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CROSSING BORDERS

A quality-oriented investigation of Voluntary Geographic Information

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FOREWORD

This Master thesis report is the result of 8 months research, performed for my study Master Geo-Information Science at Wageningen University. I would not have managed to complete this research without the support of several people. Many thanks for the proofreading, correcting and advising that helped me to get to this final result.

I would like to thank some people in particular however. First of all I would like to thank my supervisor Prof. Dr. Ir. Arnold Bregt, who was always there for me when I had my doubts and questions. I always left our meetings with a clear vision and full of confidence. Also the fact that I wrote this thesis from home, gave us some challenges that we mastered well together. Other thanks go to Wim Witteveen, Louis Minnebach and Wilco Stalknecht from the Kadaster. Without their time, input and cooperation, this project would not have been possible in its current setting.

Furthermore I would like to thank my fiancée Anna, who stood by my side and gave me the necessary motivation. She always knew the right things to say when I had my doubts about the progress of my research. The same goes for my dad, Kees, who really helped me a lot with his input and the correction of large pieces of text. Last but not least I want to thank God, who gave me peace and confidence during the entire process.

Then of course I also like to thank you, as reader, for your interest in this Thesis. I hope that it will bring you to new insights and hopefully answer some of your questions.

Mark Noorlander, 25-02-2013

SUMMARY

The concept of Voluntary Geographic Information (VGI) has been subject to a lot of research. The underlying quality on the other hand is a less commonly addressed theme in these researches. This is even more remarkable, considering the fact that there are quite some concerns about this quality. The variety of contributors combined with possible lacking knowledge and insight makes it hard to assess the quality level of the data.

This research dives deeper into the concept of VGI data quality, to investigate how the quality can be tested and where necessary improved. In order to do so, a project of the Dutch land registry office (Kadaster) is selected as a case study. One of the tasks of the Kadaster is to monitor the condition of landmarks on the frontier between Germany and the Netherlands. To reduce time and money spend on this monitoring, crowd-sourcing came up as a possibility. About a year ago, the Kadaster launched a website and an app, enabling volunteers to report the condition of these landmarks. Since this project fulfilled the main criteria of being completely VGI based, it seemed like a very good project to investigate the quality of VGI data.

To gain more insight into VGI data quality in general, this concept was investigated in a broader perspective. The quality of VGI consists of several different quality aspects that all together form the concept of quality. It turned out that the quality of VGI is largely comparable to that of spatial data in general. From this concept of spatial data, VGI uses the *data-oriented* quality elements. These are for example completeness, attribute accuracy, temporal accuracy etc. Even more interesting was the distinction of another group of quality elements. This group is mainly applicable for VGI and named the group of *community-oriented* quality elements, containing among others the motivation and credibility of volunteers. These quality elements are harder to grasp and investigate, nevertheless they have a considerable influence on VGI data quality.

Having found the quality elements, a selection based on the properties of the Kadaster landmark project could be made. Some of the elements had to be eliminated, among others the positional accuracy, since they are not measured by the Kadaster. For the remaining quality elements, a testing method was formulated.

In order to be able to assess whether the Landmark VGI database is up-to-date, a trace of the frontier has been selected for fieldwork. Along this trace, observations concerning the condition of landmarks are collected by two persons. This fieldwork served two goals. The first goal was that Landmark test-data was collected. The second was that the search for landmarks was experienced in person. In this way, recommendations for the improvement of the project could be made based on experiences. These experiences were used in the course of answering the third research question.

During the research it became clear that the Kadaster project leaves room for improvement. Only 55% of the complete set of landmarks has been reported during the past year, by only 19 volunteers. However, the observations that remained after filtering out spam and error, turned out to be of quite good quality. Still, the VGI database cannot be used as replacement for expert observations yet. This project shows once again that solitary, small VGI projects only have a limited usability, since they address a narrow group of volunteers. Therefore another approach should be chosen in order to make more use of the potential of VGI in this landmark project. This could either be done by broadening the group of potential volunteers, for example by shifting the emphasis from landmark-quest to hiking-tour. Another option would be the use of a strong, existing VGI community as base. As an example the Geocaching community can be taken, a similar approach could be chosen for the landmarks.

It is relatively simple to test the quality of VGI, when looking solely at the data-oriented quality elements of this concept. The community-oriented elements on the other hand, are harder to grasp. More research is needed in order to find out what motivates people to contribute, and maybe of even more importance: how to keep them motivated over a longer period of time. Overall, this research showed that there is potential in VGI.

However, a lot of effort from the initiator will be required to achieve its full potential. First, effort will be needed to make sure that the observations are correctly filtered from spam and errors. Secondly, effort will be needed in order to make the project more interesting for volunteers. This last point will create possibilities for a broader public, meaning more observations and thus an increase in quality.

Keywords: VGI, Voluntary Geographic Information, Data quality, Public participation

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 CONTEXT AND BACKGROUND

Field data collection is a commonly used practice in research. This way of data collection is very important, as it supports research and testing of hypothesises. Furthermore, it helps to visualize trends and developments. Some examples of methods used for data capture are: land survey, photogrammetry, remote sensing and sensor networks. [*Castelein et al.*, 2010]

In general, this data gathering is done by trained professionals with expensive and accurate equipment. Apart from the costs for this equipment, the costs and time spend by these professionals should not be underestimated. Due to the high costs and efforts of such data gatherings, in some cases not all data is collected to cut costs (e.g. if it is not of interest for the particular project). This results in so called spatial and temporal monitoring gaps, which decrease the usefulness of monitoring systems [*Gouveiaa et al.*, 2004]. According to Gouveiaa et al. (2004) the data collected by these systems is quite often not open accessible and therefore not available to the public. This limits data access which results in information gaps.

The lack of monitoring systems is not a new development. It was brought up already in 1994, where Estes and Mooneyhan (1994) addressed the so called 'mapping myth'[*Estes and Mooneyhan*, 1994]. Goodchild (2007) summarized this mapping myth as following: "*the mistaken belief that the world is well mapped, and that maps are constantly being updated and becoming more accurate. … Programs of map updating are seriously lagging in many countries, including the U.S., and few if any efforts exist to improve the levels of detail of existing maps. Mapping is costly and labour-intensive, with the exception of those themes that can be readily gathered through automated means, and governments are less and less willing to absorb the costs." [M F Goodchild, 2007]*

The information gaps caused citizens to start searching for possibilities to collect and combine their own data and information. Craglia (2008) who also discusses this trend stated that *"recent developments like Web 2.0 platforms, GPS enabled cell phones and sensor technology make capturing of geographic data no longer the exclusive domain of well trained professionals, but opens new possibilities for involvement of citizens"* ([*Craglia*, 2008] in[*Castelein et al.*, 2010]), this trend is confirmed by others, among whom Haklay [*Haklay*, 2010]. Over the years, the term of crowdsourcing was created. This term is derived from the more familiar term of outsourcing, which means in this case that the data is obtained from an outside supplier or source. Already in 1960 the early form of crowdsourcing, at that moment known as public participation, was addressed [*Seldes*, 1960]. In 2007, Goodchild termed this development: Volunteered Geographic Information, or abbreviated 'VGI' [*M F Goodchild*, 2007]. This abbreviation will be used in this research.

VGI has been the main topic for many authors since then e.g. [*Coleman et al.*, 2009; *Elwood*, 2008] and [*Flanagin and Metzger*, 2008]. From different points of view they investigated for example the credibility, the usability and the motivation of volunteers contributing to VGI projects. Terms like Neogeography [*Turner*, 2006] came up to describe the combination of cartography and GIS, accessible and editable for non-expert users. In 2008 Sui even called VGI: *"a new geography without geographers"* [*Sui*, 2008]. Here also the term of 'produser' [*Coleman et al.*, 2009] was born, which is a combination of producer and user. It means that the volunteers involved in the process of information production are both producers and users.

Nowadays there are a lot of different VGI projects in the field of GIS. *"Collaborative Web-based efforts like Open Street Map (OSM), Tagzania, Wayfaring.com, the People's Map, and Platial: The People's Atlas, now enable experts and amateur enthusiasts alike to create and share limited, theme oriented geospatial information."* [*Coleman et al.*, 2009]. These projects have a lot of different aspects which can be assessed and investigated. This includes for example aspects like the motivation of users, the updating of the data and data quality.

The aspect of quality is rather interesting, since concerns about the general quality of VGI were raised soon after its appearance. Flanagin and Metzger discussed this, seeing both the positive and negative effects. They wrote that VGI enriched the domain of geographic data, but they also had their concerns with regard to the quality, reliability, and overall value of amateur added information [*Flanagin and Metzger*, 2008], [*Coleman et al.*, 2010].

Next to the growth in private use of VGI, there is an increasing use and potential of VGI as input for authoritative spatial databases in commercial projects [*Elwood*, 2008] (e.g. OSM as background layer [*Exel*, 2010]). Because of the mentioned concerns about the quality of VGI, it is wise to do more research on this aspect. Therefore a quality approach on VGI is adopted in this research.

1.2 PROBLEM DEFINITION

As already described shortly in the introduction, the use of amateurs for data collection can influence the quality of the results. The problem is that, most of the time, these amateurs lack the training and accurate equipment of professionals, which can lead to more subjective results [*Gouveiaa et al.*, 2004]. Besides that, their motivation to contribute might be unclear, for example the contribution might be deliberately false.

As Stark (2010) already mentioned, the value of the collected data is highly determined by its quality [*Stark*, 2010]. For some of the larger and well known VGI projects, like Open Street Map (OSM), the quality has been assessed. Haklay (2010) found that *"OSM information can be fairly accurate" [Haklay, 2010].* These concerns about the quality are shared by other authors as well, Gouveia et al. stated in 2004 that *'data credibility is one of the major obstacles to maximize the use of volunteer collected data. Additionally, access to volunteer collected data is usually difficult, as they are dispersed and non-structured'* [*Gouveiaa et al.*, 2004]. This was confirmed by Agichtein et al. (2008), who wrote that *'the quality of user-generated content varies drastically from excellent to abuse and spam.'* [*Agichtein et al.*, 2008]. In short, the problems of VGI are mainly the uncertainty about the quality, the structuring of the data, the accessibility and continuity.

Improvement in the quality is therefore possible and wanted in order to increase the credibility of VGI. But quality in itself is a rather broad concept, which consists of several sub-concepts that have to be specified in more detail. There is no consensus among experts about the concept of quality [*Stark*, 2010]. The quality of VGI is related to the quality of spatial data and geographic information. These information sources have been subject of quality investigations more often and serve as a base for this VGI investigation.

Van Oort (2006) wrote a PhD thesis about the quality of spatial data [*Van Oort*, 2006]. In the second chapter of this thesis he summarized and combined information of five leading information sources at that time. In this way an overview was created of the, at that moment, most important elements of spatial data quality. A selection of these elements can be found in table 1.

Table 1: Selection of Spatial Data Quality elements based on [Van Oort, 2006], description added

Spatial Data quality element	Short description
Lineage	History (including source and transformations) of the dataset
Positional accuracy	Accuracy of coordinate values
Attribute accuracy	Accuracy of all other attributes other than positional and temporal
Logical consistency	*"Fidelity of relationships encoded in the data structure"*
Completeness	Measure for the absence and presence of data
Usage, purpose and constraints	Measure for the relation between intended and actual use
Temporal quality	How up-to-date is the data and correctness of the order of events
Variation in quality	Homogeneity of the quality level
Meta-quality	Measure for the quality of the quality description

To ensure that most of the data meets the going quality standards, the International Organization for Standardization (ISO) covered the above mentioned quality aspects in a report [*ISO/DIS19157*, 2011]. In this way, central rules and standards have been set. These rules should be applied in order to keep the quality of data worldwide at the same level. This to ensure the comparability and usability of data for different users. The ISO also deals with the evaluation of data quality, providing "*a quality assurance framework for the producer and customer in their production relationship." [ISO/TS19158, 2011].* This document is a guideline for the management of quality, enabling improvement within "*geographic information quality principles, quality evaluation procedures and quality management systems*"[*ISO/TS19158*, 2011]. In this last document the continuity of data plays are large role. So, instead of focusing only on the data that is there, the data that is not there should be taken into account as well. This due to the fact that missing data can influence the quality of a dataset just as much as present data.

Other authors that investigated the quality of spatial data used the in table 1 mentioned quality elements for their research as well [*Aragó et al.*, 2011; *Stark*, 2010]. Even though these elements are still up-to-date and usable for VGI, more research has to be done on the quality aspect and its elements. Nevertheless, the in table 1 mentioned quality elements, combined with the ISO reports can serve as a base for further investigation of the quality of VGI data.

1.3 GENERAL OBJECTIVE AND RESEARCH QUESTIONS

The objective of this research is: To investigate the quality of Voluntary Geographic Information (VGI).

To achieve the general objective, the following research questions (RQ) have been formulated:

- **RQ 1:** What are quality elements of VGI data?
- **RQ 2:** How can the quality of VGI data be tested and what is the quality in a case study?
- **RQ 3:** How can the quality of VGI data in the case study be improved?

1.4 REPORT OUTLINE

Chapter 2 focuses on the methodology of the topic. The research questions are dealt with in more detail, providing insight in the processes and work behind this report. In chapter 3 till 5 the three research questions are elaborated together with their results and answers. The discussion about the results can be found in chapter 6. The report is rounded off by the conclusion and recommendation in chapter 7.

CHAPTER 2: METHODOLOGY

The methodology of this research combines literature research with experimental field work in a case study. By searching for quality elements of spatial data in relevant literature a base is made for the execution of this case study. In the field the quality elements that are defined in research question 1 are tested in a real VGI project. Testing within a pilot project will give an overview of the quality on this moment and at the same time show possibilities for improvement. Recommendations for these improvements are made in research question 3. An overview of the methodology is visualized in figure 1. After that, the methodology is explained in more detail per research question including a short elaboration on the suitability of these methods.

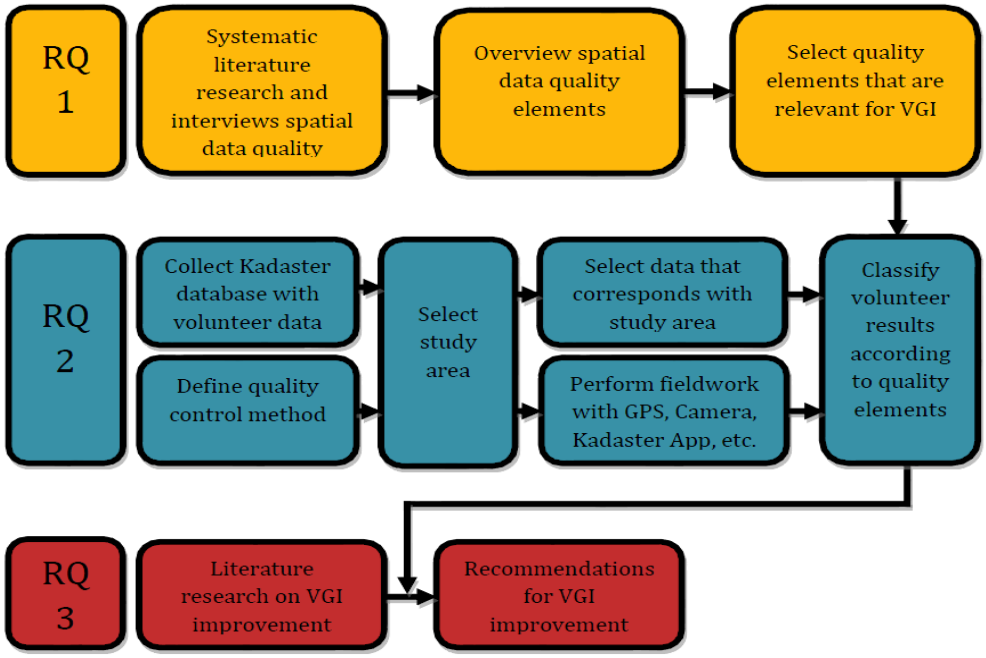

Figure 1: Flowchart of the methodology

Research Question 1: *What are quality elements of VGI data?*

The quality of VGI data is based on various aspects, altogether forming the concept of quality. But this concept of quality is described by a lot of different authors in different ways. This confirms that the concept of data quality is a broad and subjective concept that can be explained in more than one way. In order to create more clarity, the methodology for answering of this first research question is literature research. This is done in order to create an overview of the concept of quality and its elements, as it is described by experts in the field of GIS and VGI. Furthermore, there are a lot of companies working with VGI data (e.g. TomTom, NavTeq, etc.). Short interviews with the VGI experts of these companies should give more insight in important elements of VGI data. These interviews will also serve as input for the quality control method of RQ2 and the recommendations of RQ3.

The research that has been done on the quality of VGI is quite limited. Therefore the literature research is broadened to include research about spatial data quality in general. This literature research will be done based on a systematic review system. This process involves the selection of keywords that can be used for searching and reviewing of articles. Most of these keywords are already mentioned in table 1 (page 2). If a relevant keyword occurs to be missing, this will be added during the process. By keeping track of the times that a certain keyword (e.g. temporal & spatial accuracy, completeness, lineage etc.) is used in combination with the quality of spatial data, the importance of this element for the quality will become clear. The literature research will result in an overview of the most important quality defining elements. As mentioned before, not all of the quality elements might be applicable to VGI data. Therefore a selection will be made, based on quality elements that can be tested in a case study.

Since the field of VGI quality research is rather new, not all knowledge and information might be documented. Besides that, new insights will appear more faster than new articles, meaning that literature cannot keep up the rapid evolvement of knowledge. By combining already present and described knowledge in literature with new knowledge obtained from interviews, new insights can be obtained. In this way, the most recent knowledge from experts and researchers working in VGI quality related disciplines is gathered and used.

Research Question 2: *How can the quality of VGI data be tested and what is the quality in a case study?*
The second research question has a more practical set-up, but will also start with desk research. As mentioned, a case study is used to test and apply the quality elements that are defined in the previous research question. This case study is a project of the Dutch Kadaster (cadastral service). In this project volunteers are used to monitor the condition of landmarks on the frontier between the Netherlands and Germany.

On 30 October 1980, the Netherlands and Germany signed an agreement in which they agreed to collaborate on the maintenance of the frontier landmarks. Every three years a check is performed alternately by one of the countries, in order to keep sight on the condition of these landmarks. Within these three years considerable changes may be found in the condition of the landmarks. Therefore the Dutch Kadaster decided to start-up a VGI project, in which they use volunteers. Using an app, these volunteers can report the status and condition of the landmarks.

Figure 2: Screenshot Internet version landmark app

With this app, the volunteer has the possibility to select the landmark at which he is currently looking. Figure 2 gives an impression of what this app looks like. On the left we see an overview of the area, where the blue points are landmarks. On the right we see an overview of the selected landmark. Here the volunteer can report for example whether the landmark is present, whether it has been damaged and even add a picture. The app has been up and running since the beginning of this year and downloaded around 250 times. The data has been collected and stored in a database of the Kadaster.

In this VGI landmark-project, the earlier mentioned quality aspects of RQ1 can be tested as well. This is interesting for the Kadaster, because they can get insight in the reliability and quality of the voluntarily provided information. In order to do so, a representative part of the frontier has to be selected and investigated in the field. Therefore the available database with VGI from the Kadaster will be analysed. This analysis will show how the measurements are divided along the frontier both in space and time and what kind of people have contributed to the database. Especially for the selection of the route that will be used in the fieldwork, this distribution in space and time over the frontier is very interesting. It will make sure that the results of the selected route are applicable for the whole frontier.

In this fieldwork the landmarks will be checked by walking along the border with at least two persons. One of them will be equipped with a digital camera, a handheld GPS and a check-table on paper. The other will use the Kadaster app. By doing so, the same actions are executed as expected to be done by the volunteers. As an extra check, the trace is walked in two directions. This results in two observations per landmark, which increases the

quality of the measurements. The resulting fieldwork-database will form a good base for the comparison of the volunteer data in the VGI-database.

The selected VGI quality elements from RQ1 serve as input for the first part of RQ2. The data in the Kadaster reference database will be assessed by using these quality elements and by comparing them to the results of the fieldwork. Here it will also become clear where the strengths and weaknesses of the pilot project are. This will serve as an input for the last research question.

The case-study suits this VGI research well and has been selected because the project meets the following criteria:

- The project should be based on real VGI data;
- The results of this research and the VGI project itself should be applicable in a professional context. As mentioned earlier, VGI data is more and more accepted and used in professional projects. This makes it interesting to adapt a professional point of view;
- The project should be rather small and manageable in the given time; and
- The quality aspects should be applicable and testable.

Fieldwork is in this case the only way to obtain reference data with a high temporal resolution, meaning that it is up-to-date. There is no high-quality reference data-set present, since the condition of the landmarks can change quite rapidly. By following the same steps and filling in the same data as the volunteers, a good comparison dataset can be created. To ensure that this landmark test dataset can indeed be used for comparison, a clear fieldwork protocol is defined. This is also done in order to make the procedure transparent and repeatable.

Research Question 3:

How can the quality of VGI data in the case study be improved?

Given the fact that VGI data is still not perfect yet ([*Agichtein et al.*, 2008],[*Gouveiaa et al.*, 2004]), this third research question aims at finding a method for the improvement of VGI data in the case study. A part of the answer on this research question can be derived from previous research made by other authors, obtained from the available literature. It should become clear from literature where the gaps and problems of the VGI data are. This can be verified using the results of the field work.

The combination of literature and the results of the field work will clearly show where the main problems of VGI are (structure, quality control, metadata, knowledge, bad intensions of users, etc.). Besides that, it will become clear whether or not these problems are common, or just specific for this landmark-project. After that, relations between the different problems can lead to recommendations and solutions for the further improvement of VGI data. In first instance these recommendations are relevant for this case study, but it is the ambition to generalize them to other projects as well.

CHAPTER 3: SPATIAL DATA QUALITY

3.1 INTRODUCTION TO SPATIAL DATA QUALITY (SDQ)

Soon after the emerge of Geographical Information Systems (GIS) concerns about the quality of spatial data increased. *"After the introduction of digital mapping techniques in the 1960s and than GIS shortly afterwards, researchers realized that error and uncertainty in digital spatial data had the potential to cause problems.."* [*Stankute and Asche*, 2011]. This was due to the fact that the users of this digital data expected a large increase in quality compared to paper maps. It became clear that just this digitalization would not bring the desired improvement in quality.

As a result, research in the field of SDQ increased in the eighties and nineties. To support the development of quality, guidelines and standards were created. Already in 1987 Moellering [*NCDCDS*, 1987] was the editor of a series of documents for the American Congress on Surveying and Mapping. In this standard the nowadays used quality elements were already mentioned as an important base for SDQ.

One of the first leading documents about quality standards was the U.S. Spatial Data Transfer Standard (SDTS) [*NIST*, 1992]. Later on, Europe also came up with an own standardization document. The Comité Européen de Normalisation (CEN) wrote the Technical Committee287[*CEN*, 1998]. Most of the content in these documents are covered in the later developed Technical Committees of the International Organisation for Standardisation (ISO) [*CEN and ISO*, 2001].

Despite these documents and research done in the field of SDQ, no clear and uniform definition of quality has been formulated. This is probably due to the fact that the concept of quality is a rather subjective one. Nevertheless, these CEN documents provide all together an overview of the elements that form the concept of quality. These quality elements will be elaborated in more detail in section 3.2. In section 3.3 a description of the most relevant quality elements of VGI can be found, followed by a final selection of quality elements. This chapter deals with the first research question, trying to find an answers to the question "*What are quality elements of VGI data?*".

3.2 QUALITY ELEMENTS OF SPATIAL DATA

In the introduction (chapter 1), a short overview and selection of spatial data quality elements was given. These quality elements are: lineage, positional accuracy, attribute accuracy, logical consistency, completeness, usage (, purpose and constraints), temporal quality, variation in quality and meta-quality. This selection was based on the Thesis of Van Oort (2006), where he compared reports of five sources and investigated whether the quality elements were mentioned in these reports. The domain of SDQ has been subject of many investigations since then. As a result, some of these quality elements might be outdated or replaced by new quality elements. Therefore, a literature research is executed in which the above mentioned quality elements serve as a base and starting point.

Next to the literature research, an elaboration of the quality elements is needed to gain insight in the different elements and their contribution to the data quality. This is also necessary for the selection of relevant quality elements for VGI data in the next paragraph. The short description in table 1 (section 1.2) can be seen as a summary of the more extensive definitions below. The descriptions are based on the thesis of Van Oort (2006), the book of the ICA (1995), the U.S. Spatial Data Transfer Standard (SDTS) of the NIST (1992) and the Content Standard for Digital Geospatial Metadata of the FGDC (1998).

3.2.1 SYSTEMATIC REVIEW OF SPATIAL DATA QUALITY ELEMENTS

In order to find out which quality elements are relevant for the SDQ a systematic literature research has been performed. The quality elements as mentioned in the introduction of this chapter served as a base for this review. Used as separate keywords, these quality elements were combined with the keywords 'spatial data' and 'quality'. By reading through the found articles and keeping track of the times a keyword was mentioned in relation to the SDQ, an overview was created of the most relevant quality elements. The result of this literature research can be found below, in table 2.

Table 2: Result of systematic literature review, present elements have a blue square

	[NIST, 1992]	[ICA, 1995]	[FGDC, 1998]	[Hunter et al., 2001]	[Van Oort and Bregt, 2005]	[R. Devillers and Jeansoulin, 2006]	[Van Oort, 2006]	[Frew, 2007]	[Flanagin and Metzger, 2008]	[Hunter et al., 2009]	[R. Devillers et al., 2010]	[Exel, 2010]	[ISO/DIS19157, 2011]	[ISO/TS19158, 2011]	[Aragó et al., 2011]
Spatial data quality elements															
Lineage	■	■	■	■	■	■	■	■		■	■	■	■		■
Positional accuracy	■	■	■	■	■	■	■			■	■	■	■	■	■
Attribute accuracy	■	■	■	■	■	■	■			■	■	■	■	■	■
Logical consistency	■	■	■	■	■	■	■			■	■	■	■	■	■
Completeness	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Usage, purpose, constraints							■					■	■		■
Temporal quality (currency)		■		■		■	■			■		■	■		■
Variation in quality							■	■				■	■		■
Meta-quality							■	■		■	■	■	■		■

As can be seen in table 2, the view on spatial data quality elements has not changed much over the past 20 years. Remarkable is the fact that there are five elements that apparently are of most importance for the definition of the SDQ. The first five elements are mentioned by almost all authors. The last four quality elements on the other hand are more and more accepted and only mentioned in the newer articles. It seems that a division can be made there. This division is between basic data elements and a more underlying aspect of the data quality. The basic data elements contain descriptions concerning the actual data, like completeness and positional accuracy. The other group concerning the more underlying aspects seems already a bit more psychological, for example the fitness-for-use. This is quite remarkable, since this would imply that over the years a broader definition of SDQ has been defined, concerning not only raw data quality elements.

Although the quality of VGI data is related to the quality of spatial data, not all quality elements are necessarily the same. Therefore all in table 2 mentioned quality elements are explored and explained in the next paragraph. In this way it will become clear what the properties and definitions of the different quality elements are. Only in this way a good insight in the quality elements can be created, which is necessary for the selection of quality elements for VGI.

3.2.2 DEFINITION OF SPATIAL DATA QUALITY ELEMENTS

1. **Lineage**

   Describes the history of a spatial data set, from the moment of acquisition until now. It provides a description of the processes and operations that have been performed on the dataset. Lineage is seen as one of the most important quality elements [*Frew*, 2007]. This is because most of the other quality elements are affected by the transformations that are described in the lineage. Contents of the lineage can also relate to properties of the measurement device, a quality description of the 'parent' material or a description of the field work that was performed to collect the data. According to Clark and Clarke in [*ICA*, 1995], lineage gets oft too few attention from the users, because the purpose and importance of this quality element are not clear to them.

   As an example can be thought of geo-referencing or transformations into other projection systems. Either of these two actions, among many others that may have been performed, should be added in the description that belongs to the dataset. The quality of this description on the transformations is referred to as lineage.

2. **Positional accuracy**

   The most obvious and simple definition would be: how far off is a certain point in the data set from its actual coordinates? But the positional accuracy describes more than that. *"Accuracy can be defined as the difference between a measurement … and some comparable measurement known to be of higher accuracy."* [Goodchild in [*ICA*, 1995]]. A distinction between several aspects can be made: relative & absolute positional accuracy and vertical & horizontal positional accuracy. The **relative positional accuracy** describes the accuracy of data compared to other data in the same data set. In other words, is the accuracy of the data within the dataset equally distributed, or are there also outliers present. The definition of **absolute positional accuracy** is indeed the one mentioned in the first line of this indention. If a dataset is in the same coordinate systems as a test dataset, are the points on the exact same location, or is there a difference? This difference describes the absolute positional accuracy. The vertical and horizontal positional accuracy describes respectively the positional accuracy in the vertical (height and depth) and in the horizontal (location) level.

3. **Attribute accuracy**

   Attributes are facts about data or a dataset. For example when the dataset is about roads, attributes can describe the name, number of lanes, number of ramps and lane width. "*Attributes serve to distinguish one location or set of locations from another or one feature from another."* [Goodchild in [*ICA*, 1995]]. Attributes can have a high level of uncertainty. This can be caused by human failures, e.g. when an attribute is placed to wrong data, or due to measurement device inaccuracy. There are different measurement scales that can be used for attributes. These scales are: nominal, ordinal, interval and ratio. Nominal and interval are according to Goodchild in [*ICA*, 1995] the two measurement scales that are the most relevant for geographic data.

   As simple example, the descriptions of roads in a dataset can be taken. When volunteers are asked to describe the roads in their neighbourhood, different observations can occur. If a certain road is described by volunteers as a secondary road, while it is a highway, the attribute accuracy is low. This means that the attribute accuracy is influenced, maybe even more than other quality elements, by the subjectivity of the observer

4. **Logical consistency**

This data quality elements deals with the logic of the structuring of data and their attributes. Or, as the USA-SDTS [*NIST*, 1992] describes it: *".. logical consistency shall describe the fidelity of relationships encoded in the data structure of the digital spatial data"*. This means that when a data set is logical consistent, there are no contradictions in the description or values within that particular data set. Kainz [*ICA*, 1995] states that logical consistency does not only apply to the representation of objects. It also applies to relationships and composition of relationships between objects. For example if one volunteer states that two roads are crossing, while they are parallel, there is something wrong with the logical consistency in that particular part of the observation.

5. **Completeness**

Out of all the spatial data quality elements, completeness might be the one that seems the most obvious. If a data set is not complete, quality suffers. But completeness contains more aspects and goes deeper than just that superficial definition. First of all, completeness can be subdivided into incompleteness (omission) and over-completeness (commission). These two errors can only be found either by knowing exactly what the contents of the original data set are, or by validation in the field. In order to prevent a false error classification, it should be clear what the selection and measurement criteria, definitions and other mapping rules were. If someone on purpose only measured a part of the complete dataset, it should be clear what part that was and under which conditions, in order to prevent an omission classification for the whole dataset.

Brassel et al. [*ICA*, 1995] made a more detailed and elaborated subdivision of completeness. According to them data completeness can be further subdivided into *formal completeness, entity object completeness* and *attribute completeness*. For now this subdivision will not be dealt with in more detail, since it is of less relevance for this research.

6. **Usage, purpose and constraints (fitness-for-use)**

This quality element or actually these quality elements could form for a large part the base of SDQ. The term *fitness for use* (how suitable is a given dataset for the project) [*Chrisman*, 1990] is very applicable here. In short, this cluster of quality elements describes whether the data is used as it was intended and how it fits the needs of the user [*R. Devillers et al.*, 2010]. The **purpose** is the intention with which the data was collected. What was the idea and motivation behind the data collection, for what kind of use and project was it intended? The **usage** describes the actual use of the data, which might be for a completely different goal than the intended use. The **constraints** describe the possible hurdles that have to be taken in order to make use of the data. Such constraints can be for example high costs, restricted access or limited knowledge from the user. If there are few constraints and a corresponding purpose and usage, the *fitness for use* is high.

7. **Temporal quality (currency)**

The temporal quality is a quality element that is a bit harder to grasp, since it consists of several subdivisions and a number of different interpretations among the standards and literature. The first subdivision is a rather logical one: how up-to-date is the data. When looking for example at a monitoring system: how long does it take before a change in the real world is represented in the data set. This is also described as the **temporal lapse** or last update, which indicates the average and last update time of a dataset [*CEN*, 1998]. A second part of the temporal quality consists of the **temporal consistency** [*ISO/DIS19157*, 2011]. The temporal consistency describes whether the order of events is realistic and correct. As a last important aspect, the **temporal validity** plays a role. Van Oort (2006) described that the temporal validity can take several different values, corresponding to the status of the data. These values are: "out_of_date", "valid" or "not_yet_valid" [*Van Oort*, 2006].

8. **Variation in quality**
   The name for this quality element is proposed by Van Oort (2006). He argues that this element is only relevant if there actually is a variation in the quality of the data. Variation in quality, also called the **homogeneity** of quality, describes the distribution of the quality within the data set. It gives insight in the reliability of the data. Not all of the reports have an explicit statement about the variation in quality, but all of them refer in some way to this concept. The SDTS has in a couple of sections a statement similar to: "*Variations in positional accuracy must be reported either as additional attributes of each spatial object or through a quality overlay (reliability diagram)" [NIST, 1992].* The variation in quality is an element that will show-up after a data-analysis and is only use full when there are several different contributors.

9. **Meta-quality**
   The meta-quality is actually a covering document or quality element. It should contain descriptions about all of the above mentioned quality aspects. Van Oort(2006) describes it as an element that "*provides information on the quality of the quality description*". Which assumptions have been made during the assessment of the quality and which settings and definitions were used. Most of the time the meta-quality is part of the description of other quality elements and therefore not explicitly mentioned as a separate quality element.

3.2.3 CONCLUSION AND REMARKS ON SPATIAL DATA QUALITY ELEMENTS

As can be concluded from the above definitions, the quality of spatial data is a complex phenomenon. There is a lot of interaction, intertwining and interdependency. All of the elements are related to each other and can even have proportions that are similar to that of other quality elements. For example the temporal validity can also be seen as some sort of attribute quality: VGI data representing an attribute that has not been reported officially can easily be seen as over-completeness when a proper description is missing. The relative positional accuracy on the other hand can easily be confused with variation in quality. Here again it shows that SDQ does not consist of a couple of independent elements. Instead it consists of several different interdependent elements that are strongly related to each other.

3.3 QUALITY ELEMENTS OF VOLUNTARY GEOGRAPHIC INFORMATION

3.3.1 VGI QUALITY ELEMENTS

As mentioned before, the quality of VGI data is correlated with the SDQ. This means that the quality elements mentioned in section 2.2 are also applicable here. There are however differences between these two data sources that have their influence on the quality of VGI data. Flanagin and Metzger (2008) stated that "*the origin of geographic information, and thus its quality and veracity, are now in many cases less clear than ever before, resulting in an unparalleled burden on individuals to locate appropriate information and assess its meaning and relevance accurately.*" This can partly be caused by the emerge of Web2.0, which opened a new world of sharing, accessing and networking. "*Perhaps the greatest change to emerge from web 2.0 tools and practices is that digital media have provided access to an unprecedented amount of information available for public consumption*." [*Flanagin and Metzger*, 2008].

Flanagin and Metzger (2008) based an article on one of the main quality elements of VGI data, the **credibility**. According to them, the issue with credibility is somewhat comparable to that of quality, it is quite subjective and open to various interpretations. Credibility can best be explained as information accuracy, giving information about the provenance of the data. In their paper, Flanagin and Metzger (2008) state that the credibility is a rather difficult quality element. This due to the fact that 'credibility' itself is a very subjective concept. When is something

credible? Only when it comes from an expert source? Or can someone unknown also provide credible data? This elaboration shows that credibility might be in the eye of the information receiver and whether or not he thinks the source is credible. Credibility also has a lot to do with trust: knowing someone over a longer period of time, might make the choice whether to trust him more easy. This results in the fact that an assessment on the credibility of his information can be made more easy. SDQ elements that can be shared under the umbrella of credibility are: lineage, completeness, positional and temporal accuracy and variation in quality.

Tulloch [in [*Flanagin and Metzger*, 2008]], described that many of the present amateur mapping systems are set up and developed without knowledge and interest in the academic quality and design traditions that form the base of these systems [*Tulloch*, 2007]. This means that there is less focus on data storage, quality and standards, making it more difficult to access and integrate the data from several of these systems. A second quality aspect of VGI that can be derived from these problems is **accessibility**. SD quality elements that can be placed under accessibility are meta-quality, fitness-for-use, logical consistency and attribute accuracy.

Another important quality aspect is stressed by Coleman et al. (2010). They wrote an article about the **motivation** of individuals to contribute to a VGI system. The need to understand why people contribute is recognized by many other authors, see for example [*Flanagin and Metzger*, 2008], [*Coleman et al.*, 2009], [*Fritz et al.*, 2012]. Questions that arise here are of a more psychological background and may be harder to answer. Why do individuals contribute to VGI projects in the first place, and just as important, how can they be motivated to keep on contributing. A quality aspect that can be derived from the motivation of users is the **continuity**. This quality element describes how the contribution of individuals is distributed over time. If at the emerge of a VGI project a lot of contributions are added, while after a couple months hardly any volunteers are left, the continuity and thus quality of the dataset is doubtable.

Looking at the above described VGI quality elements, it seems that a division can be made into two different sets of elements. The first group are the **data-oriented VGI quality elements** which contains the credibility and the accessibility. The second group are the more **community-oriented VGI quality elements**, which have a more psychological perspective, containing the motivation and continuation. This last group of elements forms the real distinction of VGI quality elements to SD quality elements. For regular projects, a paid expert or bureau is given an assignment that has to be executed before a set date. There is no question about the motivation or whether the data continuation is secured. When new data is needed, a new assignment is given. The psychological aspect is of less, or no, importance. The data aspect is more relevant, but at first instance no questions will be asked since the data collection has been done by trained professionals.

For VGI on the other hand, the psychological aspect maybe even of more importance than the data-aspect. Who are the volunteers that contribute to the project? Why do they contribute? And how can they be motivated to keep contributing? These questions can be summarized in the community-oriented quality elements of VGI, motivation and continuity. Unfortunately these questions are not easy to answer or investigate. Nevertheless they are of importance and even when they are not dealt with explicitly in the fieldwork of this research, they will come back in a later stage during the quality improvement in chapter 6.

3.3.2 SELECTION OF VGI QUALITY ELEMENTS FOR THE KADASTER CASE STUDY

In order to test the quality of VGI data in the landmark case study of the Kadaster, a selection of testable quality elements has to be made. This will make it easier to grasp the quality of VGI and keep a good overview of the investigation. The definitions of SD and VGI quality elements in the previous two sections can be combined into one large overview. Some of the elements can be easily erased from the selection, because they do not suit the nature of VGI. Lineage for example is one of these elements, since most, if not all, of the data is first-hand volunteer collected. No transformations or adaptations have been made, which makes the lineage superfluous in

this particular case. Other elements can be excluded from the selection due to limitations of the case study. For example positional accuracy, since the coordinates are not recorded in the landmark project.

For each of the quality elements a consideration based on the properties of VGI and the Landmark project has been made. The results of this selection, including a short explanation, can be found in table 3. The definition of the included quality elements needs a bit more elaboration. This, in order to provide insight in the ideas and assumptions behind the inclusion of these elements. Furthermore, these definitions are needed to make the different elements measurable. For the excluded elements it is shortly explained why the particular element is excluded. Again, it is important to realize that this selection is made only for the fieldwork of the case study. Some of the elements that are excluded from the case study will be discussed in a later stage of this research. This is because they do have an influence on the quality, but are not relevant for the landmark case study.

Table 3: Result of the quality element selection for the case study

Included	
Attribute accuracy	Are the observations complete including all of the sub-questions? This will be investigated during the data analysis. In the database columns containing answers on the sub-questions should be present. When all of these answers are filled in, the attribute accuracy is sufficient.
Completeness	Are all landmarks measured or are some landmarks (whether or not systematically) missing? Conclusions about this quality element can be done after the fieldwork. At that moment it will show whether the volunteer data corresponds with the observations from the fieldwork. In addition the results of Herman Posthumus will be taken into account, who is a landmark expert and author of the book 'Opzoek naar grenspalen'.
Temporal quality	Is the database up to date and do the observations correspond with the actual condition of the landmarks?
Quality variation	Is the quality of the observations equally divided over the database, or are there a lot of outliers?
Credibility	Who posted the observation, is this a Kadaster employee or a volunteer? When the observation is from a Kadaster employee, the credibility is higher than from a volunteer, assuming that the Kadaster employee has more experience.
Continuity	Is the activity and use of the app stable or increasing over time, or is there a decline after a certain amount of time? This will be visible after the data analysis.
Accessibility	Are the observations easy to read, interpret and use or is there a lot of pollution and corrupted data?
Fitness-for-use	The purpose of the Kadaster is to increase the number of observations per landmark, does this work as expected and is the fitness-for-use indeed high?
Excluded	
Lineage	First-hand volunteer observations, no transformations or editing applied.
Positional accuracy	Not measured by the Kadaster in this landmark project, coordinates cannot be entered by volunteers.
Logical consistency	Not suitable in this case since the database consists of point observations.
Meta-quality	No meta-quality added by volunteer, thus not measurable.
Motivation	Discussed later in this research in chapter 5, not measurable during the fieldwork.

CHAPTER 4: CASE STUDY DATA AND METHODS

VGI data quality has been the subject of only a few researchers. Research concerning the actual testing of this quality, however, is even less common. Among the few reports, Haklay (2010) has assessed the quality of British Open Street Map (OSM) data, by comparing it to the British Ordnance Survey (OS) datasets. After that, the same was done for the French OSM data [*Girres and Touya*, 2010]. This kind of quality control consists of a lot of desk research. Due to the fact that a high quality reference dataset was present, a good comparison could be made.

In the particular case of this Kadaster landmark VGI project however, this reference data is only partly present. The Kadaster has provided a reference-dataset that contains locations of the landmarks, the condition of the landmarks is not present. This condition can undergo sudden changes due to e.g. vandalism, accidents or weather influences. These changes cannot be processed immediately, only after a visual inspection these problems will show up. To say something about the quality of the second provided dataset, the VGI data, a comparison has to be made with "as up-to-date data" as possible. To ensure a high temporal accuracy in this case, the reference data has to be collected in the field.

Before the fieldwork is performed, it is necessary to create a clear defined quality testing method. First a general review of quality testing methods will be performed, after that a method specific for this landmark project is designed. This method should give an answer to the first part of research question two: "How can the quality of VGI data be tested in a case study?" The quality elements selected in chapter 3 will serve as input for this testing method. After the formulation of the method, a fieldwork plan is written and executed. The results of this fieldwork can be compared to the database with volunteer data from the Kadaster. With this practical part, an answer to the second part of research question 2 is sought: "What is the quality of VGI data in the case study?"

4.1 CASE STUDY: KADASTER LANDMARK PROJECT

On the frontier that separates the Netherlands from Germany are over a thousand landmarks that mark the border. Since 1980 the Netherlands and Germany collaborate on the maintenance of the border landmarks. Every three years a check has to be done alternately by one of the countries. In the Netherlands this check and the maintenance of the border landmarks are a task of the Kadaster. Since the next check is performed not earlier than three years later, the landmarks could have sustained damage. To increase the number of times that the condition of a landmark is checked, the Kadaster has chosen this project to practice with crowdsourcing. They wanted to get a feeling of working with volunteers, and see whether it works at all. Besides that, the case should be relatively small and easy, to gain experience in using apps for the collection of information. Together with experts an app was created to report the condition of landmarks, an impression of this app can be found in figure 3.

Figure 3: Impression of the border landmark app

The app is used as a complementation and addition of the work that is done by trained Kadaster employees and has been active for around a year now. It turned out that not only volunteers were attracted, employees of the Kadaster also started using the app. They use the app during their inspection of the landmarks to create some sort of back-up of the observations they make. The observations from both the volunteers and Kadaster employees have been stored in the database and can be used for a quality assessment of this VGI project.

Now that the app has been up and running for a while, some questions arise at the Kadaster. First of all, the question of the quality level plays a role. Can the observations from the volunteers be used as a full addition to the 3-yearly survey and trusted completely? Or is the quality still not what it should be in order to trust every single observation? An answer to this question might be found during the execution of the fieldwork and the processing of the results. Other questions are dealt with in more detail in chapter 6, since they are more dealing with the improvement of the process.

4.2 CASE STUDY: AVAILABLE DATA

The available datasets have been discussed briefly in the previous chapters. However, in order to create clarity in the rest of this research more elaboration is needed. In total, three datasets will be used for this research. Two of these are provided by the Kadaster, the third dataset is composed during and after the fieldwork. The used datasets and their products and relations are made visible in figure 4 below:

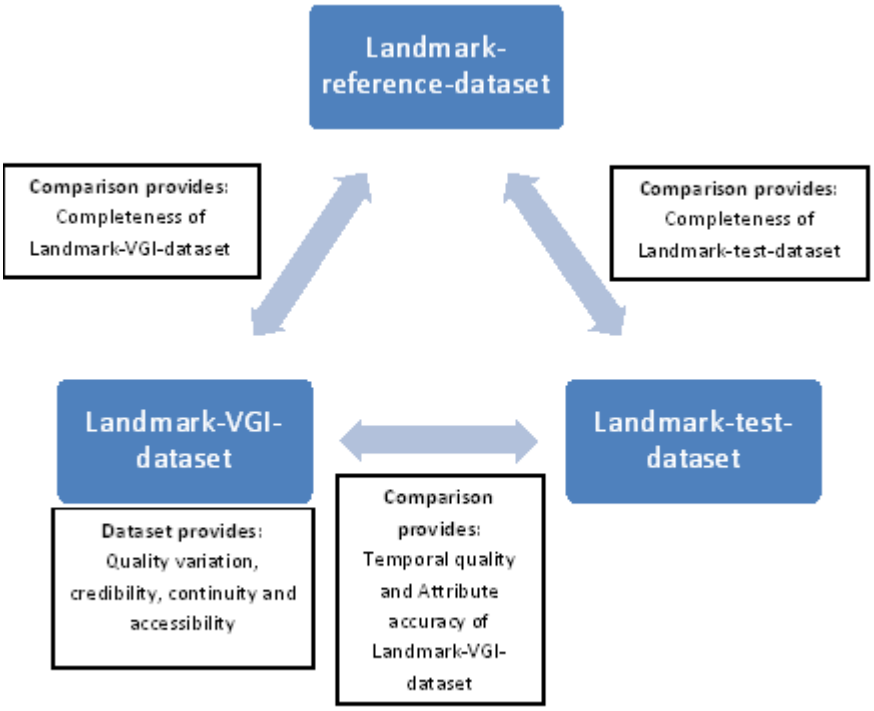

Figure 4: Relation between used datasets and the provided VGI quality elements

- **Landmark-reference-dataset:** This is one of the two datasets that are provided by the Kadaster. It contains the location of all the landmarks on the frontier between the Netherlands and Germany. This dataset does not contain descriptions on the condition of the landmarks and is therefore only used as reference about the presence or absence and the location of landmarks. This dataset provides the following information:
    - Location of each individual landmark
    - Presence or absence of each individual landmark

  The Landmark-reference-dataset is in this case used to assess the completeness of the Landmark-VGI-dataset.

- **Landmark-VGI-dataset:** This is the second dataset provided by the Kadaster. It contains the observations reported by volunteers. This is the most important data source for this project, since it will show how good this Landmark VGI project actually is. The database contains as many records as there are observations, which means one record per observation. This dataset provides the following information:
    - A record per volunteer landmark observation
    - Each record contains attributes concerning the questions that are asked in the app (presence, damage, etc.)

- **Landmark-test-dataset:** This dataset is not yet present, but will be filled with data collected in the fieldwork. This dataset will serve as a comparison dataset for the VGI observations. By using the same set-up as that from the Landmark-VGI-dataset, differences and similarities can be found.

4.3 CASE STUDY: DEFINING THE FIELD WORK

For the field work a route has to be selected that serves as a sample of the whole frontier. Preliminary data analysis showed that the VGI observations are equally divided over the frontier. In addition four experts were consulted for their opinion about a suitable route. These experts are perfervid landmark enthusiasts and they have experience in the search for landmarks, including mastering the hurdles that the terrain can have. One of these experts even wrote a book, called *Op zoek naar Grenspalen [Posthumus, 2010]*, which means freely translated: *Searching for Landmarks.* Consultation of these experts and the just mentioned book brought to light that well trained hikers should be able to walk a route along the frontier of 10 kilometres a day maximum.

A route of in total 30 kilometres was selected, starting at the most north-eastern part of the Netherlands at the Dollard basin, to the small historical city of Bourtange as the most southern limit. This route can be seen in figure 5. Dividing this 30 kilometre over five days gives an average of six kilometres a day. Since the route, while doing observations, is walked in both directions with two persons this sums up to a total of 12 km and four observations per landmark a day.

Observations are done in the way volunteers would do them. This means that observations are done with the app as well as on paper, without using accurate measurement equipment. The app contains the exact locations of the landmarks, so by using the GPS functionality of a smartphone/tablet a fairly good indication of the location is given. By executing the fieldwork in a volunteer way, a good overview can be created of how accurate the volunteers work and how they would experience such a search for landmarks. On top of that, it becomes clear where improvements can be made in the Kadaster project, since hurdles and problems that volunteers would encounter are experienced by the observers themselves. In order to validate the results, at the end of the fieldwork a random selection of landmarks will be observed for a third time.

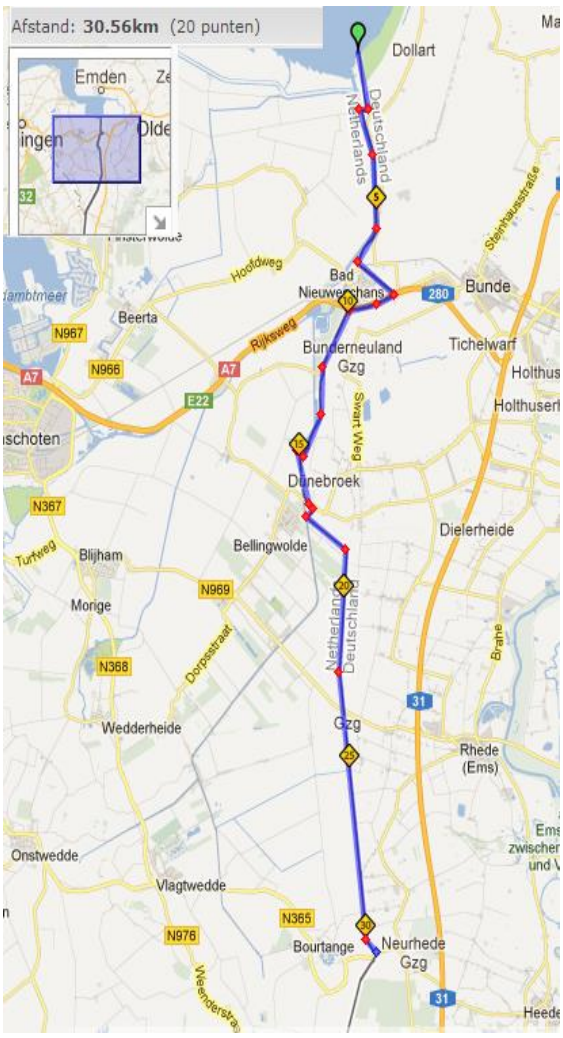

Figure 5: Route from the northern Dollard basin to Bourtange

4.4 STRATEGIES FOR QUALITY TESTING

Most of the time a single quality element of VGI is investigated on its own [*Flanagin and Metzger*, 2008; *Frew*, 2007; *Koukoletsos et al.*, 2012; *Maué and Schade*, 2008]. This research on the other hand aims at interpreting quality of a specific project as a whole. This brings the challenge of adopting a quite flexible approach, since the individual quality elements require different methods. Some quality aspects can be individually assessed while others can only be described in respect to their whole feature set [*Maué and Schade*, 2008].

In the previous chapter (3) VGI quality elements have been selected for this research. In order to assess these quality elements, an overview of specified quality testing methodology is needed. Therefore literature research is used to search for methods that can be applied for the testing of these elements. These results will be the basis for formulating the approach in this research. Although research has been done on the quality of spatial data, this concept is not always clear. As Maué and Schade (2008) concluded, the "*quality of spatial data is and has always been a neglected issue within GI science, and with evolving applications for VGI and their use also within quality-critical applications (for example for participatory GIS), this lack of solutions for managing and communicating quality gets even more apparent*."[*Maué and Schade*, 2008]. This implicates that finding clear defined quality control methods might not be as easy as it sounds. Especially the in chapter 3 defined quality elements for VGI are rather new and unknown. Therefore discussions with experts working in the field of VGI are used for these quality control methods as well. In the following paragraphs the resulting methodologies for each of the selected quality elements can be found.

The starting point for the practical part of this research is a rather uncommon one. Official data from the Kadaster containing the complete research population is present in the Kadaster-reference-dataset, something not commonly the case for VGI data. VGI normally consists of new information that has not been reported officially, making a comparison hardly possible.

Due to the presence of the landmark-reference-dataset, an assessment can be made both for the whole, as well as for a part of the frontier. Data analysis is used to assess the quality of the whole dataset. After that, a representative part of the border is selected for the collection of data during fieldwork. The results will be stored in the Landmark-test-dataset. This dataset can be compared to the Landmark-VGI-data to gain insight in the quality.

4.4.1 QUALITY TESTING METHODS

To test the quality of the different quality elements, quality measurement methods need to be selected. In table 4 an overview of these methods can be found. Some of these methods may not be clear at first instance, therefore for each of the quality elements a short elaboration about the assumptions and rationale can be found below the table.

Table 4: Measurement methodology for the different quality elements

Quality element	Measurement method
Attribute accuracy	$\frac{\text{Amount of VGI records corresponding with Test dataset}}{\text{Total amount of records within VGI dataset}} * 100$
Completeness	$\frac{\text{Observed number of landmarks in VGI dataset}}{\text{Observed number of landmarks in Reference dataset}} * 100$
Temporal quality	$\frac{\text{Amount VGI observations that correspond with Test dataset}}{\text{Total amount of observations in VGI dataset}} * 100$
Quality variation	$\frac{\text{Number of VGI observations with all attributes filled in}}{\text{Total number of observations in VGI dataset}} * 100$
Credibility	$\frac{(0{,}7 * \text{Amount of Kadaster employees}) + (0{,}3 * \text{Number of volunteers})}{\text{Total amount of contributors in VGI dataset}} * 100$
Continuity	$(\text{Expected average date of observation}) - (\text{Actual average date of observation})$
Accessibility	$\frac{\text{Number of non-spam entries in VGI dataset}}{\text{Total number of entries in VGI dataset}} * 100$

Attribute accuracy

In this research, each records in the VGI-dataset represents an observation and each record consist of several attributes. The attributes contain answers on the questions that are asked to the volunteer (for example: is the landmark present, is it damaged/moved etc.). By checking whether the filled-in VGI-dataset attributes are the same as those in the Test-dataset attributes, the attribute accuracy can be derived.

Completeness

Measures for completeness can be derived by comparing the number of features that are in the VGI-dataset with the total number of features that are present in reality [Maué and Schade, 2008]. In this particular research, this reality is present in the form of the Reference-dataset. The completeness will be calculated as a percentage, which will show how much of the original features have been covered. The division between over-completeness (commission) and incompleteness (omission) will be made as well. This can be done for the entire VGI data-set. Additionally, the VGI-dataset can be compared to the Test-dataset to assess the completeness at a lower scale.

Temporal quality

In general, when the observations are up-to-date, the temporal quality is high. This forms the base of the method that is applied in this research. First up-to-date data is collected in the field and stored in the Test-dataset. This collected data is compared with the VGI-dataset. There is a linear relationship between the amount of corresponding observations and the level of temporal quality. The result is a percentage that states how many of the attributes were up-to-date.

Quality variation

The variation in quality can be assessed by comparing different measurements within one dataset with each other. Quality variation measures whether all the observations have a similar usability, credibility and thus the division of quality over the dataset. When the quality variation is high, this means there is a large difference between the various observations. In this landmark case, the quality of an observation is the highest when all attributes are filled in. Therefore, the amount of filled in records is used as measurement for the quality variation. The result will be a percentage that indicates how many of the records had a complete set of attributes within the VGI-dataset.

Credibility

The credibility is, in contrast to most of the quality elements until now, a rather vague and subjective quality element. The nature and background of the contributor influences the credibility. This implies that someone with a lot of regional knowledge would deliver observations that are more credible than the observations from a foreigner. Or that an employee from the Kadaster would deliver more credible observations than an enthusiastic volunteer. It does not need further explanation that this is not necessarily the case. Without knowing more background information about the observations it is hard to make the distinction between an observation that is credible and one that is not.

However, in order to make an assessment of the credibility for this research, choices have to be made. This means that the rather blunt assumption is made that Kadaster employees have a higher credibility than volunteers. Most of these Kadaster employees are trained experts in surveying the condition of landmarks. Since they use the app next to their original equipment, the results should be of a higher quality than those of volunteers. Being aware of the fact that this assumption is a rather blunt one, it still is the best division since the backgrounds of other volunteers are unknown. In order to make this distinction, it is assumed that a Kadaster employee has a credibility of 0.7, indicating that 70% of his observations are correct. For the volunteers this number is set to 0.3 (30%). As mentioned, the credibility is a hard to grasp and complicated element, resulting in the fact that the above mentioned percentages are more a very rough indicator than a scientific weighting method. The division between Kadaster employees and volunteers can be easily made, due to the fact that Kadaster employees have to fill in their Kadaster email address when they post an observation.

Continuity

The continuity is an indication for the division of the measurements over time. It is a well-known problem that a new project only gets a lot of attention in the first period that it is active. This is due to the fact that it is new and volunteers are curious to see how it works, after a certain amount of time this attention decreases and the amount of observations gets less and less. Quality can only be maintained if the volunteers keep adding new observations and information to the project. Therefore the continuity can be measured by checking whether the observations are equally divided over time. This is done by calculating the average date of observation over a selected period of time. In this particular case, the database covers observations of around one year. When the calculated average observation date is mid-year, activity is spread equally over the period of time. When this is before or after mid-year, activity is shifted towards the beginning or the end of the year respectively. If the calculated average observation date is mid-year or later, this means that there is still activity and thus sufficient continuity.

Accessibility

In this case, the accessibility is also an indication for the usability of the VGI-dataset. In other words, is the data ready to be used, or is filtering required to get rid of spam and errors? When this need for filtering is there, the accessibility decreases since it makes the VGI-dataset harder to interpret and read. Moreover, it will cost extra time and thus money to prepare the data. In this research the accessibility will be a percentage, showing how many of the records are real observations and how many of the records are spam or contain errors. The higher the percentage, the higher is the accessibility of the dataset.

CHAPTER 5: CASE STUDY RESULTS AND DISCUSSION

5.1 GENERAL DATA ANALYSIS

The data analysis starts with an assessment of the whole landmark VGI dataset, representative for the whole frontier. For one of the VGI quality elements a comparison can be made to the Reference-database, this quality element is completeness. Other elements, for example the continuation or credibility, can be assessed and calculated by using the VGI-dataset itself.

This analysis is executed in Excel, by manual calculation, comparison and observation of the data. At a first glance a lot of pollution and spam appears to be in the database, which is no surprise since the data is saved completely unfiltered in the database. Therefore some filtering had to be done first, since there are also a lot of blank records. In a conversation with the responsible data expert of the Kadaster it became clear where these blank records came from. Immediately when a volunteer selects a landmark in the app, a new record is created in the database. If the volunteer closes the app without filling in any information, the record is saved as a blank one. Apart from the blank records there are also a number of polluted records. For example, both employees and volunteers have added records to see how the app works or to show it to others. If the record was obviously spam, e.g. because a computer keyboard was on the attached picture, it was filtered out during the data analysis.

In the following paragraphs the results of this general data analysis will be elaborated in more detail. For this general data assessment some of the quality elements have to be left out. This is caused by properties of the Reference-dataset. This dataset only contains the location of landmarks, attributes concerning e.g. the condition are not included. This makes it impossible to assess for example the temporal quality or quality variation for the whole frontier. As stated, this general data analysis will be kept rather broad. For the analysis of the fieldwork data a more detailed approach is adopted. A more detailed and extensive table with results can be found in appendix A at the end of this report.

5.1.1 RESULTS OF DATA ANALYSIS

Attribute accuracy

The volunteers are asked to fill in four closed and two open (email address and remarks) questions after the selection of a landmark in the app. With these questions, the condition of the landmark should become clear for the Kadaster. The choice for closed questions was made in order to create uniformity in the observations and avoid subjectivity as much as possible. Besides that it simplifies the observations in the field, which are most of the time done on a rather small smart-phone screen. Below the attributes of each landmark can be found. Since the app is available only in Dutch, the attributes are translated to English to support the explanation here. The attributes of the VGI database are the following, the abbreviations between brackets serve as explanation for the used headers in table 5 on the next page:

- Email:
- Is the selected landmark present (LM pres.): yes/no
- Is the identification plate present (Nr. pres.): yes/no
- Nature of disturbance (Disturbance): none/moved/skewed
- Damaged (Damaged): yes/no
- Remarks:
- Attachment

In table 5, an overview of the number of the filled in attributes of the whole VGI dataset can be found. Since the Reference-dataset does not offer more information than the presence or absence of landmarks, the actual accuracy of the attributes cannot be assessed. Therefore, the attribute accuracy is based on the amount of attributes that have been filled in.

Table 5: Attribute accuracy overview showing the amount of filled in records per attribute

	Amount of filled in records per attribute						
Total number of Records	*Email*	*LM pres.*	*Nr. pres.*	*Disturbance*	*Damaged*	*Remark*	*Attachment*
2731	2728	2572	2488	2185	2093	1082	500
Percentage of total	*99%*	*94%*	*91%*	*80%*	*77%*	*40%*	*18%*

Per attribute, or question in the app, the percentage of records that has been filled in is calculated. A remarkable fact here is that the amount of filled in records decreases to the right. Table 5 shows clearly that the mandatory first question is filled in much more consequently than the other questions: for example 99% of the observations contained an email address, but only 40% of the observations contained a remark. This is probably caused by the fact that only an answer to the first question, the email address, is obligatory in order to report an observation. The observations that contained no contact data are in this case error and are filtered out in a later stage.

Stunning is the fact that only 500 of the observations had an attachment in the form of a photo. A photo could give much more information than the observation, since a photo is much less sensitive to subjectivity. Apparently some of the volunteers think that filling in whether a landmark is present or not is the most important part, the other questions seem to be of less interest.

Having empty attributes makes it hard to draw conclusions about the condition of a landmark. This is due to the fact that it could also be blank as result of an error in the app, since normally a '0' would indicate no damage or disturbance. The most obvious questions about the presence of both landmark and identification number are filled in sufficiently. The more important questions about the condition of the landmark on the other hand are too often blank (20%-25%). The attribute accuracy of the whole dataset is not sufficient in this case, because there are too many uncertainties about the condition of the landmarks left open by the attributes.

Completeness

The completeness is a quality element for which a comparison between the VGI dataset and the Reference dataset can be made. The Reference dataset serves as the dataset that is known to be complete. That dataset contains the locations of each landmark, including the coordinates. All of these landmarks should be represented in the database, whether they are visible in the field or not. On top of that, they all should have been reported for a complete overview of the frontier, since the absence of a landmark can be reported as well. In table 6 on the next page, the results of this comparison can be found. A division is made between the two German provinces of Lower Saxony (Nieder-Sachsen in German) and North Rhine-Westphalia. The names of these provinces provided the abbreviation (NS and NRW) that is used to distinguish the landmarks that are on the border separating that particular province from the Netherlands.

Table 6: Completeness of the VGI data set

Records	VGI Dataset	Reference dataset	Completeness
North Rhine-Westphalia (NRW)			
Number of observations	2233		
Unique observed landmarks (no duplicates)	1839	3380	54%
Average number of observations per landmark	1,21	0,66	
Lower Saxony (Nieder Sachsen, NS)			
Number of observations	498		
Unique observed landmarks (no duplicates)	378	635	60%
Average number of observations per landmark	1,32	0,78	
Total			
Number of observations	2733		
Unique observed landmarks (no duplicates)	2217	4015	55%
Average number of observations per landmark	1,28	0,68	

A lot of observations have been added over the past year. After the filtering of spam and error more than 2700 observations remained. Nevertheless, only around half of the complete number of landmarks has been observed, the total coverage of the frontier is around 55%. When looking at for example Lower Saxony, according to the VGI database 498 observations were made of in total 378 landmarks. This leads to an average observation of 498 / 378 = 1,32 per landmark. Bringing in the Kadaster database for comparison, instead of the observed 378, a total of 635 landmarks should be present. Recalculating the observation per landmark quote, it now comes down to 635/498 = 0,78 observations per landmark. This confirms the fact that not all landmarks are observed.

Most of the missing landmarks are secondary ones, which are harder to find since they are smaller and thus more easily covered by mud or grass. Still, reports should have been made of missing landmarks, something which does not seem to happen. With a total completeness of around 55%, this quality element is not sufficient.

Credibility and motivation

After the filtering of the data by removing all the errors and spam records, a total of 19 different observers was left. As can be seen in table 7, 12 of them are Kadaster employees, recognizable by their Kadaster email address. Filling in the described formula for the credibility gives a credibility of 55% for the complete dataset. As explained, the credibility is in this research depending on the type of volunteer. In this case it means that the credibility should be rather high, due to the majority of Kadaster employees. However, a credibility of 55% does not seem very use full.

Table 7: Division of volunteers in the VGI-dataset and calculation of credibility

		Weighting	Result
Total amount of volunteers	19		
Kadaster employees	12	((12 * 0,7) / 19) * 100	44%
Other volunteers	7	((7 * 0,3) / 19) * 100	11%
Total credibility			**55%**

Very remarkable is the fact that Kadaster volunteers also contribute using their private email address. It is not clear why they randomly seem to enter an email address or even just their name. This could be caused while some of the observations are done outside office-hours, another reason might be that these different email addresses were not entered on purpose.

Considering the fact that the app has been active for over a year, 19 contributors is not very much. On top of that, only seven of them seem to be real volunteers. This indicates that there are only a few volunteers that have affiliation with landmarks. This says something about the motivation, and shows that people only contribute to projects when they have affiliation with the subject. An advantage of such dedicated volunteers is that they have a heart for landmarks, making them even more motivated to report the condition of landmarks as good as possible. They will probably also be willing to endure more, for example in terms of bad terrain conditions, than less motivated volunteers.

Continuity

Also in the temporal dimension the data is quite well distributed. The expected average observation date is around one month later than the actual average observation date, indicating that there was slightly more activity in the first few months. This trend is also visible in figure 5, where the declining linear shows that the activity is decreasing over time.

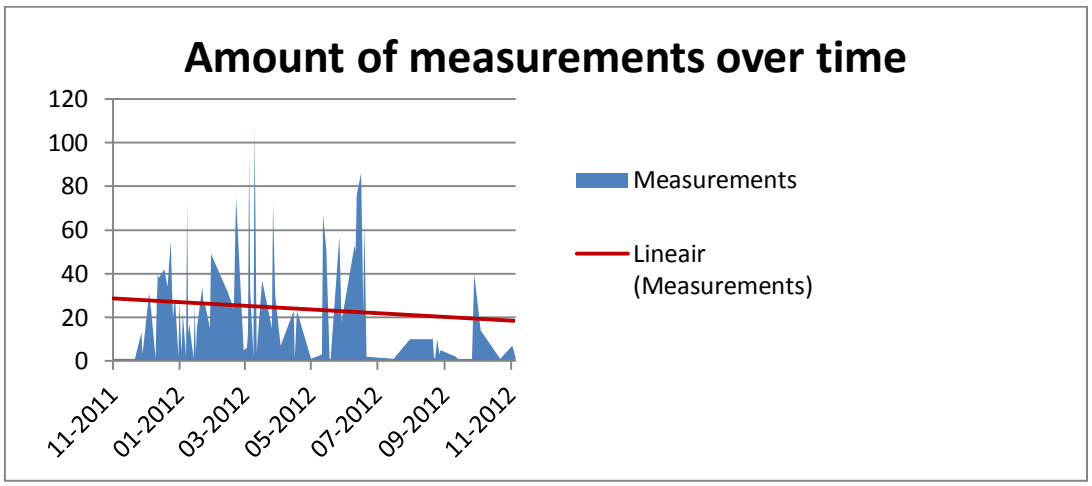

Figure 5: Amount of measurements over time based on the whole frontier

At the date of data subtraction from the internet, the last observation was done only 3 days before. This means that there is still activity and still observations are added. However, more than one or two observations per landmark are not reported. When looking at figure 5, the question can be asked whether or not the continuity is sufficient. When keeping in the back of the mind that there are parts of the frontier with hardly any observations, the continuity is doubtable.

Accessibility

The total amount of useful records that remains in the dataset after filtering is around 87%. This means that 13% of the attributes consists of error and spam. As mentioned before, the data in the VGI database is added without any automatic filtering or processing. As a result mistakes, corrupted entries and spam remain in the database between the actual observations.

Table 8: Amount of spam and error in the VGI database

Records	VGI Dataset	Percentage
Total number of records	3154	
Number of blank records / errors	256	8%
Number of spam/test records	165	5%
Number of actual observations	2733	87%

In order to clean-up the database, manual filtering is needed. Time has to be spent by Kadaster employees on the maintenance of the database to keep it as clear as possible. The higher the amount of useful entries is, the easier is

the interpretation of the information. In a conversation with the designer of the database, he stated that he had just spent a couple of hours on deleting entries. Still, the database was far from clean, as can be seen in table 8 on the previous page.

During the cleaning and processing of the data, even two entries were found containing a commercial text for a popular television channel. Overall, most of the spam records consisted of test records that are created when individuals want to see how the app works. These records are harder to identify, because most of the time the attributes are filled in automatically. Only when it is explicitly stated that a record is used as test, the record can be filtered out. The accessibility suffers under the difficulties in the using and accessing of the data.

5.1.2 FITNESS-FOR-USE ASSESSMENT

The concept fitness-for-use can be used to assess how certain data fits the intended use. In other words, how suitable the chosen dataset for the particular project is. However, as Devillers et al. (2007) already indicated, information about the data quality is often quite hard to understand. This leads to the fact that the fitness for use is most of the time ignored, bringing the risk of wrong data usage [*R. Devillers et al.*, 2007].

The fitness-for-use is a concept which is of importance for VGI and is intertwined with the quality of a VGI dataset. When the quality of a certain dataset is too low for use in a project, this indicates that the dataset is not fit for use. But of more importance than the fitness-for-use at project level, is the fitness-for-use compared to the actual use of the dataset itself.

In this landmark project, the fitness-for-use is also depending on the use of the data. Due to the limited amount of observations, the VGI dataset is not fit-for-use as a complete replacement of expert observations. At this stage, the Kadaster could also decide to use the VGI dataset as an extra source, an addition to the expert observations. In that case the VGI dataset would be fit-for-use. This is caused by the fact that the observations are of a good quality, as was shown in the previous paragraph.

As such, the Kadaster should think about how they want to use the VGI dataset. In both of the above discussed options is still room for improvement. However, the actions that have to be taken depend on the goals the Kadaster wants to achieve. At this moment, this Landmark project is set-up as an indicator for the Kadaster. They wanted to get an idea of what it takes to launch a VGI project and when possible use parts of the dataset. Therefore, the fitness-for-use seems to be sufficient. When they change their goals in the future, changes have to be made in order to increase the quality and thus fitness-for-use.

Further, a small investigation on the fitness-for-use of the app is made. The general set-up of the app seems to be effective. All of the points that are of interest for the Kadaster have been included in the app. There are however, some points that could improve the fitness-for-use of data provided by the app. For example the amount of subjectivity that some of the questions allow. This subjectivity should be eliminated more by either changing the questions, making them multiple choice or ask other questions. The way the questions are formulated now, easily allows wrong interpretation by the Kadaster due to the subjectivity of answers from volunteers. When several volunteers are asked whether a landmark is skewed, different answers can be expected. Since uniformity and clearness are wanted as well as they are expected, improvements can be made.

Another problem is that there are a lot of incomplete records. In order to increase the fitness for use, only records that have been filled in completely should be accepted. On one hand this will decrease the amount of spam, since it will take more effort to complete the observation. On the other hand it will increase the usefulness for the Kadaster, since they have to filter the data less intensive as at this moment. Besides that, by only accepting complete records, the chance of having erroneous records due to accidently reported records can be reduced.

5.2 FIELDWORK DATA ANALYSIS

During the general data assessment, no conclusions could be drawn on the quality of the individual observations. In order to see whether the collected observations from volunteers are useful, a comparison with recent data about the condition of the landmarks is necessary. This comparative data is not available and has to be collected in the field. The earlier elaborated fieldwork plan (paragraph 4.3) was executed and observations were both stored in the Kadaster VGI database as well as on paper. In the following paragraph this data will be assessed and compared to the observations that are made by the volunteers. For the assessment, the same quality elements are used as in the general data assessment of paragraph 5.1.

Here again the assessment of the data is done manually. For the data analysis only a part of the complete VGI database was extracted, that part contains the observations of landmark NS181 till NS203-II. The data is in the format of tables and can therefore easily be processed in Excel. For each of the attributes a comparison can be made between the VGI data and the data collected in the field. As an extra, the earlier mentioned book of Posthumus [*Posthumus*, 2010] is used in this comparison as well. At the end of the book, a list containing the landmarks number NS133 till NS203-II is stated, including whether they should be present or not. This means that for the chosen route, consisting of the landmarks NS181 till 203-II, the extra observation can be added. Unfortunately, this is only possible for the attribute of landmark presence, since the condition of the landmarks is not mentioned in the book. These observations of Posthumus will only be used as an indication, since they do not belong to the VGI project.

5.2.1 RESULTS

Attribute accuracy

By comparing the total amount of observations with the amount of differing records between the VGI-dataset and the Test-dataset, a percentage for the attribute accuracy can be calculated. The results of this calculation can be found in table 9.

Table 9: Attribute accuracy percentages of the VGI-dataset compared to the Test-dataset

Attribute	LM pres.	Nr. pres.	Disturbance	Damaged
Total observations	123	123	123	123
Different observations	12	19	27	9
Percentage	90%	85%	78%	93%

When looking at table 9, it seems indeed correct to conclude that the most objective attributes have the highest accuracy. This is actually not very surprising, since it is plausible that subjectivity has a large influence on the observations. Overall, the attribute accuracy remains well above the 75%, which is quite a good result. This means that more than ¾ of the attributes is useful and correct. An average for the attribute accuracy can be calculated as well, this is 86%. There is still room for improvement here, but for a start this result is not bad.

Compared to the whole data set, the attribute accuracy of this part of the dataset forms a very large contrast. Almost all of the attributes are filled in here. When the attribute of 'remarks' is left out, only three times out of 139 observations one of the other attributes is not filled in. Remarkable here is the fact that these three observations were done by the same volunteer, apparently something went wrong there.

When looking in more detail at these records, an overview can be created of the differences and similarities, comparing them to the results of the field work. Already at the first glance it shows that the more subjective attribute 'disturbance' differs much more from the fieldwork data than the attribute 'landmark present'. This is probably caused by different interpretations and point of views.

Due to the rather small amount of observations, in general one per landmark, it is even more important that the attributes are correct. After a second closer look to the data, it became clear that many of the attributes were not filled in correctly. Some observations stated that a specific landmark was present, while in the remarks of that observation was entered that the 'landmark was not found'. This was also the case for some of the other attributes. For example the attribute of 'disturbance' often did not report any disturbance, while in the remarks 'landmark is skewed' was reported. This kind of contradictions and errors in the attributes makes it harder to interpret the data.

Remarkable also is the fact that the app does not work completely correct. There are errors and empty attributes in the results from the fieldwork done during this research. They must have occurred in the database during the saving process, since none of these attributes was left empty. During the fieldwork, the app was used in the offline mode. The observations are automatically uploaded the next time a connection to the internet is made. It could be that during this uploading or the offline saving something went wrong indicating an incorrect functioning of the app.

Completeness

The amount of records with present landmarks is rather high. According to the VGI-dataset there are 94 out of 110 landmarks present, according to the Test-dataset 90 out of 110 and according to Posthumus 91 out of 110. Peculiar enough volunteers found landmarks that are not present, meaning that over completeness is occurring as well. The results are summarized in table 10 below.

Table 10: Completeness of the different datasets

	VGI-dataset	Test-dataset	Posthumus
Original amount of landmarks	110	110	110
Amount of observations	105	110	110
Completeness	**95%**	**100%**	**100%**
Landmarks reported as present	94	90	91
	85%	82%	83%

These missing landmarks are confirmed both by myself and Posthumus, still the volunteers found them in good shape in February 2012. This is impossible since the original correct location was known both during the fieldwork as well as for Posthumus 2010. In his book there are even historical pictures of these landmarks, so there is no misinterpretation possible. Here again it becomes evident that mistakes can be, and will be made. This is also clear when looking at the results from another perspective. One of the contributors is a Kadaster employee, who should have an advantage in finding the landmarks due to his training and experience. When looking at the results, this assumption could not be confirmed. It could be that this person adopted the same approach as a volunteer would have probably done. This means that he worked under the same conditions as those during the field work, meaning no accurate equipment, search time around 15 minutes per landmark, etc. Nevertheless, a completeness of 95,5% is a result that can be seen. If the entire database would come only near this completeness result, it would already have a much higher usability.

The completeness of the whole database was found to be low (paragraph 5.1.1), only around 55%. For this fieldwork part of the VGI database the percentage is much higher, around 95%. Only five out of the 110 records are missing, meaning that the incompleteness (omission) is around 5%. The reason why these landmarks are missing is not clear. It could be that the app did not process the observation, or that the landmarks were not found. The last reason seems less plausible since the previous and following landmarks were reported, indicating that someone should have passed the landmark.

Temporal quality

As can be seen in table 11, the condition of 18 out of the 110 landmarks has undergone changes, forming 16,3% of the total sample.

Table 11: Temporal accuracy, comparing the VGI-dataset with the Test-dataset

	VGI-dataset vs. Test-dataset
Original amount of landmarks	110
Landmarks with changed condition	18
Percentage	16%
Temporal accuracy	**84%**

This is quite a large amount considering the fact that these changes happened in only half a year. Still, it is important to keep in mind that these changes are not always severe. In order to be able to place the observation in a better perspective, a photo of the landmark can be added by the volunteer. During the field work, it became clear that landmarks actually can undergo quite sudden changes due to external circumstances. Most of the landmarks are on the edges of agricultural land, meaning that large tractors and machinery could easily damage these landmarks. Next to that, maintenance of ditches and bushes has an influence. Due to dredging two landmarks are damaged and several landmarks were probably covered under piles of leaf and branches.

The temporal quality is a quality element that is difficult to assess, because it almost totally depends on the nature of the measured objects. In this landmark case there are no rapid or expected changes, in most cases the condition of the landmarks can be stable over years. Therefore it is assessed whether or not the condition of the landmarks has undergone changes since the last observations. This last observation is in 96% of the records done about half a year ago in February 2012.

Here again the problem with the inaccurate attributes shows up. In five cases the 'disturbance' attributes were marked with no disturbance, while the remark stated that the landmark is a bit off or skewed. This makes that the results are hard to interpret. When taking the remarks into account, the combination of the attributes of 'damage' and 'disturbance' leads to 18 landmarks that have undergone changes in a 'negative way'. This negative way indicates that in February no problem was reported, while during the field work either one of the attributes was marked. Attentive readers will note that mentioning this 'negative way', means that there should also be changes in a positive way. This is true; nine of the landmarks have undergone a mysterious healing process. Unfortunately, this is probably caused by subjectivity of the observer. For example, when a landmark lies flat on the ground, a decision has to be made whether the landmark is damaged or disturbed. Some will say, it is only disturbed because it is still in one piece, others will report this as damage.

Credibility and motivation

The data that was collected in the field however showed around 90% similar observations as the volunteer, which was in this case a Kadaster employee. Since the assumption is made that the credibility of Kadaster employees is higher than that of volunteers, the credibility of the data should be high. Nevertheless, looking at the results from the previous quality elements, this high credibility does not seem to be obvious. This confirms the thought that the assumption about credibility was indeed a rather blunt one. Unfortunately, there are no comparisons with real volunteer data to validate or invalidate the credibility program.

The motivation of the volunteers shows similar results. The Kadaster tried to keep the group of volunteers rather small, in order to keep the amount of nuisance that the volunteers could cause as little as possible. The group of real landmark enthusiasts in the Netherlands consists of less than 25 people. Not all of them are aware of the app, as an interview with one of these experts showed. When assuming that people only contribute to projects they have a strong affiliation with, the fact that there is a total amount of six volunteer measurements comes as no surprise. Motivating people to contribute is definitely something that needs improvement.

Continuity

The continuity is a quality element that is hard to apply in this Kadaster case. The observations that are done are mainly from only one contributor. In addition to that volunteer, two other volunteers have over some period of time added a couple of observations (not much more than 6 in total). This means that for 6 landmarks there are two measurements that differ in time. Between these different measurements is an average of 5 months, indicating there still is some activity. Nevertheless, the fast majority of landmarks have only one observation. Which means there is next to none continuity.

5.3 IMPRESSION OF THE FIELD WORK

During the first day in the field it became clear that searching for landmarks is harder than expected. The rough terrain conditions and hard search for hidden landmarks do not always combine very well. Differences in landmark heights, exact location and appearances made it even harder to find the landmarks. Next to that, the mentioned terrain conditions make it sometimes impossible to keep up a good pace. Fences with barbed wire, ditches and swamp are examples of what can be expected along the frontier. This led to the fact that the selected 12 kilometres on one day turned out to be a bit too optimistic at the end of most of the days. Real volunteers would probably have changed this planning, something that was not done for the fieldwork.

Delay was also caused by missing information and details in the Kadaster app. The app is connected to the Kadaster database, which means that it shows the locations of all the landmarks that were originally present. Due to different reasons not all of these landmarks are still visible. This is for example the case when it is covered by mud and dirt or just disappeared. Apparently this is of no concern, since Posthumus also indicated that these landmarks were missing in 2010 and still no action has been taken. Searching for a landmark that cannot be found does not have a positive effect on the motivation. But also the landmarks that should be there are not always very easy to find. Covered with blackberry bushes, hidden at the bottom of ditches, landmarks show up at the most unexpected places. Due to the GPS functionality of the app, these landmarks can be found with some effort though.

This does not mean that the search for landmarks is all doom and gloom. The trip along the frontier leads to a lot of beautiful places with undisturbed nature and great views. On the frontier a lot of history can be seen as well. For example, there are a couple of very old fortified villages that are worth visiting. Therefore a lot of unused potential hides within this landmark project. Recommendations and improvements concerning this unused potential will be described in chapter 6.

CHAPTER 6: CASE STUDY QUALITY IMPROVEMENT

The first two research questions have been answered, which brings the research to the third and final research question. This third question concerns the quality improvement of the Kadaster landmark project. By looking back, lessons can be learned both from the literature as well as from this case study. Found problems and lacking quality can be combined and substantiated with literature, together serving as input for quality improvement. The earlier discovered division of quality between a data- and community oriented part is used as a framework for this chapter as well. Recommendations are based on both the data assessment, questions of the Kadaster and the fieldwork.

In order to make more out of the database and use the potential of VGI, improvements will have to be made. But how can a broader public be addressed and stimulated to contribute to this project? And maybe of even more interest, how can they be stimulated to keep on contributing? These and other questions will be dealt with in this chapter, trying to find an answer to the third and last research question: *How can the quality of VGI data in the case study be improved?*

6.1 RECOMMENDATIONS

One of the questions that were raised by the Kadaster was: "how can we motivate people to contribute to our project?". The idea behind this question became clear during the data assessment, a group of only seven real volunteers is disappointing. Before recommendations on the stimulation of volunteers can be made, more insight in the motivation behind volunteer contributions must be gained. Research concerning the motivation of voluntary contributors is not new. Goodchild stated that the most surprising fact about the world of VGI is that "*tens of thousands of citizens are willing to spend large amounts of time contributing, without any hope of financial reward, and often without any assurance that anyone will ever make use of their contributions.*"[*M F Goodchild*, 2007] So why do people contribute to these projects? The statement that Goodchild (2007) made seems to contain already a large part of the answer to this question.

6.1.1 COMMUNITY ORIENTED: RESPOND ON OBSERVATIONS

The first recommendation is based on the idea that volunteers want to feel useful and even might want something in return. Spending a lot of spare time on a hobby is quite easy. But when this is combined with the fact that the efforts are of value for a certain project or company, it might become even more attractive for the volunteer. One of the reasons for volunteers to contribute to a certain project is probably the drive to feel useful. This is described by many other authors as the concept of altruism [*Budhathoki*, 2010], [*M F Goodchild*, 2007]. This concept discusses the fact that people find it important that their contribution is used and valued high by others.

Therefore it is important to give the volunteer this feeling of usefulness. This can be either by keeping the volunteer informed about the follow-up of their contribution, or by thanking them in another way. The fact that volunteers have to fill in their email address when posting observations creates possibilities for a first automated reaction. It can be made clear to the volunteer that filling in this email address is of importance to keep them informed about their observations.

These kinds of small rewards can make the process of contributing more satisfying for the volunteer, knowing that he helped to improve his environment or a project. The first recommendation is therefore to give the volunteers something in return for their observations. This can either be by giving them more insight in the reconstruction of the landmarks or by keeping them informed on the actions taken after their observation. This involves having feedback meetings in which the progress of the project is discussed and where volunteers can exchange their experiences.

6.1.2 COMMUNITY ORIENTED: ENLARGE GROUP OF POTENTIAL VOLUNTEERS

The second recommendation is to widen the group of potential volunteers. The Kadaster approach of addressing only a small group eliminated the option of using an existing project as base for this landmark project. This is unfortunate, since there are a number of interesting projects with a large community that would be suitable. The Geocaching community for example is based on a principle where participants hide small artefacts and post the coordinates on a website. Other participants can search for these artefacts by using these coordinates. Addressing this large Geocaching community or adopting a similar principle could be a good starting point in order to increase the number of volunteers.

There are however other options to increase the number of volunteers. Since the group of landmark enthusiasts in the Netherlands is rather small, another approach could benefit the project. The terrain along the border consists mainly of untouched nature and agricultural land. The combination of these landscapes with serenity and beautiful views can be used to attract other volunteers. By investing a small amount of money the terrain along the border can be made much more attractive for walkers, nature enthusiasts and other outdoor activities. But for example for families with small kids too. In this way, the search for landmarks becomes more some kind of game. A somewhat comparative idea has been formulated by other authors as well. Budhathoki discussed the fact that collecting VGI data provides time to spend outside and meet new people with the same interests [*Budhathoki*, 2010]. This is confirmed by O'Hara, who called this phenomenon '*Social Walking*' [*O'Hara*, 2008].

The emphasis can be shifted from the searching of landmarks to enjoying the great landscape while keeping an eye on the landmarks. When the landmarks are not the primary goal, more people will go for a walk and use the app as well. It is then no longer some kind of quest for the landmarks that attracts only landmark enthusiasts. By making the landmarks easier to find, also 'normal' walkers can find them without a lot of effort, while still enjoying the view. Shift the emphasis from the landmarks to the beautiful landscape around the border and keep the reporting of landmark condition as a 'bonus'. The drive to go out and explore is found to be one of the main reasons to participate in geocaching, [*O'Hara*, 2008].

In that sense, it might be interesting to involve the history of the border into the project. For example by using the quite popular QR-codes, which is some kind of barcode. By attaching these codes along the frontier, people can request more info about the history of the frontier and the surrounding cities and landscape by scanning these QR-codes. One option could be to provide this info in parts, so that people will have to collect the entire story by walking along the frontier. In order to increase the number of observations, this could be coupled as well. When people are asked to report the condition of a landmark before they receive information, multiple goals are reached at the same time. Of course this is just one of many options, but it is one that sounds interesting and also viable.

But also an active community might help to involve more motivated volunteers. The feeling of being part of an active community can boost the motivation and attract new volunteers. Kuznetsov (2006) wrote for example about *social rewards* where the contribution to a large online project creates a unity that encourages further participation [*Kuznetsov*, 2006].

In addition to that, Coleman et al. (2010) discussed the concept of an *'enhanced personal reputation'.* This enhanced personal reputation describes the development of *'on-line identities that are respected, trusted and valued by their peers, thereby increasing their own sense of self-worth'* [*Coleman et al.*, 2010].

Open Street Map serves as a good example of a strong community. There is a forum on which the volunteers can exchange their experiences, talk about new observations and so on. By creating a relation to the project and other volunteers, people will feel more driven to do contributions of a high quality. Even some sort of competition element could come in. Volunteers could try to be the first to find all landmarks or be the first to report changes in the condition of certain landmarks. O'Hara found a similar reason for geocaching volunteers, he described this phenomenon as '*First to find: competition and urgency*' [*O'Hara*, 2008].

In this way, the completeness and continuity of the dataset could be improved as well. According to the Kadaster it seems that volunteers only report the landmarks when something is wrong, not the ones that are in a good condition. But also the reporting of landmarks in good condition is important. By doing so, the Kadaster knows that they do not have to visit that particular landmark because the observation is up-to-date. It is now not possible to assess whether the landmark is not reported because it is in a good condition or because it could not be found at all. Furthermore continuity will be improved. At the moment it seems that once every landmark has been observed, people think that their observation is not needed anymore. However when you address it as normal walking, people will go much more often and still report the condition of landmarks. Therefore the amount of observations, both in numbers as well as over time, will increase.

6.1.3 DATA ORIENTED: KEEP DATABASE AND APP UP-TO-DATE

One of the first points that became clear very soon during the first day of fieldwork was the fact that the database behind the app is outdated. This means that all the originally present landmarks are visible in the app and observations can be done on them. In the first half hour of day one, already two out of four landmarks were not found. Is this a continuing trend throughout the day? That would mean that only half of the amount of landmarks will be found. Luckily this was not the case, but there were several more landmarks that could not be located, although the search for them was perfervid. At the end of the day, data was compared with the VGI-dataset and the book from Posthumus [*Posthumus*, 2010]. It turned out that a lot of the unfound landmarks have been reported absent by these two sources as well. Knowing this could have saved a lot of time. Therefore the first recommendation based on the fieldwork, is that the Kadaster should either keep the database more up to date or react more responsive on observations and replace lost landmarks. The way it is now, the impression is created that the landmarks do not have a high priority to the Kadaster, as they do not seem to take action based on the observations. This can cause a lack of motivation for the volunteers, since they could get the feeling that their observations are not processed seriously. On top of that not everyone will be eager to put their time and effort in a project that seems to be hardly used.

A similar approach as for OSM could be chosen. Next to normal contributors, there is the Data Working Group (DWG). This group deals *'with vandalism, copyright violation, disputes, etc.'* [*Goodchild and Li*, 2012]. When there are difficulties or problems, the DWG has the power to decide what to do. In case of the Kadaster this could be one or two employees that keep the database up-to-date, respond to observations and invest whether or not observations are correct. However, in the current situation of low participation, this is not really necessary.

6.1.4 DATA ORIENTED: INCREASE QUALITY OF PROVIDED MATERIALS

Currently the quality of given maps and information is too low. Actually the only information that is provided is the app containing an interactive map with the coarse location of the landmarks. This is not always sufficient to easily find the exact location of landmarks. For example at the part around landmarks NS-198 and NS-199: the border switched suddenly from the left side of the dike (along the water) to the right side, where the landmarks are hidden behind a fence with long grass. This cannot be seen in the landscape neither in the app. Since the last landmarks were all on the left side, a small remark would have been helpful. As untrained volunteer you will keep looking to the left side, missing quite a lot of landmarks, meaning that you will have to go back to search for those missed landmarks.

Another example is when the landmark is somewhere in an area covered with blackberry bushes. Searching for a landmark there can quite easily destroy the motivation. First of all you don't know exactly where the landmark is (searching for a needle in a haystack) and secondly the blackberry bushes are a painful experience. Both killing the motivation to find the landmarks. This last remark can also be seen as an addition to the recommendations in paragraph 6.1.1. It is discussed there that the terrain along the border should be easier to enter, and landmarks should be easier to find.

Next to that, more explanation might be needed. In order to make sure that the volunteers do what the Kadaster wants, a guidebook or manual could be of great help. Especially when a broader public is addressed, volunteers might lack the necessary insight. Not only should the app be self-explaining, background information and a tutorial on how to report landmarks should be included as well. Assumptions made by the Kadaster and explanation on the assessment of the landmark condition can be described there. In that way it can be made sure that all landmarks are reported, even the ones that cannot be found or are in a good condition. This is a minor effort, but it can have a large influence on the results, because the subjectivity can be minimized.

6.1.5 DATA ORIENTED: ADAPT STORAGE OF OBSERVATIONS

As seen in chapter 5, the database is quite messy and not very user friendly. It contains a lot of spam, tests and empty records. At this moment, these records are filtered out by hand by Kadaster employees. Not only is this very time consuming, it is also not the best way to deal with the observations. This manual filtering creates the risk of deleting useful observations or keeping useless observations per accident. Therefore, the way of handling this data should be changed. There are ways to automate the filtering and handling of data, for example by searching on word patterns, specific words and empty cells. Although this is beyond the scope of this research, this recommendation can still make a large difference for the Kadaster. The consultation of an expert is advised, since that will give more insight in the possibilities.

A part of the database pollution can be prevented in an earlier stage, during the actual posting of the observations. When people have to confirm their observation before actually uploading it, tests might be separated from the real observations partly. In this way, already a part of the pollution is dealt with. Even when the filtering of data remains a manual task, this confirmation step will already save a large amount of time. Here again, the recommendation of improved materials and explanation, as discussed in paragraph 6.1.1, is of importance. It should be made clear to the volunteers how certain questions have to be answered and how helpful it is that all questions are filled in.

7 OVERALL DISCUSSION

This research has reached one of its final parts, the discussion. In contrast to many other researches, this overall discussion aims to evaluate the results in a broader context. Also lessons learned, important remarks and comparisons of this research to international literature are discussed. This approach is chosen, since the majority of data and results have been discussed in the previous chapters.

One of the first important steps in this research was the investigation of VGI quality elements. The first quality elements were found rather easy and also confirmed by other literature. This group of data-oriented quality elements forms a stable, but also rather standard base for VGI quality. They have been used by other researchers to describe the quality of VGI as well, see among others [*Aragó et al.*, 2011] and [*Exel*, 2010]. Of more interest are the so called community-oriented quality elements. Elements from this group have been addressed partly by other authors as well, for example [*Coleman et al.*, 2009]. However, the distinction of two different groups of quality elements and division of the elements into these groups is rather new. It has not been addressed by others and the VGI research community has not adopted this view yet.

There is however a large potential in the second group of community oriented quality elements. The motivation and credibility of volunteers next to the continuity of contributions is of large influence on the quality. This became clear during the second part of the research, where the database was assessed. The quality of the observations as such was sufficient. Which is not the case for the fact that in one year only one observation per landmark was done. This shows that the quality is not solely determined by the quantity of observations However, quality definitely improves when the quantity increases. This is confirmed by Haklay et al. (2010), who found an increasing quality with increasing numbers of volunteers, this effect was present up to 13 volunteers [*Haklay et al.*, 2010]. A similar point is discussed by Goodchild and Li (2012), they discussed that *'crowd-sourcing … refers to the ability of a group to validate and correct the errors that an individual might make*' [*Goodchild and Li*, 2012]. The results from this research differs partly from existing literature. This by showing on one hand that the stimulation of volunteers is important, in order to provide a sufficient continuity. On the other hand it shows that also a low amount of volunteers can provide a good quality.

The execution of the fieldwork gave a good insight in the project of the Kadaster. It became clear what the limitations were and which parts could be improved. The terrain along the frontier was quite rough and impassable, making it sometimes hard to book progress. This confirms the idea that in order for volunteers to participate, this should either be very interesting or be very easy. Neither of these two seems to be the case in this project. However, the quality does not suffer severely. It that sense this research does not stroke with other researches to VGI projects, where the quality is mainly based on the amount of contributors [*Haklay et al.*, 2010]. Nevertheless, here again it has to be said that more observations, creates better possibilities for a data quality assessment. This is for example the case when there is no dataset for comparison present. More observations will make it easier to assess whether the observations are of high quality.

This low participation leads to the question whether VGI really is as booming as some of us would like to believe. The type of project seems to be of influence on the answer to this question as well. When looking for example at Open Street Map the answer would be yes. Currently OSM has more than one million members. This is caused by the concept that Budhathoki describes as *'Instrumentality of local knowledge'* [*Budhathoki*, 2010], which describes the use of local knowledge to enrich projects. It is also caused by the fact that it is quite easy to add data from the area where the participant lives.

However, it seems quite valid to put question marks to these kinds of participant numbers. In a research of Mooney and Corcoran (2012) concerning British OSM data, remarkable results were found. They found that in 84% of the cases frequently edited elements, meaning more than 15 edits, were edited by only 12% of the contributors. [*Mooney and Corcoran*, 2012] This points towards the conclusion that there is only a rather small group of real VGI enthusiasts.

So when the scope is on this particular Kadaster project, the small amount of volunteers is not necessarily a problem. The low interest is caused by the fact that the frontier is a local feature and that the area around the frontier is rather sparsely populated. Next to that, the search for landmarks will not be at the top of everyone's to-do list. This can only indicate that the set-up and subject of the project have a large influence on the activity of volunteers. This should be investigated more deeply, but also should be kept in the back of the mind while designing a new VGI project. In order to attract new volunteers and keep them interested through time, contributions to the project should be either challenging or quite easy.

The fact remains that there definitely are enough volunteers, since every single person is in fact a potential contributor. How to address these volunteers is a another issue, since their interests probably differ a lot from each other. Research to the motivations of volunteers is more of a psychological nature, and thus out of the scope of this particular research. In order to be able to serve the wishes and needs of volunteers as good as possible, more research is needed to the motivation of volunteers. In that way, their contributions can be optimized by making the projects attractive as possible for the target group.

One of the main points that this research brings forward is the fact that VGI data quality goes further than the ordinary data-oriented quality aspects. This has to do with the fact that VGI is based on a different principle than normal data collection, since it is done voluntary. The more fun and pleasure the participation in a project gives, the more energy and time a volunteer will spend on doing contributions. This is confirmed by research to the motivation of volunteers participating in the Geocaching community [*O'Hara*, 2008]. The next main point is that the quality of a project does not necessarily depend only on the amount of volunteers that contribute. This last point is quite controversial, since until now the concept of 'the more', the better' was accepted. This is not completely false, but elements like motivation and credibility are definitely of the same importance.

8. CONCLUSIONS

Now that we have come to the end of this research it is time to draw conclusions. The main objective for this research was: 'To investigate the quality of Voluntary Geographic Information (VGI).' In order to achieve this objective three research questions were formulated. During this research and in this report, answers to these questions have been found and presented. In the following chapter conclusions about and answers to these research questions, are presented.

8.1 RESEARCH QUESTION 1: ELEMENTS

- **Research Question 1:** What are quality elements of VGI data?

In an early stage of this research it became clear that the quality of VGI is closely related to that of Spatial Data. This was positive, since the quality of Spatial Data has been subject of many researches. Just like normal spatial data, the quality of VGI is formed by several different elements. All these elements together form the concept of quality. These elements influence each other; they are strongly correlated and interdepended.

It was found that VGI quality elements can be separated in two different groups. On one hand there are the data-oriented quality elements. These data-oriented quality elements are those as they are known from the spatial data quality researches (see for example [*Van Oort*, 2006]). Among these quality elements are for example the positional and temporal accuracy, completeness and attribute accuracy.

It turned out however, that the quality of VGI goes beyond just this data-oriented point of view on quality. There is also a more psychological aspect that comes in, and that can be seen as an addition to spatial data quality. At this point, the real difference between these two types of data becomes clear. I call this group of quality elements the community-oriented quality elements. In this group are for example the **motivation** of volunteers, telling something about the 'why' of a voluntary contribution. But also the **continuity** is found in this group, telling something about the division of observations over time. Last but not least, the **credibility** is part of this group. The credibility says something about the volunteer, for example how sure can you be that the observation is accurate?

This last group of community-oriented quality elements is a bit more abstract and harder to grasp. They seem to be of more interest however, because things like the motivation and continuity are of large influence on the quality of VGI databases and projects. When people are highly motivated, they will put more effort in the optimization of their observations. Research on these community oriented quality elements is quite limited however, because they are quite vague and not easy to capture in a couple of words. The community oriented quality elements should therefore be researched in more detail.

8.2 RESEARCH QUESTION 2: TESTING

- **RQ 2:** How can the quality of VGI data be tested and what is the quality in a case study?

It turned out that the data-oriented quality elements can be tested quite easily. The calculation of the quality level can be done as percentages. In this way, it can be easily seen whether a certain VGI project suits the needs of the potential user. On forehand the user has to think about the most important quality aspects for their project. By doing these calculations, the fitness-for-use can be assessed. The fitness-for-use says something about the suitability of a certain dataset for a project.

The quality of the VGI observations itself are actually quite useful. In table 12 on the next page an overview is created of the different data oriented quality elements.

Table 12: Overview of the quality elements assessment

Attribute	Percentage
Attribute accuracy	86%
Completeness	96%
Temporal quality	84%

However, the amount of contributors and observations per landmark is too small to draw founded conclusions. It could easily be that this particular contributor did a very good job. Observations from another volunteer could have led to completely different results.

The community-oriented quality elements have not been tested in this research. It was not within the scope of this project to find out what motivates people to contribute voluntary to projects or how to assess the credibility of observations. This does not implicate that no conclusions can be drawn about these group of quality elements. Most probably the motivation of people to contribute is the drive to feel useful or part of a community. By using some sort of review system where volunteers value each other's observations, credibility can be improved. It needs to be said that these are more assumptions than conclusions. However, it did become clear that for a healthy and useful VGI project, a larger group of volunteers is needed. Both to ensure sufficient quality as well as continuity.

For the project of the Kadaster it turned out that this quality is quite low. However, for the static and very slow changing system of the landmarks, this low quality seems to be sufficient. The majority of the VGI observations is still up-to-date. This does not outweigh the fact that one observation per landmark is too few to be useful as complete replacement for expert observations. Nor the fact that the database contained a lot of pollution and spam records. The data has to be filtered out by hand, bringing the risk of accidentally erasing useful observations or keeping spam.

8.3 RESEARCH QUESTION 3: IMPROVEMENTS

- **RQ 3:** How can the quality of VGI data in the case study be improved?

There is still quite a long way to go if the Kadaster really wants to use these VGI observations as only source of information. However, improvement of VGI quality in this case might sound easier than it actually is. The Kadaster choose a rather small approach, in order to keep the amount of volunteers on private property to a minimum. If the Kadaster wants to set this project through and intend to make serious use of it, this has to change. A broader and larger public should be addressed, in order to increase the amount of observations. As stated by other authors, the strength of VGI lays in most cases in the masses [*Haklay et al.*, 2010].

Although the quality of this Landmark project turned out to be quite good, in most cases it takes more than just one volunteer to create useful observations. Therefore, the Kadaster should consider drawing the attention of a larger group of potential volunteers. An increase in the number of volunteers will turn out to be a solution for most of the found problems in this project. This means a large step in the increase of the quality. There are several options to stimulate the contribution of more volunteers.

One of these is to broaden the group of potential interested individuals. The terrain along the frontier is beautiful and provides stunning views of pristine nature. There are massive amounts of people who would love to walk there and enjoy the view. The terrain along the frontier is at this moment rather inaccessible, but by making small adaptions this could change. By cutting down some bushes, placing a bench here and there and providing parking places, the frontier suddenly provides a great walking path. In this way, the emphasis shifts more towards walking and keeping an eye on the landmarks, which makes it more interesting for a larger public than a landmark-quest.

Another option could be the use of an existing project as base. When the large community of an existing and comparable project can be stimulated to participate, the amount of volunteers could increase quite rapidly. A good example here could be the Geocaching-community. In order to keep the amount of nuisance to a minimum, certain parts of the border could be excluded from the project. These parts, that form a fast minority on the whole frontier, could still be observed by experts. This would still save a lot of money and time.

It showed that VGI projects need input from the founder. It just does not work to drop an app on the Market and expect that it will find its way to the volunteers. As can be seen in this case, when a project is set-up solitary with a small group of volunteers, the chance of success is rather small. The main improvement is still the gain of new volunteers. Next to that, subjectivity should be banned as much as possible, in order to create the highest chance on good quality. This could either be done by formulating questions differently or adding a more elaborated explanation to the app.

8.4 FUTURE RESEARCH

This research shows quite clear that for an useful project, a larger group of volunteers is needed. This is no breaking news however, since an old knowledge already says: “one observation is no observation, two observations show the truth and the capabilities”. For VGI, even this last part would be not sufficient, ‘the more, the better’ seems to be more appropriate here. To address this larger group of potential volunteers, it is wise to make sure in advance that the project is interesting for a broad public by itself. When this is not the case, using an existing project as base could multiply the number of volunteers and thus the chance on a higher quality.

For future research, the community-oriented quality elements are of most interest. In order to increase the amount of contributors to VGI projects, it is important to know what drives them to participate in such projects. What makes it particularly interesting for them to invest their free time, unpaid into VGI projects? The orientation of that research will be of a more psychological nature. This is an essential step in increasing the amount of volunteers, since these motivations can be taken into account during the set-up of a VGI project. In that way, making them as satisfying as possible for the volunteer.

Furthermore investigation to improve insight in the quality of particular observations and datasets should be done. This kind of meta-data, or in this case, meta-quality will help to assess whether data or observations are useful. This involves research to the credibility of users and how this can be made visible to users. For example ranking-systems, where users can rate observations of other volunteers. An increased meta-quality will help a lot in the assessment of fitness-for-use of a dataset. It will make it easier for the user and provide a better insight in the quality of that dataset.

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APPENDIX A: DATA ASSESSMENT TABLE

Date of extraction: 14-11-2012				
Records	**VGI Database**	**Kadaster data**	**Difference**	**Coverage of total**
Total				
Total number of records	3154			
Number of blank records / errors	421			
Number of spam/test records	165			
Number of observations	2731			
Number of unique observed landmarks (no duplicates)	2217	4015	1798	55,22%
Average number of observations per landmark	1,28	0,68	0,60	
North Rhine-Westphalia (NRW)				
Number of observations	2233			
Number of unique observed landmarks (no duplicates)	1839	3380	1541	54,41%
Average number of observations per landmark	1,21	0,66	0,55	
Lower Saxony(Nieder Sachsen)				
Number of observations	498			
Number of unique observed landmarks (no duplicates)	378	635	257	59,53%
Average number of observations per landmark	1,32	0,78	0,53	
Contributors	**VGI Database**			
Total number of observers	19			
Number of Kadaster employees	12			
Division in space	**VGI Database**	**Kadaster data**	**Difference**	
North Rhine-Westphalia (NRW)				
Most southern landmark NRW	NRW_193-N	193	41	
Most northern landmark NRW	NRW_862	NRW_862	0	
Lower Saxony (Nieder Sachsen)				
Most southern landmark NS	NS_11-01	NS_001	25	
Most northern landmark NS	NS_203-02	NS_203-02	0	
Division in time	**VGI Database**	**Expected outcome**	**Difference**	
Date of first observation	10-11-11			
Date of last observation	11-11-12			
Average date of observation	02-04-12	10-05-12	38 days	