendipity**). In such projects the results are unpredicted beforehand. This makes this goal less likely to be applied by water authorities, as it may be difficult to defend the expenses on a project with unknown outcomes.

Example – The Tuintelling (Garden Count) was initiated to fill knowledge gaps about the distribution of several classes of species in urban areas. For some classes of species (e.g. birds) there were expectations, based on similar programmes in other countries, but for some classes of species (e.g. amphibians) cities are blank spaces. The results are therefore likely to contain surprising results. [1]

Citizen science lends itself perfectly for **social scientific or economic research**. Social studies could focus on how people behave in a citizen science project or whether the project increased citizen knowledge on a certain topic. Economic research could investigate whether citizen science projects can reduce the increasing financial pressure on water management that is persistent especially in areas with a low population density and corresponding high per capita costs of water management.

Example – The iSPEX project focused on measuring particulate matter with increasing scientific knowledge and public education as main goals. On top of this a social research took place to investigate why people had participated in the project and to assess to what extent participation had increased knowledge on the topic. [2]

Interested in reading more about citizen science goals in general?
This scientific article provides deeper insight in the difference between the discussed goals (except policy development) using examples from bird monitoring programmes.
→ "Realising the Full Potential of Citizen Science Monitoring Programs" as published by Tulloch et al. in 2013

Design tip: Comprehend what citizen science is and decide whether it is suitable as a means

13.3.1 Step 1a. Formulate clear goals of the project.

The first step in deciding whether or not to use citizen science is to clearly state goals. Is the project aiming at knowledge generation, at increased awareness or at one of the other goals?

This does not have to be a single goal. It is even arguable that the best projects, or at least the best citizen science projects, combine multiple goals.

> *Example – iSPEX clearly stated two goals: increase knowledge and public education. These goals can enhance each other as the iSPEX consortium, who facilitated the project, could learn themselves (increase knowledge) by teaching citizens (public education) on particulate matter and the iSPEX device. [2]*

13.3.2 Step 1b. Formulate sub-goals and related products

If the goals are stated one can formulate sub-goals. For each sub-goal a tangible or intangible product should be defined. Is the goal to increase knowledge? A list of what needs to be known on what topic would be a tangible product. Is the goal to raise awareness and change behaviour? A definition of what this awareness consists of which knowledge/information needs to be provided could be an intangible product. One goal can have multiple sub-goals.

> *Example – In Tuintelling (Garden Count) the facilitator Vogelbescherming aims to raise awareness on the importance for conservation. A sub-goal could, for instance, be raising citizen understanding of the importance of trees for garden birds, as it can be used to illustrate the importance of planting trees in a bird protection programme. [1]*

13.3.3 Step 1c. Determine which activities are most suitable to deliver the products.

Now the goals and sub-goals are formulated and tangible and intangible products are defined. The next step is an important decision: what are the most suitable means to deliver the products and achieve the goals?

Several different means are available for each goals and it will be context dependent what means are most suitable. All alternatives should be considered and an informed decision should be made. A combination of means could also be preferred, and one of these could be citizen science.

> *Example - Awareness can be created via a media campaign or by having citizens monitor and inform them about the implications and causes of certain results. Alternatively a combination of the two can be chosen.*[9]

[9] A water authority employee gave this example in the post-sort interview in the Q methodological approach to identify viewpoints on citizen science.

13.4 How to set up a citizen science project?

Once citizen science is chosen as (one of) the means to achieve ones goals, the details of the project need to be filled in.

Design tip: Collaborate with partners

13.4.1 Step 2. Identify partners

Now that it is decided to use citizen science, it is important to identify strategic partners. Strategic partners could:

- attract a wider audience or have access to a specific audience;
- fill gaps in knowledge, skills and resources;
- increase the credibility of the project.

Various cases demonstrate such partners can host a wide range: research institutes (e.g. universities), similar organizations (e.g. other water authorities or municipalities), commercial partners (e.g. outdoor stores or software developers) and interest groups (e.g. environmental protection groups or neighbourhood committees).

Firstly, partner organizations can increase the audience reached. Although the number of participants varies greatly among projects, most citizen science projects encountered in the research conducted to develop these guidelines aim at large numbers of participants. Based on the goals a target audience was defined. These people need to be reached in the most effective and efficient way.

In general the profile of a typical volunteer is that s/he is: higher educated, employed, native Dutch and middle-aged. Without targeted marketing and recruitment this group is the most likely to participate. Partnering with relevant organizations is therefore a key success factor. Partner organizations increase the reach of the project and can attract a different audience.

> *Example – The iSPEX project used a plug-in device for iPhones to measure particulate matter in the atmosphere. The nature of the project and the complex topic meant that it mainly attracted higher educated participants. By partnering with the Longfonds (Lung Fund) the project had access to people with a lower socio-economic status as well, as this group represents the majority of people suffering a lung disease.10 [2]*

Secondly, a partner organisation may have knowledge, skills or expertise that is not present within the water authority.

> *Example – The Vogelbescherming and SOVON recently started a citizen science project that requires volunteers to monitor year round. This will attract a different audience of both experienced and inexperienced volunteers. The Vogelbescherming primarily has worked with inexperienced volunteers, while SOVON usually works with experienced volunteers. By combining their experiences they were able to set up a project that is both attractive to inexperienced and experienced volunteers. [1]*

Partner organizations may also enhance the credibility of a project. Since there is little experience with citizen science organised by authorities it may be advisable to partner with organizations with similar interests.

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[10] The latter claim comes from an interviewee and was not verified afterwards, as it is used as an illustrative example in this context.

It must be kept in mind that these partner organizations have goals and interests as well. These need to be aligned to increase collaboration efficiency and maximise impact of the project. Additionally citizens have reasons to participate as well. By identifying factors that motivate them, the participant rate can be increased.

An important 'partner' that is easily overlooked is the own organisation. Citizen science is a new phenomenon and may suffer from a lack of internal support, caused by a lack of understanding of citizen science, or because they do not recognise the added value of the data collected by citizens.

> *Example – In iSPEX a main challenge perceived by the coordinators was to create internal support for the project. Colleagues criticised the simplifications made, although these were necessary to make the project accessible for citizens. [2]*

Design tip: Beware of financial motivations

Citizen science is known as a low-cost data collection method, but it should be kept in mind that large investments are associated with citizen science as well. There is a need of infrastructure to process the data, there should be a coordinating team throughout the project and possibly investments are needed to facilitate equipment for participants.

> *Example – Several employees at water authorities indicated in interviews[11] that citizen science data might require additional infrastructure. In case the citizen science data has the same format as current data sources the additional costs will be minimal, as it implies doing the same analysis steps on a larger database. In case citizen science data differs (e.g. in monitoring locations or sampling frequency) additional software will be needed to integrate this data with the existing database.*

Whether citizen science is a low-cost monitoring method depends on the number of participants; the costs per participant/per data entry decrease with large numbers of participants and the project. The required number of participants depends on the investments needed and the value assigned to the outcomes of the project. Citizen science may be preferred even if the direct financial balance is negative. Citizen science can create other values on other fields (e.g. social value or environmental value). It might even contribute indirectly when changed citizen behaviour improves water quality and reduces management expenses.

> *Example – In both the citizen science projects Crowdsourcing in Reeuwijkse Plassen (CiRP) and Tuintelling (Garden Count) a small number of people (<5) works part-time on the citizen science project in a coordinating function. The investment in terms of time and effort is similar, but the collected dataset are from a different order of magnitude: Tuintelling collects weekly data from 3300 participants, compared to weekly data entries from ten participants in CiRP. Costs per data point are higher for CiRP, but this is considered subordinate as the project adds value by building trust among residents and reducing unrest. [1] [3]*

[11] The post-sort interviews in the Q methodological approach to identify viewpoints on citizen science.

Key success factor: Match patterns of collaboration with organisational capacity (regarding coordination and support)

13.4.2 Step 3. Determine patterns of collaboration: governance and level of involvement

The goals of a project and the corresponding activities determine the characteristics of a project to a great extent. The level of citizen involvement can be classified in three levels of involvement: contributory, collaborative or co-created.

A water authority will be most likely to plan a contributory project, as collaborative and co-created projects are irregular. The research conducted to develop these guidelines found support for contributory projects only in the eight investigated water authorities. This is a logical situation, rather than an issue. There is little experience with citizen science in Dutch water authorities, thus a natural step is starting with projects with lower level of involvement. These guidelines focus on the contributory projects, for this reason.

Table: the three different levels of involvement

	Contributory projects	Collaborative projects	Co-created projects	Support base found for
Choose or define question(s) for study			x	
Gather information and resources			x	
Develop explanations (hypotheses)			x	
Design data collection methodologies		(x)	x	
Collect samples and/or record data	x	x	x	x
Analyse samples		x	x	x
Analyse data	(x)	x	x	x
Interpret data and draw conclusions		(x)	x	x
Disseminate conclusions/translate results to action	(x)	(x)	x	
Discuss results and ask new questions			x	

Contributory citizen science
In a contributory project the water authority will define the question, analyse the data and translate the results into action.

Example – iSPEX emerged from a question defined by scientists, namely 'would this iSPEX device be able to measure particulate matter?'. Citizens were involved in data collection, but scientists do all other research steps. [2]

Collaborative citizen science
In a collaborative project citizens are involved in more steps of the process, but the water authority stays in control and defines the question and the measures taken.

Example – Crowdsourcing in Reeuwijkse Plassen is categorized as a contributory project with elements of collaborative citizen science. Citizens were primarily involved in data collection, but were invited to share their thoughts on the interpretation of the data as well. Water authority Rijnland provided a rough data analysis, but interested citizens could access the full data set to analyse the data themselves. [3]

Co-created citizen science
In a co-created project citizens are involved in all steps and they may even initiate the project. There are no examples identified in the research conducted to develop these guidelines.

We advice to start with contributory projects and only turn to collaborative projects after gaining experience. This advice should not hamper choosing a collaborative project though, as experience could naturally be sought outside the own water authority, see step 2. In the near future co-created projects are not expected, at least not on a large scale, as the water authority is bound to a restricted set of activities and cannot engage in all initiatives.

Interested in reading more on governance structures in citizen-based monitoring?
This scientific article provides deeper insight in the three types of governance and provides examples for all of them.
→ "A Review of Citizen Science and Community-based Environmental Monitoring: Issues and Opportunities." by Conrad & Hilchey in 2011.

Besides the level of engagement it is important to define a governance structure. There are three possible structures for governance with increasing citizen initiative.

Consultative governance
In consultative governance the water authority identifies a problem, while citizens do the actual monitoring. This is the most common governance structure for government-led projects. This structure can lead to short-term success. It is especially suitable to build time series in long-term monitoring. This governance structure is less suitable if there are many stakeholders to be involved.

Example – Crowdsourcing in Reeuwijkse Plassen is a citizen science project where citizens monitor water levels. The water authority in the area identified a problem, namely insufficient understanding of citizens in the dynamics of groundwater and surface water levels in the area. The water authority subsequently recruited citizens to monitor water levels. [3]

There are no examples of collaborative and transformative governance available in the three cases studied. Given the nature of these governance structures they are not the most likely option for water authorities, but for reasons of completeness they are included.

Collaborative governance
The collaborative governance structure is suitable for a project with many stakeholders. It is most often applied in areas without political demarcation, for example nature areas. A board representing a wide range of stakeholders administers projects with collaborative governance. In this governance structure citizens have a higher influence on decision making than in the other structures.

Transformative governance
In a transformative structure citizens identify a problem and try to raise awareness of, for example, governments. Any stakeholder but the water authority could initiate a transformative citizen science scheme. Transformative governance can be successful if the water authority supports the local initiative, although these projects have most chance of success if they are executed with a small group of people.

It is important to keep limitations within the organisation into account when deciding on the level of collaboration. For example: it might be that it follows from the goals that citizens should be involved from the design of methods to the analysis of results. If the organization has insufficient capacity or resources to coordinate and support the participating citizens it may be necessary to reduce the number of participants or to choose a lower level of participation.

Interested in reading more on governance structures in citizen-based monitoring?
This scientific article provides deeper insight in the three types of governance and gives examples for each governance structure.
→ "A Review of Citizen Science and Community-based Environmental Monitoring: Issues and Opportunities." by Conrad & Hilchey in 2011.

13.4.3 Step 4. Define techniques and tools

Techniques and tools included all practical means that are used to facilitate the collaboration pattern. These could be:

- Monitoring equipment
- Meetings
- Evaluation reports
- Citizen training
- (Online) participant community

Design tip: Match techniques with organisational capacity (regarding data processing)

Low-cost and easy-to-use test kits and monitoring equipment are becoming increasingly available. Not all available instruments will be discussed. These guidelines zoom in to a specific technological tool: the smartphone. Monitoring with smartphones by citizens is called mobile crowd sensing (MCS).

Three reasons make smartphones interesting monitoring devices. First, a majority of Dutch adults possesses a smartphone. Second the increasing technological developments result in high quality sensors in smartphones that can be used to collect data and third in an increasing availability of plug-in devices for smartphones. The quality of smartphone sensors is increasing and the costs of plug-in devices are decreasing, offering a lot of opportunities.

Example – Smartphones are equipped with sensors that measure the battery temperature. The battery's temperature is translated to air temperature using a special formula.[12] *Climate change predictions include a rise in temperature, which is expected to negatively affect water quality, for example because it advances algal blooming. This application can be used to measure air temperature on a high resolution in cities.*

Example – Sensorex develops external sensor that can be plugged into a smartphone.[13] *An example is the displayed sensor to measure pH, Oxidation Reduction Potential, temperature and Electric Conductivity.*

Example – Mobile Water Management developed software that uses the microphone of a smartphone to measure groundwater levels.[14] *Using a special application a sound is send into a groundwater tube. The echo is recorded and processed into a groundwater level.*

Mobile crowd sensing is associated with strengths and weaknesses though. These should be kept in mind, when designing a project. The strengths of using mobile phone sensing:

- Highly mobile and scalable;
- Low-cost;
- Automatic time stamp and GPS possible;
- Citizens could interfere when necessary.

Example – iSPEX used the strengths of mobile crowd sensing in the measurement campaign of particulate matter. It would have been unmanageable to collect data on this scale without a smartphone application, due to the complexity of the measurement. Over 3000 citizens used iSPEX to

[12] See www.weathersignal.com
[13] See www.sensorex.com
[14] See www.mobilewatermanagement.com

measure; developing a device capable of the same as combination of iSPEX add-on and the iSPEX application would be costly. [2]

Weaknesses of mobile crowd sensing:

- The devices' hardware is not specially developed for the sensing task;
- The target audience may not familiar with smartphones;
- Difficult to ensure data trustworthiness;
- High risk of privacy invasion.

Example – Crowdsourcing in Reeuwijkse Plassen used a smartphone application that initially used the smartphone's camera to read a measurement tape to determine groundwater levels. This method proved to be inefficient and had to be adjusted. Additionally the users (ten senior citizens) have difficulties operating the application, as they are not as familiar with applications as younger generations. [3]

The latter two weaknesses are most challenging to tackle, because an increase in data trustworthiness often leads to a decrease in privacy protection and the other way around. As an organisation with the status of a local government, a water authority may have access to privacy sensitive data, especially when it is combined with data obtained from mobile sensing. Privacy invasion should be prevented.

Example – In a citizen science project water authority X decides to register each contribution per participant. However, because of this the water authority gains insights in where participant Y was at certain times. This may be an invasion of privacy of participant Y. Ensuring his/her privacy by making data entries anonymous results in a lack of control over the origin of data.

Interested in reading more on mobile crowd sensing and privacy vs. data quality?
This scientific article gives a clear overview of the advantages and disadvantages of mobile crowd sensing over online monitoring. It further gives insight in the balance between data trustworthiness and the prevention of privacy invasion.
→ "User privacy and data trustworthiness in mobile crowd sensing" published by He et al. in 2015.

Design tip: an MCS application should be useful rather than easy-to-use

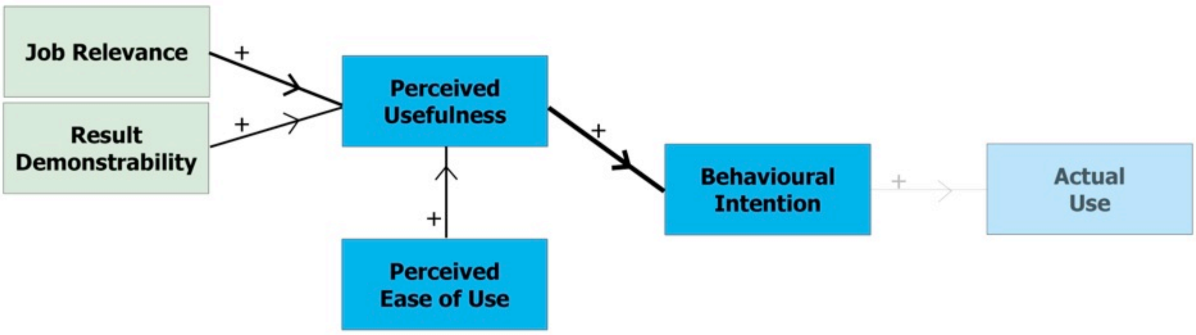
Designing a mobile crowd sensing project has a clear technological component: the measuring method and associated software have to be developed. There is a large social component as well. The mobile crowd sensing technology may be beneficial for the water authority, but how can one know if people will accept the technology? And how to know whether the application is suitable for the job? There are several ways to investigate whether people are willing to use the technology. In the research conducted to develop these guidelines such methods were applied. Using a Technology Acceptance Model (TAM, see the example below) it was discovered that citizens value the usefulness of an MCS application over ease of use. Social research methods offer great value, as they allow for a user-centred design, which could result in higher participation rates and more active contributions.

Example – A water authority and nature manager played with the idea to start a mobile crowd sensing project on water quality monitoring. The topics to monitor were defined and a first prototype of the mobile application was designed on paper. It was unknown whether citizens would be willing to use the application and what they would consider important. One of the methods to assess people's willingness to use a technology is the Technology Acceptance Model (TAM). This model is used to model drivers for a certain behaviour (using the application) and was used in this case study.

The used TAM consists of three basic elements: Ease of Use, Usefulness, Behavioural Intention to Use a product. The behavioural intention to use a technology is a strong predictor of actual Use, which could not be measured as it concerns a prototype test. Drivers for perceived Usefulness and Ease of Use were defined based on literature. Questions were formulated to measure each of the elements, *for example "I have the intention to use this application". Respondents had to indicate to what extent they agreed on a scale of 1 to 7. This questionnaire was spread and results were analysed using statistical methods.*

On average, respondents had the intention to use the application with a 5.9 on a scale of 1 to 7. After running the model perceived Usefulness positively influenced behavioural intention and Ease of Use did not. Ease of Use, Job Relevance (does the application enhance the job) and Result Demonstrability (are the advantages of the technology clear) fuel Usefulness.

This model has demonstrated that participants value usefulness over ease of use. This implies that the usefulness of technology is more important than whether the use of a technology is free of effort. Additionally the strongest factors influencing usefulness are the relevance and the result demonstrability of a technology. The first refers to perception that the technology improves the task to be done (either by improving efficiency or productivity) and the second to the degree to which results are tangible, observable and communicable.



Interested in reading more on the Technology Acceptance Model?
These scientific article introduce the original TAM and an adjusted version (TAM 3):
→ "Perceived usefulness, perceived ease of use, and user acceptance of information technology" as published by F.D. Davis in 1989.
→ "Technology acceptance model 3 and a research agenda on interventions." Published by V. Venkatesh & H. Bala in 2008.

13.4.4 Step 5. Develop protocols

The final design step describes the protocols that should be used. Protocols for data collection and validations are important, but protocols should also include, among others: how and when feedback is provided and how and when evaluation will take place.

Design tip: Organise a pilot or have a trial period

These protocols have to be thoroughly tested before being trusted to collect trustworthy data. It is therefore advisable to start with a pilot, especially when the water authority has little experience with citizen science. Such a trial period could reveal problems with organisational capacity, data collection protocols or other aspects of the projects that do not work out satisfactory yet.

Example – In Tuintelling the facilitator Vogelbescherming organised a pilot to test the developed protocols. This pilot of six months enabled the organisation to fine-tune the instructions and identify flaws in the protocols. [1]

13.5 How can citizens be motivated to participate for longer time periods?

Citizen science needs participating citizens for the project to be successful. If the project aims at long-term monitoring there should be a sufficient number of participants at all times. Here we provide some tips on how to ensure sufficient numbers of contributors throughout the project. What a sufficient number of participants is depends on the context of the project.

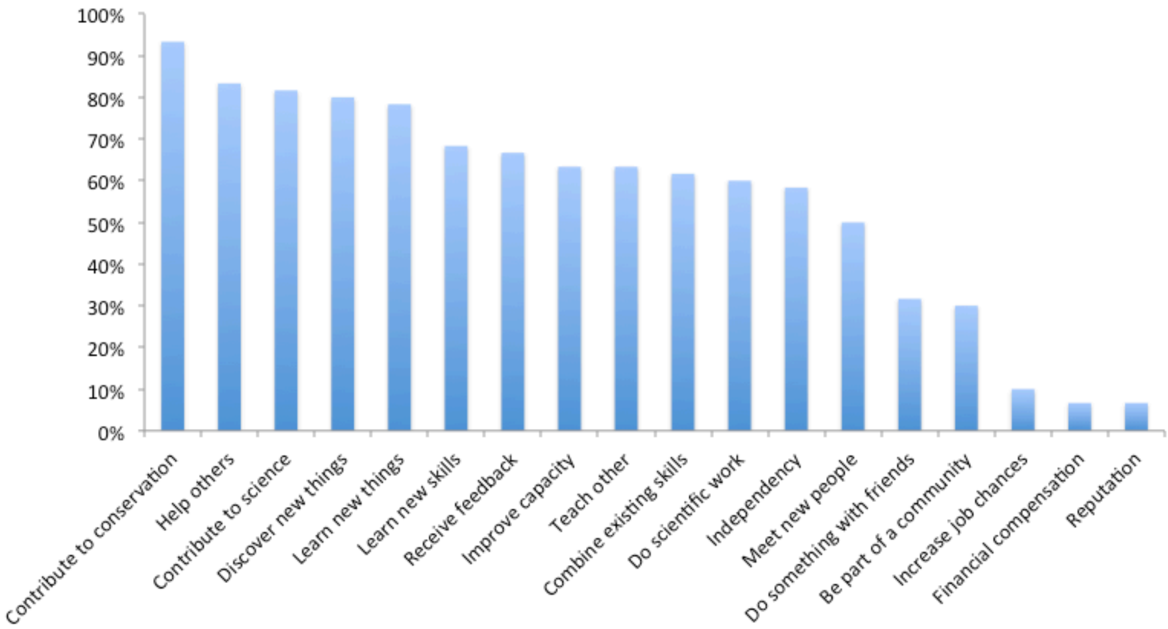
Example – In Crowdsourcing in Reeuwijkse Plassen the water authority created a map with areas of interest, for example urban area. Participants were required to monitor one location on or in the direct surroundings of their property, thus ideally there would be one participant in each area of interest. This way the preferred number of participants was defined. [3]

Design tip: Align organisation interest/motivation with citizen interest/motivation

Citizens are more likely to participate if they are triggered by intrinsic motivations. Extrinsic motivations, such as a financial compensation or gaining reputation, play a role as well. However, these may result in lower commitment levels, which could cause the participant to work sloppier or drop out. Naturally a water authority could not force a citizen to have an interest in water quality. Incorporating local issues may tap into something that intrinsically motivates citizens and causes them to participate.

Example – In the research conducted to develop these guidelines an investigation of citizen's motivations took place. A water authority and nature manager played with the idea to apply citizen science in water quality monitoring. Over thirty motivational factors were presented to citizens in a questionnaire. They were asked to indicate which they considered important. The motivational factors to nature conservation, to contribute to science, to help others, to learn new things and to discover new things were mentioned most often. In the project design these can be taken into account, for example by including an educational aspect to ensure that citizens will learn new things during the project.

Ranking of identified motivations:

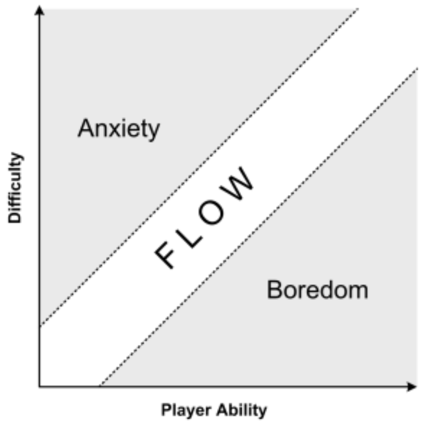


Additionally a water authority could try to maintain participants by creating ownership. This could be done by involving citizens in other parts of the process, such as data interpretation or translating the results into action. If participants make an investment first, they are also more likely to prolong participation.

Example – In iSPEX citizens had to buy a smartphone add-on before they could measure particulate matter. This was said to create citizen ownership of the project. [2]

Example – In Crowdsourcing in Reeuwijkse Plassen the water authority faced challenges with the technology facilitating the monitoring technique. The monitoring methods for groundwater levels had to be changed from a measuring tape to an echo-based method. This created a group feeling and increased participant's commitment according to the facilitating water authority. [3]

Another important aspect to keep citizens motivated over time is to provide citizens with a clear, small task to start with. However, there should be opportunities offered to increase the level of difficulty over time. When a task is too easy for the abilities of the participant, s/he will get bored easily and drop out. The protocol should not be too complex on the other hand either. If data collection protocols require skills the participant does not have (yet) or when the topic is too complex for the level of knowledge the participant has s/he will get anxious and will not proceed either. A pilot or inquire among potential participants might provide indications in the general level of complexity that citizens can grasp and what they like and dislike.



Example – In Tuintelling participants have the opportunity to select as many tasks as they like. They start with a simple list, but can expand monitoring activities or increase their task level. It is for instance possible to add species to monitor or to collect more details about the species they monitoring. [1]

Design tip: Make sure the data is used and provide feedback

To make a contribution is one of the main motivations to join citizen science projects. The different goals put different restrictions on the required quality of the data. To give an example: a project that aims at raising awareness focuses on trends and thus allows larger error margins than a project where gaining insight of temperature distribution over the day is important. However, even if data is not going to be used to formulate policy or if it does not really provide new knowledge, the data should always be used in some way.

It was proven that participants value the provision of feedback on three levels:

- the results (outcomes of the data);
- impact of the individual contribution;
- impact of the collective contribution.

Example – In Tuintelling, a long-term citizen science project on garden wildlife, the facilitator Vogelbescherming aims to use the results to increase knowledge about city wildlife and to use the results for conservation. However, building such a time series will take time. In the meantime they present updates on the data collected so far (how many data entries). Additionally they stress the collective contribution by emphasizing the importance of the data collected and the individual contribution by underlining the weight of every individual garden. [1]

Design tip: Constantly recruit new participants.

No matter how many precautions there are, there will always be a dropout of certain participants. The previous key success factors can only retain participants up to a certain extent. Therefore continuous recruitment is essential for long-term projects.

Example – Vogelbescherming started less than six months ago for a project that is planned to run for multiple years, but they are still recruiting participants via diverse media channels. They expect this to be necessary. [1]

13.6 List of citizen science schemes used to illustrate the guidelines:

[1] Jaarrond Tuintelling (Garden Count).
www.tuintelling.nl
Information obtained from two case study interviews at Vogelbescherming, one of the organizations that initiated the project.

[2] iSPEX
www.ispex.nl/en
Information obtained from two interviews at RIVM, the initiating organisation of iSPEX.

[3] Crowdsourcing in Reeuwijkse Plassen (CiRP)
http://waterinnovatieprijs.nl/inzendingen/peilbesluit-van-de-reeuwijkse-plassen-in-hetk-ader-van-het-uitvoeringsplan-schoon-en-mooi.html
Information obtained from two case study interviews at water authority Rijnland, initiator of CiRP.

[4] Zwemmen in Brabant
No website
Information obtained from an explorative interview at Brabantse Delta and from Almoradie (2014).

Part V – Conclusion and discussion

The previous parts of this thesis have outlined a research (Part 0) and a set of mixed methods has been applied to review the topic of citizen science from three angles. Key success factors for project set-up were identified (Part I) and the motivation to engage in citizen science was studied from the perspectives of citizens (Part II) and water authorities (Part III). In the synthesis step these findings were combined and guidelines for water authorities were designed (Part IV).

This final part will present the overall conclusion of the research, therewith evaluating whether this thesis achieved its objective to "*gain insight in the motivation to engage in citizen science, both from the perspective of water authorities and citizens, and to develop design guidelines that can guide water authorities in setting up citizen science project."*

Chapter 14
Conclusions of the full thesis

In this chapter the conclusion of this thesis will be presented. This chapter provides a summary of findings (section 14.1) and an answer to the main research question in the form of recommendations for practice (section 14.2).

14.1 Summary of findings

There is an increasing interest in citizen science by water authorities in the Netherlands. Using mixed methods this thesis identified general characteristics of citizen science projects and their set-up and investigated how water authorities in the Netherlands could apply citizen science.

Sub-question 1: key success factors.
The thesis aimed to identify key success factors for setting up a citizen science projects. An extensive literature review resulted in a framework of key success factors, consisting of three time steps in the project: during project design, at the start of the project and while the project is running. Key success factors were identified at the level of the participant, at the level of the organisation and for the set-up as whole. A comparison of key success factors in three case studies in citizen science confirmed literature findings to a great extent. Especially establishing clear goals is an important factor. The goals define to a large extent the characteristics of a citizen science project, such as required level of data quality, time-span and level of citizen involvement. Nine different goals were identified: Raise Awareness, Education, Policy Development, Management, Increase Knowledge, Improve Methods, Serendipity, Recreation and Social Research. In each case a combination of these goals was applicable.

Sub-question 2: participant motivation
One success factor is having insight in motivations of citizens. Thirty possible motivations were obtained from literature on a wide range of projects and were ordered according to the Self-Determination Theory. Using a hypothetical project on water quality monitoring citizen motivations were inquired via a survey. This study confirmed literature findings that extrinsic, external regulated motivational factors are less important than intrinsic and fully internal regulated motivations. The most prominent reasons to participate in water quality monitoring are: contribute to conservation (97%), contribute to science (84%) and discover new things (80%). Least important are improve one's reputation (7%) financial compensation (9%) and increase the chance of a job via participation (10%). It was further suggested that people with a lower intention to participate value extrinsic motivations more than people with a higher intention to participate. This suggestion should be further explored, because insight in motivation of non-participants holds the promise of involving hard-to-reach groups.

Sub-question 3: water authorities viewpoint
The attitude towards citizen science in water quality is positive overall. However, alike other citizen science fields, the trustworthiness of the data is an issue or at least a concern. Three viewpoints on citizen participation in water quality monitoring were identified using Q methodology. There is a data driven viewpoint, a viewpoint that prefers to use citizen science as an additional source and a viewpoint focussing on education.

Several of these goals were supported by the identified viewpoints as goals of citizen science that could enhance water authorities' activities. These are: knowledge generation, create a support base for policy, raise awareness, improve management and create a support base for policy. Using citizen science to increase awareness and ultimately change the behaviour of citizens was added as a goals. Citizen involvement is often classified on three levels: contributory, collaborative and co-created. There was no support base found for collaborative and co-created projects.

Sub-question 4: Characteristics of Mobile crowd sensing
The literature review mentioned under sub-question 1 was also used to answer sub-question 4. Citizen science in water resource management is triggered by a rapidly progressing technological development. Cheap and easy-to-use devices are increasingly available and enable a non-expert to collect water quality data. Mobile crowd sensing is suggested as an interesting innovation for water authorities.

An important question is whether mobile sensing will offer advantages over 'traditional' forms of data collection (e.g. test kits) and ways of submission (e.g. submission on a website or via a paper form). Whether MCS is preferred depends on the target audience, the required level of data accuracy and whether data is required near real-time or not.

Water authorities could prefer MCS over wireless sensor networks, for its mobility, lower costs and scalability. Internal smartphone sensors are not yet able to measure water quality parameters directly, but with low-cost plug-in sensors or by measuring auxiliary data (e.g. air temperature or the manual reporting of odours).Water authorities should be aware of the challenge to balance privacy issues with data trustworthiness. As an organisation with the status of a local government, a water authority may have access to privacy sensitive data.

Sub-question 5: Technology Acceptance of a mobile crowd sensing application
If a mobile crowd sensing technology may match water authority's needs, it is important to investigate how users evaluate this technology. An adapted version of the Technology Acceptance Model (Venkatesh & Bala 2008) was applied on a paper model of a mobile crowd sensing application. This resulted in findings that match previous studies, although the model was inadequate in predicting drivers for Ease of Use. Usefulness is the most important for behavioural intention. Job relevance and result demonstrability of the technology are the most important drivers of this usefulness. A mobile crowd sensing technology should be useful rather than free of effort.

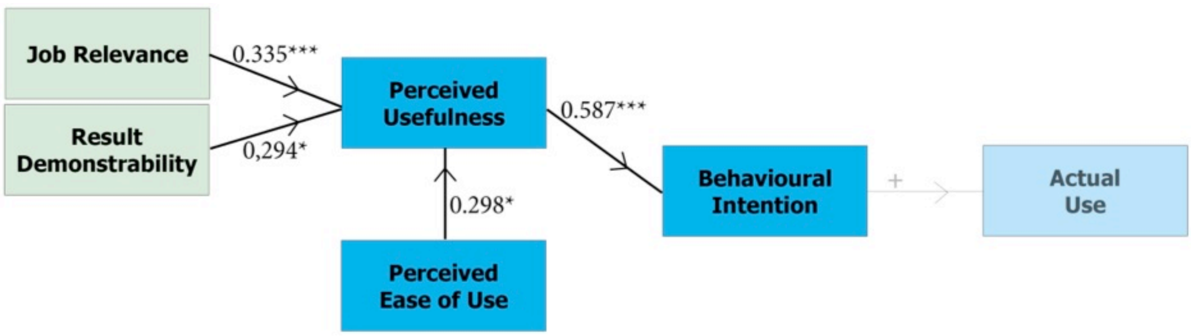


Figure 14.1 – The final Technology Acceptance Model as confirmed in this thesis (author 2015).

Development of guidelines for setting up a citizen science project
The findings of this study were combined following the design pattern of the Seven-Layer of Collaboration Model to develop guidelines for practitioners in water authorities. The model consists of the layers Goals, Products, Activities, Collaboration Patterns, Techniques, Tools and Scripts. The guidelines start with a description of citizen science and its potential for water authorities. An important acknowledgement is that citizen science is a means and could not be a goal itself: it should always serve a higher end. Next in four steps the decision points and considerations necessary to make an informed decision are presented. These are: Determine strategic partners; Decide on level of governance and citizen involvement; Choose techniques and tools and Develop protocols. The guidelines close off with practical advice on how to sustain citizen participation for a longer period. Iteration of the design of the guidelines is necessary to validate them and improve them were possible.

14.2 Recommendations for practice

The answer to the main question is based on the guidelines and formulated in the form of recommendations for practice at water authorities. The advices are split in recommendations at the national level to the Dutch Water Authorities and at the local level to individual water authorities.

14.2.1 National level

Collaborate between projects
Two key success factors identified are the alignment of local projects and the collaboration with other organizations. Water authorities should collaborate to ensure nationwide unity in data collection methods, which will enhance comparison and combination of datasets. Exchanging information and sharing experiences will further enhance the application of citizen science in water quality monitoring, as such examples can be an inspiration for other water authorities.

14.2.2 Local level

Guidelines were developed for regional water authorities. The guidelines are based on all research steps and are illustrated by examples from practice. Specific recommendations are included for mobile crowd sensing (MCS) besides the more general guidelines.

Consider the design elements to make informed decisions
The design elements can assist water authorities in considering all essential project design steps and aids making informed decisions to increase effectiveness of a project.

The most important question that should be answered is whether citizen science is suitable as a means to accomplish set goals. In the guidelines a description of citizen science was given. The seven goals identified in the research were presented, accompanied with an example for each of the goals.

A second guideline is to collaborate with strategic partners. Such partners can attract a wider or different audience, can fill gaps in knowledge, skills and resources and may increase the credibility of the project. Moreover, the growing adoption of citizen science by local authorities and other organizations may result in fatigue or confusion among citizens. Collaboration could prevent this and further strive for win-win situations in aligning mutual goals and by reaching a larger share of the audience.

Thirdly, it is important to have insight in the associated costs. Citizen science is generally seen as an inexpensive way to collect data, but the costs of development, infrastructure and coordination can be high. The larger the number of participants and the more data is collected, the smaller this overhead costs will relatively be.

Fourth, there are three general types of citizen science defined, with an increasing level of citizen science. The type of citizen science chosen should match organisational capacity (regarding coordination and support). The used collaboration techniques and tools should also match organisational capacity and the target audience.

Fifth, it is recommended to take use of (social) scientific knowledge into account. The contribution this knowledge can make was demonstrated with an Technology Acceptance Model to assess user (citizen) acceptance of a smartphone application.

Sixth, it is advisable to start with a pilot project before launching the project as a whole.. A pilot can identify gaps in monitoring protocols and acts as a trial whether the project matches the capacities of citizens and the authority.

Mobile crowd sensing
Finally, it is important to keep the capacity of the target audience, of the water authority and of mobile devices into account when designing an MCS project. Mobile crowd sensing can be a resolution if the goals and nature of the project require highly scalable, mobile and low-cost data collection, although the main challenge in MCS is to balance data trustworthiness with privacy.

Higher levels of participation
The guidelines are formulated for contributory projects, as there was a support base found for this type of citizen science. To achieve higher levels of participation the water authority should aim for collaborative and co-created projects on the longer term.

Chapter 15
Discussion of the full thesis

So far the topic of contributory citizen science has been introduced, several research steps took place and conclusions were formulated together with guidelines for water authorities. This final chapter consists of a discussion on the used mixed methods approach, recommendations for future studies and completes the thesis with the relevance for practice and the scientific fields of water management and science communication. In this chapter I switch to the active voice, since I will discuss my actions, believes and other personal influences on the research as well.

15.1 Discussion of methodology

In the previous chapters a diversity of methods was used and combined to develop a design pattern for water authorities that consider citizen science in water quality monitoring. A mixed method approach was used in this design-based research (DBR). Methods used include quantitative and qualitative methods that served deductive (testing theory) and abductive (explain phenomena) approaches. Additionally the potential for mobile crowd sensing in the same context was examined.

The used methods are:
1) Literature review;
2) Semi-structured interviews (with case study organizations);
3) Quantitative survey (based on motivations mapped on the Self-Determination Theory);
4) Quantitative survey (based on the Technology Acceptance Model);
5) Q methodological approach;
6) Structured interviews (with Q methodology participants);
7) Design-based research (following the Seven-Layer Model of Collaboration).

In this chapter the integrated methods within the design-based research framework will be discussed. For a discussion of the individual methods the reader is referred to Part I for the literature review, Part II for the survey and the Technology Acceptance Model (TAM) and Part III for the Q methodological approach.

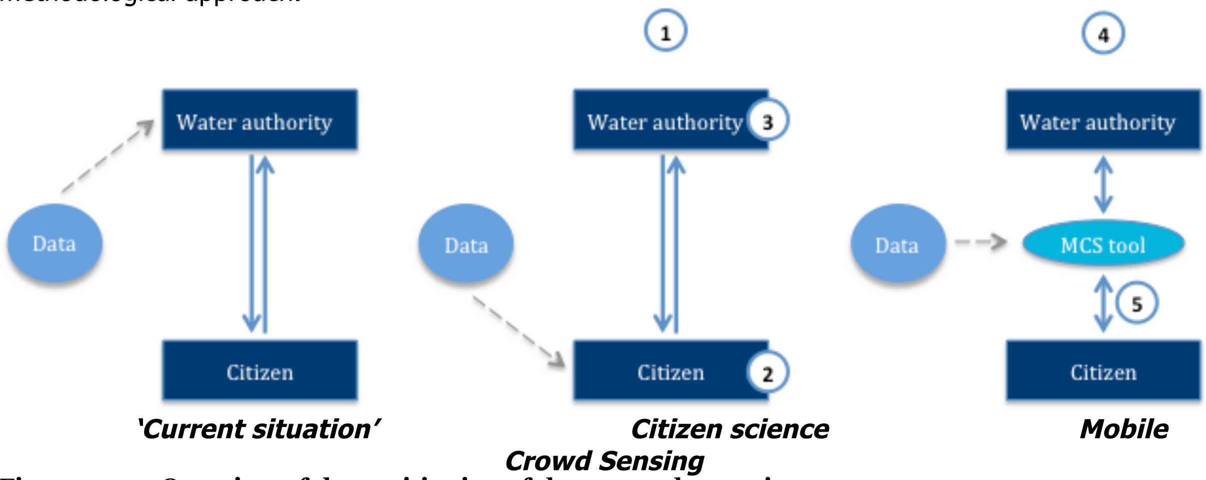


Figure 15.1 – Overview of the positioning of the research questions.

Questions 1 and 4 were primarily answered via literature review and semi-structured interviews in a case study. Question 2 was answered with a quantitative survey, question 3 was answered with a Q methodological approach and 5 with a survey based on an adjusted Technology Acceptance Model.

15.1.1 Reflection on design-based research

In Chapter 2 (Research methodology) I announced to use a design-based research (DBR) set-up. It can be argued though that this thesis is not DBR, as three other characteristics of DBR are not fully met. A DBR requires multiple iterations (Anderson & Shattuck 2012), although only implicit iteration steps were taken in this thesis. Implicit iteration took place in the form of refining the guidelines with every research step that was added to the thesis. The key success factors identified in Chapter 4 and Chapter 5 can be considered a preliminary version of the guidelines. This preliminary version was revised, based on insights from the other research components.

Linking theory and practice is important in DBR, but this research failed to start a collaborative partnership between practitioners and researchers. Multiple practitioners at several water authorities were approached to design a citizen science project together and test it in practice. In one case plans for setting up mobile crowd sensing were in a developed stage, but had to be terminated due to practical reasons. The developed smartphone application could not be tested in a real world practice as a consequence. This was unfortunate, as the design and testing of an intervention are considered a key quality of design-based research (Anderson & Shattuck 2012).

With the guidelines an intervention was designed, although the designed intervention could not be tested in this research. This is not exceptional, as Anderson & Shattuck (2012) found that 17% of the DBR publications in the field of education is research in a similar preliminary stage with limited iteration performed. The design of the intervention complies with all three essential steps though (Anderson & Shattuck 2012). First, I made an assessment of the local context of Dutch water management, making the intervention applicable to the average water authority. Second, I used relevant theories, literature and practices from other contexts in Part I. Third, I designed the guidelines with specific problems (inadequate governance structures and a lack of awareness, see Chapter 1 Introduction) in mind. I provide a thorough design of the intervention, such that the guidelines are ready for application and testing in a real world context in future research.

This thesis complies with the definition of design-based research in the broad interpretation of DBR, namely that the research bridges theory and practice. I developed practical design principles in the broad context of regional water management in the Netherlands using a design pattern and based on extensive set of theory and practical research.

Reflection on the Seven-Layer Model of Collaboration

Design-based research (DBR) uses and leads to design principles (Anderson & Shattuck 2012). A design pattern was chosen to guide the synthesis leading to design principles in the form of guidelines for water authorities.

The Seven-Layer Model of Collaboration (Briggs et al. 2009) was not developed to design citizen science projects, but merely to give practical meaning to partnerships. However, citizen science is a form of collaboration and the design pattern proved to be useful as it helped to structure the development of the guidelines. Van Diggelen & Overdijk (2009) noted that although the use of a design pattern may change when it is applied in other domains, the basic concept of the design process will be preserved when applied to other fields. That notation applies to this thesis, as I used the idea of layers in designing an interaction with a collaborative nature rather than limiting myself to the, for example, techniques mentioned in the original paper.

Figure 15.2 – The Seven-Layer Model of Collaboration

Discussion of researcher bias
A main challenge of design-based research (DBR) is to ensure credibility and trustworthiness (Anderson & Shattuck 2012). Researcher bias has been discussed in the separate parts already, but their impact on the synthesis has not. The synthesis itself was entirely based on the researcher's interpretation.

The main concern for researcher bias was that I initially perceived water authorities as conservative organizations, as was discussed in the discussion of Part III already. Although this belief was nuanced over time, the guidelines may be developed while underestimating the willingness of water authorities to adopt collaborative or co-created forms of citizen science. As a result, the guidelines may be a mismatch with reality and a missed opportunity to develop guidelines for citizen science with higher levels of collaboration.

To minimise individual bias it would have been advantageous to involve multiple researchers in the synthesis process or to have at least one person revise the procedure. This was considered unfeasible within the scope of this study, because the outsiders would have to go through all research steps and results to be able to reproduce or revise the choices made. To limit the impact of the mentioned and other possible biases I asked feedback from practitioners. I provided all interviewees in the case study and Q methodology with a draft version of the results and my interpretation. All interviewees substantively agreed with my interpretation, therefore I expect that researcher bias had inconsequential impact on the results.

15.1.2 Mixed methods

To facilitate the design-based research (DBR) a mixed methods approach was chosen. In this thesis the mixed methods approach had three main weaknesses. First, I had experience in only one of the research methods, namely the survey. I was inexperienced with abductive approaches, as well as with semi-structured interviews and Q sorts as data collection methods. Furthermore, this was the first time that I used the statistical methods applied to the data analysis, being the Q methodological factor analysis and the Structural Equation Modelling used for the TAM. I increased my knowledge by reviewing texts books (e.g. Watts & Stenner 2012) and learned while doing by discussing the interview protocols with peers. Additionally I sought contact with experts on both statistical methods. I further made sure that each step of the method was fully understood before moving on the next step in the methods, for example by studying previous studies and textbooks on the methods.

Second, the use of seven different research methods (see chapter 3) in a limited time frame results in a diffusion of attention for each of the methods. In particular the survey on motivations and the TAM, that was used to answer the citizen-oriented research questions 2 and 5, were explorative in nature in terms of sample size and depth of the analysis. This rather explorative nature is considered acceptable, because the focus was on the water authorities; the citizen-oriented questions are mainly illustrative to the claim that it is important to consider citizen motivations, drivers and barriers.

Third, it has proven difficult to integrate the separate methods, because of their individual shortcomings. For example the framework of key success factors did not take into account the pre-decision phase, where it is decided to use citizen science, and the TAM focussed on a particular technology in a very specific context. An encompassing model was needed to integrate these findings in varying time frames and in differing levels of context. Such a model was found with the Seven-Layer Model of Collaboration (SLMC), but it would have been advantageous to take this model as a starting point, to increase alignment of the separate methods and findings.

The strengths of the mixed method approach outweigh the weaknesses though, because different methods fit different questions and the combination offers completeness. Most important advantage of mixed methods is that the best research method was chosen for each (sub-)question. To give a few examples: determining drivers and barriers of citizens' intention to participate focuses on larger groups; a quantitative method fits this focus on group averages best. The case studies on the other hand require a qualitative method, because they inquire about specific aspects of an individual case.

Moreover, this study is, to my knowledge, the first of this scope. This limited the possibilities to go in-depth, because of necessary background study, but the use of mixed methods allowed to explore a wide range of aspects of citizen science, including the perspectives of the two most important actors: citizens (motivations, citizen drivers and barriers) and water authorities (viewpoints). Additionally the consequences were incorporated of using smartphones as a specific type of measuring equipment. Doing so, the methods on the level of individual cases (e.g. the case study interviews) could complement methods on a more general level (e.g. the Q methodological approach) and so provide insights on all aspects of citizen science and mobile crowd sensing (see Figure 15.1).

15.1.3 Reflection on generalizability

The methods used focussed on a general topic (e.g. Q methodology and the literature review) and on specific contexts (e.g. the case study, TAM and the survey). Figure 15.1 illustrates that the five sub-research questions focused on different types of citizen science; on different actors and the level of context varied. In the synthesis these differences were ignored. This generalisation was necessary to combine the results, however, it must be noted that the results are context specific and different results may be found in other contexts. Also, these different levels are defendable, because topics like participation intention and technology acceptance are better asked by providing context in a vignette type of question.

The framework of key success factors as derived from literature, was based on a diverse set of sources, ranging from online crowdsourcing to co-created citizen science. In the cases studied a majority of key success factors was being applied. Although the successfulness of the projects was not measured the applied key success factors are believed to have a positive influence on the projects. The diverse origin of the key success factors and the confirmation of the application of the key success factors indicate that they can be generalised to citizen science in general, thus including water quality monitoring.

The three identified viewpoints in the Q methodology (‘Citizen participation for data collection’, ‘Water authorities in control’ and ‘Education and local knowledge’) suggest that there is primarily a support-base for contributory projects. The Q methodology intends to be representative for water quality departments in water authorities, although it is possible that there are other viewpoints in departments or water authorities that were not included in the sample. It is suggested that a generalisation to Dutch water authorities could be justified though, since the included water authorities were purposely selected for their diversity.

The survey (used for the TAM and that was used to define citizen motivations, barriers and drivers) was used illustrative only, as it is highly context specific. A nature manger was named to be the initiating organisation and respondents were primarily middle-aged and member of this nature manager’s newsletter. Additionally one specific project was described. It would be unfounded to generalise conclusions on citizen motivation and barriers to the Dutch citizens in general. The same goes for the TAM: the findings are representative for this particular application in this particular setting only, as only one specific application was inquired in the previously specific context. As a consequence, the

The value of the synthesis

The guidelines developed in the synthesis are not validated in practice, but they still provide value to practice and science. The most important added value of these guidelines is that they bridge theory and practice. Research findings are translated to practice in a structured way and scientific from the study are illustrated with examples from practice (either obtained from literature, study participant anecdotes or the case studies). As was mentioned in the introduction, the main question practitioners at water authorities have is how to implement citizen science. Although the synthesis is neither scientifically rigour nor endorsed by practice, I believe the guidelines bridges scientifically sound, but unspecified advices, such as “include participant motivations”, and concrete examples how this can be done in practice.

Higher levels of citizen participation (collaboration and co-creation) were omitted from the guidelines, as support was only found for contribution. However, it is expected that with growing experience in the application of citizen science, the application of citizen science will have more variation. These guidelines should not be considered static, but are appropriate for the status quo of most water authorities of being at the start of using citizen science.

Citizen science vs. participatory monitoring
A more philosophical question is whether this thesis really studied citizen science. Citizen science is "a hot topic" as one of the Q participants named it. Such as with other hypes or trends, incorrect use of the terms is a major pitfall. That brings me to the question: what is citizen science? I used the following definition:

If citizens work for researchers in a research project it is clearly citizen science. However, is the type of citizen science that thesis refers to really citizen science? Water authorities refer to it as 'participatory monitoring' and maybe that is all that it is. That does not mean that it is not valuable, but it is just not citizen science. Other terms have been used: citizen observatories, community based monitoring and participatory monitoring, as water authorities named it. Participatory monitoring, as I will call it from now, can be useful to increase the density of a monitoring network. Furthermore it is an interesting communication tool in the light of science communication. Correspondingly water managers should be interested in participatory monitoring in the light of integrated water management.

15.2 Suggestions for further research

Future research could focus on expanding this research by studying the applicability of the guidelines in several case studies on contributory citizen science projects at Dutch water authorities. Additionally the Q methodology could be followed by a quantitative determination of the distribution of the viewpoints. The proposed guidelines are an important topic of future research as well. Studies on the applicability and suitability of the guidelines for water authorities could enhance knowledge of citizen science in the field of water resource management.

This thesis put an emphasis on water quality. As argued before, it is expected that the results and the guidelines are applicable for water quantity management as well. Extending the current research to the field of water quantity management might broaden the view on citizen science again.

This study further aimed to grasp the motivations and barriers experienced by non-participants to engage in scientific projects. Although the response rate of the survey that was used to this end was disappointingly low, the results show that there are substantial and significant differences between participants with a high intention to participate and those with a low intention. This opens the door for further research in this direction.

The developed guidelines are based on several sources, which increased their credibility, but they are not validated yet. A workshop could act as a validation in practice. There was the intention to organise a workshop with water authorities, where the guidelines would have been discussed on their feasibility with practitioners. Case studies where the guidelines are used to set up a citizen science project would be interesting research directions as well, to see if the guidelines stay upright in different contexts.

15.3 Practical and scientific relevance

This research has delivered a contribution to both scientific and management knowledge. In this section first the scientific relevance of the study is discussed, followed by the practical relevance.

15.3.1 Scientific relevance of this study

By using Q methodology this thesis adds a new method to the toolbox of water management and science communication, since this method is unconventional in both departments at TU Delft.

Scientific relevance in the field of water management

Studies in water resources often investigate physical phenomena in the field of hydrology. Social scientific studies seem to put an emphasis on governance, river basin management or collaboration between stakeholders. This thesis zooms in to citizen science as a rather unexplored form of collaboration in water resource management in the Netherlands.

The mixed methods approach to collect field data, which combines semi-structured interviews (case interviews), structured interviews (post-sort interviews), a quantitative survey and Q methodology, is rather unique for a master thesis at water resource management. The survey and Q methodology are rather unconventional method. To illustrate this I looked up what methods the 60 master students used that graduated the past 24 months. 50 theses were of a technological nature and in the latter ten the most used method is interviews, which were used by nine of the students, and in particular semi-structured interviews. Four conducted semi-structured interviews, one unstructured, one structured and three did not define the interview strategy. Other methods include observations (four times), document analysis (twice) and focus group meetings (once). Two students reported to use a survey, although one of them in fact used Q methodology. Seven students reported mixed method approaches, although interviews seemed dominant over the other methods used. This is in contract to this thesis, were all methods are more or less equally contributing to the development of guidelines.

In the department of water management Q methodology has been used before water management (Raadgever 2009; Raadgever et al. 2012; Meyer zu Schlochtern 2013), but is far from common practice. The use of Q methodology in water resource management research is rare, as a quick scan on Web of Science revealed. Searching topic, title and keywords for **"water" AND "Q method" OR "Q methodology"** returned only sixteen results.

Scientific relevance in the field of science communication

This thesis offers value to the field of science communication by introducing citizen science as a science communication topic and Q methodology as a method. Additionally the thesis bridges the gap between theory and practice by translating the research findings into guidelines for a specific, practical context.

This thesis introduced citizen science as a research topic, as it is the first to study citizen science in the Delft Science Communication department. Citizen science is an interesting field of study for science communicators because it shows parallels with all four quadrants of the model on Public Understanding, Awareness, Engagement and Participation in Science (PUS/PES/PAS/PPS; Auweraert 2005) that is often referred to at SEC. The typology of Bonney et al. (2009) and the goals identified by Tulloch et al. (2013) and Hollow et al. (2015) show that citizen science ranges from education-oriented project to fully co-created projects, where citizens and researchers (scientists or practitioners) design and execute projects aiming at knowledge generation and mutual learning. In citizen science a focus on public awareness does not exclude the others.

This brings me to the second contribution, the strong link between theory and practice in this thesis. The research question emerged from a gap in the available literature, but also from questions from practitioners. Throughout the study findings in theory are compared to practical case studies and vice versa. In the end the scientific research on drivers and barriers (for citizens and water authorities) was used to formulate a practical advice to water authorities. This will contributes to the ambition of SEC to link research and theory to practice.

Third, it introduced Q methodology as a new research method. Personal opinions and subjectivity play a role in several studies performed at the SEC department. Previous master theses mainly used document analysis, semi-structured and unstructured interviews and observations. The focus on viewpoint classification of Q methodology makes it a suitable research method to investigate these personal perceptions and makes Q methodology fit for many of the topics studied at SEC.

15.3.2 Practical relevance of this study

This thesis started off with a reference to a report issued by the Organisation for Economic Cooperation and Development (OECD) that warned for a striking awareness gap regarding water risks in the Netherlands (OECD 2014). The Dutch Water Authorities responded with a policy vision encouraging citizen participation. Citizen science was named as one of the possibilities to increase awareness and engage citizens in new governance structures.

This thesis adds value to the development of citizen science at water authorities, as they are new players in the field of citizen science in the Netherlands. I observed an immense interest in citizen science within the water authorities that participated in this research. That citizen science is 'a hot topic' was further stressed by the workshop organised by Delfland in November 2014 and by the notion of the Dutch Water Authorities (UvW 2015) that citizen science can considerably contribute to raising awareness. In this thesis I confirmed that citizen science could serve raising awareness using a literature review and a case study in the Netherlands. I further demonstrated that there is a support base to deploy citizen science as a means to raise awareness, as it was identified in several viewpoints of water authority employees on citizen science.

There is potential to move towards more flexible governance structures via citizen science in water quality monitoring, but based on the research findings this is not expected on the short term. Support was found within the three viewpoints at water authorities for contributory citizen science, which implies to involve citizens in data collection, but not in higher levels of decision making. Such higher levels of involvement are expected on the longer term though, as with increasing experience more variation in citizen science application is expected.

This study is one of the first to study citizen science in the context of water authorities in the Netherlands. Moreover, it provides a strong link between theory and practice by focussing on the formulation of design patterns and key success factors that can aid water authorities. In citizen science projects a lot of attention is given to the monitoring protocols and data validation. Naturally this is important, but this study reveals the importance of social research. By identifying viewpoints of water managers using Q methodology and investigating citizen motivations and barriers using a quantitative survey and an application of the Technology Acceptance Model I concurrently demonstrated how it could enhance setting up citizen science projects for water managers.

Citizen science in water quality monitoring is a promising way to increase water awareness and transform governance structures, but there is a long way to go before it will be matured to common practice. The research agenda for scientists and water authorities includes many topics, including case studies to gain deeper insight in practical issues and implications.

15.3.3 The value of combining water management and science communication

Projects in civil engineering and water management in particular are interwoven with society. There is a direct interaction needed between experts and non-experts that are directly involved. Projects (e.g. flood protection) often take place in the built environment and issues such as shortage of fresh water threaten everyday life. This close relation between experts and laypeople in water resource management has two important consequences. First, various non-expert stakeholders are involved with personal interests and needs, which may differ from professional stakeholders. Second, a diverse set of social-scientific questions arises when water related issues meet society.

Abovementioned matters require water managers to find not only a technological feasible, but also a socially acceptable solution. In integrated water resource management societal issues are equally important to address as technological issues. Additionally, the interaction between professionals and citizens needs to be facilitated by communication processes and tools.

Integrating water resource management with science communication allows for the best of both worlds. I gained insight in the value and practice of social scientific research via my science communication background, while I also benefitted from my background in water management during the project. Several participants at water authorities asked how they could successfully apply citizen science in terms of citizen engagement and in terms of possible monitoring items. The first of these questions is a typical question for science communication, while the second is difficult to answer without knowledge of water resource management. The combination of both fields enabled to have use sound methods. The second question requires knowledge of the water management system in the Netherlands. It was essential in this thesis to understand issues with water quality monitoring in the Netherlands and have a sufficient background on the system of water authorities to place the results in context and come up with guidelines that match the real world practice.

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