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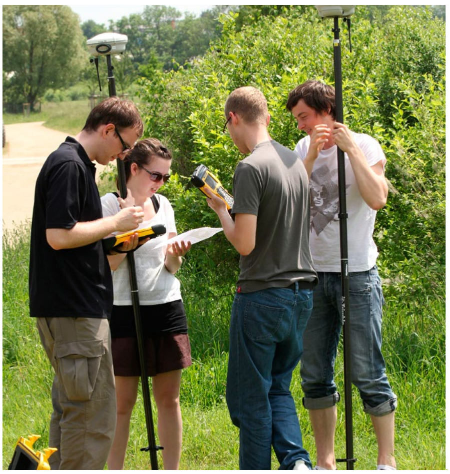
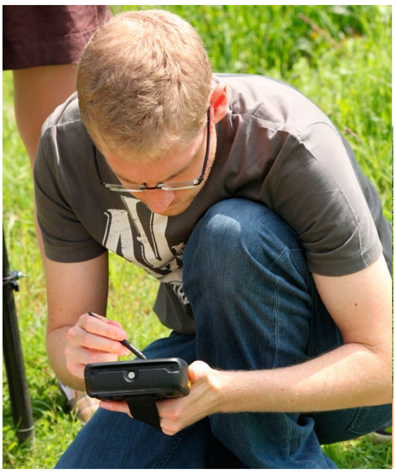
New Trends in Geospatial Information:
The Land Surveyors Role in the Era of Crowdsourcing and VGI


CURRENT STATE AND PRACTICES WITHIN
THE LAND SURVEYING, MAPPING AND GEO-SCIENCE COMMUNITIES

FIG Commission 3

INTERNATIONAL FEDERATION
OF SURVEYORS (FIG)

New Trends in Geospatial Information:

The Land Surveyors Role in the Era of Crowdsourcing and VGI

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FOREWORD

The geographic data and knowledge collection and dissemination via authoritative professionals only – characterized as the top-down scheme – has been shifting in the past few years to the bottom-up scheme, in which citizens and laymen generate data they later use as information in various applications and services. This is a new era in the history of human mapping efforts, mainly in terms of data collection, but also for knowledge production.

This neogeography revolution is fundamentally transforming how geographic data are acquired, maintained, analyzed, visualized, and consequently – used.

With today's technology, availability, access and ease of use there is a potential of a geographer within everybody.

In view of these changes in the mapping and land surveying domain over the past few years, Commission 3 has undertaken the mission to prepare this publication within the framework of FIG, aiming to emphasize the accessibility, the potential, and the use of crowdsourcing and VGI as a basic tool for land surveyors and mappers professionals.

During the 2011–2014 and 2015–2018 periods, FIG Commission 3 has addressed this phenomenon of shifting from the top-down mapping scheme to the bottom-up one. Its particular focus has been on SIM Infrastructure, Technical Aspect of SIM, and on Crowdsourcing and VGI.

In this effort, FIG Commission 3 has established valuable collaborations in an effort to adopt a multi-sector approach, and bring together people with relevant expertise, such as academics, experts from the public sector as well as from the private sector, to share experience and knowledge on crowdsourcing and VGI. FIG Commission 3 cooperates closely with UN-agencies (UN ECE WPLA, and UN-HABITAT and GLTN), UNESCO, the World Bank, ISPRS and other sister associations.

This publication integrates the output of research studies done by Commission 3 working groups and resolutions from the past annual workshops (Paris 2011, Athens 2012, Skopje 2013, Bologna 2014, Malta 2015, Iasi 2016, Lisbon 2017 and Napoli 2018).

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Disclaimer: Note that the views expressed within this publication are those of the authors of this publication and do not represent a formal opinion of FIG.

EXECUTIVE SUMMARY

Background to Study

The International Federation of Surveyors (FIG) is an international, non-government organization whose purpose is to support international collaboration for the progress of land surveying and administration in all fields and applications. FIG Commission 3 (Spatial Information Management) has undertaken during the last two terms (2011–2014, 2015–2018) a study about the new trends in Geospatial Information in the Era of Crowdsourcing and Volunteered Geographic Information (VGI). The study was focused on the current state and practices within the land surveying, mapping and geo-science communities, on practical as well as theoretical levels. The study has included the aspects of Geospatial Data Infrastructures in general and Crowdsourcing of Geospatial Data Collection in particular. More specifically, the study discusses aspects related to the quality of geospatial data and information, focusing on crowdsourcing; the implementation of Geospatial Crowdsourcing; the inter-relations between National Mapping Agencies (NMAs) and crowdsourcing; VGI Practices in Cadastre and Land Administration in developed and less developed countries; and a review of several typical case studies.

Geospatial Data Infrastructures

Enormous volumes of geospatial data are generated day by day, by Earth Observation and other sensor observation systems, by many public administrations, by private firms, by research institutions, and by citizens. A major challenge over the past decades is to enhance the accessibility, communication, and use of spatially referenced data to support a wide variety of decisions at all levels of society – by the implementation of geospatial data infrastructures. These geospatial data infrastructures are composed of geographic, environmental, economic, social, and institutional databases. Furthermore, their level of detail goes from local through national and eventually up to global databases. In the developed countries considerable efforts were made in the past decades to develop their own geospatial databases at the national level, consisting of geographic data and metadata, as well as policies and standards to facilitate the access and use of the spatial data. In parallel, huge efforts are also invested in developing regions to establish their geospatial databases despite the technological and financial difficulties involved in setting up these systems. In many developed countries and regions of the world, geospatial data infrastructures already have reached a mature status. In such developed environments the geospatial data infrastructures more and more shifts from a data-centric to a service-centric and governance-centric framework.

Many of the current challenges of today's world are based or connected to the geospatial databases and infrastructures. These challenges are complex, ranging from economic and social problems – such as poverty and inequality, demographic change, and lack of good governance; to environmental problems – such as natural disasters, food insecurity and insufficient water supplies, and environmental degradation. Meeting these challenges requires feasible exchange of information between many different stakeholders. Through linking information to location, the concept of geospatial information infrastructures and geospatial information management can deliver highly valuable methods for designing and implementing appropriate solutions to humanity's problems.

Crowdsourcing of Geospatial Data Collection

An overwhelming transformation process of how geospatial data, information, and knowledge are being produced and disseminated is taking place in the last two decades. The relatively new term Volunteered Geographic Information (VGI), defines the idea of using the internet to create, share, visualize, and analyze user generated geographic information and knowledge, envisioned via the use of numerous computing devices and platforms. This neogeography revolution has fundamentally transformed how geospatial data are acquired, maintained, analyzed, visualized, and consequently – used. This influences on common practices since it allows a more complete and broad knowledge of the environment we live in on all aspects of life, encompassing new services to take place, applications and processes to be developed – all of which are location based; we now have the potential to track where and when everything is occurring – and in real time.

Vast amount of geographic data is constantly being collected and stored by the public, backed-up by new technologies development to empower Citizens Science. It has a large potential and relevance in contributing to the building and maintaining of reliable, qualitative and usable mapping, GIS, and Geospatial Data Infrastructure. As a natural continuation of the idea of Volunteered Geographic Information the crowdsourcing paradigm has been derived. This is based on the fact that users nowadays can search for geographic-based information relying not only on traditional or official and authoritative geospatial and map information, but also on a variety of user-generated geographic and geo-tagged digital information data-sources being established and maintained by the public and private citizens. Consequently, the update process of geospatial data and Spatial Data Infrastructures (SDIs) is now shifting to be an event based – and not a cyclical time based, as in authoritative data.

Implementation of Geospatial Crowdsourcing

There is no universal way in which crowdsourced data is being generated. As with quality and reliability expectations, the methodology to collect the data should fit specific purpose and context. In all types of crowdsourcing activities, be it an activity that engage few participants or one that involves hundreds of thousands of participants, there is a need to consider the engagement with the crowd as an integral part of the work methodology. There is also a need for dedicated resources to recruit, support and maintain the relationships with the participants in the crowdsourced project. Similar to organized field survey work, the methodology must consider who the people that will contribute to the operation are and what process will be followed to motivate them to participate. In addition, it is a need to identify the correct tools that will be used for data collection and recording, and finally, the approach that will be used to record the data and validate it.

Within crowdsourced projects, we can identify several aspects that will influence the methodology and approach to collect the information. One differentiation is between a passive data collection, where sensors and automatic logging of the data from them is used to record geographical data, and active data collection, which requires the participants to actively notice something in their environment and record it. A second differentiation is between the aspects of spatial vs. temporal coverage. If the place of interest is at the center of a highly populated area and a center of economic activity, then it is likely that enough people will visit it to provide information. The temporal aspect of crowdsourced data collection is influenced by the scale of the project, meaning that we can motivate a huge crowd for a very short time, or by few for a long time. The challenge, therefore, of crowdsourcing projects is the need to engage a wide range of participants with varying levels of experience and knowledge, using different methodologies that take into account the specific spatial, temporal and thematic domain of the data collection activities.

National Mapping Agencies (NMA) and Geospatial Crowdsourcing

In the last two decades, we have witnessed the internet revolution as a "disruptive technology" influencing the way National Mapping Agencies (NMAs) work. This technology provides the best platform starting from viewing and downloading information from on-line databases and geospatial portals (Web 1.0), to one that enables user's engagement and the use of crowdsourcing methodologies to acquire data (Web 2.0), to one that included data and information for computers to work with (Web 3.0).

This evolution has also affected the way NMAs operate and work. At first, NMAs developed tools and means to distribute their data and share their maps on-line (Web 1.0). Many of the NMAs have nowadays an active geospatial portal. Moreover, many NMAs are investigating the use of Web 2.0 to improve their operations using crowdsourcing methodologies. Some examples include: The US Geological Survey's VGI project that encourages citizens to collect and edit data using the National Geospatial Portal about man-made structures to improve the USGS authoritative spatial database; The Dutch Cadastre in the Netherlands and the Finnish Geospatial Research Institute are researching the use of crowdsourcing methods to enrich their topographic databases; the Vicmap Editing Service encourages registered public users to notify the Australian state of Victoria of changes required to the Vicmap core spatial data products; the Survey of Israel is using its national geospatial portal to get citizens' feedback on its national map, as well as investigates crowdsourcing methods to map defibrillators. However, most NMAs are cautious about integrating crowdsourced data with authoritative data, as this may reduce the quality and consistency of their national datasets.

Quality of Geospatial Data

The geospatial data, originating from many different sources, can be used by many different users for various purposes, by combining and by processing them in different ways, thus creating new knowledge. However, the reliability of such knowledge largely depends on the properties of the input data. Consequently, attempts are being made to describe the properties of geospatial data and processes in a transparent way. Two perspectives toward the geospatial data can be identified: formal well-established processes of standardization reflecting a top down approach; and non-formal processes of standardization, emerging from advances and perspectives of the past two decades, that can be described as the bottom up approach, which is commonly referred to as crowdsourcing and Volunteered Geographic Information.

Technologies are being designed and implemented today to allow for everyone to easily collect geospatial data, even without being a qualified geographer or land surveyor. Such that two main channels are practiced: the collection of volunteered geographic information on the one hand, and the handling of big geodata on the other hand. These two channels were handled in the past only by professionals. However, very often, nowadays geospatial data users, and especially the amateurs, do not know much about data quality. Thus, it is even more important to be able to evaluate its adaptability for the intended purpose as geospatial data quality is important for both the users and producers of geospatial data.

The data quality issue in geospatial science is not new to professionals, such as land surveyors, cartographers, soil scientists, etc. They always had a sound knowledge of errors that could arise during field surveys and map production. In contrast, current interoperability and the SDI programs in most cases have not clearly identified quality as a major issue. The term "quality" expresses various unquantifiable characteristics, and no consensus can be found among experts on a single definition. In the context of spatial data, the term fitness for use is used quite often. It suggests that, used in different contexts, the same product may conform to the quality requirements in one context but not in another.

Volunteered Geographic Information (VGI) Practices in Developed Countries

State government agencies and local authorities who traditionally lead a top-down approach in data capture are interested in gaining access to crowdsourced information collected by volunteers; they investigate methods to integrate VGI into their authoritative databases, especially when pressing financial or social conditions emerge, where traditional surveying methods for updating old maps are costly and require time. A few governments' forward-thinking organizations in USA, Australia, and Germany have already introduced methods to verify and integrate VGI into their products (such as the US Geological Survey, which was the first to introduce such technology for updating the National Map; and the Ordnance Survey, which as well is experimenting in the accuracy of VGI). The current trends in the Developed Countries in this type of research aim to identify "how to get the best of both worlds".

However, it is recognized that: Land surveyors are the experts to identify the methods and tools for helping government organizations to implement Gov 2.0 initiatives in order to achieve their goals, whether these would be "saving money", or "saving time", or "saving lives". Furthermore, Land surveyors are the professionals responsible for capturing authoritative spatial data; therefore, they are not expected to compromise their professional reputation by using unverified data. Introducing VGI techniques into the land surveying profession may in general provide professional land surveyors with several potential benefits, when the main benefits are: increase in speed of data collection, both for spatial data and attributes; increase in the volume of data that may be collected within a limited time period; reduction of data collection costs; reduction of data updating costs; and, improvement of the quality of data in specific projects, especially in cases when the local people know the local special issues much better than the land surveyor. In all cases, however, care must be taken to ensure that the final product conforms to well-defined quality requirements.

Crowdsourcing in Developing Regions

The dearth of authoritative map information across much of the world in general and in developing regions in particular pushed map users to collaborate in mapping projects to generate their information ensuring that the information is free and available to all that need it. Such successful crowdsourced or VGI initiatives in developing region are OpenStreetMap and Wikimapia, that have largely been applied in creating and revising basic topographic maps. The high frequency of social media activities in developing regions is attributed to increased internet penetration and mobile subscriptions as this has contributed to the growth of locally generated content and the corresponding proliferation of the blogging and social media communities.

In Kenya, as a country representing the developing regions, the absence of a functional SDI has created a situation in which various crowdsourced and VGI platforms have emerged to fill the gap. Returning to the same representative example of a developing region, Kenya has not yet fully integrated geospatial technology in its systems at all stages of geospatial use. Stages of geospatial use include: mapping, asset management, analytics and workflow, system integration and enterprise-wide use. Kenya's Geospatial user adoption is limited to spatial mapping. Accordingly, this situation then created room for alternative VGI solutions to address the location problem. Initially, VGI was intended to address the problem of inaccessibility and unavailability of authoritative basic topographic information, but the overlap of the Sensor Web with the Social web has resulted in the rise of the applications of VGI. VGI finds application not only in topographic mapping, but also in transportation and security – among others. As VGI becomes increasingly popular in developing regions, it becomes important to establish the practice of VGI application also in land surveying and planning. In contrast to developed regions, where well-established SDIs are available, crowdsourced VGI activities in developing regions have a high potential to boost the broad availability of up to date geospatial information.

Recommendations and Opportunities

- New technologies and citizen participation: citizen activities and participation can significantly contribute and lead to successful mapping-related projects, resulting in new prospects and possibilities that were not possible until recently, namely in terms of volume, coverage and update.
- Crowdsourcing and VGI initiatives for land administration: crowdsourcing and VGI initiatives can assist in acquiring missing and updating out-of-date land tenure information, conditions that could be due to the lack of human, budgetary or other resources, which might occur also in developed countries. Moreover, it could provide new initiatives that replace non-existing authoritative agencies, as it might be the case in some developing countries.
- Designing integrated processes and SDIs: crowdsourcing and VGI should not be seen as a threat and in competition with authoritative efforts. On the contrary, the two should be made alongside, making use of the community strengths of both parties.
- Quality assessment and maintenance: this is still an open issue that has been only partly dealt with. In most cases, VGI data is not equal to authoritative data in terms of quality and standardization.

- The role of the land surveyors: the expertise of land surveyors should also include knowledge of technicalities and statistical science, alongside data and information analysis and management (data scientists). Furthermore, they should be responsible for the accuracy of attributes and relationships of data; accuracy assessment; completeness and reliability of data; certification; and system design of formal and informal systems for security of land.
- Non-technical skills of land surveying: in a working environment including actors from many different fields, non-technical skills are required for interpersonal communication, including responsibility for participation management, handling of appeal procedures, and conflict resolution.
- Further tasks for land surveyors: crowdsourcing and VGI activities have a high potential to deliver highly valuable information in the field of land administration. Land surveyors have the potential to perform high quality geospatial data and information management.

1 INTRODUCTION

In a world in which demographics and urbanization are rapidly driving change, technology brings more automation in business and government. Since the launch of the internet and the creation of the online world in the 1990s, a new branch of economics called the *digital economy* or *internet economy* or *web economy* gradually emerged and has been defined as the branch of economics studying zero marginal cost of intangible goods over the internet. Digital networking and communication infrastructures have provided a global platform over which people and organizations devise strategies, interact, communicate, participate, collaborate and search for information. New terminology has appeared in the everyday life of e-government, e-business, e-commerce, e-democracy, e-participation, and m-government. Much of the information exchanged through this activity is geo-referenced. During the past 15 years, such location information has changed people's perceptions of what is possible with their economies. Senior leaders of the world now understand that we cannot measure and monitor sustainability without accurate, evidence-based geospatial data. Geospatial information supports a great number of sectors such as transportation, agriculture and water management, property markets, taxation, access to credit mechanisms, construction, city modeling and monitoring, disaster recovery and humanitarian support, and so on. Geospatial information and modern technology also help in uncovering and reducing social inequalities.

The Internet and the cloud have enabled a massive creation and consumption of structured or unstructured geo-data, and the extended use of affordable smart devices allows us to reach out to people even in the most remote corners of the planet with information and services at high speeds. The impact of such technological developments is broad and has dramatically influenced the way we think, the way we live and the way we work, in a manner similar to the impact caused by the invention of electricity and the telephone in the past. Governments invest in digital infrastructure; the private sector is trying to innovate and improve traditional business, and academics and professionals are actively assessing how to respond to these changes. Surveyors, like all other professionals, try to adjust and redefine their role in this "age of disruption." Competition gradually became more global and more intense as a result of these changes. Many fears the loss of jobs digitalization may bring and all aim to improve their performance and skills.

Despite the progress achieved so far, the road to digital transformation is not yet clear; there are hundreds of opportunities, but also there are several challenges and many unanswered questions. According to the World Economic Forum, "with a 10% increase in high-speed Internet connections, economic growth increases by 1.3%" and leads to "democratization of innovation". "In a world where only 40% of the population have access to the internet; the global GDP may be increased by $1 trillion by connecting another 327 million people. Thus, 5G is expected to enable low-cost, low-power sensors to be embedded in buildings, appliances, and vehicles". This will be a key enabler of the "internet of things". Challenges that governments still face include issues like providing the necessary digital infrastructure; dealing with existing informalities to improve openness, stability and trust for investors; investing in affordable energy while developing the relevant platforms; increasing connectivity in society in order to maximize the benefits from such investments; enabling digital financial inclusion to support sustainable digital and technological entrepreneurship; and creating a digital society, that is, improving the digital skills of the public, providing on-line training to minimize the gap between the developed and the developing worlds, and providing information about skill-flow and job opportunities.

Already there are many geospatial data collection devices available. We collect authoritative but also non-authoritative data, both through crowd sensing and through crowdsourcing techniques adequate for various purposes. We all ask for more digital services, higher downloading speeds, and more personalized information. Largely unheard a few years ago, the coming together of this new powerful and affordable technology (e.g., UAVs, smartphones and mobile apps, digital cameras, etc.) with surveying is rapidly becoming central to the long-term strategy of the United Nations Organization and its 193-member states as well as their national mapping agencies.

Surveyors are alternately challenged and excited by new concepts like the "internet of things", data mining, and crowdsourcing. Responsively, surveyors are taking a long, hard look at their role as change agents for global sustainable development to ensure democratization and make digitalization a peaceful transition for the benefit of all. Surveyors and geospatial experts are expected to make a practical application of the available technology, update their tools and manage a "tsunami" of available geo-data in order to serve the continuously increasing needs of society as clearly defined in the UN Sustainable Development Agenda 2030. Surveyors should be able to collect, integrate, manage, visualize, process and provide reliable and personalized geospatial information for their clients reliably and timely, as it is needed. Meanwhile, they must be prepared to provide affordable and fit-for-purpose solutions for their clients.

In fact, it's about using the latest technology and developing the appropriate tools and methods to do what we already do – but better. It is about serving society's economic and environmental needs. It is all about improving our skills. Using the latest technology surveyors are positioned to provide reliable, appropriate and affordable geospatial information, tools and services in a timely manner to support all 17 Sustainable Development Goals (SDGs) and the 169 targets of Agenda 2030. The profession, with the application of evidence-based geospatial information, will address, among other societal disparities, digital transformation, and decentralized business models; a volatile economy; evolving new city design models; and natural disasters, climate change, and anthropogenic environmental damage. The SDGs cover social and economic development issues including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environmental and social justice. New technology, combined with crowdsourcing techniques, may support the operation of smart cities, the management of natural and manmade disasters and the management of epidemics, as well as the management of land. The establishment of property rights is one of the drivers of economic growth and economic freedom. The use of crowdsourcing techniques may help to secure tenure and property rights on land, real estate and natural resources for all while eliminating the economic divide between the 2.5 billion people who can register property rights and the other 5 billion people who cannot.

In this effort, surveyors, like other professionals, are determined to work together with all major actors for change to make this change happen soon. Among other targets significant for our profession, FIG has a clear technical focus to motivate surveyors to improve their qualifications for the "Geospatial Transformation of the World". FIG cooperates closely with the various UN bodies, the World Bank, the regional professional associations and other professional bodies as well as with their own governments. In this great collective journey, we have set our targets and we work to see tangible results in all places and for all people, taking into account the various local needs, specific realities, capacity and urgent priorities that confront us, in order to develop fit-for-purpose solutions with a particular focus on the most vulnerable peoples.

Surveyors offer their expertise to create solutions for the relief of the helpless and marginalized when confronted with rapid economic and technological change. There are many who fear the loss of jobs or property tenure security, who feel the growing need for more transparency, more safety, more environmental quality, more fairness, more education, more gender equality, and more efficiency in the governance of urban and rural areas. There are those in the low and middle classes who seek personal advancement, for economic freedom and for an end to public corruption. The investigation of the potential for using the new technology in our work, the development of guidelines and the sharing of principles and current trends in legal and policy frameworks is vital as we assist nations and institutions to take steps to achieve a digital transformation, and to bridge the geospatial digital divide in the implementation of the 2030 Agenda for Sustainable Development. Governments can involve their peoples in a powerful way; they can enable people in the collection and processing of geospatial data in order to increase the usability of such data. With the participation of the public, the full potential of the digital economy may be achieved. In this respect, surveyors and other professionals are encouraged by all actors of change to investigate the potential for integrating crowdsourcing techniques in our work.

Crowdsourcing, a relatively new concept in surveying today, is the subject of this publication and like all new concepts are defined differently by different experts. One definition explains, "*How the power of the many can be leveraged to accomplish feats that were once the responsibility of a specialized few*." Another says that crowdsourcing is "*The practice of obtaining needed services, ideas or content by soliciting contributions from a large group of people…*".

The principle advantage of crowdsourcing is, apparently, that more heads are better than one, and every person has something of value to contribute. How, then, is crowdsourcing a benefit to surveying? Much of what we read about crowdsourcing has to do with so-called ideation, meaning that the technique is applied in a search for new ideas. Crowdsourcing is often used in micro-tasking, that is, in breaking work into very small tasks and sending the work out to the crowd. The theory is that work may be done *faster* and *cheaper* but most importantly it allows the collection of such data – in volume and type – that would never be possible to be collected by traditional methods, and in many cases would enable the delivery of better services with even *fewer errors* when validation systems are in place.

We understand that when crowdsourcing is utilized in surveying its primary value is in the geo-data collection process. For instance, collecting data on pedestrian traffic in a large urban commercial district can be accomplished by the crowd and does not require specific training. But when used in surveying the issue of validation is critical, and assumes a certain amount of preparation and training of members of the so-called crowd. In which case, is it really a "crowd" or should it be thought of as "a collection of amateur volunteers"? So far, several research studies have attempted a definition of the word "crowd" when the crowdsourcing technique is used for surveying, mapping and/or land administration. There have also been studies of the motivation and evaluation of volunteers and their potential role not only in the data collection phase but also in the editing of geo-data and even further in providing their experience for defining policies and procedures. But is crowdsourcing suitable for identification of fixed objects and material features, as is the objective of much surveying? The presentation of such information in x, y, z format is what surveyors do so that other professionals, like engineers and constructors, will incorporate the information into their own professional operations. For the professional surveyor in this type of activity precision and accuracy are paramount and the risk of liability is problematic.

In this publication, the situations in which crowdsourcing is of great value for the surveying profession will be elaborated, as well as other aspects useful to the surveyor. Surveyors are at a turning point where they are taking a long, hard look at their current role in a wide range of global sustainable developments, adjust and redefine their role as experts, where crowdsourcing of volunteered geographic information has a lead role in this transformation.

2 GEOSPATIAL DATA INFRASTRUCTURES – SDI / GSDI

2.1 Introduction

Economic, environmental, and social well-being in a modern society is closely linked with rapid access to data and information. Spatially referenced digital data, the so-called geospatial data, play a crucial role. Enormous volumes of such data are generated day by day, by Earth Observation Systems, by many public administrations, by private firms, by research institutions, and by citizens. At the beginning of the 1990s, the US National Research Council, stating that 'a major challenge over the next decade will be to enhance the accessibility, communication, and use of spatially referenced data to support a wide variety of decisions at all levels of society', recommended an implementation of a National Spatial Data Infrastructure (NSDI). In such an NSDI 'data could be readily transported and easily integrated both horizontally (e.g., across environmental, economic, and institutional data bases) and vertically (e.g., from local to national and eventually to global levels). In the following years, considerable efforts were made in many countries to develop their own NSDIs, consisting of spatial data bases, policies, and standards to facilitate the access and use of spatial data nationally.

Extending the view of NSDI to other SDI levels, Rajabifard et al. (2000) presented a so-called building block view to describe the nature of Spatial Data Infrastructures SDI. Seen from a worldwide perspective, one or several global SDIs, the GSDI, are related to an undefined number of different blocks of SDI, at different levels. In this view Local SDIs LSDI, State SDIs SSDI, National SDIs NSDI, Regional SDIs RSDI, and Global SDIs all are part of an SDI network.

In many countries and regions of the world, NSDI already has reached a mature status. In such developed environments an SDI more and more shifts from a data-centric to a service-centric and governance-centric framework (Georgiadou et al., 2006, Crompvoets et al., 2018). Considering the regularly limited resources in developing countries, Moreri and Maphale (2018) argue in favor of building functional partnerships for successful SDI implementation in such environments.

2.2 Needs, Requirements and Problems in Implementation

2.2.1 Needs

Many of the pressing current challenges of today's world are complex, ranging from economic and social problems, such as health and employment issues, poverty and inequality, demographic change, and lack of good governance, to environmental problems, such as natural disasters, food insecurity and insufficient water supplies, and environmental degradation (Figure 1 depicts a schematic layer sub-division of the related geodata). Meeting these challenges requires feasible exchange of information between many different stakeholders. Through linking information to location, the concept of geospatial information management can deliver a highly valuable method for designing and implementing appropriate flows of information.

From the economic point of view, Oxera (2013) concludes that the "Geo services sector generates \$150-\$270 billion of revenue globally", which is "broadly equivalent to the \$140 billion of revenues from the global security services industry, or around one-

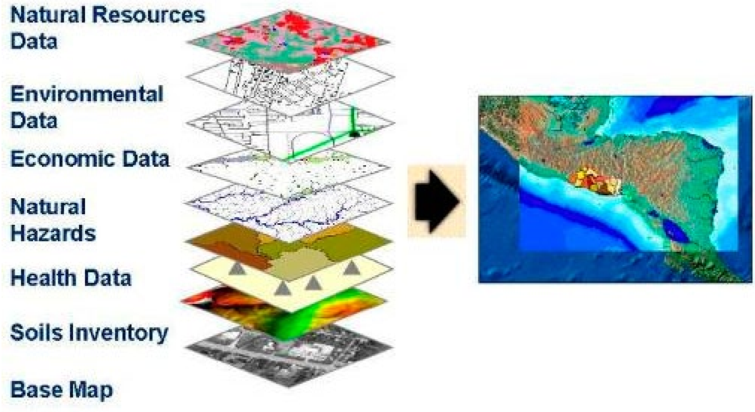


***Figure 1:** Integration of social, economic and environmental data through space and time. (Source: Henrickson, 2007)*

third of the global airline industry's revenues of $594 billion". Such numbers illustrate the potential economic impact of feasible geospatial data management, which is the fundamental base for the provision of Geo services.

Traditionally, information in the geospatial domain predominantly was provided in the form of paper maps. The community of paper map users created and maintained paper-based registers, which were linked to the map contents. Cadastral maps provided information on land property; large, medium and small-scale topographic maps served as foundation maps for spatial planning, infrastructure planning and documentation, military purposes, and many other uses.

The situation changed with the advent of GIS technology. Mass-market affordable IT solutions enabled a large user community to create their own maps, based on software packages dealing with GIS, GNSS, satellite imagery, scanning of paper maps etc. The opportunities of this new technology engaged a large number of users to make efforts to create their own data sets designed to meet specific requirements. Not surprisingly, in most cases the result of uncoordinated efforts led to a vast amount of incompatible data sets. Many data sets were – and still are – developed without considering existing data sets, because the actors are not aware of the existence of appropriate data, or that access to available data is difficult or is considered to be difficult for a number of logistical and technological reasons. Accordingly, no business processes for data sharing are defined, and little cross-domain knowledge is available. Typically, geospatial data sets have been poorly documented. Therefore, essential core information to establish data exchange mechanisms regularly is not available. In that way, this undesirable situation of non-interoperable geospatial data sets is made permanent.

2.2.2 Requirements

Strategies to overcome the serious existing shortcomings were developed and included under the name Spatial Data Infrastructure (SDI). Different definitions of the term Spatial Data Infrastructure (SDI) are available. To facilitate matters, the SDI Cookbook description (Nebert, 2004) adopted by the United Nations (Henrickson, 2007), will be cited here.

The term "Spatial Data Infrastructure" (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general.

An SDI must be more than a single data set or database; an SDI hosts geographic data and attributes, sufficient documentation (metadata), a means to discover, visualize, and evaluate the data (catalogues and Web mapping), and some method to provide access to the geographic data. Beyond this are additional services or software to support applications of the data. To make an SDI functional, it must also include the organisational agreements needed to coordinate and administer it on a local, regional, national, and or trans-national scale. Although the core SDI concept includes within its scope neither base data collection activities nor myriad applications built upon it, the infrastructure provides the ideal environment to connect applications to data – influencing both data collection and applications construction through minimal appropriate standards and policies. (SDI cookbook 2.0, p8)

From this description, it becomes clear that the development of an SDI is designed to provide mechanisms for retrieval and access of geospatial data sets created by heterogeneous data sources, thus it can be an arduous task, which regularly requires considerable joint efforts of various institutions. A schematic description of the essential components of an SDI are depicted in Figure 2.

Since the 1990's, spatial data infrastructures have been established primarily by national governments to foster more efficient and effective use of available spatial information, thereby improving management of natural resources and assisting in protection of the environment, leading to the strengthening of economic, environmental and socially

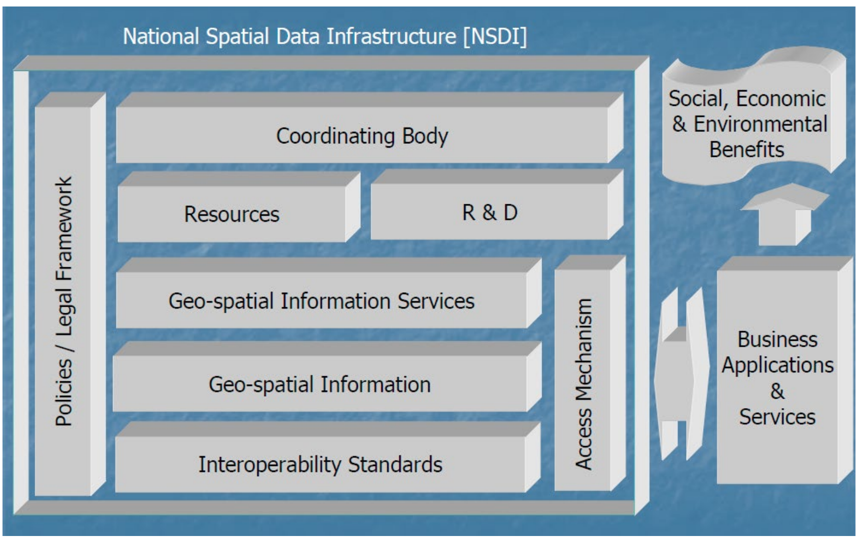


Figure 2: *Schematic of the essential components of an SDI (Source McLaren, 2006).*

sustainable development. The success of SDI's rests both on the technical implementation, and the ability of people to reach cross-organizational agreements to create an environment that supports information sharing for the benefits of the community.

Even if the use of spatial data to support development at supranational, national, and local levels is well-recognized, and great advances in technology have been achieved, some of the strategic questions of SDI development still remain and should be discussed collaboratively. There is still much work to be done to overcome data sharing barriers that exist among government departments due to a range of factors.

2.2.3 Implementation Issues

(a) OGC/ISO/W3C standards

Interoperability of geospatial data can only be achieved based on agreed standards. International standardization, in general, aims at facilitating the exchange of goods and services. The International Organization for Standardization (ISO), formed by the National Standard Bodies of some 162-member countries (October 2018), is the legal organization which is responsible for the planning, development and adoption of International Standards. Principles of global openness, transparency, consensus and technical coherence are safeguarded in ISO Technical Committees (ISO/TC's). ISO/TC211 has the mandate to develop an integrated set of standards for geographic information. In 1998, ISO/TC211 started a close cooperation with the Open Geospatial Consortium (OGC). With many key players as members, the OGC establishes the commitment of the geospatial industry to standardisation, and therefore creates a better chance of implementation. Since 1998, ISO/TC 211 standards and OGC abstract specifications interact in a way of mutual adoption and further development. Likewise, considering the great significance of the World Wide Web within SDI design, high priority has to be given to the technical specifications and guidelines developed by W3C. In summary, numerous state-of-the-art standards are available to facilitate interoperable interaction in the geospatial domain.

(b) Basic data and thematic data

Geospatial data users from virtually all disciplines have a recurring need for a small subset of basic geospatial data themes. The subset usually includes geodetic reference, geographical names, administrative units, cadastral information, transportation, hydrography, elevation and orthoimagery. In many countries a framework of organisations exists which produces and uses such data daily. The existing framework can serve as the foundation for basic content provision for the core data themes. By defining a common data schema the framework can also provide a common platform of information exchange and therefore help to generate added value.

Users who are not part of the basic data framework community can still greatly benefit from readily available basic data by simply attaching their own geospatial data to the already available reference data. Building new applications can be done more easily and with less expense by using this basic data as a reference for various uses, including accurately registering and compiling participants' own data sets, for displaying the locations and the results of their own data analysis or for creating thematic maps. A working SDI, which provides ready-to-use data provided by many different organisations can potentially generate an enormous savings.

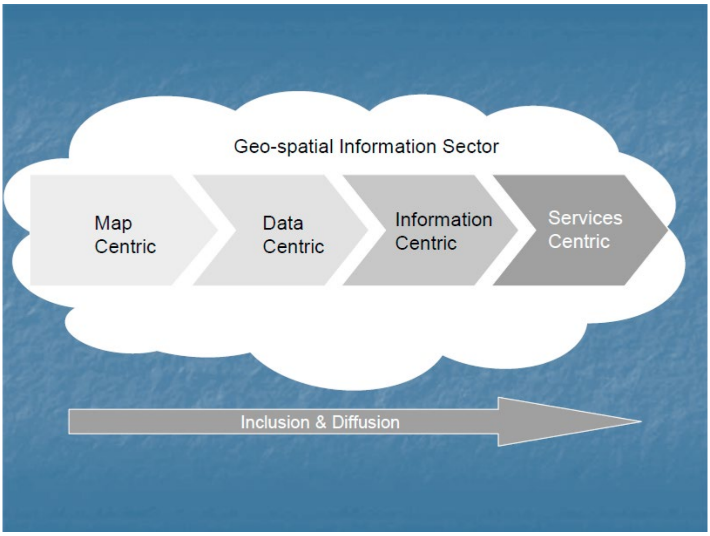


Figure 3: *From maps to services, the evolution of geospatial information management. (Source McLaren, 2006)*

Figure 4: *The INSPIRE geo-portal provides access to geospatial information from the EU Member States.*
(Source http://inspire-geoportal.ec.europa.eu/ (accessed 13 October 2018))

(c) Software

SDI Software implementation regularly takes place within a Service-Oriented Architecture (SOA). An SOA provides a flexible tool to establish software functionality via services. The evolution of geospatial information management from maps to services is depicted in Figure 3.

Service providers publish information on services in a registry; software clients can find such information there to bind the retrieved services thus creating specific applications. By using well-established open Internet standards such as Hypertext Transfer Protocol (HTTP), identification through Uniform Resource Identifier (URI), and content specification with eXtensible Markup Language (XML), web services not only provide interoperability among different software components, but also facilitate cross-institutional data and service exchange. Web-oriented SDI software solutions rely on W3C standards such as the Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS). Access to the SDI is given by a one-stop user interface, a "geoportal," built according to the Catalogue Service for Web (CSW) specification (Figure 4).

3 CROWDSOURCING OF GEOSPATIAL DATA COLLECTION

3.1 *From Experts to Amateurs*

The past decade has witnessed an overwhelming transformation of how geospatial data, information, and knowledge are being produced and disseminated. The term Volunteered Geographic Information (VGI), coined by Goodchild (2007), encapsulates the idea of using the internet to create, share, visualize, and analyze user generated geographic information and knowledge, envisioned via the use of numerous computing devices and platforms. This neogeography revolution has fundamentally transformed how geospatial data are acquired, maintained, analyzed, visualized, and consequently – used. This influences on common practices since it allows a more complete and broad knowledge of the environment we live in on all aspects of life, encompassing new services to take place, applications and processes to be developed – all of which are location based; we now have the potential to track *where* and *when* 'everything' is occurring – and in real time. Though vast amount of geographic data is constantly being collected and stored by the public, backed-up by new technologies development to empower Citizens Science, research is still required to learn and analyze its importance and usability in having large potential and relevance in contributing to the building and maintaining of reliable, qualitative and usable mapping, GIS, and (Geo-) Spatial Data Infrastructure (SDI) (e.g., Wikimapia, OpenStreetMap (OSM)). Furthermore, in a little over a decade OSM has become the leading example of VGI on the Internet. OSM is not just a crowdsourced spatial database of VGI; rather, it has grown to become a vast ecosystem of data, software systems and applications, tools, and Web-based information stores such as wikis (Mooney and Minghini, 2017). Automatic processes and methodologies establishment are still required to prove user-generated geographic data and information as a reliable and valid SDI, and thus deliver with central spatio-temporal information and knowledgebase. These will benefit in maintaining and augmenting better environmental and sustainable development processes, infrastructures and services.

Perhaps one of the main advantages – that also yields principal transformation in working perception – that is derived from the crowdsourcing paradigm, is the fact that users nowadays can search for geographic-based information relying not only on traditional or official (authoritative) geospatial and map information, but also on a variety of user-generated geographic and geo-tagged digital information data-sources being established and maintained by the public and private citizens (e.g. Wikipedia entries, Facebook and Twitter postings, OSM features). The update process of geospatial data and SDIs is now shifting to being an event based – and not a cyclical time based, as in authoritative data. VGI enables reduction of dependency on experts while relying on the fact that data can be collected and produced via diverse sources (Newman et al., 2011). The diversity of applications and disciplines making use of VG data, or proposing working frameworks to work with VG data, ranging from transportation networks (e.g., Zhang et al., 2013; Sultan et al., 2017, depicted in Figure 5), to meteorological conditions (e.g., Manzoni et al., 2010; Sosko and Dalyot, 2017), natural disaster decision making systems (e.g., Zook et al., 2010), and monitoring and exploring child well-being globally (Dalyot and Dalyot, 2018) – to name a few, prove the importance of the VGI paradigm and working methodologies, and its critical relevance today. Still, vast amount of geodata – from genetic to global levels – does not assure that the produced

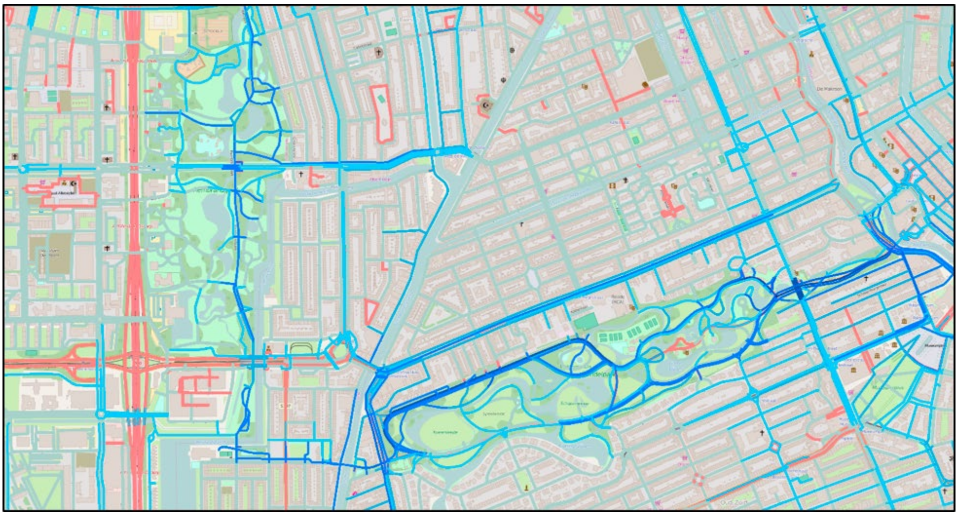


Figure 5: *Analysis of user-generated bicycle trajectories showing usability patterns in Amsterdam; favoring of major bicycle lanes and parks channel cycle-traffic in the city. Darker blue lines denote roads more frequently-used. (Source: Sultan et al., 2017)*

information is credible, i.e., its quality, reliability, completeness and overall value are somewhat questionable, such that usability aspects have to be investigated. These are derived from human, technological and quality measures factors.

3.2 What is Crowdsourcing

What exactly is Crowdsourcing? What does this working scheme and paradigm have to satisfy to be considered as one? Howe (2006) referred to crowdsourcing as a new business model, which since then has expanded to other fields, such as economics, computing, mapping – and more, mainly due to web innovations. Howe's definition stated that …"Crowdsourcing is the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call". Brabham (2008) added that it is also …"a distributed problem-solving model, (that) is not, however, open-source practice… and can be explained through a theory of crowd wisdom, an exercise of collective intelligence… a model capable of aggregating talent, leveraging ingenuity… enabled only through the technology of the web". In 2012, with the support of current developments and applications, an integrated definition was given in Estelles-Arolas and Gonzalez-Ladron-de-Guevara (2012), stating …"Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task… (thus, it) entails mutual benefit… the user will receive the satisfaction of a given type of need, be it economic, social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilize to their advantage that what the user has brought to the venture, whose form will depend on the type of activity undertaken".

Let it be social, economic or mapping-driven, a crowdsourced campaign – to some extent and with varying magnitude – involves eight elements in the process (Dror et al., 2015). The four principle ones are: 1) ***Diversity***, where each individual contributes diverse pieces of data or information; 2) ***Decentralization***, pointing to the fact the crowd's input are not subjective or biased from the inner groups' hierarchy; 3) ***Independence***, indicating the person's opinion is not influenced by people from the group that exist in his close vicinity, but from their own personal judgment; 4) ***Aggregation***, facilitating a mechanism that combines the individual opinions received unto a single collective decision, conclusion or infrastructure. The remaining supplementary four elements are: 5) ***Knowledge***, the previous familiarity or realization volunteers are assumed to have to supply with the data and information; 6) ***Activity***, the measure of volunteers functionality, i.e., how diligent and actively contributing the volunteer should be, to initiate a beneficial task or mission; 7) ***Privacy***, how the data and information collected from volunteers – and on volunteers – is used (and to what extent), and what options do volunteers have in regard to these issues; 8) ***Exploitation,*** the deliberate misuse of service and the damage that is caused in case of fake or misleading data and information input from the volunteers. According to these eight elements, OSM, for example, is a very good example of a social-driven mapping-based service, even when the privacy and exploitation elements are evaluated, which are less of an interest to such Web2.0 efforts (Dror et al., 2015).

3.3 Aspects of Public Willingness

There exists an impression that the whole world is mapped. Most countries make use of official professional and governmental mapping agencies and bodies that are responsible for producing and updating SDIs, focusing on cartographic information – making "everything" more accurate. The truth is quite the opposite: in reality, the process of mapping of the world via authoritative bodies has been gradually declining in the last several decades (Ganapati, 2010). Reasons for this decline, among others, are (Crampton, 2010): increasing labor costs and the fact that there exist ever-increasing mapping projects and new phenomena needed to be mapped and updated – including services making use of designated geospatial knowledge. In the early 90s of the last century, the Mapping Science Committee in the US released a report (NRC, 1993), which described new ideas in respect to mapping practices. Among these new ideas, the report presented the issue of patchwork working-practice, suggesting mapping agencies not provide uniform coverage of the country being mapped, but alternatively, publish standards and protocols that will meet a number of bodies or entities who will create the required infrastructure: scale, coverage and accuracy might vary as needed. VGI concept was 'born' from this premise: a collection of people working independently ("crowdsourcing") while responding to the needs of the local committees working together to create a patchwork mapping coverage. Given a server with the proper tools, different patches (parts) can be adjusted (aligned) together, certain data can be removed (discrepancies) – and more. The term Citizen Science is often used to describe communities or networks of people who act as observers in various fields of science (Hart and Martinez, 2006). Furthermore, the motivations for developing citizen science and citizens' observatories and how these initiatives can contribute to awareness raising and decision support systems are unclear and not certain (Liuet et al., 2017).

The public is interested and want to contribute and share information – whether it is geographically oriented – or not. Public participation in general – and more specifically, participatory mapping – through the provisions of appropriate analytical tools and platforms in support of spatial planning processes is usually willingly adopted by the potential participants, i.e., the public (e.g., Bugs et al., 2010; Hand, 2010). This is mainly ascribed to the fact that data collection is carried out intuitively and directly via computerized processes and digital sensors. Thus, it is assumed that no special expertise is required by the data-collector (contributor), and that the data is collected with great effectiveness in a straight-forward manner that can be done by all. This is to some extent a misrepresentative assumption due to the fact that certain applications and end-products require specific knowledge of and expertise from the contributor during the data-collection process (Ellul et al., 2012). Depending on the phenomena observed and collected, specific working-enhancements should be incorporated during the collection-process to raise the volunteers' awareness, ensuring that the desired data is indeed collected, and perhaps more importantly – in a qualitative manner (e.g., Zhang et al., 2011). Understanding and learning the challenges that are needed to be faced when implementing a working methodology that relies on the 'crowd' is therefore essential.

It is perceived that scientifically this exists somewhat in a void; this is because most services and applications that make use of citizens that voluntarily collect geographic data rely on a basic working premise, which assumes that giving the laymen a data-collecting device (e.g., smartphone) is satisfactory enough to deliver with the required information. This premise does not always stand. At first, focusing on subjective, objective and spatial cognition and applicative aspects and factors of volunteers and tasks are required. The insights and conclusions are later to be incorporated as a preliminary design stage in any working methodology that relies on the crowd and makes use of VG data.

Among the main topics related to sociotechnical applicative aspects and factors of volunteers and tasks are:

- type and nature of data or phenomenon planned for collection, together with available options for collecting it and purpose and objectives for which the data is collected;
- potential participating public knowledge and expertise for a specific task, improving of technical skills, knowledge and experience aiming at making aware the importance of data-collection contribution and sharing;
- understanding and learning that physical and theoretical limitations, constraints or dangers exist;
- finding the balance between preservation of data quality while prompting intellectual stimulation to benefit the processes.

Such factors increase the motivation among potential participants, and are important for a framework that is based on crowdsourcing: finding the balance in which for the non-professional participants the operation of collecting and contributing data is not too complex in a way that might impair the quality of the data; but on the other hand, making sure that the contributor is motivated – intellectually and practically – will benefit the processes. Moreover, if the contributor understands, and perhaps immediately observes, the benefit and contribution of his effort, and how it contributes to his community and society, it will certainly encourage more citizens to join the campaign to collect data and raise awareness.

Studies have shown that the public is collaborating in sharing and collecting information (e.g., Bugs et al., 2010; Coleman et al., 2009). Consequently, VGI has the potential to be (while current research suggest that it is already is) an important primary geographical source for understanding of the earth, in terms of data and information augmenting SDIs, where authorities also rely on geographic data collected by the public. Numerous examples exist that incorporate to some extent the use of collaborative data; among these, three are presented here: mapping for national SDIs; early warning and disaster management; and transportation infrastructure and planning.

These are only a few examples promoting the use of VGI and crowdsourcing for the construction and production of reliable SDIs to augment – and perhaps one day even replace – existing authoritative ones, encouraging the public to engage in such campaigns, and as such to contribute to their community and society. Consequently, all processes and projects benefit, possessing better understanding of our environment in spatio-temporal terms.

3.3.1 Mapping for National SDIs

National Mapping agencies (NMAs), such as the Ordnance Survey in the UK or IGN in France, are currently beginning to understand and sense the great potential of using the public to gather geographic data, thanks to the adoption of Open Data Policy (INSPIRE), in which many government datasets are now freely available to the public (e.g., Foody et al., 2014). Still, perhaps the real reason for this is the lack of enough manpower, and the growing amount of data and information that today is required for collection, a process that is not strictly concerned with land surveying only.

A recent survey made by Olteanu-Raimond et al. (2017), showed that different levels of engagement with the community exist in European NMAs (Figure 6). While in most cases much of the VGI that was acquired with a positional accuracy that is less than that typically acquired by NMAs, it still exceeded the requirements of the nominal data capture scale used by most NMAs. In NMAs that use a continuous rather than cyclical

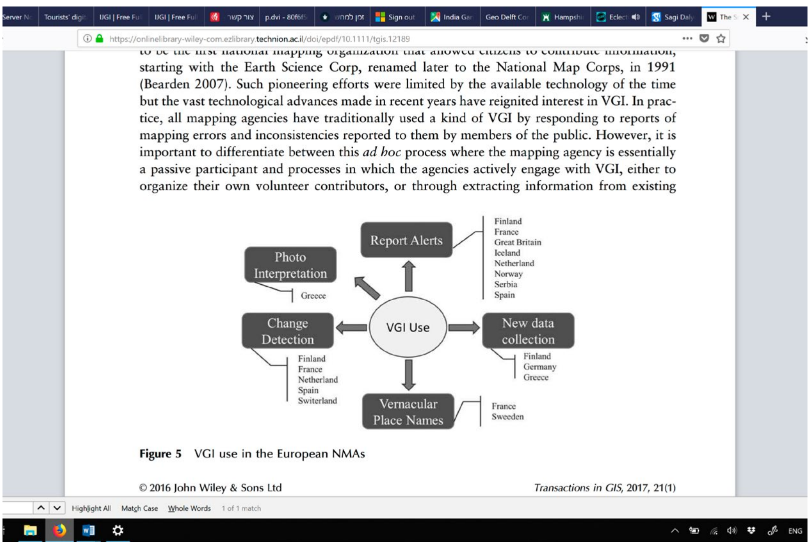


Figure 6: *VGI use in the Europeans NMAs. (Source: Olteanu-Raimond et al., 2017)*

updating policy, VGI use was much more mature and natural to use, whereas specific systems were developed to allow contributors to deliver the data. On the downside, since VGI encompasses the possibility to collect all types of physical data and phenomenon, this potential was not fully used by the NMAs, thus restricting the process to only existing and predefined features, not-exploiting the full flexibility that VGI has. Moreover, though data collected by the public can show today a high accuracy and completion rate, still most NMAs are concerned with (and sometime develop specific protocols and systems to provide for) issues related to data quality and reliability. More concerns that delay the full incorporation of VGI are the nature and motivation of the contributors (credibility), legal issues, and not surprisingly – issues related to employment fears of the NMAs staff. In the case of NMAs that make use of citizens to collect geographic data, VGI was usually used for change detection and the identification of errors; only rarely was VGI integrated directly into the authoritative databases. Still, there is a great improvement in recent years of authorities using crowdsourced geographic data, and in coming years will most evidently show new ideas and protocols concerned with the use of VGI by NMAs. Developing countries are a very good example where VGI can augment the building-up of a reliable SDI that is managed by the local NMA (see section 8).

3.3.2 Early warning and disaster management

Dealing with natural disasters requires the ability to gather information, then analyzing and disseminating it in real-time. Evidently, be it fire, flooding, or earthquake, one of the main failures in such events is the lack of systematic and real-time collection and analysis of vital information in identifying critical risks and rescue options. Crowdsourced working scheme, 'backed up' by modern sensing and communication technologies, now enables virtually everybody to collect data about the immediate environment – and disseminate it – with almost no effort; thus allowing real-time and continuous aggregation of data and production of information (e.g., Goodchild and Glennon, 2010; Zook et al., 2010). In disaster situations, geospatial data and tools play an indispensable part in many aspects of disaster management (planning, response, recovery and more). Using crowdsourcing tools data can be collected by different means (e.g., SMS, MMS, Social Networks), and is often geo-tagged (GPS location). Therefore, relief organizations have the possibility to react and act better (e.g., Gao et al., 2011). It is widely acknowledged that real-time geospatial data provide the best early warning source of information on damage (US National Research Council, 2007). In cases of emergencies and disasters, the public's motivation for data collection is even bigger than usual, e.g. "Tweak the Tweet", "Voluntweeters", and "Ushahidi" (e.g., Starbird, 2011; Hand, 2010).

VGI have the potential to provide timely and immediate information, because the update process of such data is usually event-based (and not time based as in authoritative data), such that temporal aspects can also be integrated into the process of data retrieval. Various different VGI-based applications are emerging in the field of monitoring, emergency and disaster response in terms of SDIs. An example is the crowdsourced real-time radiation maps for monitoring radiation level across Japan after the Fukushima power plant disaster (Saenz, 2011). Ushahidi crowdsourcing platform is another common platform for the creation of crisis maps on the basis of integrating data from multiple sources used in various crises, such as: the earthquake in Haiti (2010), the tsunami in Japan (2011), the Kenyan post-election violence crisis (2007–2008) (Zook et al., 2010). Another example is pollution monitoring carried out by the Common Scent platform that provides near real-time air quality data based on physical sensors mounted

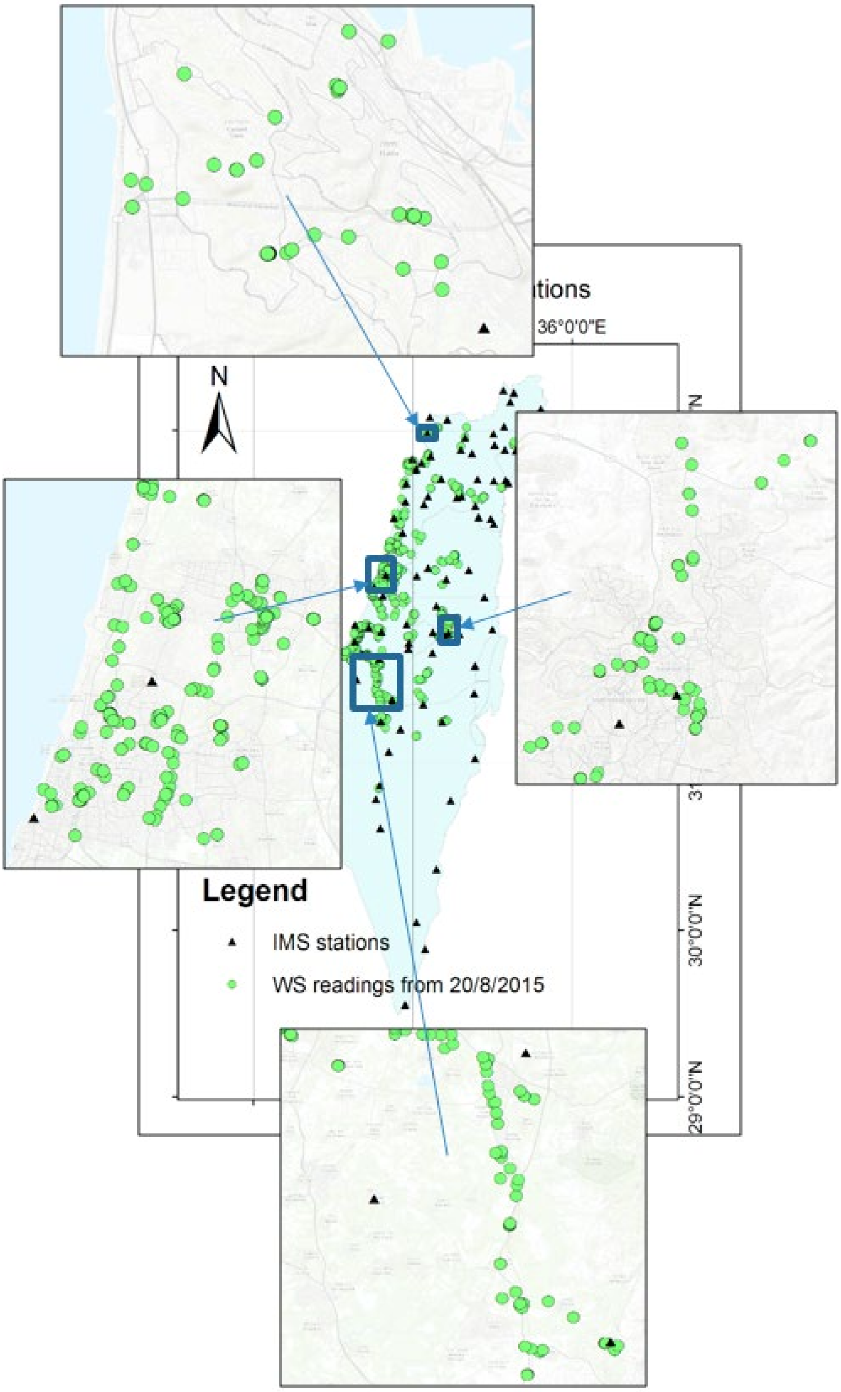


Figure 7: *An example showing the potential of using crowdsourced user-generated weather data: locations of authoritative static geosensor network in Israel in black triangles, locations of citizens' contributed data in green circles; densification and augmentation of new data in areas having low and no observations.*
(Source: Sosko and Dalyot, 2017)

on bicycles (Resch et al., 2009). All the above prove that a crowdsourced VGI working paradigm, where participants (citizens) understand and immediately appreciate the help and importance of their contribution, assists in better managing, monitoring, and recovering from disaster situations, and also for environmental awareness. It promotes new spatio-temporal means of data collection – and knowledge – that could not be retrieved otherwise. Data sources can be physical sensors networks mounted on a portable platforms to collect spatio-temporal environmental data augmented with time and location (using GPS), transmitted in real-time to processing units for further analysis and visualization (e.g., Resch et al., 2009; Goodchild and Glennon, 2010; Zook et al., 2010; Gao et al., 2011). The VGI paradigm proved to be an effective method for data collection that can be used for expanding the variety of data sources, thus enhancing – and augmenting – information derived from static geosensors networks (e.g., Sosko and Dalyot, 2017, depicted in Figure 7; see section 9.2.2 for more details on this research). This is amplified when the nature of the geographic information is dynamic, while the crowd is present in the vicinity and can inspect (collect, measure, report) these changes (e.g., Liu et al., 2012).

3.3.3 Transportation Infrastructure and Planning

Transportation planning, which is one of the fundamental components of urban planning and urban systems, focuses today on environmental planning and sustainable development aspects. This requires integrating information on a spatio-temporal level that can constitute various data-types: obstacles, volume, physical activities, road infrastructure, landmarks – and more. This knowledge primarily relates to two issues: the urban space and the corresponding human dynamics. The urban space acts as a carrier for associated geographic activities and knowledge, which helps in understanding current social aspects within urban systems, and human dynamics. The latter reveals human (and thus travel) behavior in urban space, which helps in understanding complex mobility and activity patterns. An investigation into these factors allows the derivation of underlying influences of urban planning, traffic management and modeling – and more (e.g., Zhang et al., 2013; Ahas et al., 2010; Sultan et al., 2017). VGI can contribute in changing transportation planning paradigms, such as the travel behavior surveys that are an exhaustive process, time consuming, costly, and often limited, even in cases where travel routes are collected via GPS, since it is constrained to observational techniques. Exploring and analyzing travel patterns and travel behavior in built environments through crowdsourced VGI, having mass volumes of volunteered spatial and temporal data (e.g., physical parameters, temporal and social aspects) has proved to augment and perhaps even replace such observational surveys. Moreover, while navigation and wayfinding processes normally rely on authoritative map infrastructure, research today focuses on the retrieval of user-generated data, as landmarks, that are more up-to-date, might consist of data-types that authoritative SDIs do not maintain and is tuned to the user's requirements, to augment and complete information that is otherwise missing (e.g., Sester and Dalyot, 2015; Binski et al., 2016, depicted in Figure 8).

Perhaps two of the main examples of using location-based crowdsourced data in regard to transportation planning are the WAZE application, used by vehicular users, and the MOOVIT application, used by commuters in public transit. Both make use of public participation in contributing to better planning of mass transportation, while reducing 'uncertainties' during that process. As of March 2018, WAZE was used by more than 100

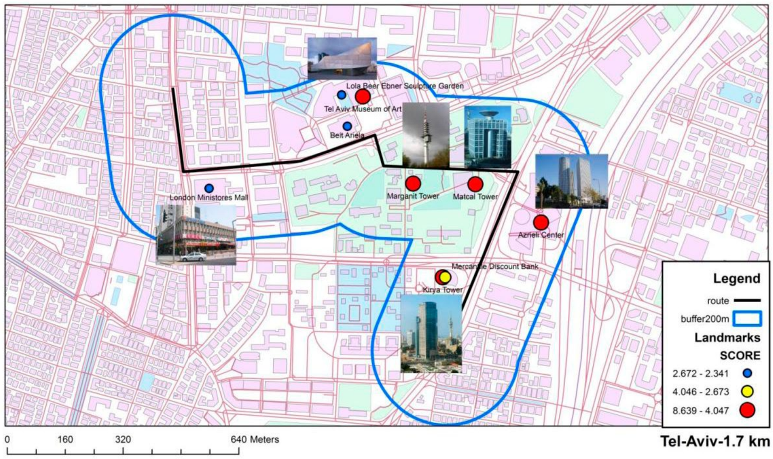


Figure 8: *Route in Tel-Aviv (black line), and selected Wikipedia landmarks with scores that should contribute to navigation process. (Source: Binski et al., 2016)*

million active users worldwide[1], and MOOVIT by more than 200 million users worldwide[2]. The next stage of such applications is that they will serve as an independent and reliable SDI, functioning as an input to authoritative transportation systems, such as traffic design models with citizens serving as contributing sensors. Consequently, developing methods and designing theoretical models related to urban space and mobility factors and patterns can benefit from the crowdsourced VGI working paradigm.

3.4 Technical Aspects

The availability of geographic data that is produced by users has undoubtedly improved SDIs and geographic information in many ways. The variety and masses of location-based data, geo-tagged photos and other relevant geographic information now organized and available increases significantly the amount and reliability of spatial information.

To understand the concept of VGI and neogeography, the main technological aspects that enable this *working* paradigm (some might say 'phenomenon') are given below (Figure 9):

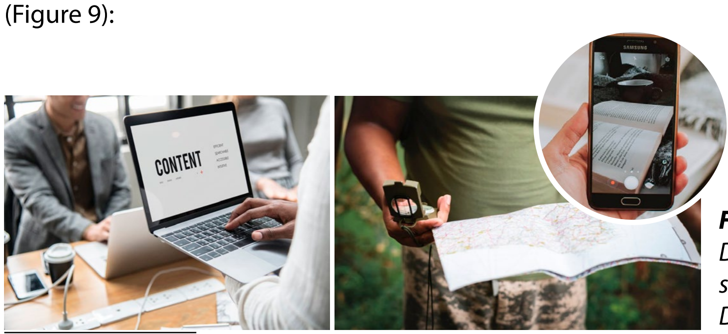


Figure 9: *Technical Drivers of Crowd-sourced Geospatial Data Collection.*

1 https://searchengineland.com/waze-launches-local-ads-primarily-aimed-at-smbs-and-franchises-295285 (accessed 30/09/2018).

2 https://www.businesswire.com/news/home/20180812005004/en/Moovit-Named-Official-Mobility-App-Asian-Games (accessed 30/09/2018).

3.4.1 Web 2.0

Even before the Web 2.0 technology was established on the internet in its full potential and capacity as it is today, people and users could log on to remote websites through interfaces (web browsers) to upload data, mostly textual. Still, the 'relationship' between the user and the web was essentially one-way, where the user's role was in creating on-line content (Hand, 2010). The development of protocols that made it possible for users also to retrieve information from databases existing on the web (servers), together with giving users the possibility to add records via forms, began changing these basic roles. With the turning of the millennia, users had the ability to provide and upload information to specific websites, thus establishing a content-based infrastructure that was based on the users creating records; still, a data-restriction was commonly made on the content type, its quality and quantity (which varied between different websites).

This later grew and formed into content-categories known today as blogs and Wiki websites, customary treated nowadays as Web 2.0: user-created and user-shared information. The content development related to VGI is a direct result of the development – or evolution – of these: interpretation, visualization and sharing of VGI. The new form of communication that evolved via Web 2.0 made relationships between individuals (i.e., the public, contributors) and authorities (i.e., services) much more efficient and effective, increasing the degree to which *citizens* become *scientists*, and participate in decision-making and also information building. E-governance initiatives are perhaps one of the main examples, sometime requiring location-based aspects in the process of crowdsourced data (e.g., traffic reports, land use development). The Geospatial Web 2.0 (Geoweb2.0) is the next step in such services, providing geospatially enabled online tools and data supporting and serving such initiatives (Ganapati, 2010). This leads to a two-way process, in which citizens contribute to authorities, later contributing back to the citizens: a correspondence that enables citizens' awareness and reaction to specific concerns.

3.4.2 GNSS

The GNSS is without question a revolution in respect to positional measurements of objects and phenomena on and near the earth's surface: this is the first system in human history that enables the instant measurement of location on earth. GNSS receivers are intuitive devices as to ease of use, whereas handheld devices (such as in smartphones and tablets) make it possible to receive location accuracy with uncertainties (in most scenarios) that are less than 10 meters (horizontal) (e.g., Zandbergen and Barbeau, 2011). GNSS is accessed by a wide range of consumer products allowing location to be measured, thus georeferencing (and geo-tagging) specific phenomena and features. As of June 2015[3], 2.1 Billion people own a smart mobile device, either a smartphone and/or tablet (~36% of the world's population), where this number is expected to rise to 6.1 Billion by 2020. This means that as of today, more than to 2 billion GNSS sensors are constantly and continuously bustling on the surface of the globe, making it possible for vast location-based activities to take place (e.g., in-car navigation, geocaching, traveling, seismic activities), and thus derived services and application to be provided.

Since GNSS sensors are nowadays cheap to install on portable devices and are instantaneous to use, it is undoubtedly the main means of location sensing capabilities that

3 http://techcrunch.com/2015/06/02/6-1b-smartphone-users-globally-by-2020-overtaking-basic-fixed-phone-subscriptions/#.kyve4o:RPIH (accessed:30/09/2018)

is associated with VGI, more than aerial photographs and other free sources available to contributors. OSM is without doubt the main example of this paradigm, where users contribute georeferenced points (sets of locations, nodes) to the OSM database created via on-site GNSS measurements. This leads to the fact that OSM is becoming valid and reliable mapping and SDI for location-based services. One of the main sources of data to VGI is the use of GPS trajectories, collected by pedestrians and commuters. This form of data enables tracking daily activities and travels, thus retrieving and uncovering implicit mental phenomena and physical attributes in supporting various location based services and geospatial infrastructure features, such as road networks creation (e.g., Zhang et al., 2011). Another use of massive volumes of GPS trajectories was proposed in Massad and Dalyot (2018) who showed that these can be used to establish a reliable topographic (3-D) infrastructure by implementing the appropriate filtering processes.

3.4.3 Smartphones

Smartphones, and other mobile devices, are increasingly becoming a significant part of people's lives. Worldwide, the number of smartphone users has risen from 1.06 Billion in 2012 to more than 2.5 Billion in 2015[4]. By 2020, it expected that more than 80% of the world's population will own a mobile device for accessing the internet, mainly due to the fact that it is portable and versatile. This implies that as of today, more than 2 billion mobile modern physical sensors and detectors are out there, having the possibility to collect and disseminate data: we have the ability to know where and when things are occurring, and in near real-time. Smartphones are spatially aware devices since they are equipped with imbedded GNSS receivers and other physical sensors. This ability is being tapped in a variety of markets providing location-based services, mapping and routing utilities. Mobile smartphones are capable of collecting data either implicitly (via tracking applications) or explicitly, allowing users to collect data that are spatially oriented, thus making them VGI-orientation devices.

Most existing mobile applications that serve as VGI tools facilitate a collection of geometries, such as point (node), line and polygon features, enabling storage these on the device later to be uploaded to a spatial GIS database engine. The adding, updating, modifying (editing), and removal of features is made straightforward, later to be viewed by other users. Mostly, data is uploaded via Wi-Fi connection or data access through 3G or 4G or Long-Term Evolution (LTE) capability, i.e., broadband communication. Not only can data be collected and disseminated in contributing to better SDIs formation, but also smartphones serve as a pivot technology for emergency and disaster response since they have the capacity to share data in real time. One main example is the Ushahidi crowdsourcing platform used for the creation of crisis maps on the basis of integrating data from multiple devices and sources used in time of crises, mainly by citizens in the area. This enables use of the platform for disaster situations characterized by the need for up-to-date maps (as in the 2010 Haitian earthquake, e.g., Zook et al., 2010).

3.4.4 Humans

Though humans do not fall under the category of technical aspects, still in potential there are more than 7 billion human-sensors out there, having big influence on this

4 http://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/(accessed: 30/09/2018).

emerging paradigm. For the first time in history, physical modern and reliable sensors are carried by humans, having the capacity to collect different forms, types and amounts of geographic data that could not have been otherwise retrieved. As outlined by Goodchild (2007): …"(there exists a) network of human sensors… each an intelligent synthesizer and interpreter of local information".

Nonetheless, certain factors should be considered (addressed in further detail in section 4.3):

- socio-technical aspects: since VGI is intertwined with technology – human senses with digital technologies – there exist a digital divide in terms of access to digital technologies (developed countries vs. developing countries is one of these aspects, e.g., Crampton, 2010).
- data heterogeneity: since at least 2 billion sensors are interconnected through an array of digital devices, due to the diversity of citizens (cognitive, intellectual, culture), heterogeneity is bound to have an effect on the information collected and knowledge retrieved (multiple representations, formats, standards).
- nature of the crowd, motivation: although potentially anyone can contribute with VGI, the community of volunteers is often very unrepresentative of the population. For example, with OSM, the typical contributor is a male, well-educated and technology savvy (Schmidt and Klettner, 2013). Maintaining the interest of contributors is important, by feedback or communities, for example, where the contributor perceives and understands the benefit of his/her work.

3.5 Reliability of Crowdsourced Geospatial Data

Due to heterogeneity and the fact that data is not collected by experts, VGI is raising concerns in regard to its quality, reliability and value as a valid information resource. The propagation of different VGI information-sources (e.g., sensors, knowledge), and the fact that the data-collection activities are carried out by a large group of non-professional volunteers working independently – almost without any coordination and without following common standards in terms of data collection, verification, and use – is prompting significant changes in respect to geographic data-working methodologies and protocols (availability, amount) and data heterogeneity. This is magnified since in many cases the source of information is unknown, making the task of data verification more difficult. An assessment of the credibility of information is extremely important because it can have implications for the economic, scientific, social, personal, educational and even political service or application that make use of these data and knowledge. As a result, the determination of data reliability and credibility on both temporal and spatial bases is becoming nowadays critical since the number of people and services making use of VGI as a valid SDI is growing constantly. In order to fully understand the issues affecting these factors, one must understand the social and technical environment in which VGI was produced (e.g., Bajpai and Yadav, 2013). Individuals (i.e., the contributors) are in many cases the only ones who can provide information that might require a good understanding of the physical environment, together with current information on the local environmental state of things. Information can also be regarded as personal experience having cognitive aspects, and thus can be experienced by individuals differently under similar conditions.

Perhaps one of the main fundamental questions and concerns prompted constantly is related to the collected data credibility, in terms of quality (accuracy, completeness, level-of-detailing), reliability (organization, up-to-date) and overall value; this is mainly due to the fact that this data is collected by the public – and not by authoritative organizations. The information credibility is a function of its relatively objective properties and characteristics to some conventional standard (e.g., geometry, semantics, etc.); thus, an investigation with respect to VGI data with the development and establishment of adaptive quality measures and evaluation is still required (see section 5 for more details on these issues). Also, compatibility in terms of ISO codes 19113 (quality principles) and 19114 (quality evaluation procedures), known today as ISO 19157, considered with quality aspects of authoritative geographical information, is required to enhance the credibility of this knowledge. The expansion of these ISO codes should also be investigated and modified if found required to handle crowdsourced VGI.

The issue of VGI's geospatial accuracy was discussed by many authors. For example, differences between data collected from satellite imagery vs. VGI mobile application are depicted in Figure 10 (Asiama et al., 2017), and differences between digitized parcels from orthophoto maps and those collected by VGI volunteers are depicted in Figure 11 (Apostolopoulos et al., 2018)

Quality analysis strategies allow the assessment of VGI credibility (e.g., Koukoletsos et al., 2012; Ludwig et al., 2011), mainly with relatively large VGI infrastructure (usually OSM features). Still, additional investigation is required, with emphasize on a global scale and on the temporal space, mainly due to recent technological developments, multiple data sources (data heterogeneity) and vast amount of data that is available; this is vital in order to achieve a more comprehensive understanding of the nature of this data and its novel implications. The investigation into data and information attrib-

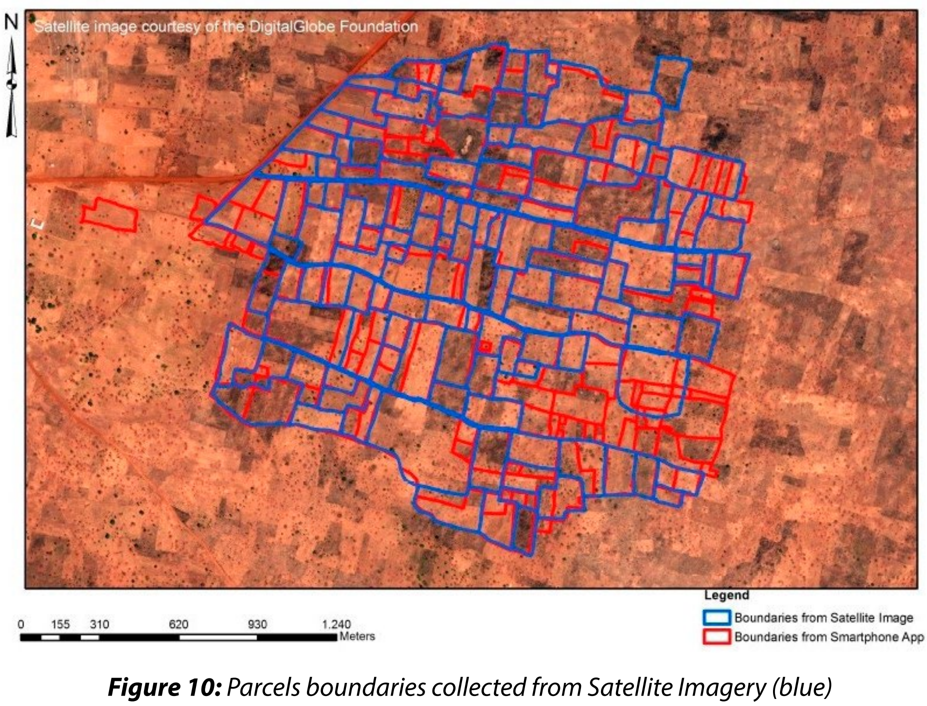


***Figure 10:** Parcels boundaries collected from Satellite Imagery (blue) and Mobile Application (red). (Source: Asiama et al., 2017)*

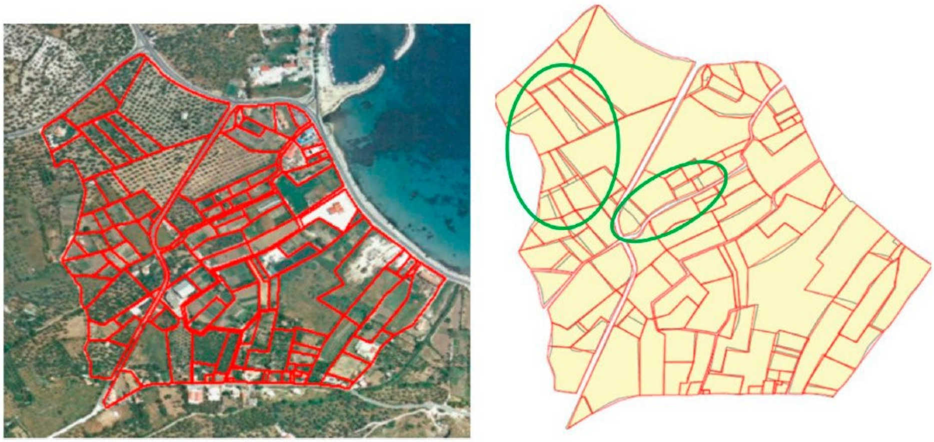


Figure 11: *Left – digitized parcels in Greece; Right – comparison between polygons collected by volunteers (in red) and by surveyors (in blue).*
(Source: Apostolopoulos et al., 2018)

utes, such as lineage, positional and semantic accuracy, logical consistency, completeness, usage, purpose (i.e., value) and temporal quality, should serve as the basis for better understanding the nature and aspects (including limitations) associated with VGI credibility and reliability. This will allow an optimization analysis and assessment on how to preserve and maintain these factors with future developments that will ensure its legitimacy and usability as valid geospatial data infrastructure – while to some extent it can serve and fit under the umbrella of the National SDI (NSDI) model.

3.6 Benefits, Limitations and Concerns

The VGI working paradigm prompts and promotes new topics – while modifying others. From working procedures, available technologies and shared data, VGI raises new limitations and concerns, while promoting new benefits – never before available. Outlined here are some of the major concerns and limitations faced by and associated with the VGI working paradigm:

- Privacy concerns and ethics: the basic concept is that modern applications and services require the users' identification to enable the access to geospatial data; or vice versa – require the need to know the actual position to access data. This is the premise of all location-based services – the more familiar the service is of the user and his needs, the more tuned the service will be. Such that, it is made easy to follow contributors of data and information in the sense of: parameters and values contributed by the user, precision of data contributed, frequency of data entries – and so forth. This type of registered users identification and the analysis of patterns and behavior via data-mining procedures, allows access to specific private data of the users. This is magnified when collecting large amounts of GPS travel trajectories, enabling the retrieval of attributed data, such as home or work addresses – even though these were not made explicitly and inserted by the user. Hacking and accessing users' GPS receiver might also be possible, when these are made communal on a public domain. It should also be noted that some intrusion into a person's privacy are possible even without the specific request to allow this in the system.

Also, on this level, ethical norms are introduced: since VGI data is volunteered, in respect to geographic information science this concern is somewhat not explored or addressed since it was assumed that it was otherwise not existent; and assuming that specific limitations and protocols might harm this initiative and its overall value. Still, since Big Data is collected and analyzed by large companies such as Google, Apple, Facebook and Microsoft without the users' knowledge, it raises awareness in regard to ethical, privacy and legal issues which should still be incorporated to some extent during the process. Also, a question arises as to the ownership of the data – do all applications and information retrieved and gained from the collected data belong in the public domain, or to the process initiator? Nevertheless, some might claim that since we live in a new era, it might be the right time to leave these concerns behind, since they are outdated.

- Technology: Although there appears to be a full openness and availability of services and platforms featuring VGI, it is to some extent a false view. This is due to the fact that the option to contribute and use volunteered data and information is mainly reserved to those who have access to the internet – in particular those with high bandwidth. While the number of people with access to the internet is growing, together with users who have mobile devices, this is mainly the issue with people living in developed countries (see also chapter 7). A report made by the UN in 2017[5] stated that as of 2017, close to 80% of people in developed countries have access to the Internet, but in countries that are still developing, the percentage of connected users drops dramatically to around 30% of the population. That means that 60% of the world's population – about 4.2 billion – still remain unconnected, and do not use the internet (as can be seen by recent campaigns from Google with "Project Loon" and Facebook with "Internet.org", aiming to deliver free internet to all). When comparing developing to developed countries, users in developed countries are 77% of all users worldwide. Furthermore, issues such as language and writing (and literacy) also affect this issue, contributing to the fact that most VGI platforms and services support English language, i.e., the use of Latin characters only.
- The human factor: Websites, such as Wikimapia, are open to all contributors, similar to various other VGI initiatives. However, other volunteered-based initiatives, such as the Christmas Bird Count[6] limits the participation of people having no background, knowledge or experience to ensure the quality and reliability of the output. The question of who can volunteer and contribute is mainly related to the quality aspired to be achieved from the final product, such that there exists a wide range of options and levels of participation (as presented in section 4.1).
- Accuracy and data validation: Traditional mapping and SDI agencies are committed to comply with specifications and to monitor the deliverables produced from the geographic information they collect (legal issues). In addition, these agencies employ only qualified and trained cartographers and geographers. Consequently, their products are approved and valid for public service, as well as commercial services and companies. Google, however, is an exception, since it does not have any previous reputation of being a producer of spatial information, and yet it seems that users rely on the quality of the maps that Google produces under the platform service of Google Maps, despite the fact that there

5 https://www.itu.int/dms_pub/itu-s/opb/pol/S-POL-BROADBAND.18-2017-PDF-E.pdf (accessed:30/09/2018)
6 http://birds.audubon.org/christmas-bird-count (accessed: 30/09/2018).

exist errors and contradictions in various geographic representations of their products when compared to authoritative data. The reason for this probably depends on the reputation the company has gained, specifically as a reliable and groundbreaking search engine: an accomplishment and reputation that users project onto Google Maps. The success of Google Maps has led to the fact that users want to contribute and rely on maps and SDIs produced from VGI, i.e., citizens science, though research is still required to fully appreciate and validate the data and information such services provide (see section 4.4 for more information). This is also the concern of recent NMAs' campaigns using crowdsourced VGI, which are still concerned with legal issues related to the use of these types of data. On the other side, dozens of location-based services and applications from all over the world, some of which are commercial, make use and rely on maps and SDIs provided by OSM.

On the benefit side, one can outline numerous topics, where perhaps the major ones that can be pointed out are in respect to SDIs are:

- Disaster Management: Catastrophes, such as the Indian Ocean tsunami or Hurricane Katrina, drew attention to the importance of geographic information in all aspects of disaster management, and the problems arising from the need to wait for satellite images (with delays of several days, sometimes due to meteorological conditions) to assess properly the damage and prepare rescue and assistance missions. Additionally, environmental conditions in the area (e.g., electricity shortage, software and hardware limitations) might also prevent authoritative data from being received. In contrast, the population in the disaster area know the area and can provide with informative and sensible information in real time. Such that, as with examples presented in section 4.1, VGI can contribute and augment crisis management via the formalization of tools for data collection, analysis, processing and verification (e.g., Ushahidi). The potential of collecting live field data and information retrieval is therefore tremendous.
- Accessible and free digital information: VGI contributes to the creation of SDIs, e.g., maps, geographic databases, atmospheric databases. Most of the collected data is validated and processed by central organizations, while products are presented and visualized in various platforms and services (OSM, Wikimapia, Project GLOBE) free of charge (open source) – to the benefit of all. This advantage allows people a fast retrieval of geographic information, virtually (almost) from anywhere on the planet.
- Data completion, augmentation and update: The world around us is constantly changing while the "traditional" (authoritative) mapping agencies find it difficult to keep up with the changes, thus renewal and updating of SDIs is made once every few years, i.e., cyclically time-based. Added to this costs and labor result in an update rate that constantly drops. As opposed to this, VGI proposes an event-based update, thus when changes occur (in the residence, for example), an update is made instantly; the update to the SDI is made simultaneously, and with no cost. Also, VGI encapsulates the possibility to collect data that could not be collected otherwise, with higher levels of resolution and detail, thus making it possible to augment existing services or even add new amenities and products that did not exist before.

4 QUALITY OF GEOSPATIAL DATA

4.1 Introduction

With the advent of the Internet and communication technologies, huge volumes of geospatial data over time have become available. The data, originating from many different sources, can be used by many different users for various purposes, by combining and by processing them in different ways, thus creating new knowledge. However, the reliability of such knowledge largely depends on the properties of the input data. Consequently, attempts are being made to describe the properties of geospatial data and processes – let alone, crowdsourced and contributed ones – in a transparent way. Advances in Information and Communication Technologies (ICT) are fostering the production and the sharing of georeferenced user-generated contents (VGI) as well as Social Media Geographic Information (SMGI), which may complement traditional spatial data sources (Massa and Campagna, 2016). Two perspectives shall be described in the following sections. Formal well-established processes of standardization, such as defined by the International Standardization Organization (ISO), reflecting a top down approach. Non-formal processes of standardization, emerging from advances and perspectives of the past two decades, described as the bottom up approach, which is commonly referred to Geographic User Generated Content, Participatory Mapping and Volunteered Geographic Information (VGI).

4.2 Quality of the Collected Geospatial Data – Fit-For-Purpose

We are witnessing each day that more and more geospatial data is being collected by different sensors (e.g., GNSS, mobile mapping, UAV, etc.). Technologies are being designed and implemented today to allow for everyone to easily collect geospatial data, even without being a qualified geographer or land surveyor. Such that two main channels, normally handled by professionals, are practiced: the collection of volunteered geographic information on the one hand, and the handling of big geodata on the other hand (both fall under the umbrella of "citizen science").

Development of Spatial Data Infrastructures (SDIs) and Information Communications Technology (ICT) enable geospatial data to be increasingly shared by many users across different fields and applications (Tóth and Tomas, 2011). However, very often geospatial data users do not know much about data quality. Thus, it is even more important to be able to evaluate its adaptability for the intended purpose as geospatial data quality is important for both the users and producers of geospatial data.

The data quality issue in geospatial science is not new to professionals, such as land surveyors, cartographers, soil scientists, etc. They always had a sound knowledge of errors that could arise during field surveys and map production (Hunter et al., 2009). Under the continuous drive to produce better (more detailed, more complete, more accurate, etc.) data these professions largely contributed to build up product specification methodology, quality assurance, adjustment computations, statistics, and conformance testing. This experience has been embedded in standards dealing with the quality of geoinformation delivered by ISO/TC211 and the OGC.

Current interoperability and the SDI programs have not clearly identified quality as a major issue. Most of the efforts concentrate on solving interoperability issues at data or system level, ignoring organizational issues. Quality is often regarded as one of the meta-data labels, which can be addressed by reporting it to the users. However, if users wish to combine multiple sources, quality has a major role. The term "quality" expresses various unquantifiable characteristics, and no consensus can be found among experts on a single definition. Yet, according to ISO 8402 (1994) the widely accepted general definition of quality can be defined as "the totality of characteristics of an entity that bear upon its ability to satisfy stated and implied needs". In the context of spatial data, the term fitness for use (Jakobsson and Tsoulos, 2007) is used quite often. It suggests that, used in different contexts, the same product may conform to the quality requirements in one context but not in another.

Even though the term "data quality" may seem to be self-explanatory, it is rather difficult to discuss because of the prevailing assumptions, incoherent terminology, and

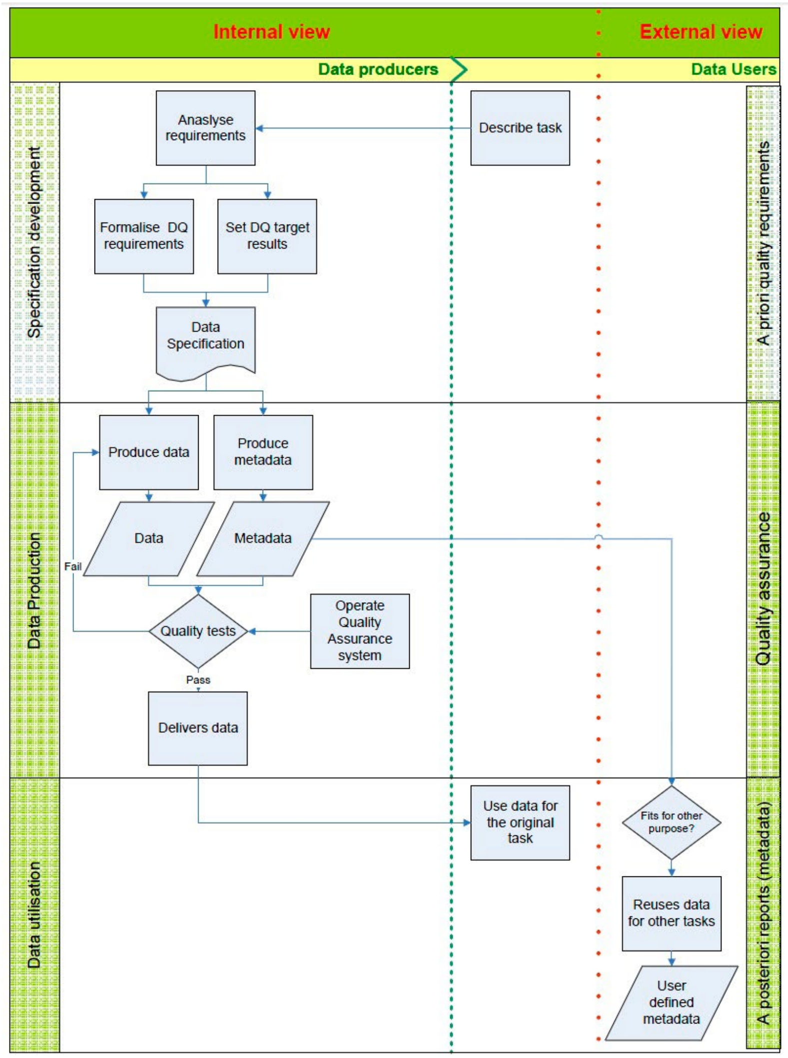


Figure 12: *Steps and products in production of geospatial data. (Source: Tóth and Tomas, 2011).*

the diverging viewpoints to which it is subject to (Tóth et al., 2013). However, it can be summarized in two simple viewpoints: internal and external. The internal viewpoint is related to the activities performed by data producers and providers, while the external viewpoint on the side of users describes the aspects necessary for reusing the data (Figure 12). In addition, while most analyses focus on geometric and positional quality, only sporadic attention has been devoted to the interpretation of the data, i.e., the communication process through which consumers try to reconstruct the meaning of information intended by its producers (Ballatore and Zipf., 2015).

The *a priori* requirements are conceptually formalized in the related data product specification, which describes those entities of the real world that are of interest to the original user exactly with the necessary level of details. The selection criteria, the data quality elements with their measures and results, as well as the quality assurance system, guarantee meeting the requirements of the user. Ideally, at the end of the process the results of the quality assessment, a conformity statement to the data product specification is published as metadata (that is, data about data) for evaluation and use.

Data quality can be defined as fitness for purpose, including both quality of design, conformance to the design (production-oriented quality), customer satisfaction and the fulfilment of the needs of society or environment. Most of the quality descriptions of geospatial data have been developed to serve the production-oriented approach. The new ISO 19157 standard (Figure 13 depicts this standard towards INSPIRE project) and previous ISO 19113, ISO 19114 and ISO/TS 19138 standards follow this approach based on the data quality concepts developed already in the 1980's (e.g. Guptill and Morrison, 1995).

Data quality is described using data quality elements. Data quality elements and their descriptors are components of data quality and are used to describe how well a dataset

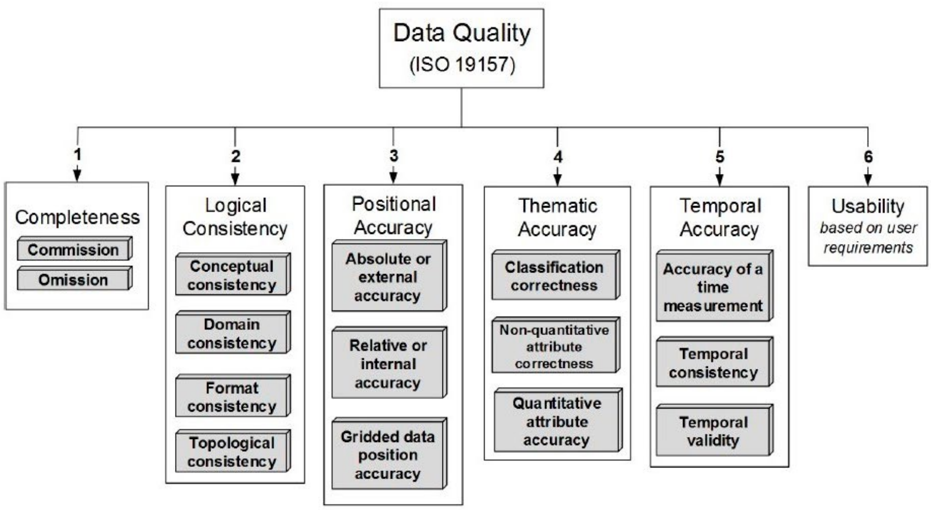


Figure 13: *INSPIRE Technical Guidelines Using ISO 19157 (Geographic Information Data Quality). (Source: https://inspire.ec.europa.eu/sites/default/files/presentations/Docan_INSPIRE_2017_Print.pdf)*

meets the criteria set forth in its data product specification or user requirements and provide quantitative quality information. ISO 19157 defines several data quality elements:

- Completeness. It is defined as the presence and absence of features, their attributes and relationships
- Logical consistency. It is defined as the degree of adherence to logical rules of data structure, attribution and relationships (data structure can be conceptual, logical or physical)
- Positional accuracy. It is defined as the accuracy of the position of features within a spatial reference system
- Thematic accuracy. It is defined as the accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships
- Temporal quality. It is defined as the quality of the temporal attributes and temporal relationships of features
- Usability element. It is based on user requirements. All quality elements may be used to evaluate usability. Usability evaluation may be based on specific user requirements that cannot be described using the quality elements described above. In this case, the usability element shall be used to describe specific quality information about a dataset's suitability for a particular application or conformance to a set of requirements.

Metadata for evaluation and use provides *a posteriori* statements about data quality based on direct measurements, calculations, specific aggregation rules, and other knowledge, expressed as non-quantitative information. Metadata includes one or more data quality elements, each of them expressed by a selected data quality measure and the corresponding data quality result (ISO 19115). Metadata on data quality is an essential content of every SDI.

4.3 Quality of the Crowdsourced Data

In geospatial crowdsourcing and VGI the issue of geospatial data quality has so far not been solved satisfyingly. As useful as the integration of volunteers into information collection may be, the quality of the gathered information remains a valid concern (Goodchild 2008b). The large volumes of VGI that can already be found on the internet have been created by a heterogeneous and often disparate group of authors often with no reference to, and little understanding of, relevance and coordinated data quality standards and protocols (Severinsen and Reitsma, 2013).

Goodchild introduced three approaches (Figure 14) for assuring the quality of VGI (Goodchild and Li 2012):

- Crowdsourcing approach: Information provided by a group of people tends to be more accurate than by a single individual
- Social approach: The administrators or high-level users, check new data in order to avoid gross errors, vandalism, etc.

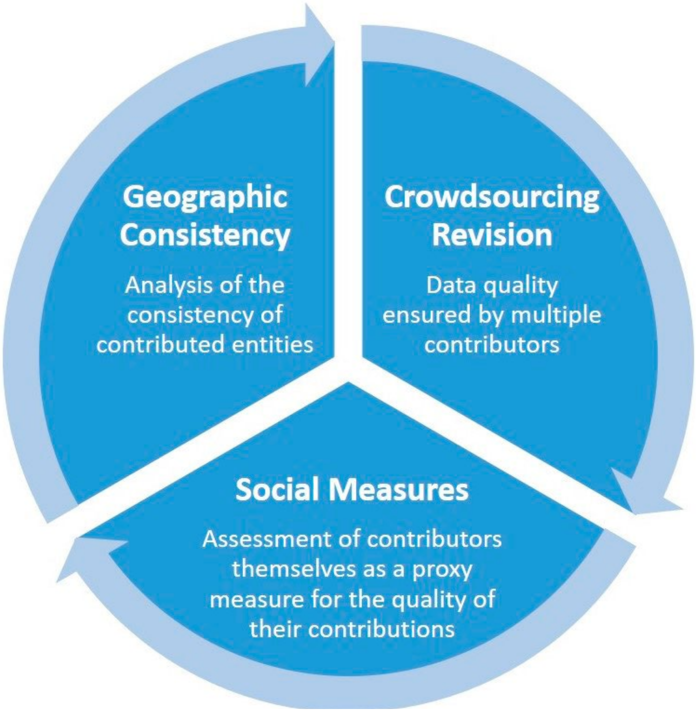


Figure 14: *Three domains of a VGI Quality Framework. (Source: Goodchild and Li, 2012)*

- Geographic approach: This approach has been specifically designed for geographic data and could be automated. It suggests checking the geographic data according to some rules

Some authors (Karimipour et al., 2013) are proposing visual elements to provide the non-expert VGI users with the quality information of geospatial data, in order to help them evaluating the datasets for the application at hand.

For the quality assessment of VGI two types of metadata (De Longueville et al., 2010) could be determined:

- User-encoded vagueness metadata: The user may contribute in giving more information about the collected data
- System-created vagueness metadata: The system itself stores some parameters related to the quality of data, e.g. the scale in which the data has been added

For the time being it seems that the establishment of rigorous quality control in geospatial crowdsourcing and VGI is a big challenge and very difficult task to enforce. There is a big risk that this may also discourage volunteer geospatial data collection. On the other hand, there is also a poor environment to implement quality control.

The problem with most crowdsourced data, for example in a land administration system, is that there is only a small group of people that can verify the correctness of the information. The correct location of a boundary, for example, can only be assessed by the owners of the pieces of land touching at the boundary and surveyors after investigation and measurement (Navratil and Frank, 2013). While a number of early VGI studies used conventional methods to assess data quality, such approaches are not always well adapted to VGI. Since VGI is a user-generated content, features and places mapped by contributors largely reflect the contributors' personal interests (Bégin et al., 2013). Due to the lack of a comprehensive framework for modelling, distribution and analysis of data quality of heterogeneous geospatial data, users are often forced to deal with data of unknown or unclear quality, an unpredictable level of risk is hence inevitable (Hong and Huang, 2013). VGI can, however, in some contexts, reach a high positional accuracy. In many other cases a large spatial heterogeneity in positional accuracy and completeness, but also with regards to the semantics of the objects, can be found. Such high semantic heterogeneity of VGI datasets becomes a significant obstacle to several possible uses that could be made of the data (Vandecasteele and Devillers, 2013).

In the available research different quality measures are mentioned regarding map content in general and crowdsourced data in particular. The volunteer-contributed data come with varying quality as the data is produced by heterogeneous contributors, using various technologies and tools, having different levels of details and precision, serving heterogeneous purposes, and a lack of gatekeepers (Senaratne et al., 2017). Various efforts in past years have focused on the use of well-established methodologies for the evaluation of VGI quality elements against authoritative data. (Antoniou and Skopeliti, (2015) defined four domains of a VGI Quality Framework (Figure 15). According to Senaratne et al. (2017), 17 quality measures can be analyzed and assessed in map credibility that is based on crowdsourced data. Still, a majority of studies on the matter are focused on positional accuracy that has generated vast interest among researchers in the past decade. Haklay (2010), analyzing OpenStreetMap (OSM) accuracy and completeness of linear objects representing motorways in relation to an authoritative map by implementing geometrical-based buffering, highlighted the fact that OSM data was already fairly accurate, with an average positional discrepancy of 6 meters. OSM is usually being evaluated by researchers as it is one of the prominent examples of crowdsourcing mapping. Since then, a majority of studies examining OSM's positional accuracy and rate of completion of linear objects for different areas by implementing various analyses methodologies came to similar conclusions: proving that in urban areas both measures continue to improve, whereas in rural areas and undeveloped regions inferior results occurred. (e.g., Ciepłuch et al., 2011; Ludwig et al., 2011; Neis et al., 2011; Zielstra and Hochmair, 2011; Arsanjani et al., 2013; Zheng and Zheng, 2014; Tenney, 2014; Hochmair et al., 2015).

Other research examining point accuracy of POIs (e.g., hospitals, schools etc.) or road junctions extracted from linear features, such as Hristova et al., (2012) and Girres and Touya (2010), used Euclidian distance from reference point objects to evaluate OSM positional accuracy; the latter found similar average discrepancies in the value of positional accuracy of about 6.65 meters. Al-Bakri and Fairbairn (2010) compared point data from OSM to reference 'ground truth' field survey dataset using the RMSE measure to estimate OSM's positional accuracy. Results showed that positional accuracy have large discrepancy values, i.e., geometrically they do not match the reference dataset used, with values larger than 10 meters. Helbich et al., (2012) presented a spatial statistical comparative method to compute the positional accuracy of OSM road junctions by comparing them to precise survey data and commercial Tele Atlas datasets. Analyzing a well-mapped city in Germany, results showed that both OSM and Tele Atlas datasets have similar spatial deviations from the survey data. Furthermore, OSM data showed

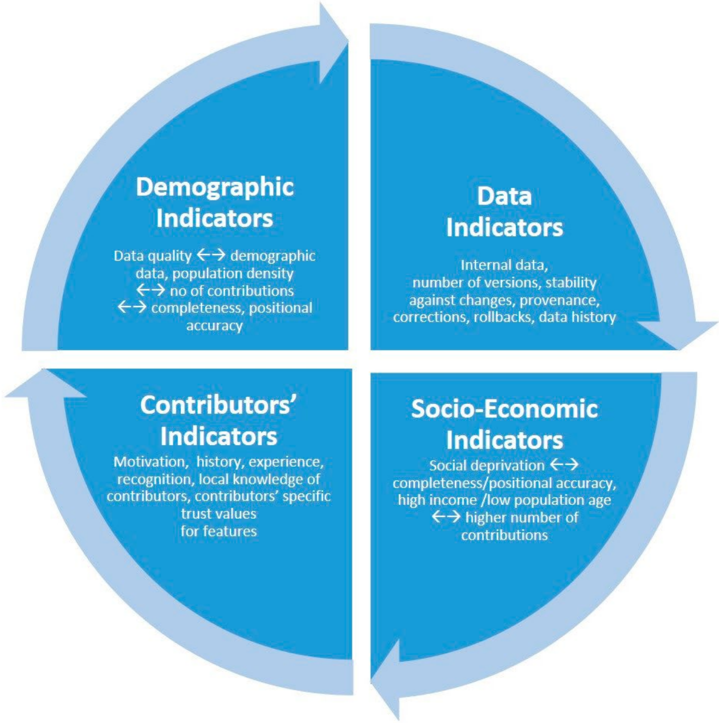


Figure 15: *Four domains of a VGI Quality Framework. (Source: Antoniou and Skopeliti, 2015)*

spatial heterogeneity in the positional error distribution, leading to significant clusters of high and low positional accuracy. As in Jackson et al., (2013), the authors concluded that OSM data can be used for small and medium scale mapping applications. A broader analysis on crowdsourcing accuracy in general and OSM accuracy in particular was carried out later by Mooney and Minghini (2017).

All aforementioned studies focused on examining crowdsourced data accuracy at a specific time stamp, all analyzing the most current and updated available version of maps based on the collected data. Authors assumed that datasets used are certain to show the most accurate and reliable existing mapping data, thus analyzed in respect to an external authoritative mapping data. Only rarely is the examination and investigation of historical crowdsourced data addressed. One example is Haklay et al., (2010), analyzing whether the positional accuracy of intersection features improve as the number of contributors increases. Authors have concluded that the overall aggregated location accuracy did improve, although no effort was made to study whether previous versions can contribute the overall positional accuracy. Other authors concluded that the higher the number of POI edits in crowdsourced data the higher its quality, while the quality of contributions in OSM is independent of the number of edits they have undergone. Mooney and Corcoran (2012) examined OSM methods having 15 or more edits in respect of tagging, i.e., validating attribute and semantic completeness of features. They showed that a small number of contributors created or edited most of the existing data, without finding a strong correlation between the number of versions and the number of tags.

None of the aforementioned research made an effort to propose an alternative way of improving crowdsourced data quality by using versions and historical location records. One effort was made in Vandecasteele and Devillers (2015), exploring the use of semantic similarity for historic features, introducing a tag recommender system that automatically suggests relevant and appropriate tags to contributors, improving the semantic quality and reducing the semantic heterogeneity of crowdsourced data tagging; handling of location accuracy improvement was not made. Keßler and De Groot (2013) introduced a set of trust measures derived from feature provenance, such as number of versions, contributors, confirmations, etc. To evaluate the trust measures, results where compared to quality measures obtained from a field survey, proving that user generated feature quality can be assessed by using a trust model that is based on data provenance. Quality measures were based on thematic accuracy, topological consistency, and information completeness, with no positional accuracy assessment. Zhao et al., (2016) introduced a spatio-temporal VGI model that considers contributor reputation and object trustworthiness, among others: contributor's experience, contributor's trust and version. In addition, means to characterize the quality of volunteers, based only on the data they contribute, can be used to explore issues connected with the quantity and quality of volunteers for attribute mapping (Foody et al., 2015).

5 IMPLEMENTATION OF GEOSPATIAL CROWDSOURCING

5.1 Work Methodologies

As the discussion has so far demonstrated, there is no universal way in which VGI is being generated. As with quality and reliability expectations, the methodology to collect the data should fit specific purpose and context. In this section, the range of methodologies and approaches to generate and collate VGI will be explored, with examples that will help the reader understand the specific issues that are highlighted here. The aim here is not to provide a comprehensive coverage of all the issues with work methodologies, rather to explore some of the major considerations that are required for a successful VGI project.

A likely misconception from the name of the phenomena and the use of terminologies, such as *crowd* or *volunteers*, is that it is an inherently unruly and disorganized activity, with very lose methodology. Moreover, the emphasis in both business and academic literatures on projects, such as Wikipedia and OpenStreetMap, may reinforce this impression, as they adopted highly open methodology that allow participants to work in a distributed manner and with significant autonomy regarding what is covered and how. Therefore, it is important to understand that these projects, while highly important in providing open and free geospatial information, are not representatives of the majority of VGI. As we explore and understand crowdsourcing activities, we can see how different methodologies and techniques fit each context.

There are, however, some general guiding rules. For example, in all types of crowdsourcing activities, be it an activity that engage few participants or one that involves hundreds of thousands of participants, there is a need to consider the engagement with the 'crowd' as an integral part of the work methodology. While aspects of motivation and incentive were reviewed, there is a need for dedicated resources to recruit, support and maintain the relationships with the participants in the project. Crowdsourcing is not a process in which a system can be built, with the participants emerging by magic; and without a full commitment to working with the participants communicating with them and listening to their suggestions, it is likely to fail.

Other factors depend on the specific context of the project. We will start with one of the defining factors of mapping since the second half of the twentieth century – the need for ground truth. The ability to capture remotely sensed information and imagery has progressed immensely, and today it is possible to access sub-meter resolution imagery from space. Yet, the need to validate information on the ground or record information that cannot be sensed remotely has remained. Thus, the first differentiation when it comes to methodologies is the need for physical presence on the ground.

If the process requires capturing information that can be gleaned from imagery, especially earth observation imagery, then a methodology that uses distributed participants who can reside in any location can be used. The approach will be to provide the participants access to imagery, usually through their web-browser, with a set of tools that allow them to annotate the image or trace features that they see in it. The set of tools can be restricted to the specific task and ideally designed to facilitate the efficient use of participants' efforts. The tools should also consider the amount of training that the participants will need to operate the tools in a successful way, and this will be based on the characteristics of the participants that will be recruited and the amount of time that they can dedicate to the task.

An example for a simple implementation of such framework was provided in the aftermath of the storm Sandy in November 2012, when the US Federal Emergency Management Agency (FEMA) needed assistance in sifting through imagery that was captured by the Civil Air Patrol planes. The images are oblique, and as a photo was geotagged with a location information, the task was to identify if the image shows damage that is light, moderate or severe (see Figure 16). Because the task is fairly simple, and the process is quick, it was possible to engage 4,000 volunteers, from different backgrounds, within days (Verton, 2012).

On the other hand, remote sensing tools can be structured to be used by participants with specific domain knowledge or expertise. The Virtual Disaster Viewer is an example for this type of tools (Verrucci et al., 2010). Designed to allow experts to evaluate the structural damage of buildings following earthquakes by comparing imagery that was captured before and after the disaster, the tool assumes domain knowledge and the ability to indicate damage based on satellite imagery. Because the expectation is that participants with civil engineering knowledge will participate in the classification, the interface is more complex and the terminology that is used is professional terminology.

Regardless of the complexity of the interface, it is important to remember that the participants access the imagery through their Internet connection. Therefore, there is a need to consider carefully bandwidth limitations and also the characteristics of the device on which the user will view the information – for example, these applications are usually not suitable to be used on the limited screen area of a smartphone, although simple classification can work on such devices (Herfort et al., 2017).

In addition to satellite imagery, new types of imagery that are coming from panoramic scanning of streetscapes (made popular with Google Streetview and Bing Streetside). Because this imagery provides rich details at street level, it contains valuable informa-

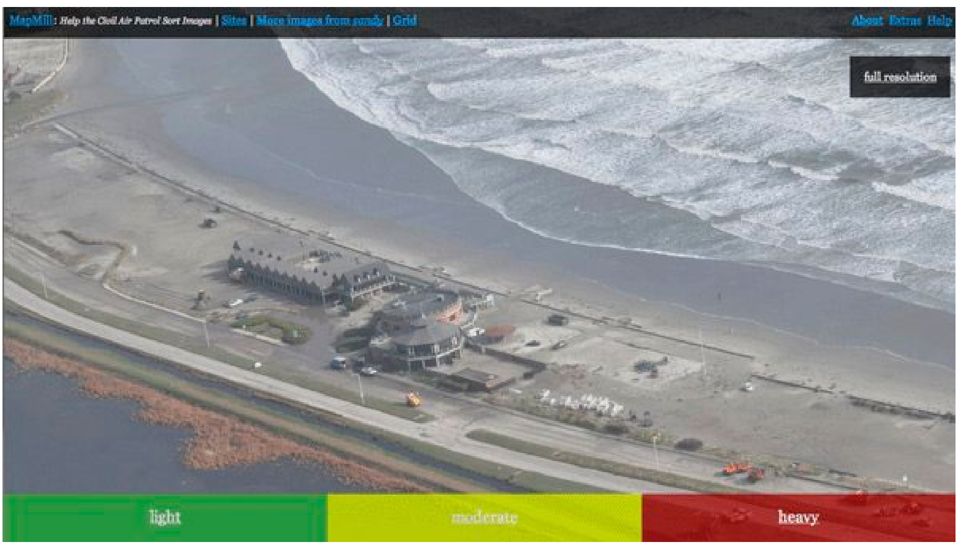


Figure 16: *Sandy image classification tool. (Source: GIS Lounge)*

tion – such as street names, house numbers, shop names and signs (Fisher, 2013). The use of such imagery in crowdsourcing activities is not inherently different then the use of satellite imagery, apart from the richness of the tasks that can be requested from the participant.

Yet, despite the advances in remote sensing there are many tasks that require physical presence on the ground. For example, while the classification of the streetscape can be done remotely, the capturing of the imagery requires driving along the street with frequent update cycles, as otherwise the image will not reflect the urban changes. Other details, such as the information about businesses that don't use signs that are visible from the road (e.g. businesses above the street level), or activities that are inside a courtyard, cannot be captured rapidly and remotely. Another example is the detailed identification of species at a specific location, for example, identifying which birds are visiting a backyard.

For cases that require such data capture, a more complex methodology is required. Similar to organized field survey work, the methodology must consider who the people that will contribute to the operation are and what process will be followed to recruit them. There will be also a need to identify the correct tools that will be used for data collection and recording and finally, the approach that will be used to record the data and validate it. Within this category of VGI, we can identify several aspects that will influence the methodology and approach to collect the information.

5.1.1 Passive and Active Engagement

The first differentiation is between data collection that is passive, where sensors and automatic logging of the data from them is used to record geographical information, and active, which requires the participants to actively notice something in their environment and record it. It is important to emphasize that the activity has a very diverse character as it can, amongst other things, as was mentioned, be active or passive, involve spatial or aspatial data and the data provided can be variable in terms of key attributes such as format, description and quality (See et al., 2016).

In passive data collection, there is a need to consider which sensors can record the needed information, the areas that will be covered and the type of participants that are most suitable to record the information. For example, users of personal-navigation devices (satellite navigation or satnav devices) can enroll into a program in which they share the information that is recorded by their GPS receivers with the vendor of their device. The satnav manufacturer TomTom is running such a program. In these cases, there is a very good match between the aim of the company to maintain an up-to-date geographical database of roads and driving or turning restrictions with the people that are recruited – their users. The methodology for such data collection is to start recording the information from the sensor at a given time, and when the process is completed, or at suitable time intervals, upload the information to a main server to allow further analysis and use. The considerations that should be taken into account are the capacity of the storage on the device, the way in which the passive sensing will start and stop, and also power consumption of the sensing and logging process, and therefore the rate of sensing.

In active engagement, there are multiple challenges that need to be taken into account when designing data collection activities and the way in which people are involved in carrying it out. There is need to consider how much training the participants will need to collect data accurately and successfully and how to deliver such training in a distributed manner, how to ensure that the participants will remember to collect and share the information, and other factors that are explored below in more details. Some applications require relatively little training, such as the application WheelMap, which allows participants to record the level of accessibility of facilities and businesses that are recorded in OpenStreetMap. As long as the participant remembers that he/she can record the information, an app for smartphones supports rapid recording. The information that is recorded about each location is one of four options and take seconds to record. While WheelMap is easy to use, some forms that are created by researchers for field survey can be fairly complex and require more training for the participants who will use it. When other contextual information is available, there is a potential of alerting the participants to record information – for example, Google Local Guides program provides an alert to inform participants that some information is needed about the location that they are currently in (Figure 17).

Another differentiation in active data collection is between data collection that is intentional and aimed toward generation of VGI, and activities that have other aims and produce VGI while doing this task (Antoniou et al., 2010). If the aim of the task is the actual recording of geographic information, the process can be tuned to ensure the quality and verification of the information. An example for such a project is the geograph.org.uk project in which the participants are trying to generate a photograph of each square kilometer in the British National Grid. The process includes the recording of the grid coordinates of the image, and in cases where the image file contains GPS coordinates, this can be used to verify the accuracy of the information. In contrast, photographs hosting services such as Flickr are aimed at allowing their users to store and share photographs

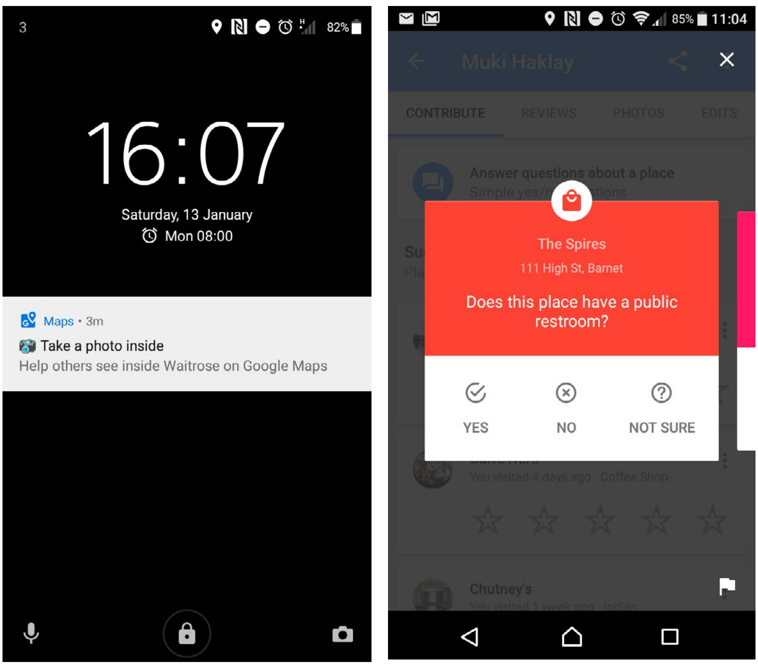


Figure 17: *Google Local Guide context aware messages.*

with friends and family. However, as noted before, many images contain GPS coordinates within their description, and therefore can be used as a source of geographic information. If there are opportunities to include VGI collection within other processes, the methodology should aim to capture useful information and metadata in a way that integrate them into the main process or aim of the activity. By necessity, these will be more limited than the case where the application is explicitly geographic.

For both passive and active data collection methodologies, there is a need to take into consideration the spatial and temporal aspects of the places and information of interest. These factors will impact the work methodologies and the consideration of recruitment, incentives and even the potential of carrying out crowdsourced data collection activities at all.

5.1.2 Spatial and Temporal Aspects of VGI

In terms of spatial coverage, if the place of interest is at the center of a highly populated area and a center of economic activity, or a center of tourism activities, then it is likely that enough people will visit it to provide information. It is possible to consider a generic probability of data collection by assuming that the higher the number of people that use or visit the study area on a regular basis, the better the likelihood that among these people there will be a person that can collect and share VGI from it. Thus, it is expected that places such as the Parthenon in Athens, popular for both locals and tourists, will be captured by a photo that is shared online at least once a day. The more remote, uninhabited, or difficult to reach a place is, the more specialized the work methodology must be. For example, consider recording the noise level with a smartphone at the main runway of Heathrow (see Figure 18). The runway is located in a highly populated area and the terminal buildings that are only few hundred meters distant are visited by many millions of people a year, and indeed, near the terminal building, where people might find themselves walking to an airplane or in a balcony, there are noise measure-

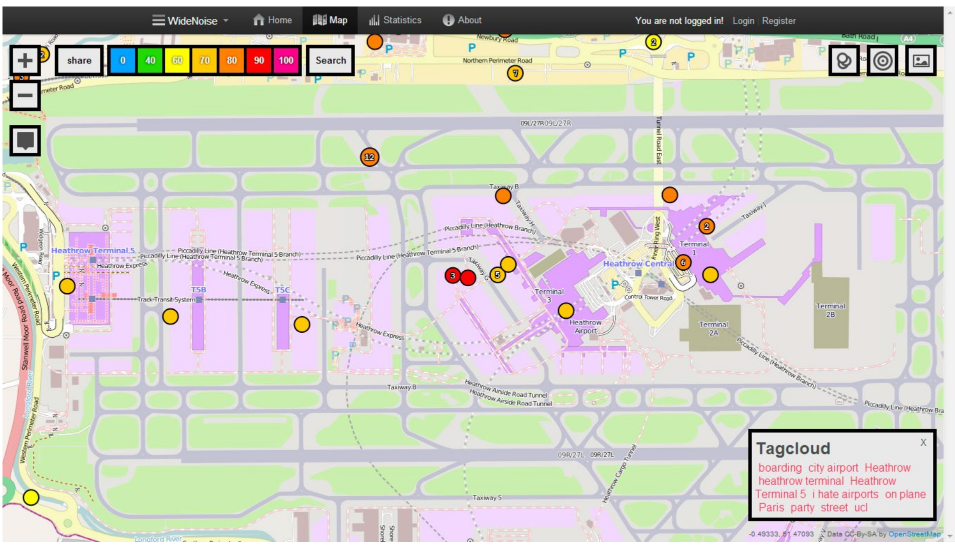


Figure 18: *Noise Level recording at Heathrow airport, notice the data points near the terminals, and a set of points near the runway (marked with an arrow).*

ments using the smartphone app WideNoise. However, despite of the high number of visitors, recording on the runway itself requires special permissions and recruitment of participants from among the relatively small pool of people that are allowed to be on the ground at this place.

When examining the distribution of photography in systems such as geograph.org.uk, it is apparent that remote places in the Highlands of Scotland are not covered at all (Antoniou et al., 2010). Therefore, regardless of the details, a project that require coverage of such places will need to include a careful analysis which groups of participants frequent such places (e.g. mountaineers, hikers) and which tools will encourage them to collect the information. In some cases, an implicit rather than explicit data collection approach will be more successful. Geocaching (O'Hara, 2008), which is inherently a game of 'treasure hunt' or 'hide & seek' in which participants use GPS coordinates to find caches that are stored in small boxes and the log of visits to them on a website is a suitable activity that can be used to encourage participants to visit remote places. Even so, the likelihood of finding a suitable participant is limited and therefore the ability to verify the data with multiple participants is limited.

As can be expected, the spatial element of a VGI project is impacted by the scale of the operation. For small scale operations, while the time that is dedicated to covering such an area can be fairly short, as in collecting the names of shops in a local shopping center, the likelihood of finding a suitable participant that is already frequenting this specific space is limited and therefore targeted recruitment and direction of the participants will be required to get such information. At a medium scale, such as a neighborhood or a town, there is the potential that with suitable planning and engagement plans, participants will be willing not only to cover their locality, but also adjacent locations, and therefore complete the gaps that will arise from the uneven distribution of participants. However, at the regional or national scale, problems arise again as, by necessity, this will include places that are less populated as noted above.

The temporal aspect of VGI is also influenced by scale and can be generalized by a rephrasing Lincoln that 'you can be supported by a huge crowd for a very short time, or by few for a long time, but you can't have a huge crowd all the time (unless data collection is passive)'. In more details, a specific, targeted task that takes a relatively short time to accomplish can include a very large crowd. For example, in the Christmas Bird Count which is coordinated by the National Audubon Society in the US, participants observe birds near the place where they live. Because this is a short activity that can take one day to complete during a holiday season, over 74,000 people participated in it in 2017. On the other hand, the number of dedicated participants in projects such as OpenStreetMap that requires continuous updating is fairly small. Out of 1 million registered users, only 24,000 are 'senior mappers' in Neis and Zipf (2012) classification and within this group only a minority are demonstrating continuous engagement over years. Therefore, the work methodology for VGI projects need to take a realistic approach to the temporal contribution from participants and design of the tasks to match what is possible. The exception to the rule is the special potential that is encapsulated in passive data collection. For example, once TomTom users agree to share their GPS trails, for as long as they continue to use the device and update the information in it, the data will continue to flow to the company servers. Notice that in some cases important ethical questions arise under this work methodology, for example, if the accumulated use of bandwidth that will be used to transfer the data will result in significant financial costs to the participants.

The final aspects relating to VGI is the consideration of practices that are suitable for conditions of scarcity or abundance in terms of data sources and number of observations or the amount of data that is being used. As Goodchild (2008a) observed, the conceptualization of geographic data collection before the emergence of VGI was one of scarcity where data is expensive and complex to collect. Therefore, every part of the process was designed to carefully collect the data on the ground by well-trained professionals who follow a strict process that integrates quality assurance steps within it. This was also true for digitizing information from remotely sense images due to the scarcity in experienced photogrammetrists. While not universally true, as we have seen in the cases of collecting data in remote places or over a long period of time, in many applications of VGI the situation is one of abundance. For example, in applications that are based on micro-volunteering, where the participant invests very little time in a fairly simple task, it is possible to give the same task to several participants and statistically compare their independent outcomes as a way to ensure the quality of the data. Another form of considering abundance as a framework is in the development of software for data collection. While in previous eras there was inherently one application that was used for data capture and editing, in VGI there is a need to consider multiple applications as different designs and workflows can appeal and be suitable for different groups of participants.

In summary, while some of the methodologies and workflows of VGI might resemble traditional methods of surveying and data collection, the framing of crowdsourcing activities, considerations of the participants' characteristics, spatial and temporal aspects of the tasks and the participants indicate that VGI does require reconsideration of the process and to be tailored to each specific context.

5.2 Crowdsourcing and SIM

As the previous section demonstrates, the need to engage a wide range of participants with varying levels of experience and knowledge, using different methodologies that take into account the specific spatial, temporal and domain of the data collection activities, is a common aspect of VGI. This, of course, has implications for the management of the resulting information.

This section focuses on the implications of VGI and crowdsourced geographic information on spatial information management (SIM), focusing on specific aspects of management as we shall see, the special characteristics of VGI require attention when integrating with other data sources, in the management of the information itself, in the metadata associated with it and in attention to ownership and licensing conditions.

The integration of VGI within SIM is in line with the general trends of dealing with continuous streaming information which is updated constantly. While within specific settings there can be internal milestones, after which the continuous streaming information is not used for current product releases, there is a need to consider how the changes that are arriving will be utilized for future releases but this, too, is not unique to VGI.

Yet, there are issues with integration, as while sensor sources can be predicted (e.g. the work schedule of Google Streetview surveys), VGI is heterogeneous spatially and temporally. While some aspects of the heterogeneity can be predicted, for example a common 'weekend bias' where more data is captured during weekend due to availability of volunteers some other aspects lend themselves less to prediction, for example a local bottom-up decision to make a major effort to collect data. Because of that, the system needs to be flexible to allow elasticity in the amount of data that is received and in providing feedback to contributors.

A second issue with VGI is interoperability of various data sources and bringing them together. VGI sources can be highly structured, especially in cases where the system controls very strictly what is collected and how. As noted before, the implication of such strict data collection is in losing further information that the participants can contribute to the system, as is the case with projects such as OpenStreetMap or Wikipedia where the participants are free to add anything that is of interest to them. Of course, having such an open approach to data collection creates challenges in understanding the semantic meaning of the information that is provided by the participants and merging it with other sources. Yet, there are examples of projects that do that, for example the OSM-GB project in which data from OpenStreetMap was converted to conform to standards, so that it can be used by local authorities in the UK (Pourabdollah et al., 2013).

Another aspect of the management of the data is the consideration of the length of the crowdsourcing activity. A short-term activity can be managed separately from other sources, and after its completion go through quality assurance steps before archiving and integrating it with other sources. The more continuous the engagement with the participants it is, the more likely it is that the investment in a process to integrate the information with existing information is worthwhile, although the technical challenge should not be underestimated.

In terms of metadata, because quality matrices of VGI are related to the participants, the time of data capture, the equipment that was used and other factors that are inherent in the heterogeneity of the information, metadata is best captured at feature level. This adds to data volumes and management efforts, but can be critical for fitness-for-use testing at later stages and should be managed as well as the geographic information itself.

Finally, aspects of ownership and licensing need to be considered carefully. Some of the data that is available through VGI, such as photographs, is provided by services that have specific licensing restriction on which metadata can be used and for what purpose, with a second level licensing set by the contributor. Thus, the use of a large number of photographs from Flickr, require attention to both Flickr terms and conditions, and the license that is set for the photograph itself. In other cases, licensing is set for the whole dataset. In most systems that are set by commercial companies, the participants transfer their rights to the company – and sometimes are happy to do so. For example, some of the participants who contribute data to the traffic reporting and navigation service Waze, feel pride in the success of the company. Therefore, the licensing is set by the company, and despite its origin from volunteered data, can be fairly restrictive – for example, Google MapMaker data is provided for researchers under highly restrictive terms and only after approval by Google. As noted before, there are both ethical and potentially legal issues when participants contribute very large amount of effort, and their data is used for purposes or in ways to which they disagree. This happened explicitly in OpenStreetMap, when the license changed and there was a very lengthy discussion within the community, resulting in a small number of participants removing their data.

6 BUILDING NATIONAL GEO-SPATIAL DATABASES USING CROWDSOURCING METHODOLOGIES

In the last two decades, we have witnessed the internet revolution as a "disruptive technology" influencing the way National Mapping Agencies (NMAs) work. This technology provides the best platform to view and download information from on-line databases and geospatial portals (Web 1.0) but it also enables user's engagement and the use of crowdsourcing methodologies to acquire data (Web 2.0). The NMAs worldwide, as well as in Israel, varied greatly in their engagement with the community generating volunteered geographic information and in their future plans (Olteanu-Raimond et al., 2017). The continuation of these processes in Israel, for example, involved in developing steps of novel crowdsourcing methodologies for updating the national geo-spatial database (mainly cadaster and topography).

6.1 Introduction

The evolution of the web is often portrayed as a transition from a Web that consisted largely of documents for humans to read (Web 1.0), to one that have greater user interactivity and collaboration (Web 2.0), to one that included data and information for computers to manipulate (Web 3.0 or the Semantic Web) (i.e. Shadbolt et al., 2006).

This evolution has also affected the way National Mapping Agencies (NMAs) operate and work. At first NMAs developed tools and means to distribute their data and share their maps on-line (Web 1.0). An overview of the Wikipedia list of NMAs shows that many of them have an active geospatial portal (Wikipedia, 2018). Currently, many NMAs are investigating the use of Web 2.0 to improve their operations using crowdsourcing methodologies. Some examples include: The US Geological Survey's (USGS) VGI project that encourages citizens to collect and edit data using the National Geospatial Portal about man-made structures to improve the USGS authoritative spatial database (McCartney et al., 2015); The Dutch Cadastre in the Netherlands and the Finnish Geospatial Research Institute are researching the use of crowdsourcing methods to enrich their topographic databases (Bol et al., 2016); and, the Vicmap Editing Service (VES, at: https://ves.land.vic.gov.au/login) encourages registered public users to notify the Australian state of Victoria of changes required to the Vicmap core spatial data products. In the same manner, the Survey of Israel is using its national geospatial portal to get citizens' feedback on its national map, at https://www.govmap.gov.il/?lang=en, and investigate crowdsourcing methods to map defibrillators, at https://med-man.co.il/.

However, most NMAs are cautious about integrating crowdsourced data with authoritative data, as this may reduce the quality and consistency of their national datasets (McLaren, 2012).

In this section, we present a new system (TopoCad) that uses crowdsourcing methods and consistently collects spatial data from mapping experts to update the national cadastral and topographical database in Israel. The previous version of the system had tools for searching and retrieval of geodetic, cadastral and topographic information of the Survey of Israel (Felus et al., 2013a). The second version of the TopoCad system includes crowdsourcing tools to upload, verify and integrate all types of surveying data and maps. In order for the approach to work, these surveying data and maps should be submitted by the crowd of mapping experts in a uniform machine-readable format.

A new set of mapping standards were published by the Survey of Israel to ensure that every map in every step of an engineering project is made in a computer readable manner and format. The TopoCad system reads these crowdsourced files, and integrates these in the national databases following a rigorous quality control process.

The system, with its crowdsourcing tools, is now operational, and is described in this section.

6.2 Creating a Common Language by Mapping Standards

Engineering projects are characterized by a large number of spatial data files and large amount of information, which is generated at every step. These data files are generated by engineers in different fields (architecture, construction, transportation, water, electricity…), but mostly by licensed surveyors who provide the basic map to overlay the data layers. Moreover, different steps in the development of an engineering project create different types of data at different scales and content. According to the Israeli Planning and Construction Law and Regulations there are 5 steps in an engineering construction process, which require the involvement of a licensed surveyor. These steps are:

1. Planning, where a master plan of the project area is made for the local authority approval (a map at a scale of 1:1250).
2. Registration, where a subdivisions plat is used to register the cadastral division of parcels at a scale of 1:1250.
3. Building permit, where a building permit map at a 1:250 scale is prepared with topographic data, precise cadastral information, above and underground infrastructure and the exact location of property corners and construction limits.
4. Construction, where the following plans are prepared:
   a. A stakeout plan with coordinates of the foundation markers and building columns.
   b. Ground floor plan used to monitor the location of the ground floor.
5. City approval of the constructed project where an as-built survey map is drawn to document the engineering activity.

In addition, most local authorities are preparing maps for their GISs. These GISs are supporting efficient management of the city infrastructure (sewage, lighting, water, power, gas, communication…) and operation (garbage collection, public safety, street cleaning…).

Each of these steps in the life cycle of an engineering project (as presented in Figure 19), require a surveyor or mapping expert to supply a map for the authorities for validation and approval. So far, these maps were submitted in different formats, sometimes even as paper documents, making it impossible to use them for updating the national geo-spatial databases.

In order to be able to use these maps to update the national database, the Survey of Israel, the Israeli National Mapping Agency, led the Inter-Government GIS committee to approve the national mapping standard. The Inter-Government GIS committee was

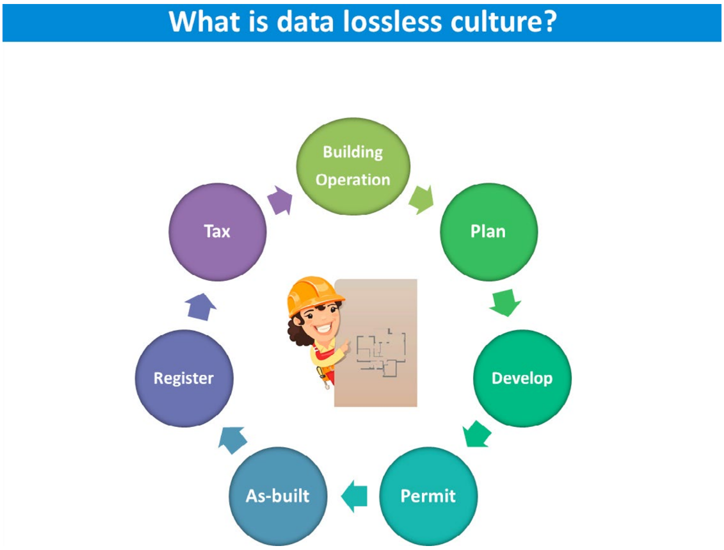


Figure 19: *The life cycle of an engineering project that requires map submission. (Image from VectorStock)*

established in 1991 by a Governmental order as the committee with representatives from 45 governmental ministries and public organizations.

The national mapping standard is based on a list of surveying and mapping regulations and instructions. It provides a comprehensive set of definitions and descriptions for the content, data acquisition accuracy, computer format, and cartography of each map in the life cycle of an engineering project. The file format is a CAD based format (DXF), and a list of layers and blocks detail the exact structure of the file (see Figure 20). For example, building polygons are placed in layer 2200, with block 2200, which has 5 attributes (building name, street address, building no., no. of floors, type).

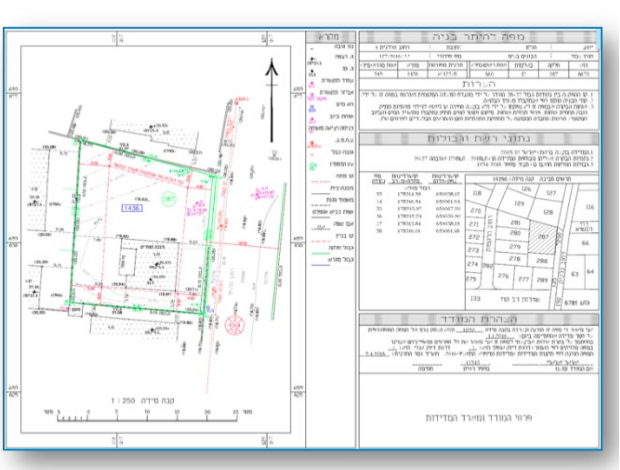


Figure 20: *Excerpt from the national mapping standard.*

Table 1: *Accuracies of the Mapping Products from the Surveying Regulations.*

Accuracy level	RMSE in Easting and Northing (m)	Largest scale	RMSE of Elevation at well-defined points (m)	Contour line interval (m)	Use
3	0.06	1:250	0.08	0.10	Building permit and As-build map
4	0.13	1:500	0.15	0.25	Detailed planning
5	0.25	1:1,000	0.30	0.50	Subdivision plat
6	0.30	1:1,250	0.38	1.00	Detailed zoning map
7	0.63	1:2,500	0.75	1.25	City master plan

The national mapping standard is based on the Surveying Regulations, which define the accuracies and the data collection methods, which are also presented in Table1 (Felus et al., 2013b).

In order to make the national mapping standard widely acceptable, the Survey of Israel held a large number of training sessions and workshops for the surveying and mapping community, as well as with CAD software developing firms (that created software tools to use the standard). Moreover, an online help desk was established to assist any professional who had troubles in adopting the national mapping standard. These efforts were successful, and in the last two years most of the maps in Israel conform to the computer and logical format, cartographic layout and layer structure of the national mapping standard.

6.3 Developing the Crowdsourcing Tools

Following the approval and the adaptation of the national mapping standard, the Survey of Israel started to develop the tools and technologies to enable the use of crowdsourced maps and information for updating the national database. The system was developed on an existing platform called TopoCad.

A key challenge in developing a crowdsourcing system is the design and development of the user interface or the software user experience (UX). The user interface should be simple and intuitive but still meet all the functional requirements. It should be one that requires no training or a user manual. The project approach was to place the user in the centre, then study the user and his work habits. Based on these insights, the project team came up with the design of the software user-interface. The design includes four steps (Figure 21), and is based on the following rules:

- Simplicity – functions should be performed in an intuitive manner that require minimum steps and minimum number of command buttons.
- Unified approach – all the functions where designed in a similar style.
- Identification – is needed only for specific functions using a special authorization card, otherwise most of the functions are open for public use.
- Visualization – graphic tools to view results on a map.

Internally, the system has two processes or modules: The Quality Control module and the Conflation module. These will be described in the following two sub-sections.

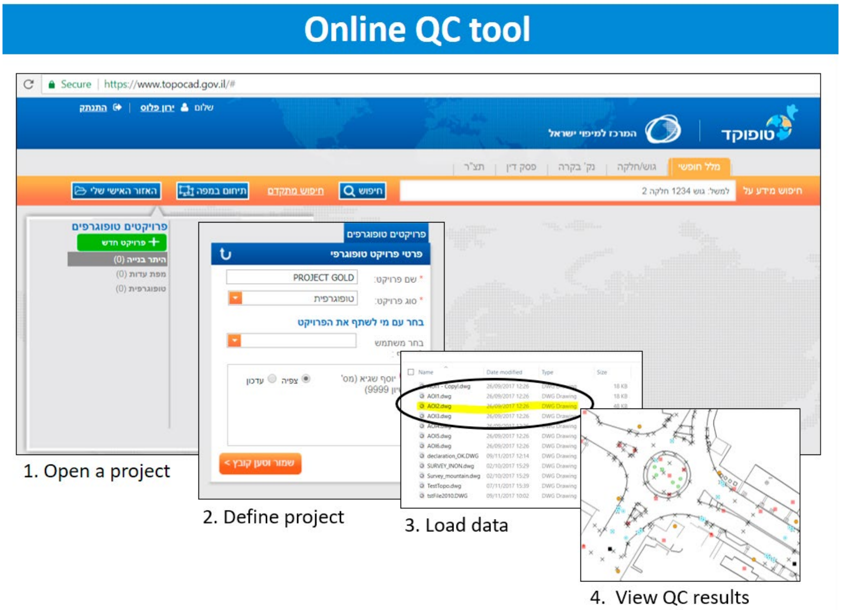


Figure 21: *The four primer-steps in the TopoCad Crowdsourcing System User Interface – (left to right) Open, Define, Load Data, and View.*

6.3.1 The Quality Control Module

Quality Control (QC) for crowdsourcing data is a critical issue and has been described in many publications (e.g., Barron et al., 2013). QC is specifically important when combining crowdsourcing files with an authoritative national database. The TopoCad system QC processes are based on the ISO 19157 (2013) standard principles and quality components. The six QC components in the standard are: logical consistency, positional accuracy, completeness, thematic accuracy, temporal accuracy, and usability. The system performs semi-automatic QC processes as presented in Figure 22, and performs these 5 tests components from the standard:

- Computer format and logical consistency tests are automatic procedures, in which the software verifies that indeed the submitted files are in DXF or DWG CAD format, and that the fidelity of the relationships in the dataset meets the requirements. Some examples for the logical consistency tests include:
  - Topological checks, such as search for overshoots or undershoots within a thematic layer.
  - Domain rules tests in the database fields and attributes, such as a test that the elevation values are not smaller than -500 m.
  - Logical tests between thematic layers, such as a test that unreasonable intersection of building layer with road layer occurs.
- Completeness tests are done in an interactive manner by a human operator, which samples the files and searches for omissions (missing features) and com-

missions. The tests are done by superimposition of the vector map on top of a high resolution (10 cm) orthophotograph or by field inspection. The selection criteria for missing and unrequired features is described by Felus et al. (2013b).

– Positional accuracy assessment is performed by field surveys to a sample of the files. A SOI surveyor calculates the RMSE of selected features on the map by comparing the map coordinates with precisely measured GPS coordinates. The map should meet the accuracy requirements, as given in Table 1.

– Thematic accuracy assessment is performed by field surveys to a sample of the files. The field surveyor verifies that the identification of entities and assignment of attribute values are correct in the data set.

– Temporal quality is the test that verifies that the map is updated to the published date, and it is performed in the same manner as the completeness tests.

These tests are performed on a sample of the submitted maps. Maps submitted by new mapping experts and surveyors are fully tested (100%). Following the five maps that have passed the QC tests, the QC process is performed on only 50% of the submitted maps, and then after five more successful submissions the process is performed on 30% of the maps (i.e.; 1 out of 3 maps is checked).

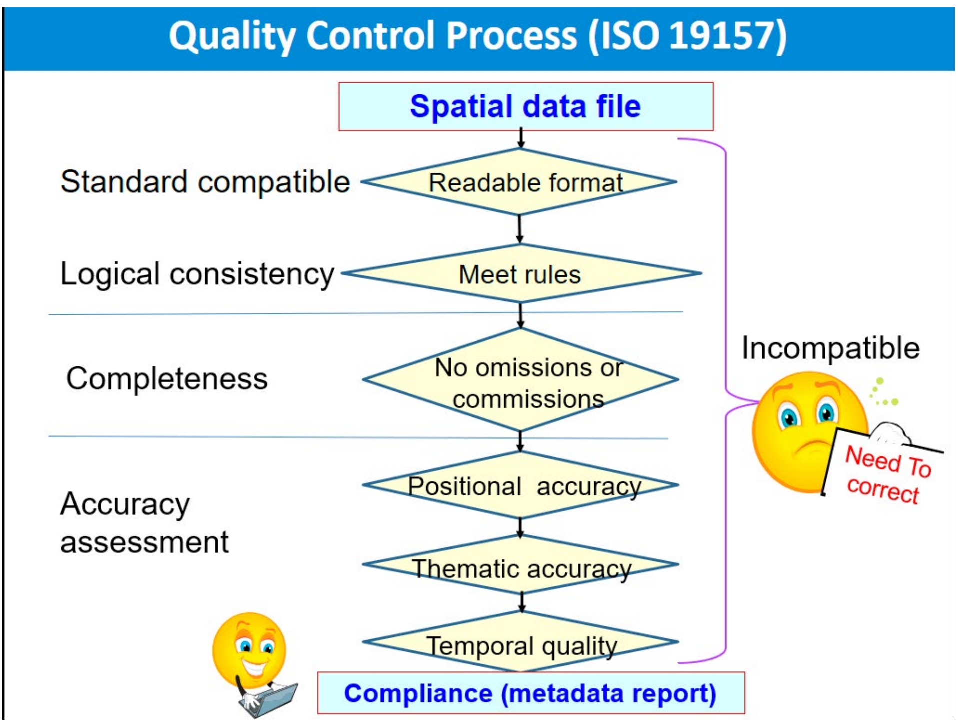


Figure 22: *The QC Processes.*

6.3.2 The Conflation Module

A map that passed the QC test should be consolidated and combined with the National Topographical Database (NTDB). The NTDB, and its properties, is described in Srebro et al. (2010). The aim of this conflation process is to merge the data of the small map (e.g., a building permit map) with the NTDB. Through the conflation process, individual strengths of the source datasets can be combined, namely the output of a conflation process should be a map with superior positional accuracy and more attributes and data associated with the map (Saalfeld, 1988). The TopoCad system has the following characteristics for its conflation process:

1. The NTDB is the main database and the small maps are merged into it with high accuracy and rich content.
2. The process is semi-automatic, which means that the system performs the conflation but presents it to the human operator for approval. This way every modification to the authoritative NTDB is double-checked. The process is very fast and the operator can scan quickly through the modifications with the background of a high-resolution orthophotograph to assist him.
3. Every feature gets a unique metadata code, which describes its source (data related to the map, scale, accuracy, creator).
4. The process has three operations to the NTDB, as depicted in Figure 23:
    a. Add – A new feature is added to the NTDB if there is no existing feature in a buffer of a given threshold. The threshold is specified by the operator, but the default is 2 meters which is double the estimated RMSE accuracy (2σ) of the NTDB.
    b. Delete – A feature is removed from the NTDB if the new map contains no feature in a buffer of a given threshold.
    c. Update – A feature, which exists in the NTDB and in the new map (in a buffer of a given threshold) but has changed its shape, position, or height, will be replaced by the new feature.
5. The conflation process on point features and buildings is performed using a specific algorithm (Keinan et al., 2016). The conflation process is more challenging with lines, polylines and polygons. Therefore, the algorithm of Filin and Doytsher (1999) is used. This algorithm employs counterpart nodes to match and transform corresponding segments and objects (see for example Figure 24).

6.4 Conclusions and Further Work

Data is generated at every step of the governmental and engineering activities. This section described a new approach of preserving these data and crowdsourcing it to update national topographic databases. The process is working successfully, and approximately more than 600 maps were integrated during every month of the initial phases of the system. It is expected that the number will grow to more than 5000 maps a month, which corresponds to the estimated number of changes occurring in Israel. Thus, the process will provide a complete methodology to update every layer in the NTDB (buildings, transportations, infrastructures).

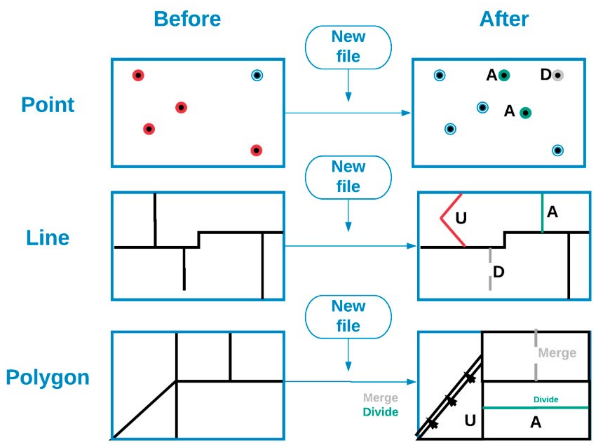


Figure 23: *The three operations of the conflation process.*

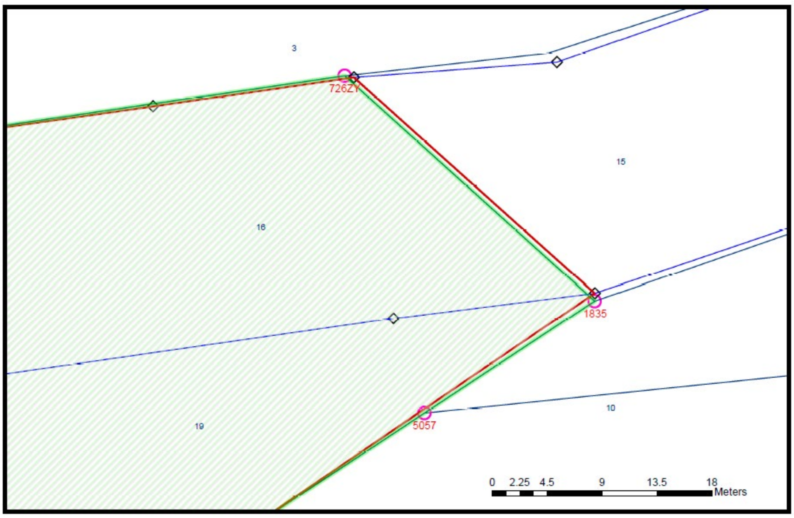


Figure 24: *Conflating two parcel files using counterpart nodes.*

The process is not yet fully automatic and requires human experts to do part of the quality control and to validate and assist the conflation process. It is hoped that in the near future these stages will be improved and become less dependent on human operators.

7 LAND SURVEYING AND CROWDSOURCING/VGI

7.1 Introduction

The easily accessible spatial technology and products like Google Earth, hand-held navigation systems, web 2.0 technology and social media allow a bottom-up approach in spatial data capture by community groups without prior experience in spatial technologies. The utilization of VGI for spatial information collection and updating is now widely used by OpenStreetMap, TeleAtlas, NAVTEQ and Google maps. There is already available spatial data collected by volunteers, community groups, citizens and land holders at grass root level in the various countries.

While a great percentage of the world's population is still deprived of internet access and therefore of the potential benefits of e-Government, according to statistics of the International Telecommunication Union there is an increasing percentage of people who have access to a mobile phone subscription: in 2017 about 98.7% in the developing world (ITU, 2017). The increased technological advancement of mobile phones allows their use as urban sensors to collect all kind of spatial information with a considerable level of accuracy to be used for several purposes, among them urban management during crisis. That may include natural disasters like flooding or earthquakes that require immediate action, but also a serious economic disaster that may also require immediate decision-making based on reliable spatial data.

It is therefore anticipated that these technological developments have opened the way to m-Government. We actually have a potential to live in an inclusive m-World in which people, business and government will soon enjoy the benefits of universal wireless connectivity and will share data and services in a fast, easy, reliable, transparent and efficient way; the developing world will benefit most as a result (GEOconnexion International, 2013).

Obviously, state government agencies and local authorities who traditionally lead a top-down approach in data capture are also interested in gaining access to such information collected by volunteers; they investigate methods to integrate VGI into their authoritative data bases, especially when pressing financial or social conditions emerge, where traditional surveying methods for updating old maps are costly and require time. A few governments' forward-thinking organizations in USA, Australia, Germany have already introduced methods to verify and integrate VGI into their products (such as the US Geological Survey, which was the first to introduce such technology for updating the National Map; and the Ordnance Survey, which as well is experimenting in the accuracy of VGI). The current trends in this type of research aim to identify "how to get the best of both worlds".

And this is a new task for land surveyors. It is recognized that:

(a) Land surveyors are the experts to identify the methods and tools for helping government organizations to implement Gov 2.0 initiatives in order to achieve their goals, whether these would be "saving money", or "saving time", or "saving lives".

(b) Land surveyors, however, are the professionals responsible for capturing authoritative spatial data; therefore, they are not expected to compromise their professional reputation by using unverified data. This new challenge should motivate surveyors to use their expertise and try to contribute to an inclusive m-World.

Actually, introducing VGI techniques into the land surveying profession may in general provide professional land surveyors with several potential benefits, such as:

- increase in speed of data collection, both spatial data and attributes;
- increase in the volume of data that may be collected within a limited time period;
- reduction of data collection costs;
- reduction of data updating costs;
- improvement of the quality of data in specific projects, especially in cases when the local people know the local special issues much better than the land surveyor.

VGI may be proved useful in several of the various tasks a land surveyor may be involved in, like projects for mapping update at various scales. In particular, rural mapping update is of greater need in the developed world, as urban data are usually well updated. In the developing world needs are more pressing, therefore VGI may be applicable for the creation of new maps in rapidly urbanized areas.

By example, some of the various tasks VGI methods might contribute are:

- transportation maps at various scales (large scale maps of paths of specific interest; road / street updating; railways; water ways; power lines, pipe lines, attributes such addresses, numbers, names, etc.);
- structures (all kind of new construction update such as houses, schools, hospitals, airports, fire stations, post offices, museums, houses of worship, etc., or all constructions that do no longer exist);
- hydrographic maps (coast and marine themes);
- elevation maps;
- land cover;
- updating of specific data bases created for various purposes such as emergency disaster related projects, environment, development and energy projects, telecommunications, education, public health;
- natural resource management (landcare, waterwatch, land for wild life, birdwatch, etc.);
- zoning, planning and land cover projects;
- GIS value-added information projects in coordination with other professionals such as architects, archaeologists, engineers;
- verification of the existing spatial data;
- compilation of draft cadastral maps for the adjudication of parcels and property owners and for other land management and administrative purposes; identification of real estate properties, updating of buildings and other features on maps; descriptions of property boundaries and collection of photos and other data and documents useful for property valuation and property markets. So far property boundaries, elevation data, land administration and property management have been the less focused issues for VGI involvement.

A caveat is recognized in the discussion of the above tasks to be adopted by the professional land surveyor: There are professional liability issues for the surveyor utilizing VGI support, not only in the quality of data, but in the possible miss-use of the data he or she may publish as a result of their work.

7.2 Land Surveyors Introducing VGI Practices and Methods

According to the experience gained through brainstorming within the various activities of those national mapping agencies (e.g., of USA, Australia, UK) that have been experimenting VGI in their products and services, as well as within FIG and World Bank conferences, a great number of issues for consideration by the land surveying community may be classified as conceptual, organizational, fiscal, technical and legal aspects:

A. Conceptual aspects may include issues like the following:

- Clarity in what is regarded as the "*peoples' map*". Responsible surveyors should ensure clarity in *defining the aim* for introducing VGI data capturing in traditional procedures. Each government organization that will introduce such methods should clarify *the mission*; explain what information needs to be collected by the organization and what information can be relayed to volunteers or the public;
- Definition of a new concept of "*quality*" of the spatial data to be collected. Surveyors need to reconsider what is quality, how quality may be assured, which aspects of quality are more important depending on the particular mission; clarity is crucial in what is regarded as acceptable quality for the mission. A "*fit-for-purpose approach*" may be communicated to all involved participants, organization staff, volunteers, government, individual users, business and society. However, it should be noted that "quality" is defined both by common use and by regulation in many jurisdictions. It may not be appropriate for the individual land surveyor to re-define "quality" in his or her work.
- Creation of "*incentives for volunteers*" to participate. It should be explained and documented why individuals may be involved in government-sponsored projects and how volunteers will be rewarded, explaining how people and society will benefit from such an approach;

B. Organizational aspects may include issues like the following:

- Depending on each mission the organization should decide to plan for the optimum "*type of the event*"; it may be either an annual event, or a one-type event, or an on-going project (e.g., for natural disaster management, map updating, etc.);
- The government organization which initiates the mission should decide about the "*organization and regulation of the website*"; clear decisions should be taken on who owns, rules, and administrates the website;
- In addition, an arrangement of the organization's staff members is expected in terms of "*staff responsibilities*"; staff contact persons should be appointed to support volunteers' work and coordinate the project; experts should consider the best way of administrating the website in order to avoid "*data vandalism*";

- According to the type of the event the "*organization of volunteers*", may then be planned. The organization may then have to decide whether it would be preferable to provide an "*hierarchical model of responsibilities*" for the volunteers, e.g., trusted volunteers, moderators, certifiers;

C. Fiscal aspects may include issues like the following:

- What would be the financial benefit if VGI methods are to be adopted and what will be the required "*budget*" for such a project;
- Costs may include "*development*" and "*operational*" costs as well as the costs for the "*processing of data*" captured by VGI.
- Costs for the professional surveyor in private practice may include increased professional liability insurance premiums.

D. Technical aspects may include issues like the following:

- Definition of the "*terminology* and *standards*"; the need for "*metadata*" should be examined and for what purposes;
- The project should enable the usage of multiple, *new and simple technology*, e.g., mobile phones with GPS technology; the use of existing authoritative data like orthophotos; attention should be paid so that topology will be maintained;
- Surveyors are responsible to decide how the evaluation of the project will be done; an option may be that other type of volunteers will be activated to evaluate the work; depending on the mission, surveyors should consider if there is a need for developing a "*quality assurance*" procedure or if the project will allow for a "*self-correcting procedure*"; at all cases there is a need for a clear definition of the adopted levels of "*authoritative control*" and/or "*self-control*"; attention should be paid so that controls will not slow down the process;
- Surveyors may consider if some kind of "*training of volunteers*" would better facilitate the results of the mission or not; should define the "*levels of access*" to the various users/volunteer groups;
- Surveyors should define in which areas the system/method is applicable, e.g., urban or rural areas; and should also define and clarify in "*which purposes the captured data are appropriate*"
- In all respects, surveyors must consider the constraints and responsibilities attendant upon them in their position as professionals and employers.

E. Legal aspects may include issues like the following:

- Ensure security of privacy for certain data, if this is required, e.g., in many countries personal data for cadastre or taxation purposes are not made public; "licensing versus public domain";
- "Premium owner of the system" should be defined;
- Level of permitted access of various groups to the national authoritative databases should be defined and protected from fraud;
- Role and responsibility of surveyors in each project should be clarified;

– Reward of the participants should be clarified;
– Liabilities and responsibilities as noted above.

7.3 Introducing VGI Practices into Cadastre and Land Administration Procedures

Crisis management is the field in which VGI has been rapidly adopted. As Maron (2010) has admitted, while talking about crowdsourcing in crisis management, emergency cases constitute "an engineering problem in the most extreme environment." Can economic crisis and the lack of data about the ownership, value and use of land in certain places justify the introduction of VGI practices in data capturing for land administration purposes? Can data of "unknown quality" or non-authoritative data become better than no data?

It is broadly accepted that no country can sustain stability within its boundaries or economic development within a wider world unless it has a property registration system that promotes internal confidence between its people its commercial enterprises and its government. In many developing countries there have been attempts to undertake a systematic registration of property rights because existing systems were dysfunctional. There have been some successes but many failures.

As mentioned earlier, land administration and property management, as well as cadastral mapping, are among the fields of surveying activity that VGI data capturing is so far most debated. Cadastral mapping is considered to be among the most demanding authoritative mapping by several mapping agencies and surveyors worldwide. The aim of this section is to examine and analyze the issue and to investigate what surveyors must consider in case of planning for such a project.

Conceptual aspects for integrating VGI practices in cadastre may require a clear definition of the *aim* of such an initiative, the "fit-for-purpose" concept of *quality* and incentives for *volunteers*. The aim may be to serve the urgent needs of the society and the government for establishing a land administration system fast and with low cost in order to improve transparency and support the national economy. The answer to the question "how to motivate volunteers" may be "make the users the volunteers!", while the answer to the quality assurance may be "make the owners the quality assurance keepers".

Adlington (2011) has suggested that the example of ECA region countries and especially the former Soviet Union countries, who although they lacked "licensed cadastral surveyors" and experience in "cadastral surveying" they have successfully managed to complete the land reform and the establishment of a property registration within a "*short period*" with a "*low budget*", may well demonstrate what really matters most for the economy. This reform was guided by experienced cadastral surveyors who however were willing to be pragmatic rather than stick strictly to historic methods and high levels of accuracy. The existence of geometric errors in positioning of properties may still need to be solved but has virtually no impact on the functioning of the property market. Adlington claims that "a geo-referenced image of any boundary or building can be recorded by any member of the public using a mobile phone and that this is sufficient for the public and professional users including banks, lawyers and estate agents in order to run the market"; in addition he claims that "the role of the cadastral surveyor of the future will be more scientific and will require skills in understanding historic and current technology and methods".

McLaren (2011) investigated Land Administration Systems (LAS) and the potential of crowdsourcing techniques with the sudden expansion of smartphones focusing on the unmapped areas and the great number of unregistered parcels worldwide. As he mentions, comprehensive LAS exist in only 50 countries, and only for the 25% of the world's 6 billion land parcels, while the rest of the world suffers from reduced security of tenure and poverty. There is a need for establishing cooperation between professionals and citizens in order to facilitate citizens' direct involvement in capturing and maintaining information about property rights. However, crowdsourcing is considered as a particular threat by the involved professionals, such as the conservative mapping and cadastral agencies, the surveyors and lawyers, and all those who suffer under or benefit from the existing chaos.

Laarakker (2011) offered a theoretical framework for an OpenCadastre by interviewing experts in Linkedin in a way to identify their motivations which are far from altruistic. Basiouka and Potsiou (2012) conceived a cadastral mapping experiment in Greece for the compilation of draft cadastral maps in some areas where the results of the official cadastral surveys were problematic, with crowdsourcing techniques (using OpenStreetMap and handheld GPS), comparing this procedure with the traditional cadastral survey procedure. In this experiment *the volunteers were the land owners and/ or residents of the areas mainly elderly people*. The editing of the data was then made by *volunteer young surveyors* using orthophotos as draft maps; the final output was compared to a recent and accurate cadastral survey. The results indicated that the location and shape of all parcels are correctly defined by crowdsourcing techniques (after a slight editing in the office) while the area size of the parcels satisfied the AAA accuracy specifications of the organization.

Organizational aspects of a cadastral mission with VGI practices may require defining the "*type of the event*"; the *"organization and regulation of the website";* the arrangement of the "*staff responsibilities";* measures to avoid "*data vandalism and fraud";* the development of an *"hierarchical model of responsibilities*" for the volunteers, e.g., trusted volunteers, moderators, certifiers.

The event may be planned as an "on-going mission to record, compile and maintain/ update a draft cadastre". The organization should develop and regulate a website and should provide staff for various responsibilities. As cadastral VGI mission may require training of volunteers as well as the adoption of a "responsibility hierarchy" for them prior to their participation.

The staff of the organization involved into such practices would be the contact persons and the trainers for the various levels of volunteers. The training responsibility may be as well transferred to the private sector if the private sector will undertake the improvement of the draft VGI cadastral maps. Surveyors should undertake an important role in the government pilot projects to increase capacity and provide guidance and training of trusted volunteers (para-professionals, community leaders, citizens and land right holders).

For the higher responsibility categories of volunteers, the solution may be "*engage young students and young surveyors*" as trusted volunteers, moderators and certifiers and develop their skills and interests accordingly.

Quality assurance is always the top issue of concern in case spatial data provided by voluntary geographic information methods are to be shared with the authorities and integrated into the authoritative products of national mapping agencies. Surveyors should develop methods in order to police the quality of data capturing. They have the knowledge to do it in a professional way. Openness in cadastral data may help in a "self-correcting" approach. Data vandalism and fraud may be avoided by an OpenCadastre. If everyone believes that someone is the owner of a parcel that may be assumed to be a fact. However, the organization may improve the draft cadastre by implementing legal controls prior to assuring the legal reality.

Adlington (2011) notices that as periodic accurate ortho-rectified imagery of properties is becoming available freely on the internet even the history of boundary information may be available. The opportunities for using lidar mounted on vehicles, cheap and quick aerial photography, existing imagery available on the internet, hand held GNSS systems, digital photography and even cell phones that can record and geo-reference properties can all be used to conduct mass survey by non-specialists. This may provide land administration capacity in places that previously could not afford such systems, and transparency in places where corruption and inefficiency is endemic.

What needs to be done? There is a need for better investigation of the capacity of governmental agencies to monitor, evaluate and interpret the volumes of collected data through crowdsourcing methods; raising public awareness about the benefits citizens will enjoy; raising public trust; establishing policy frameworks legally for the appropriate use of VGI, OpenStreetMap and OpenCadastreMap techniques.

As technology improves, more bottom-up pilot projects are expected to challenge formal systems, their constraints and inadequacies.

Siriba and Dalyot (2017) have presented examples of communities in Kenya, adopting VGI-based techniques to LADM. Authors state that to facilitate development and increase the agricultural productivity in post-colonial African countries, most governments introduced land reforms in the form of individualization of tenure through title registration programmes – either freehold or individual leasehold on state-owned land. Still, this paradigm has had mixed results, partly due to the fact that land tenure reform has got more to do with social relations and power structures than with reforms of land use. Whereas the LADM is an effort focused on formal systems, the Social Tenure Domain Model (STDM) represents the same effort targeting informal systems. STDM has given rise to an interesting trend in land administration, the involvement of the community (citizens, crowd) in mapping social tenure arrangements, those particularly considered to be informal. The incorporation of VGI into existing formal land administration frameworks is considered an overarching and crosscutting theme. Authors have identified an interplay between formal and informal LADM institutions, which largely depends on the strategic intent of the actors in both institutions. Two dimensions can be considered: the degree of convergence, and whether formal systems are effective, such that the four types of relationships are: complementary, accommodating, competing and substitutive.

To illustrate this, authors have presented two community-driven STDM campaigns. One, initiated by the community and supported by the government, included these stages: making of ownership claims by individuals, data collection by residents and community representatives using GNSS and satellite imagery, database creation, data verification by the community, and database presentation for formalization. This makes

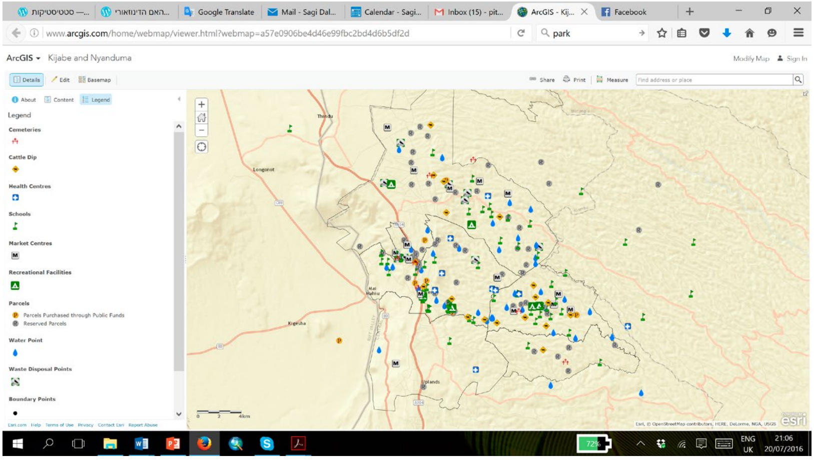


Figure 25: *Public Land Inventory for Kijabe & Nyanduma (Kiambu County, Kenya); retrieved on 20.07.2016 (http://www.arcgis.com/home/webmap/viewer.html?webmap=a57e0906be4d46e99fbc2bd4d6b5df2d).*

the outcome complementary and accommodative to the existing formal process, and as such was acknowledged by the NMA. The second, initiated by the community together with a local NGO, included these stages: assigning of data collection tools (mainly old maps), assigning data collection teams, generating a draft land inventory, validation of the draft, GIS mapping, storage and dissemination of the inventory. The GIS map is also published online via ArcGIS online, depicted in Figure 25. As opposed to the first example, since no direct government involvement is evident during this process, it is more of a competing-substitutive initiative. Still, authors state that government plays a role only when the National Land Commission is interested in using this inventory to improve on its policy, relating to the management of public lands, such that the outcome to some extent does play an authoritative role.

Both examples proved that the acceptance of information derived from crowdsourced volunteered geographic data can be recognized ranging from tacit acceptance that there is merit in an alternative system, to full government guarantee of title based on a VGI-based system. Accordingly, the participating communities intend to be directly involved in the process, proving that efforts from the two examples provide a way through which the government can achieve its development goals, as long as the eventual register is not considered to be in parallel with the existing land registries. Moreover, the introduction of a crowdsourced VGI paradigm provides new perspectives, suggesting the quickest, cheapest way to acquiring location and supplementary information about the land parcels where different interest are claimed. It is also introducing new social perspectives, encouraging the community to get involved, and thus strengthen their esteem, and making them to be a part of an important and a larger effort. Thus, not only the community gains from such campaigns, but also national cadastral and mapping agencies, even if the full information integration might still require a subsequent process.

8 THE PRACTICE OF VGI IN DEVELOPING REGIONS

8.1 *Introduction*

The dearth of authoritative map information across much of the world in general and in developing regions in particular pushed map users to collaborate in mapping projects to generate their information ensuring that the information is free and available to all that need it. Such successful initiatives termed as VGI (e.g., OpenStreetMap, Wikimapia) have largely been applied in creating and revising basic topographic maps.

The high frequency of social media activities is attributed to increased internet penetration and mobile subscriptions as this has contributed to the growth of locally generated content and the corresponding proliferation of the blogging and social media communities. According to the Communications Authority (CA) of Kenya, for example, the number of mobile subscriptions and the data/internet subscriptions stand at 41.0 million and 30.8 million respectively. Various mobile and Internet use statistics can be found in BAKE (2018).

With respect to VGI, the absence of a functional Spatial Data Infrastructure (SDI) in Kenya has created a situation in which various VGI platforms have emerged to fill the gap. According to GEOBUIZ, a Magazine that focuses on Geospatial Industry Outlook and Readiness Index, Kenya is ranked 37th with a score of 11.958 and geospatial data infrastructure score of 7.13. The Geospatial Industry readiness index is computed in terms of geospatial data Infrastructure, policy framework, institutional capacity, user adoption and industry fabric (Geospatial Media and Communications, 2018).

Kenya's geospatial industry user adoption index stands at 2.55, an indication that Kenya has not yet fully integrated geospatial technology in its systems at all stages of geospatial use. Stages of geospatial use include: mapping, asset management, analytics and workflow, system integration and enterprise-wide use. Kenya's Geospatial user adoption is limited to spatial mapping. This situation then created room for alternative VGI solutions to address the location problem.

The application of VGI is taking root in many countries finding application in traditional and new domains. Initially, VGI was intended to address the problem of inaccessibility and unavailability of authoritative basic topographic information, but the overlap of the Sensor Web with the Social web (Mian et al., 2016) has resulted in the rise of the applications of VGI. Today, VGI finds application not only in topographic mapping, but also in transportation, security among others. The concept of VGI in land administration has also been proposed as a way of getting citizens to collaborate in land administration to enhance transparency and decrease costs (McLaren, 2011). As VGI becomes increasingly popular, it becomes important to establish the practice of VGI application in land surveying and planning in developing countries. This section outlines the motivation for VGI application in land surveying, and then describes its practice with examples from some countries in Africa, because many developing counties (low income countries) are in Africa.

8.2 Conceptual Framework for VGI Application in Land Administration

Although VGI may be considered as a recent phenomenon, previous efforts with similar goals include Spatial Data Infrastructures (SDI and Public Participatory GIS (PPGIS). Whereas SDI in a formal arrangement to ensure availability and accessibility of authoritative geographic information, VGI started from an informal platform. PPGIS was traditionally established and controlled by someone with knowledge and skills in organizing and presenting geographic information but with constraints. Compared to PPGIS, VGI has a higher participation than PPGIS as the public has a greater control over the process (Tulloch, 2008).

8.2.1 From Participatory GIS (PGIS) and SDI to VGI

The National mapping agencies across the world are being challenged as the exclusive providers of spatial information because of the restriction on the use and unavailability of authoritative map information. Despite efforts to develop Spatial Data Infrastructures to enable geospatial information sharing, a recent study (Mwange et al., 2016) reveals that the majority of African countries have an SDI – readiness index of less than six, which means that more work needs to be done to successfully develop SDI. This is also due to the fact that it is tedious to organize and correct government-sanctioned data before it is released to SDI portals.

The current trend in the departure from official geospatial data to crowdsourcing has been driven by the fact that government machinery to produce spatial information is slow (UNECA, 2016). In Africa particularly, the spatial data revolution is expected to be quite significant considering the rapid increase in the use of GPS-enabled phone (mobile) technology and other devices that generate spatial data. Innovative applications to exploit this present reality VGI paradigm are being experimented and practiced with a great degree of success.

The ubiquity of geospatial technologies has enabled African countries to follow the global trends in harnessing the information contributed by citizens, specifically VGI. There are a number of cases in which African countries have implemented VGI projects. This section will outline cases of VGI application in land administration in Kenya.

8.2.2 Participatory Land Administration

The Sustainable Development Goals (SDG) set the new agenda for United Nations member states to frame their policies until 2030. The goals set in the context of societal needs and technology push provide a framework to address global social, economic and environmental challenges. Although the SDG do not directly mention land, the goals address a range of issues that relate to land including governance of tenure.

Towards monitoring the progress in achieving the SDGs for land tenure governance, the fundamental data needed will be depend on how fit-for-purpose the system for land administration is. Fit-for-purpose land administration systems are designed for managing current land issues within a specific country or region – rather than simply following more advanced technical standards. One of the key elements of a fit-for-purpose land administration is participatory in approach to data capture and use to ensure community support. According to McLaren (2011), new applications are emerging in land administration in which citizens, either individually or collectively, voluntarily collect, organizes and/or disseminate geographic data and information in such a manner that the information can be used by many others.

VGI has emerged as a disruptive paradigm to the established professional practice to the extent that academicians and professionals are trying to find how to adopt it into their practices. This is because many of the current applications of VGI have been created and promoted by individuals entirely from without the well-established academic and professional boundaries. Successful adoption of VGI in land administration and in the land surveying profession is still a debated issue because the theoretical and practical framework has not been established.

Asiama et al. (2017) have proposed a conceptual framework as the basis for understanding and adopting VGI in land administration in what they refer to as participatory land administration. The framework (depicted in Figure 26) identifies four key elements: technological innovation (the push factor); citizen contribution (the bottom-up factor); societal need (the pull factor) and institutional influence (the top-down factor). Participation is realized through the interaction of the key actors in the top-down and bottom-up approach for social inclusion.

Citizen contribution and participation in land administration should not be viewed in the traditional way, in which citizens were only involved by way of consultation but where local people take part in the process of capturing their complete tenure arrangements – the continuum of land rights, social cultural relations and needs – thus bringing a sense of ownership. Involvement is further ensured if members of the community who are deemed knowledgeable by the community members can act as trusted intermediaries.

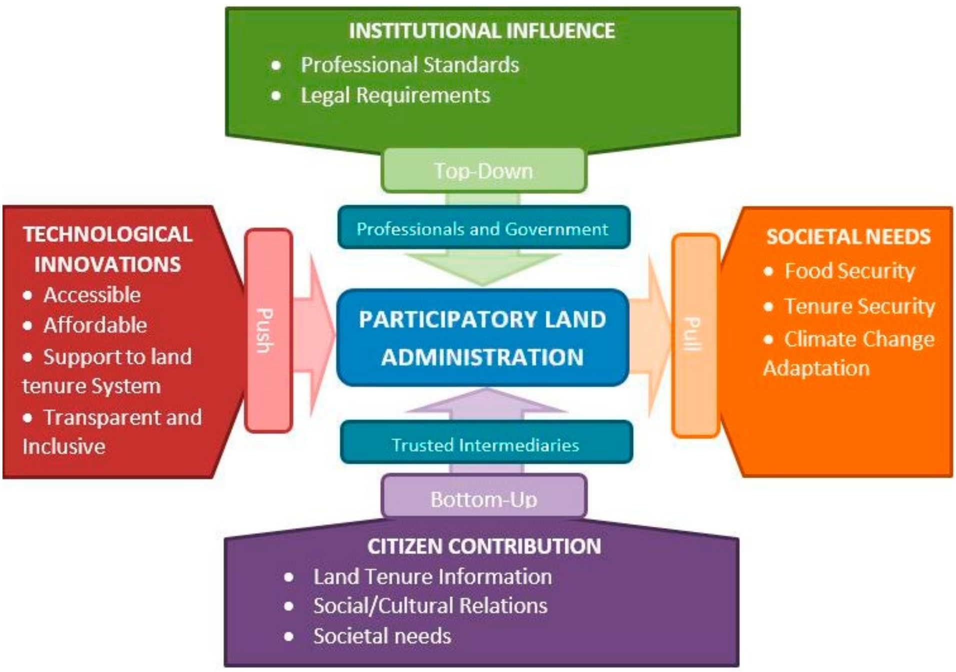


Figure 26: *VGI in Land Administration – Conceptual Framework.*
(Source: Asiama et. al., 2017)

The reason why VGI in land administration is a debated issue is also because land as a public administration activity deals with management of sensitive information and the fact that land administration is dominated by high professional standards and strict legal requirements that have long been established.

The exploitation of technological innovation through citizen contributions should serve certain societal needs. VGI for land administration should serve the societal need for securing land tenure rights, determining valuation and taxation of land, and managing the use of land and development. The next sub-section will describe examples of the application of VGI in land administration in Kenya for tenure security.

8.3 VGI Applications in Land administration in Kenya

8.3.1 VGI in Tenure Security

The adoption of VGI into a formal land adjudication process in Kenya for security of land tenure is presented using two case studies. The two case studies represent the complementary-accommodating approach and the substitutive-competing approach respectively. The complementary-accommodating approach is one in which the formal systems are considered to "fill in the gaps" left by formal systems by addressing problems or contingencies that are not explicitly dealt with in the formal rules, without violating the overarching formal rules. Also, the formal systems might be effective but the goals conflict with those of an informal actor, and in which case actors may dislike the outcomes generated by the formal rules but are unable to change or openly break those rules (Helmke and Levitsky, 2003).

Substitutive and competing approaches occur when a weak formal system with compatible actor goals fails to achieve its expected outcomes, and when weak or ineffective formal systems co-exist with informal system contradicts and/or even eventually replaces formal systems.

Table 2: *Comparison between the complementary-accommodating and substitutive-competing approaches in adopting VGI in land administration.*

Subject	**Complementary-accommodating**	**Substitutive-competing**
Initiator	The adoption of VGI is initiated by the government	The use of VGI is initiated by a Non-Government Organization
Status of registration	The land parcels involved had never been adjudicated, i.e., the ownership have never been registered before	The land parcels involved had been registered before, only that they are not in the hands of the rightful owners
Geometry	Mostly data collected is more accurate, and will generally require simple spatial transformation when integrated	The land parcels are mostly generally represented (e.g., points), and data collected is not accurate, and will require complex spatial transformation when integrated due to data-discrepancies and distortions
User	Information produced and gained is adopted (and used) by formal agencies	Information produced and gained is used by the community to strengthen its legal rights ('make a stand') and interrelations; information can be used by the government for general policy management
Approach in establishment	Usually a continuous and repeated process with updates	A one-time effort – sporadically maintained

The acceptance of information derived from crowdsourced volunteered geographic data can be recognized ranging from tacit acceptance that there is merit in an alternative system, to full government guarantee of title based on VGI-based system (Fairbairn et. al., 2015). The differences between the two case studies are summarized in Table 2.

8.3.2 Adoption of VGI in a Complementary-Accommodating Approach

In the light of continuum of land rights, there is now a world-wide trend of attempts to uphold customary land tenure on one hand, and to formalize the informal land administration arrangements on the other. In Kenya, the formalization of informal land tenure arrangements has been given more attention, for example, through the Kenya Informal Settlement Improvement Projects (KISIP). The main objective of KISIP, carried out in some selected municipalities in Kenya, is for slum upgrading and improving tenure security.

A GIS database consisting of polygons representing building structures was derived from satellite imagery, used by the community members during data collection, and verified using GNSS measurements. A resource center for administering and managing the database was set up, and is entirely managed by the community, and remains open to the community groups from the informal settlement in the area for successive update and processing. The fact that government agencies were involved in the mapping process, and the fact that it was a government initiative, makes the outcome complementary-accommodative to the existing formal process.

8.3.3 Adoption of VGI in a Substitutive-Competing Approach

The nature of informal systems, and the extent to which they are incorporated into formal systems, largely depends on the historical circumstances of each country. In Kenya, for example, since independence it was government policy to formalize land tenure – however, the customary arrangements persisted. As a result, land that was designated as government land, but was not put into any use, because of the lack of a comprehensive inventory and registry the management of such lands were faced with malpractice including illegal acquisition (land grabbing) and irregular allocations.

To protect and ensure proper management of such public land, GROOTS (Grassroots Organizations Operating Together in Sisterhood) Kenya, a local Non-Governmental Organization (NGO), initiated a community-led public land mapping process to identify, document and map all public lands within Kiambu County in Kenya (Kenya is divided into 47 counties).

The process of identifying, documenting and mapping public land in the said target area was carried out by grassroots women, with the help of youth and men. The team worked under a research expert who was not a government representative. During the GIS mapping stage, the data collection team was taken through a refresher course on GIS mapping, and was trained with the STDM. Public land was identified and mapped, among other facilities that were of interest. The public lands and facilities identified, focusing on facilities having definite significance for this community, include: cemeteries, cattle dips, health centers, schools, market centers, recreational facilities, water points and waste disposal points. In addition to these, public land parcels – either reserved or purchased through public funds – were also identified.

The involvement of the cadastral and land administration authorities in case study 2 was minimal or (as in most cases) completely absent. This is largely because the intent of the project described was to safeguard public lands, whose inventory was absent from the first instance. The process presents a case of substitution-competition with cadastral authorities not only by not engaging them directly, but also in the nature of the database, which mainly considers point features and attributes essential to the community and campaign. At best, this inventory can be used for policy analysis by one government agency, the National Land Commission.

8.4 VGI in Transportation

Transport systems across the world are faced with problems of traffic congestion. The Ma3route offers traffic updates and information via Twitter, SMS and web. Ma3Route simply stands for Matatue the public transport minibuses in Nairobi, and "Tatu" is the Swahili word for "Three". Matatu is MaThree in Sheng (a mixture of Kiswahili and English language).

Ma3Route is a mobile/web platform that crowd-sources for transport data and provides users with information on traffic, directions and driving reports. The major aim of Ma3Route is to make travelling easier in developing countries by democratizing timely transport information. This can inform city planning and transport through the provision of transport data and trend analysis (ma3route, 2016). While users can report road incidents using this application, the data provided in most traffic feed on different roads in Nairobi City (Figure 27 is an illustration of the Ma3Route application). This data is also generally unstructured and sometimes lacks positional accuracy. Users also lack a clear way of tracking the resolution of a reported incident.

Nduru is another Kenyan mobile application that is available for Android devices, that manages incidents related to road safety. Nduru is Swahili for 'scream'. Through the application, users can flag situations that could potentially lead to accidents as well as report corrupt police officers, send complaints, view first aid guide among other benefits. It gives road users the ability to take charge of their safety through the mobile phone. The application also has a speedometer to automatically detect over-speeding and re-

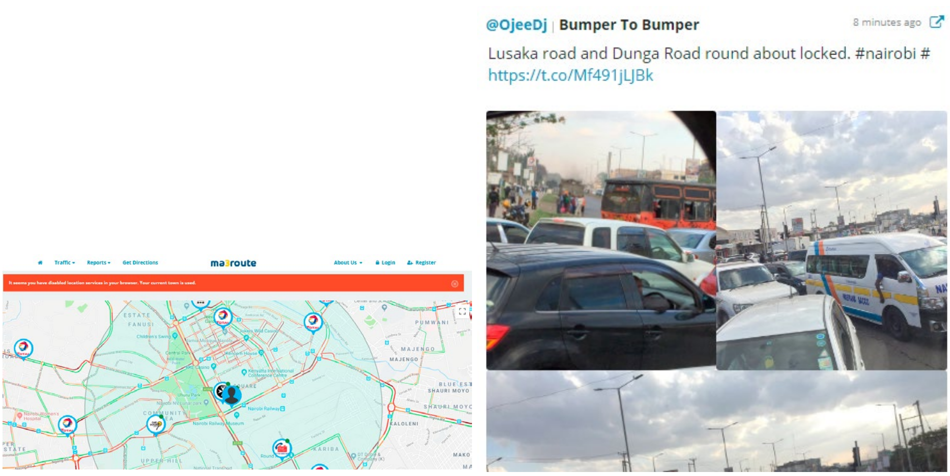


Figure 27: *Right – Ma3Route Map showing the current state of roads in Nairobi; Left – Ma3Route Traffic feed showing a tweet on an incident in a particular road segment.*

port to the police if need be. It also has a video and audio tutorial that enables people to administer first aid and access crucial information such as emergency services and information on black spots. The application is available on the Nokia Platform, SMS version as well as Android version (Jackson, 2012).
The main challenge is that the mobile application has no location or mapping capabilities that would allow users to visualize road incidents information. Moreover, a person reporting the incident has no way of following up the resolution of the incident.

8.5 VGI in Civil Governance

VGI has been employed in crime analysis and investigation with remarkable success especially when incorporated with geo-visual analytics (GVA), as shown by Jeremy and Roth (2014). Voluntary geospatial information, generally micro-blogging websites and specifically Twitter, has been successfully used for crime analysis. Thus, VGI, when applied correctly, can bridge the gap in community-based policing initiatives. Community policing is a philosophical approach to policing, where law enforcement and the community join together to identify and address issues of crime and social disorder.

Although not initially created as a community policing platform, Ushahidi platform with its roots in the Kenyan post-election crisis of 2008 has become partly the face of online community policing. The Ushahidi platform, which translates to "testimony "in Swahili was developed to aggregate and display on a google map eye witnesses' reports of violence reported by SMS, Twitter, RSS feeds and Email. The platform processes, categorizes, geo-locates and publishes the information on a map. Figure 28 shows Ushahidi platform that was created to monitor and report on Kenya's General Election held in 2017.

Since inception thousands of users have used Ushahidi's crowd-sourcing tools to raise their voice. For example, the Ushahidi platform was used to map more than 3584 events of the 2010 Haiti earthquake in close to real time, including people trapped under buildings, and the breakout of fires.

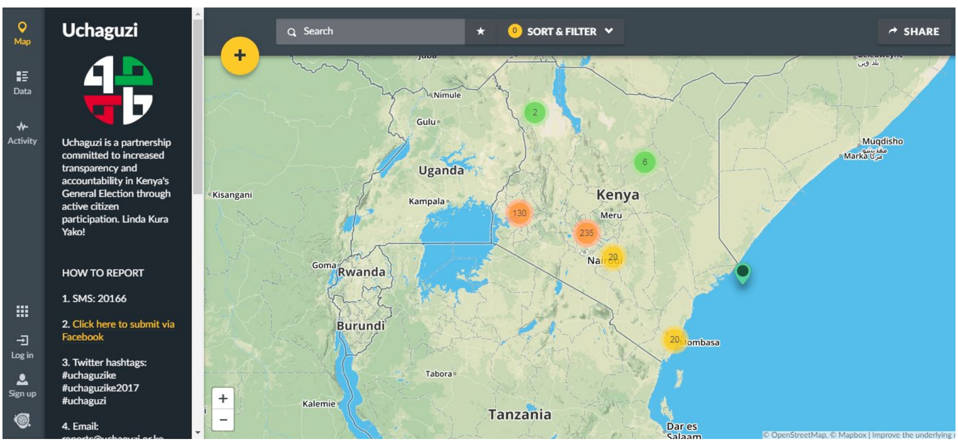


Figure 28: *Kenya's 2017 Election (Uchaguzi) based on Ushahidi Platform https://uchaguzi.or.ke/views/map.*

8.6 Concluding Remarks

The crowd-sourcing paradigm in the geospatial industry is frequently used for domains such as public emergency response but is now also finding application in other domains. In these domains, geographic context is predominantly provided by the OpenStreeMap, a successful VGI application. Therefore, improving OSM coverage would greatly support crowd-sourcing platforms that are not primarily geospatially-oriented.

The domination of social media networks where crowd-sourced information originates from multiple channels, including SMS, email, Twitter and the web do not normally have mapping capabilities. This means that tools are required that can be used to geocode non-spatially explicit crowd-sourced information in which case geography is expressed, at least, as place names. In this respect, Twitter has at least provided GeoTweeting, a feature that facilitates VGI by adding map links to tweets with optional photos. Therefore, to maximize VGI, tools should be developed within existing crowd-sourcing solutions that will help geocode or integrate information that is provided by non-professionals.

9 CROWDSOURCING APPLICATIONS

9.1 Introduction

In this chapter we present five different case studies that describe various aspects of mapping and land surveying that rely on or are based on geospatial crowdsourced data collection.

The examples refer to projects from various countries – Germany, Greece, Israel, and Colombia and they refer to: an open cultural landscape information system; densifying a static weather geosensor network; reliable 2D crowdsourced cadastral surveys; reliable 3D crowdsourced cadastral surveys; and, fit-for-purpose 2D crowdsourced cadastral surveys. We hope that these examples, which represent the contribution of crowdsourcing in different fields of the surveyors' activity, will challenge the readers of this survey and will enable them to implement the crowdsourcing methodology in their activities, whether it is surveying, engineering, administration or research.

9.2 Case Studies

9.2.1 An Open Cultural Landscape Information System in Germany

In Germany, the state of Rhineland-Palatinate initiated the development of a cultural landscape information system as a process to secure and develop its cultural assets. In an open dialogue between governing authorities and citizens, a cultural landscape information system called KuLIS was designed as a web platform, combining semantic wiki software with a geographic information system (Chudyk et al., 2013). Based on data sets from public administrations, the information about cultural assets can be extended and enhanced by interested participants. The collaborative crowdsourcing approach allows governing authorities to manage and supervise official data, while public participation enables affordable information acquisition. Gathered cultural heritage information can provide incentives for touristic valorization of communities or concepts for strengthening regional identification. It can also influence political decisions in defining significant cultural regions worthy of protection from industrial and other affecting influence.

1. System Requirements

The main objective of KuLIS is to provide a citizen-orientated and internet-accessible open platform. It is also being built following administrative and scientific regulations.

Table 3: *System requirement definition.*

Development of a feature catalogue for cultural assets in Rhineland-Palatinate
Design of a spatial database to implement the catalogue structure
Evaluation and transfer of existing data about cultural assets with spatial relation into the database
Providing OGC conformal web map services being includable in the Spatial Data Infrastructure (SDI) of Rhineland-Palatinate
Visualization and digitalization of cultural assets in a web application interface
Ability to create and update information of new or existing information about cultural assets with citizen participation
Management and validation of the provided information by scientific and administrative supervisors
Analysis tools for further investigations and definition of important cultural landscapes

Further requirements and work packages which strongly influence the system design are defined in Table 3.

The requirements led to a web platform which united semantic and spatial information about cultural assets into one system, and therefore needed a combination of different web technologies. Because independence and adaptability to further development were fundamental necessities, open source technologies were used to meet these requirements.

2. Feature Catalogue of Cultural Assets

External data sources and collected cultural knowledge were integrated into a catalogue of typical landscape features of Rhineland-Palatinate. Functional cultural landscapes were classified into twelve categories (Table 4). Each category is divided into functional complexes which cluster the unique cultural features. In the lowest level one feature can be part of a feature group or a functional ensemble.

Table 4: *Functional feature categories.*

No.	Functional feature categories
1	Urban Settlements, Health and Social Services
2	Rural Settlements, Agriculture, Horticulture and Fisheries
3	Forestry
4	Production and Processing of Raw Materials
5	Trade, Industry and Energy Production
6	Traffic, Transportation and Communication
e	Government, Administration, Law, Defence and Military
8	Religion and Worship
9	Education, Culture and Science
10	Sport, Tourism and Recreation
11	Natural Landscapes and Nature Conservation
12	Intangible Goods and Associative Features

This way, the features can be stored as point, line or surface objects in a geographical and thematically precise manner. For example, a stadium can be defined as part of sports facilities in category 'Sport, Tourism and Recreation' (Table 5).

Table 5: *Hierarchy for feature 'stadium' in the catalogue.*

Category	Complex	***Group:*** **Feature**
10. Sport, Tourism and Recreation	10.1. Sport	*Sport Facilities:* Golf Course, **Stadium**, Tennis Centre ...
	10.2. Recreation	…
	…	…

The created feature catalogue and its hierarchical structure provide the foundation for the later implementations of a database structure to store and manage information about cultural assets and their relations inside the system.

3. System Design

Considering the need for citizen participation, a system had to be designed which permitted user enhancement of information about cultural assets by volunteers both in a

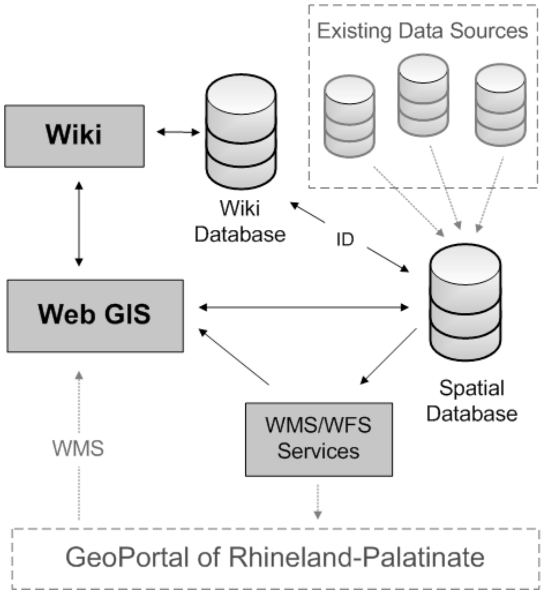


Figure 29: *KuLIS System Design.*

thematic and geographic way. The need for an intuitive and widely accepted frontend for information display and management through different editors led to a wiki approach. As a content management system, the open source software MediaWiki allows information creation and updating along with user management for editorial purposes (MediaWiki 2018). Furthermore, it is configurable for implementation of additional functionalities required in the project. To map the catalogue structure to the wiki and combine the content with geographical information derived from existing administrative data, a spatial data infrastructure structure is needed to provide an interface for the web mapping application, the spatial database and the server-side services. Linking information between MediaWiki and a spatial database of the mapping application is realised using a unique feature identifier ID for each cultural object. Figure 29 illustrates the infrastructure of the implemented cultural landscape information system.

Semantic MediaWiki: For each cultural asset in the built wiki application, a wiki article with its unique feature identifier ID exists. On top of the wiki installation, the Semantic MediaWiki extension (Semantic MediaWiki 2018) is set up to enable semantic attribution for articles. All data created within Semantic MediaWiki can be published via the Semantic Web. With this implementation, a tool is established for later analyses and investigation of the cultural assets and their semantic relationships. In combination with the spatial information, it enhances the definition of cultural landscapes.

Spatial Data Infrastructure: All software used to set up the SDI for the system is part of the OSGeo project and therefore open source (OSGeo 2018). A Web GIS interface was implemented in the wiki frontend (see Figure 30, Mapbender 2018). It enables visualization and digitization of the location of cultural assets via the services provided by the geospatial servers.

The use of a spatial database makes it possible to include information about boundaries of municipalities, cities and counties. During the location digitization process, the

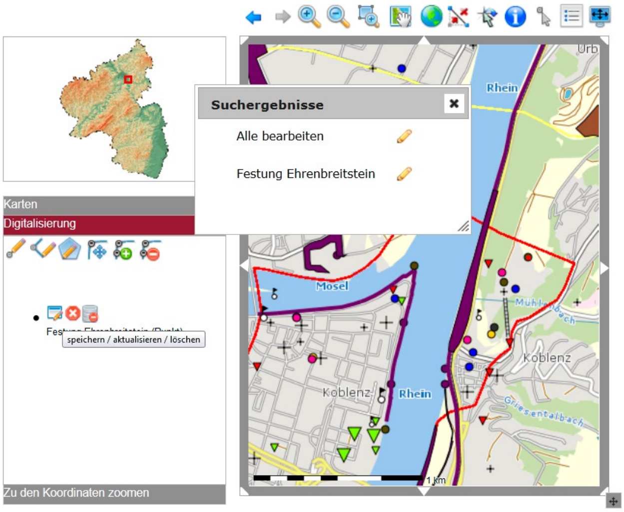


Figure 30: *Web mapping application in KuLIS.*

recorded coordinates can be allocated this way and a precise textual attribution of the site (e.g. county or city) enhances the profile of the cultural asset information automatically. Official databases and sources were processed and transferred to the spatial database of the system. In that way around 59,000 individual cultural features with point, line or surface geometries could be identified and transferred into the new data structure.

4. Quality Management

If citizens are creating the data of an official information system, this raises the question of the administrative quality assurance role. It is for both political reasons and data-quality demands (high accuracy and consistency are needed) that an administrative authority must manage and continuously supervise the public's data acquisition. To bring the data in KuLIS to this standard, a special information qualification process was required. A user class 'editor,' which has the right to mark articles as read and sifted, and a user class 'reviewer,' who can validate the correctness of articles in KuLIS, are created this way. Any registered user working with the cultural landscape information system can become an 'editor,' whereas a 'reviewer' must be an authorized person from a state

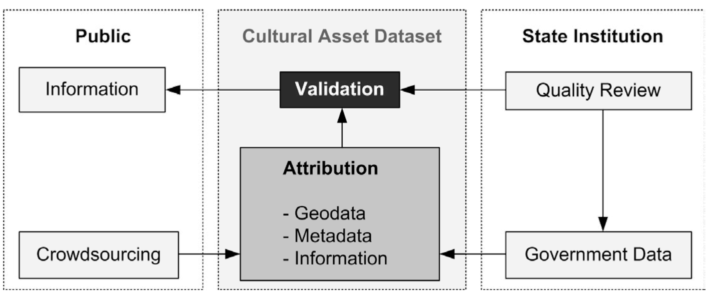


Figure 31: *Administrative quality management in KuLIS.*

Flag	Revision status of article
	New/Unsighted
	Read and Sifted
	Reviewed/Proofed

Figure 32: *Traffic light flags in KuLIS.*

institution. Figure 31 shows the concept of the quality management of the presented system and illustrates the different tasks of the public and state institutions.

In the wiki frontend flags on top of each article are placed to inform users about the information quality of cultural assets using three simple levels, symbolized by the colors of a traffic light (see Figure 32). Newly created articles are first marked as red, read and sifted articles by authorized users with orange, and quality proofed articles by state authorization with green. By implementing this intuitive and simple highlighting function, the status of the cultural asset information is shown at any time for all features.

This way, permanent public access to all information according to the idea of open government data and citizen participation is maintained. At the same time, the state authority requirements concerning clear notification of the significance of the presented information are met.

KuLIS offers possibilities to fulfill the complex requirements of a state administrative controlled Public Participation GIS (PPGIS), Obermayer (1998). Using open source tools, used and maintained by a wide community, makes it possible to adaptively consider change requests during the system development. Whereas common wiki implementations only work with point geometries, the power of spatial analysis and visualization is added to the system through a spatial data infrastructure. The combination of local and semantic attributes makes interlinking with other sources using the semantic web possible and will be more important as the number of such sources will grow in the future.

9.2.2 Densifying the Static Weather Geosensor Network in Israel by Crowdsourcing User-Generated Smartphone Data[7]

Today, early warning systems for disaster management in Israel, e.g., forest fire, rely on data retrieved from static geosensor networks that monitor environmental phenomenon in their geographic perimeter. Although the sensor data collected and disseminated from these networks are reliable and accurate, some limitations exist, largely in terms of insufficient coverage and low density. This case study investigates the possibility to crowdsource user-generated sensor weather data from smartphone devices for the creation of a unified and densified geosensor network. Stabilization algorithms, filtering and geostatistical tools are developed and implemented for determining the user-generated weather data reliability and usability. Showcasing this approach by using on-line user-generated weather data retrieved from WeatherSignal, results prove that, although user-generated weather data show some discrepancies when compared to authoritative data, with certain considerations they can be used alongside authoritative data, producing a densified and augmented weather map that is more detailed and continuous.

7 The text in this section relies on: Sosko and Dalyot, 2017, Crowdsourcing user-generated mobile sensor weather data for densifying static geosensor networks. ISPRS International Journal of Geo-Information, 6(3), 61.

1. System Requirements

Fire weather parameters are chosen for this case study, where two of the main fire weather parameters are: Ambient Temperature (AT) and Relative Humidity (RH). For analysis purposes, the Canadian Forest Fire Danger Rating System (CFFDRS) and The National Fire Danger Rating System (NFDRS) used in the United States are chosen, where both system's input requirements for AT and RH are depicted in Table 6.

Table 6: *Comparison between fire weather parameters of CFFDRS and NFDRS.*

Parameter	CFFDRS	NFDRS
Ambient Temperature (AT) accuracy (°C)	0.5	1
Ambient Temperature (AT) resolution (°C)	0.1	0.6
Relative Humidity (RH) accuracy (%)	5	2
Relative Humidity (RH) resolution (%)	1	1

2. Data Collection Application

Examining available apps suitable for the collection platform of weather data (android operating system), the application found to satisfy the requirements (variety of the recorded parameters, automation, user interface simplicity) was WeatherSignal, depicted in Figure 33. The app creates a crowdsourced based weather map, where users can collect a variety of weather data from the sensors embedded in their mobile devices.

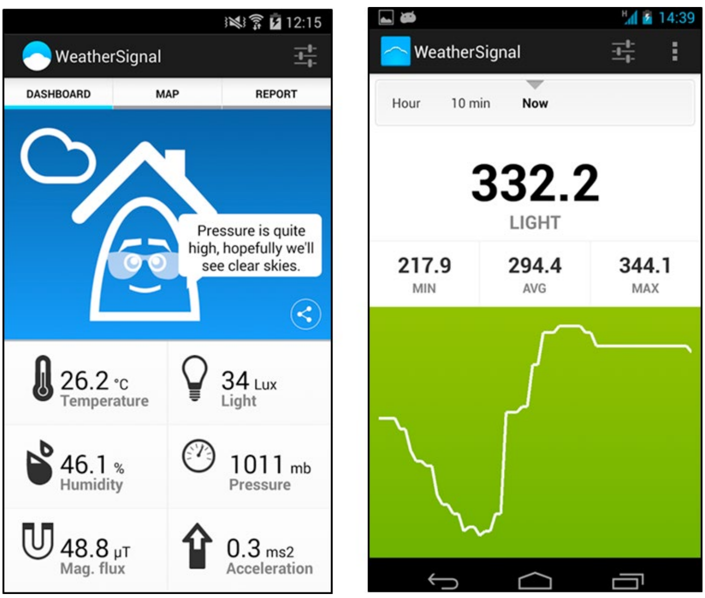


Figure 33: *WeatherSignal application dashboard.*

3. Data Validation

Data validation is aimed at developing an algorithm for indicating whether the collected user-generated data are reliable for use. The algorithm is based only on the collected data, not relying on any external (reference) data; results are later compared to the Israel Meteorological Station (IMS) reference data for statistical analysis and verification. This algorithm uses data indicators (thresholds) that categorize the stabilization point: identifying, in real-time, when the collected weather data are reliable to use. Since the sensors' calibration times (needed for obtaining reliable results) are not constant and cannot be predetermined. A set of four parameters were classified, calculated dynamically (in real-time) during measurements: (1) Gradient value; (2) Standard Deviation value; (3) Number of observations; and (4) Illumination reading. These parameters are chosen since when combined they serve as reliable indices to data measurements stabilization and continuity. The stabilization algorithm workflow is depicted in Figure 34.

Figure 35 depicts the AT readings change due to exposure to direct sunlight (55,000 lux). When the collection device was moved to the shade, the light sensor measured few hundred lux only; only few minutes later the AT is stabilized to 21°C, similar to the

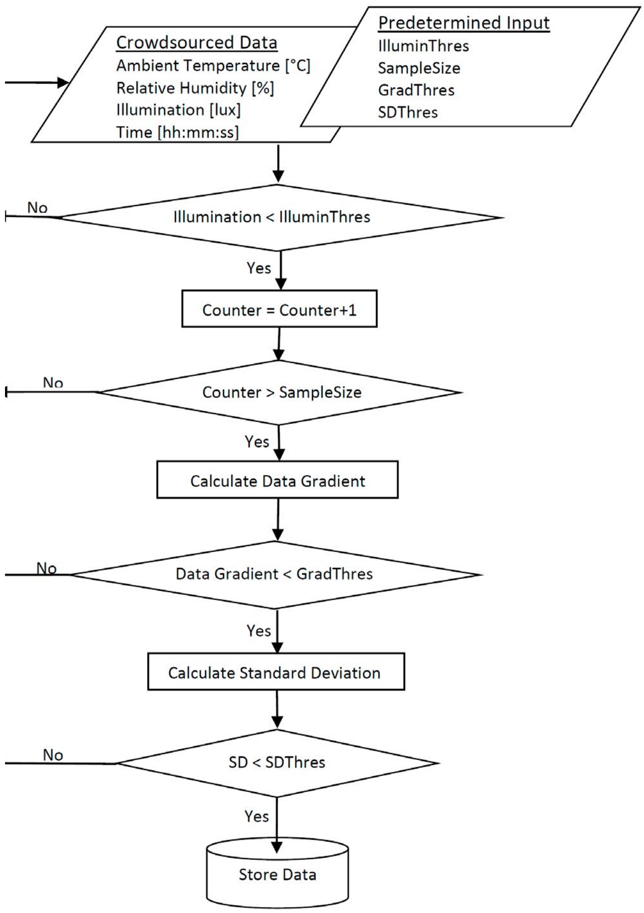


Figure 34: *Stabilization algorithm workflow.*

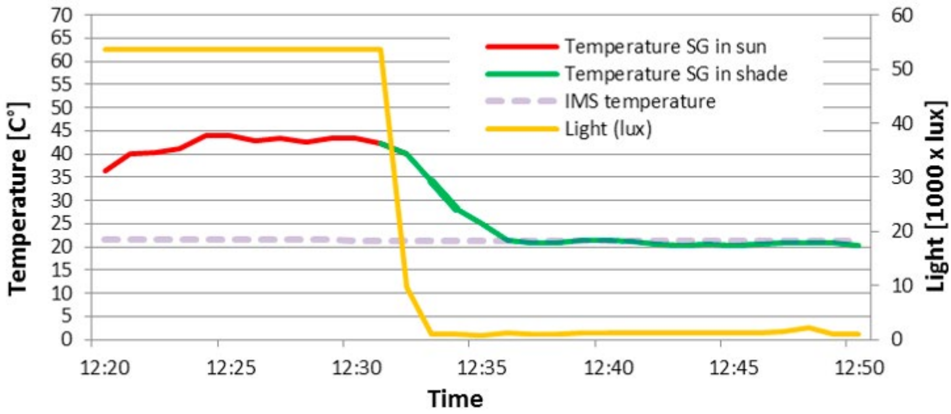


Figure 35: *Ambient Temperature (AT) stabilization time: readings change due to direct sunlight exposure, although illumination readings are not sufficient in indicating measurement stability.*

IMS reference data (the RH readings have a similar effect). This implies that although illumination value gives a good indication, only a combination of the four above-mentioned parameters can determine data stability. The four parameters, depicted in Table 7, were calculated empirically based on an optimization process.

Table 7: *Stabilization parameters and thresholds.*

Stabilization Threshold	Stabilization Parameters			
	Number of Observations	Standard Deviation	Gradient	Illumination
Ambient Temperature	30	0.5 (°C)	0.05	<50,000 (lux)
Relative Humidity	30	2 (%)	0.05	<50,000 (lux)

4. Applicable Demonstration

Examining the potential of using user-generated weather data on a larger scale, we use the on-line weather data from WeatherSignal's crowdsourced weather map (www.weathersignal.com). WeatherSignal uses embedded mobile phone sensors to measure local atmospheric conditions, which are then displayed on their online weather map. WeatherSignal is used by hundreds of thousands of users worldwide, storing millions of user-generated weather data measurements. Such that by using the data stored in WeatherSignal's database, practical use of data may be made by people who actively participate and continuously collect weather data.

Downloaded raw data have millions of data inputs, thus data filtering is necessary for eliminating irrelevant or erroneous readings. For this, an algorithm is developed, implemented in ArcMap using model-builder, depicted in Figure 36. The algorithm is composed from various queries executed in Python, among others: geospatial boundaries of the desirable perimeter, sufficient location accuracy, and auxiliary sensory data thresholds. The filtering algorithm also aims to detect if the readings are taken indoor or outdoor by a supplementary set of queries, and also filter irrelevant or erroneous readings. Indoor AT may be different from outdoor AT, such that filtering indoor observations is important. This was handled by three queries: (a) collection device is plugged

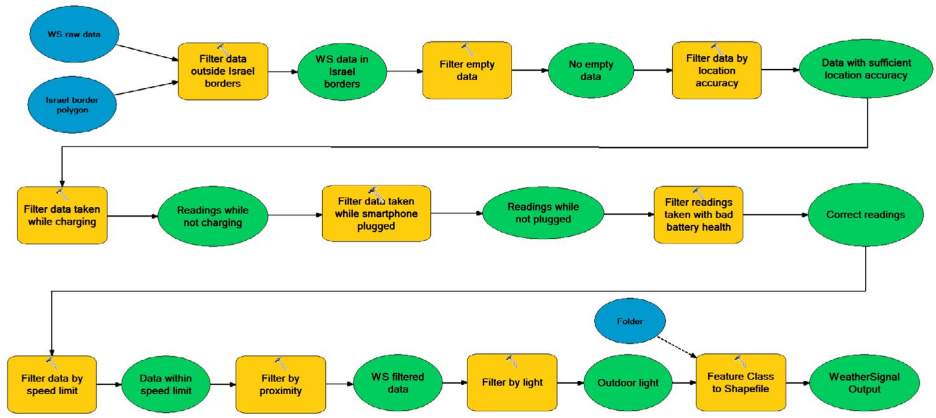


Figure 36: *WeatherSignal data filtering algorithm (ArcGIS 10.2 model builder).*

to an external device (including portable power banks); (b) device is being charged; and (c) device is moving fast, i.e., in a car. In our dataset, for example, approximately 30% of all readings were filtered based on the use of these queries and thresholds. Alternatively, the use of map matching of collection devices' positions with GIS layers (e.g., buildings, city boundaries, and roads) or Digital Surface Models of the area might be helpful. Still, accuracy of devices might be poor (bad GPS signal, multipath in built-up areas or position based on cellular network), such that matching might produce wrong results, or urban areas might be filtered out completely. To resolve this, we have applied a set of complementary statistical hypothesis tests for identifying and removing data errors and outliers that might result from indoor readings.

Observations were downloaded from the WeatherSignal database for the period of 1 June 2015 to 22 August 2015. More than two million records were retrieved, expressing approximately 24,000 readings per day, and 1,000 readings per hour. Among others, every reading (record) includes: location, AT, RH, illumination, speed, and proximity measurements. Using a simple spatial query for the area of Israel, a total of 7,600 readings for the epoch of 17 August 2015 to 20 August 2015 were downloaded, where 3,755 readings were taken on 20 August 2015 alone. Areas where the density of the user-generated WeatherSignal weather data significantly contributes to the density of existing IMS weather stations are depicted in Figure 7 (section 3.3.2). It is clear that the crowdsourced-based readings are filling gaps in areas having no coverage or sparse weather stations.

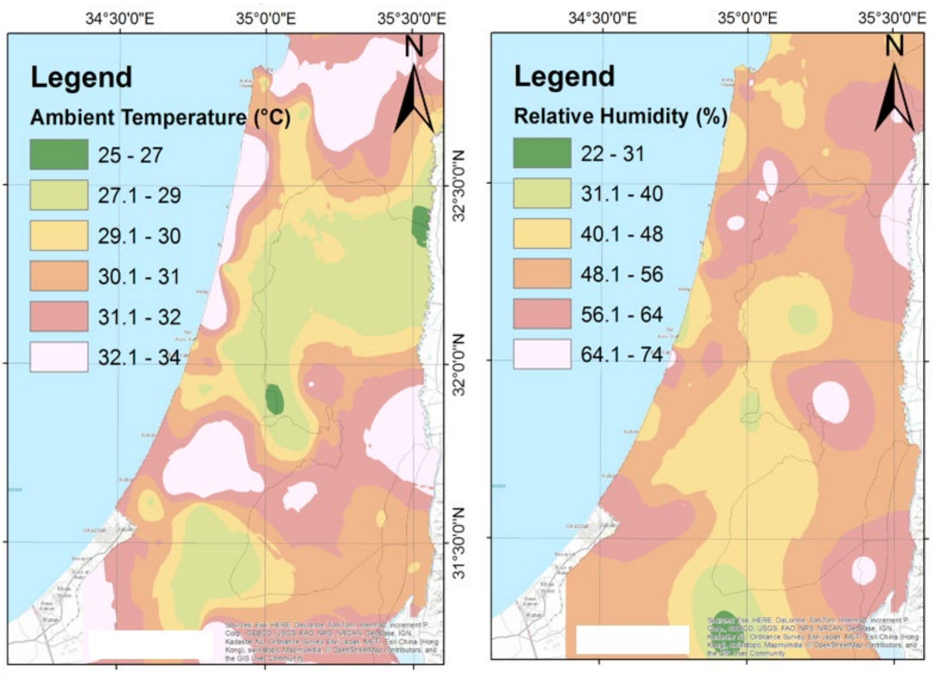
According to the filtering process, in which inaccurate GPS position (close to 1,200 readings), data that are incomplete, e.g., missing AT, RH (327 readings), or not relevant, e.g., indoor (more than 1,000 readings), are filtered and not used, resulting in 730 readings (out of the initial 3,755). Since weather is constantly changing, we have focused on a specific time epoch, in which the densification process will be executed; the epoch of 10:00 to 12:00 was chosen, resulting in 57 readings.

Results of the global spatial auto-correlation hypothesis test (according to the Anselin Global Moran's I) indicate that the null hypothesis (z-score) is rejected for both RH and AT measurements. The positive value for Moran's index of both indicates that there exist spatial clusters of homogeneous data. The output z-score value for both (6.9 and 10.4, respectively) indicates that there exists less than 1% likelihood that the clustered patterns could be the result of random chance. Since data are not random, the user-generated weather data, along with the IMS weather data, can be considered as a unified dataset having spatial correlation.

For densifying both datasets, two new weather maps were created using Ordinary Kriging interpolation, containing data from both sources. Interpolation results for AT and RH are depicted in Figure 37. Inspecting both maps, it is clear that they are continuous and similar in value, with no visible anomalies detected all over the analyzed area. This supports the premise that user-generated measurements are sound, not biasing the authoritative measurements, and can be considered for densification. More importantly, it is clear that some physical conditions are revealed and made clear on a localized level (mainly in the center area of Israel), which were hard to identify unless the user-generated data were used. Another interesting result is that the existing value levels for both interpolations correspond—to some extent—to the topography existing in Israel, and to the meteorological conditions, distributed from south to north. These are the direct result of using comprehensive observations, in this case user-generated and official weather measurements.

5. Outlook

The conception of using crowdsourced user-generated weather sensor data from smartphone devices for the augmentation and densification of static geosensor weath-



(**a**) (**b**)

Figure 37: *Ordinary Kriging interpolation of user-generated and IMS measurements: (a) Ambient Temperature (AT); and (b) Relative Humidity (RH).*

er networks was presented, accompanied by developed algorithms and tailored functionalities. Experiments showed that with the accuracies obtained, the collected data can be considered for a variety of applications. Certain issues and automatic procedures were addressed to guarantee the overall reliability, namely stabilization identification and geo-statistical filtering and analysis, enabling real-time data collection without the need of reference data. Experiments proved that with proper handling of data, the complementary crowdsourced user-generated data can be considered for the purpose of augmentation. Hypothesis tests statistically proved that user-generated weather data are considered as an integral part of the authoritative weather network, correlating to surroundings observations locally and globally. It is concluded that countries and regions with sparse dispersion of static weather geosensor networks can benefit from these working methodologies, while in the future, together with technological and communication developments, real-time user-generated weather data will be considered as reliable as authoritative weather data, and thus will be incorporated within national Environmental Sensor Networks.

9.2.3 Reliable 2D Crowdsourced Cadastral Surveys – Looking Ahead

The perception that "only developing countries may adopt crowdsourcing techniques" is untrue as are other myths, such as that "societies are reluctant to voluntary participation" and "land surveyors are hostile to crowdsourcing techniques". Countries and land surveyors are also testing and introducing crowdsourcing techniques and mobile services in land administration and management projects in developed property markets where complex legal rights exist. It is anticipated that in the coming decade we will see more action in this field as long as the procedures, roles and responsibilities are clarified. Two examples from Greece are given below.

In traditional field cadastral surveying the land surveyor would use the legal evidence of the parcel ownership and would search for evidence at the site. Land surveyors also would seek the contribution of land owner, or any other elder member of the local community, to identify boundary corners. When photogrammetry was first introduced in some systematic cadastral registration projects, demarcation of boundaries was encouraged prior to the aerial photography. In both methods citizens, mainly property owners or even some local people who had good knowledge of the parcel structure in the area being surveyed, were asked to participate and contribute in order to ensure the best outcome of the project. Cadastral surveying has always been a participatory effort.

In 1995 in Greece, a systematic, nation-wide cadastral registration was initiated aiming to move from a land registry deed system and create an accurate, authoritative and assured (AAA) cadaster. Four issues have characterized this project from the very beginning: (a) Greek land surveyors were highly qualified technical experts both in analogue and digital photogrammetry, as well as in modern surveying. They were well aware that technology was changing at a rapid pace, so they wisely agreed on *technical specifications of the final product* rather than of the method used for the compilation of the cadastral maps. The cadastral and mapping agency leadership was forward-thinking and invested in modern IT technology as well. (b) The adjudication procedure in the Greek project is a *participatory* one based on a "self-declaration" submission of legal and technical documents. An *owner, attorney, or proxy* is asked to "proceed to the cadastral office", submit an application including information about the right-holders' (and applicant's) personal data, the private property and the property rights, together with any existing legal and/or technical documentation (deeds and surveying plans), and recognize the parcel on the draft cadastral maps that are used as basemaps. Private land surveyors should integrate all pre-existing cadastral and topographic data with recent orthophotos in advance, in order to create the draft cadastral maps. (c) For quality and fit-for-purpose reasons it was decided that, preferably, *digital photogrammetric methods* should be used for the preparation of the draft cadastral maps and the majority of cadastral surveying, *while field surveying will be used in a complementary sense only where and if needed*, but *demarcation of parcel boundaries in the field should not be a prerequisite* for the production of the aerial photography to be used for the production of the orthophoto basemap. And, (d*)* Greek *citizens had been relied upon in similar participatory projects* applied extensively since 1983 for urban regeneration and land readjustment projects, but also even earlier at smaller scale for rural land consolidation projects whenever cadastral surveying was required. These four issues have been crucial and have allowed the use of scientific and technological innovation, experimentation and introduction of new technologies in the following years. Countries that intend to adopt fit-for-purpose approaches that would lead to AAA cadastres may consider these important issues.

According to the formal procedure in the Greek system, the collected information about the rights, restrictions and responsibilities (RRRs) through the self-declaration phase are to be edited and integrated into the draft cadastral maps by the land surveyors. A legal examination of the submitted deeds is necessary to prevent fraud. The output of this procedure is published for objection submission. Following the examination of objections and correction of the data, the final product is published; quality controls are applied at certain stages during the process. This final product is considered to be accurate and authoritative, and after a 7-year period of no objection titles would be issued and assured, leading to a AAA cadastre. This period has been extended into 14 years for reasons of security.

Gradually, since 1995, the cadastral agency has been continuously experimenting and improving the process making good use of technological developments. Originally, in 1995, people had to visit the surveyor's office to submit the declaration and recognize their property on a printed orthophoto on which the surveyor had integrated all available existing cadastral and topographic data. Gradually, the quality of the orthophoto was improved; for urban areas very large scale orthophotos (of 20cm pixel size) were produced, while for rural areas large scale orthophotos (of 50cm pixel size) were produced; e-services were introduced, and *e-participation* was enabled and encouraged. In 2008, people were able to submit the data through e mail. They were required to recognize their property on a digital orthophoto freely available at the agency's website, by providing the digital coordinates of one point inside the parcel. However, e-participation and digital recognition of parcels was not an easy task, therefore most people continued to visit their surveyor's office. At that time, they could only recognize the plot on the screen of the surveyor's laptop. However, several gross errors were identified after a few years of implementation, especially in the rural areas where there is no address system and there is a confusing pattern of similarity in the parcels. The recognition of the parcel on the digital orthophoto at the surveyor's laptop, even with the help of the surveyor, was proved unsuccessful in many rural areas, and the agency had to commission field surveying in such cases. While this was happening the property-market was blocked and no transactions could go forward until the data was corrected.

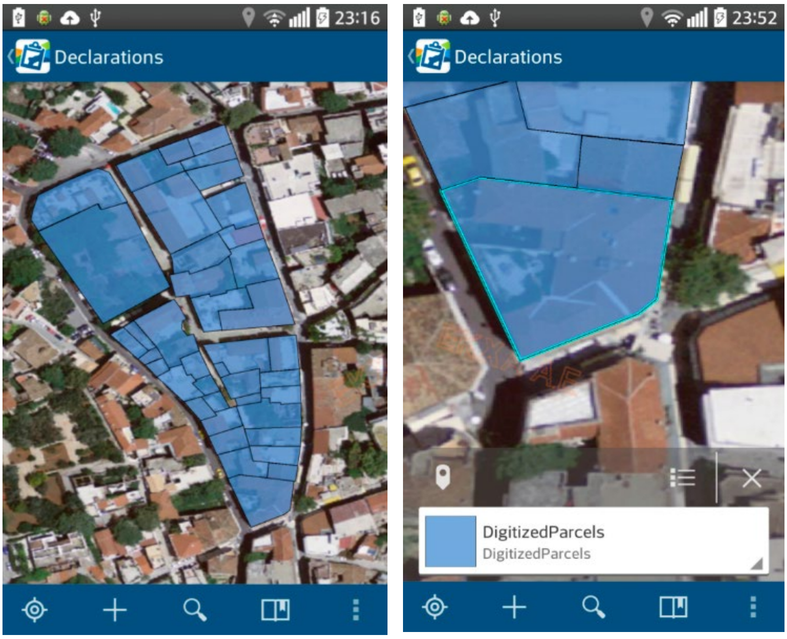


Figure 38: *Crowdsourced cadastral maps in urban areas using the ESRI's ArcGIS online application 'LADM in the Cloud'.*

At that time research was initiated at NTUA to identify the potential of introducing VGI techniques to collect parcel boundary information by people in the field using hand-held GPS (Basiouka and Potsiou, 2012a and 2012b). This research has proved that the production of crowdsourced draft cadastral maps can be low-cost, fast, and free of gross errors. Following a brief editing by the surveyor the achieved accuracies were equivalent to those required. Property owners were willing to collect the data since they had suffered from the problems of delay in the real estate market. Since then, NTUA academic research has continued in investigating the motivation of people to participate in the cadastral surveying (Basiouka and Potsiou, 2014), in testing the use of OSM in urban areas as an alternative basemap (Basiouka et al, 2015) and in enhancing the collection of crowdsourced cadastral information using the newly developed ESRI's ArcGIS online application 'LADM in the Cloud', which was available in IOS and Android (Mourafetis et al, 2015).

In the later study, land rights holders and local volunteers tested a hybrid crowd-sourced approach based on the upgraded role of people from recognizing their property at the surveyor's office to the direct digitization of their property boundaries using their smart phones in the field. The smartphone's GPS was used only for the general positioning on the basemap. Once roughly positioned, owners could then digitize the boundary coordinates on the basemap either on-line or off-line, with little training support; they could also work from a distance (not on-site). In areas where the property boundaries were easily recognized on the orthophoto basemap, such as in urban areas, boundary coordinates had the expected geometric accuracy that could technically be achieved on the orthophoto basemap while no gross errors were detected (Figure 38). The collected personal information can be saved in the cloud and can be secured. Furthermore, the specific application provides that some of the collected information is to be made available to the public and some is to be kept protected with access limited only to the agency. This feature is useful in the protection of private data. The smart phone GPS accuracy was superior in urban areas due to the dense network of telephone antennas.

Attachment of photos was also possible (e.g. photos of the property or of the deeds). A restriction of access to personal data could also be achieved. The method was also proved useful for cadastre updating purposes (e.g. updating of buildings). The method was then tested both in urban, suburban and rural areas (Figures 39, 40) and an open source application for Android mobile services, named BoundGeometry, was developed to support the people with additional geometric tools for the determination of the parcel boundaries if they are not shown, or clearly recognized, on the basemap or in the field (e.g., due to vegetation, or the hidden parts on the orthophoto, or legal boundaries not demarcated in the field) (Figure 41). The BoundGeometry application operates complementarily to the Collector for ArcGIS to overcome the difficulties of determining non-visible boundary corners (Gkeli et al, 2016), (Apostolopoulos et al., 2018).

Similar attempts were made to encourage property owners to collect geometric data about their parcels during the nation-wide cadastral project in Romania. A first attempt to model and test the procedure for crowdsourced 2D reliable cadastral surveys was made by investigating, comparing, implementing and testing the method both in Greece and Romania (Potsiou et al, 2018); in Romania, an opensource collector was developed using the MapIT application. For the development of the cadastral data collector, it was necessary to define the property's boundaries and building attributes on an orthophoto basemap and to create new layers for them (Figure 42) (Amhar et al., 1998, Nache et al., 2017). The research has proved that people may be technically enabled, not only to declare rights and identify parcels, but also to collect the geometric and attribute cadastral information reliably following a brief video instruction guide.

Although the crowdsourced procedure model still needs to be further elaborated and some brief training of the people is still needed before adopting it formally, in February 2019, the Greek Cadastral Agency has developed an in-house web application to enable citizens to optionally submit a declaration with all attribute data and to collect all geometric information about the parcel electronically through e-services or m-services. The web application uses an orthophotomap of 25cm pixel size as a draft cadastral basemap, on which citizen may either choose one parcel as predefined by the land surveyor on the basemap, or do changes, or digitize and upload a new parcel.

Figure 39: *Digitized crowdsourced parcels in urban areas.*

Figure 40: *Left: Digitized crowdsourced parcels in rural areas.*
Right: Photo of right holders recording the natural boundaries of their parcels.

Figure 41: *Examples of the use of BoundGeometry application to digitize hidden boundary corners.*

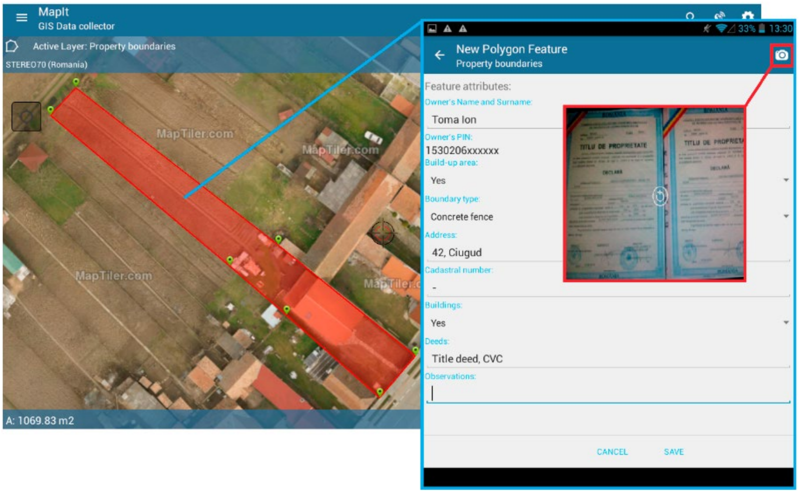


Figure 42: *Map IT's interface for parcel data collection used in Romania – uploading a deed.*

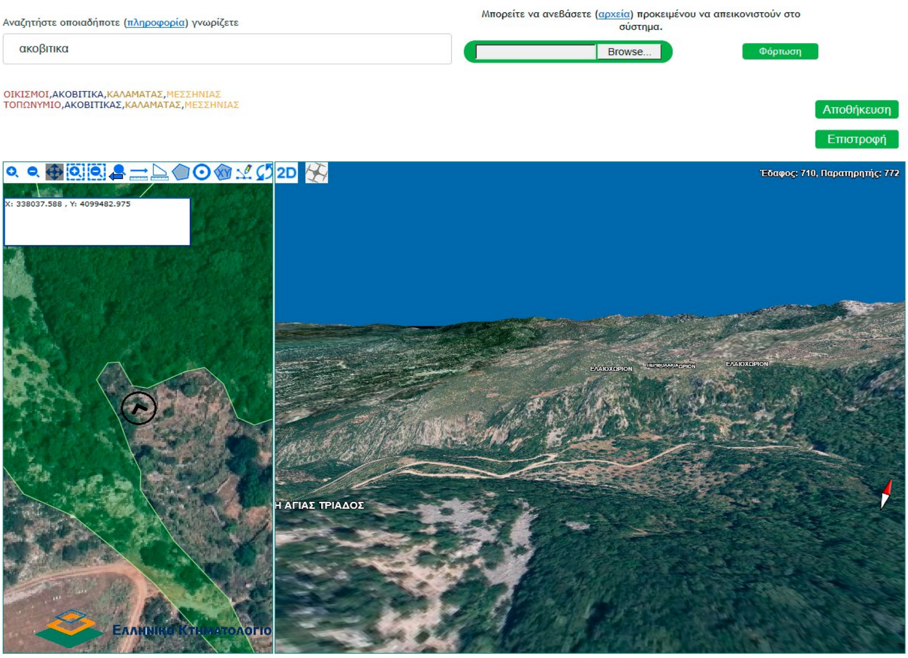


Figure 43: *Both 2D and 3D representations of the area are provided to help the user locate the parcel. Both windows can be navigated and synced.*

The newly developed web application provides several search options, such as access through the postal code, or through a point of interest, or street name, or rural parcel number, etc. For those who find it difficult to recognize and locate their parcel on the basemap by navigating on it, another in-house web application is available that can use GPS enabled devices, such as smart phones. This mobile web application asks for a valid e mail and provides tools to the user in order to select the corners of the parcel polygon while walking or driving on-site; a 2D basemap and a 3D model of the area are provided to help the user recognize and locate the parcel (Figure 43). Once the digitization of corners is finished and before submitting it, the user may choose to alter and improve the data in order to achieve a better accuracy on the basemap. It is anticipated that approximately 50% (several millions) of the population will use these services to declare their property rights.

So far the participation of people in 2D cadastral governmental projects is limited only in the data collection process for submitting the legal documents and for digitizing the boundary corners of their parcels; this task is still optional (people can always choose to visit the surveyor's office instead) and no tangible motivation is offered apart from the obvious, which is the time and cost saved from visiting the surveyor's office. It might be worth testing to enable citizens to participate in the next step of data editing, too. In addition, to promote the initiative and to stimulate participation of the contributors, the mapping agency should define and advertise some benefits for participants. More research in this field is needed.

9.2.4 Reliable 3D Crowdsourced Cadastral Surveys – Looking Ahead

Discussion on the potential of VGI in the compilation of 3D cadastres and how to utilize citizens to voluntarily collect information that would support the transition from a 2D cadaster into a 3D cadaster has started in 2015. An initial proposal was made by (Vucic et al, 2015) that attribute information about the location of the building and of the property units inside the building, the area size and the height of the units, as well as about the owners, would be provided to the mapping agency by the property owners through a mobile application; such information may then be used to upgrade a pre-existing 2D cadaster into a 3D cadaster. In 2016, an interesting research result was published by (Ellul et al, 2016) aiming to investigate whether it is worth investing government funds in expensive 3D surveys for better representation of the 3D rights. Given that the 3D complexity inside the buildings is only known to residents/occupants, crowdsourcing was considered the only fit-for-purpose approach for its capture. Within the framework of this research a web-based application was developed and the public was asked to flag different types of 3D property ownership situations in sketches. That research focused first on identifying a set of sketches representing the various types of 3D ownership situations in Coimbra, and secondly on prototyping and testing an application for multi-platform VGI data capturing.

Since 2017, a research project focusing on modelling a 3D crowdsourced cadastral surveying procedure has been initiated in NTUA: First an evaluation of the current state of the art of algorithms and techniques used for 3D modelling and their potential usage for 3D cadastre was made. A review of the progress related to utilize VGI data in visualizing the 3D world and the algorithms and techniques in 3D reconstruction which may be used to provide accurate and detailed 3D models was presented at (Gkeli et al, 2017a). Next, the potential of using VGI data in 3D reconstruction procedures, indicating the advantages and disadvantages of this approach in addition to the potential of using VGI data for 3D cadastral surveys, was published in (Gkeli et al, 2017b).

In 2019, a procedure was designed and tested that aims to save time and costs and provide a modern technical solution for the initial collection, registration and visualization of 3D crowdsourced cadastral data. An open-source, mobile application for the acquisition of 3D crowdsourced cadastral data and 3D modelling and visualization of property units as block models (LoD1) on a mobile's phone screen in real-time, was developed, tested and published. The 3D property model production was based on the use of the existing 2D architectural floor plans for each floor of the building. The geometric accuracy of the proposed procedure is adjustable.

A concept similar to the one used for 2D crowdsourced cadastral surveying is used. Once the parcel is digitized on an orthophoto basemap and stored, the footprint of the building is digitized and stored, too. Then, the 2D architectural plans for each floor of the building are used successively as basemaps. Participants should select the floor-basemap, digitize the 2D boundaries of each property unit they wish to declare on the 2D architectural floor-basemap (e.g., flat, apartment, office, etc), measure and insert the height of the unit, according to some simple instructions. Alternatively, people may insert the area size of the unit and the height of the unit as it is written in the deed.

The geometric accuracy of the final product depends on the geometric accuracy of the basemaps used for the 2D digitization of the parcel and the building footprint (e.g., large or very large scale orthophotos, or satellite image, or aerial photo, or OpenStreetMap, etc, or 2D cadastral maps) and for the floor-basemaps (e.g., 2D architectural floor plans); if the basemaps used are of high geometric accuracy, the derived 3D cadastral map will also be of high geometric accuracy, while in areas lacking such spatial infrastructure a fit-for-purpose 3D cadastral map will be created that may still provide a good enough land administration tool, timely and affordably but with lower geometric accuracy. That tool may be gradually improved in future. This innovative approach enables the creation of a useful land administration tool for the collection and visualization of 3D cadastral data including geometric data and legal information about the land parcels, property units, right holders and property rights while avoiding gross errors,

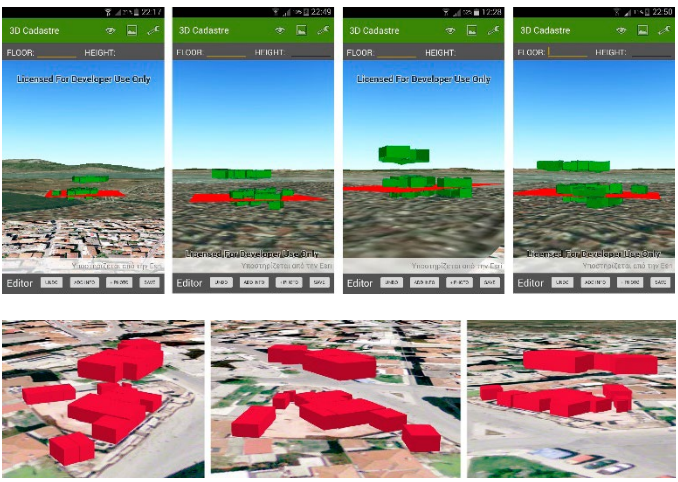


Figure 44: *3D Visualization of the declared properties (in green) in their relative position above and below the ground (in red), using the 3D Model tool of the developed mobile application (top); Visualization of 3D property unit reconstructions (in red) in their absolute position on the ground, as they are generated in the Cloud of ArcGIS Online (bottom).*

with the active participation of the owners/occupants of the property units in each building. This procedure requires some digital skills in order to collect, digitize and georeference the existing 2D architectural plans of each building and then upload them as floor-basemap options.

The developed application was tested on a multi-story apartment building in an urban area in Larisa, in Greece (Figure 44). An initial evaluation of the procedure and of the final product, in terms of its usability, affordability, reliability and implementation duration, was conducted. The first results were satisfactory and may lead to a crowdsourced procedure for a 3D cadastre for all in future (Gkeli et al, 2019). A contributor for such a 3D crowdsourced cadastral survey project may be limited to either the *owner, or an attorney, or a proxy*, for the collection of the 2D cadastral data. A team of trusted volunteers under the supervision of a team leader, following a proper simple training course, is needed in order to digitize and georeference the 2D architectural plans for each building and to work together with the property owners to collect the 3D geometric data and attributes. Training to the volunteers may be offered by a NGO, or by the contractors/private surveyors, or by the Mapping Agency, in cooperation with the local authorities.

9.2.5 Fit-For-Purpose 2D Crowdsourced Cadastral Surveys "No Peace without Land Titles"[8]

The Colombian peace agreement was signed in November 2016 and ended a long during armed conflict between the Colombian state and the guerrilla movement FARC. The principal point of the agreement is the integral rural reform. Land titles for farmers in the rural post conflict areas are vital for sustainable peace, and restoring local confidence in the government. Land titles allow farmers to develop their land and get access to credits. "No peace without land titles" as high officials say. Cadastral maps are an integral part of the land titles.

In 2018 in Colombia it is estimated that at least 60% of rural land parcels lacked legal land titles and cadastral maps. The institutional landscape for land administration in Colombia is complex. Land administration responsibility is shared among several state agencies. Since 2017, land title deeds have been issued by the Ministry of Agriculture, specifically the National Land Agency. The registry of deeds is within the responsibility of the Ministry of Justice. Land parcel mapping and land valuation is accomplished by the Geographic Institute, now under the National Statistics Bureau. In addition, there are several independent urban cadasters in the main cities of Colombia, as well as an independent cadaster of the Department of Antioquia. A fourth institutional actor, the National Planning Agency, emerged recently leading cadastral pilot projects in 23 municipalities of Colombia.

It is estimated that at least 4 million parcels have to be formalized. It costs about US $400 to measure and register a small two-hectare parcel by traditional surveying procedures, meaning that at least US $ 1.6 billion and a substantial amount of time would be required in the effort. For somewhat bigger parcels, formalization costs start at US $1000 per parcel. Costs in terms of time are predominantly related to the cumbersome

8 This is a summary of the paper titled "Land and Peace in Colombia: FFP Methodology for Field Data Collection and Data Handling", published at the World Bank Land and Poverty Conference 2018, by Mathilde Molendijk, Tatiana Santos Dukon, Christiaan Lemmen, Javier Morales, Victor Endo, Sebastián Restrepo Rodriguez, Jhon Fredy Gonzalez Dueñas, Ivan Eduardo Matiz Sanchez, Piet Spijkers, Eva Maria Unger, Ivonne Astrid Moreno Horta. The summary is made for the purposes of this publication by Chryssy Potsiou.

administrative and legal procedures. However, the government intends to finish the project in 2023 (preparation and piloting, and 5 years for data collection). Therefore, professionals and academia have teamed up to develop a new and innovative "fit-for-purpose" approach for Land Administration to be gender sensitive, transparent and highly participatory.

Pilot tests were conducted in several municipalities in order to adjust fit-for-purpose methodologies to the different realities of the Colombian post conflict rural areas, while a new Law on Multipurpose Cadaster is being prepared.

The project is carried out by national responsible agencies (National Land Agency and others), the Dutch Kadaster and two universities (ITC of the University of Twente and the Distrital University of Colombia), in close collaboration with software and hardware providers. The project builds on a "proof of concept" conducted in the municipality of Tenjo in 2015, which demonstrated that the field data collection and data handling can be carried out quickly, affordably and reliably (for results see: gip.itc.nl/projects/rvo_colombia, as well as publications Molendijk et al 2015, Brent Jones et al 2017).

Currently, two pilots are underway, one in a part of the municipality of Apartadó and another in part of the municipality of Vistahermosa.

Steps to be followed for property registration include: (a) A preparatory phase including raising social awareness and local support for the project, training, technical preparation (all in cooperation with the national and community leaders). (b) The field data collection (participatory field surveying). (c) Data handling/ checking for completeness. (d) Data provision for public inspection and examination of the correctness of the collected legal and technical information as compared to the existing documents in the land registry and the Statistics Bureau (all owners and claimants are requested to show their ID to participate in local meetings. If neighbors agree with the data, they sign an agreement and the boundary gets a green color in the system; partial agreement results in an orange boundary; and disputes are visualized in red boundaries between neighbors; complaints may lead to agreed changes; areas of no disputes can be certified with land titles, whenever the legal framework allows). A comparison of the agreed data with the legally registered parcels and rights in the existing systems follows; in case of differences various legal-administrative procedures will be started, (e) publication of the data and (f) the final decision-making for the issuing of land titles.

The field data collection is intended to create an overview of all people-to-land relationships, of the current situation in reality, with the participation of the local population. Those relationships may be formal land rights or recognized customary or indigenous land rights. Informal relationships are also observed. There may be disputes. Mapping of overlapping claims is also included in the methodology; expressed disagreements are mapped and the disputed holders are registered as "claimants" (Parties).

All people-to-land relationships should be registered; it is critical for fair resolution/ decision-making to provide an overview of parcels or boundaries under dispute while at the same time providing an overview of the areas not in dispute. State-owned lands and common-use areas should also be included in the system in order to provide complete coverage.

For the data collection phase local young adults, trusted by the local communities and trained by professionals, are collecting the spatial and administrative data of each parcel and farmer through Esri's Collector App. Owners or claimants are invited to walk the perimeters of their land parcels and to point to the vertex points of the boundaries themselves, using GPS antennae. The App uses a Bluetooth connection of the mobile to connect with the Trimble R2GPS device. The R2 is the preferred device; R1 may also be used but requires a correction signal for correction of atmospheric distortions of the GPS signals. R2 has a "quality antenna" for the reception of weak GPS signals and the reception of the required correction signals. This configuration provides, theoretically, sub-meter accuracy for the observed points. Accuracy may be worse in case of trees or mountainous environments. The interface between the R2 and the Collector App can be managed from Android smartphones. The trusted young adults recorded the observations with an App installed on a mobile device or tablet. Training duration and testing of the young adults lasted several hours. The interface with a cloud service gave a continuous overview to all who were equipped with browsers.

A 17-year old Ingrid, waitress at the local restaurant, became a grass root surveyor within a day in Termales, Vista Hermosa, 2018 (Figure 45-left). The mobile office of the Land Registry present in Termales, Vista Hermosa, February 2018. The official databases could be accessed in the field. Citizens could check available legal data on site and consult land matters with the legal experts (Figure 45-top).

Satellite imagery of the area is displayed on the screen of the mobile device. Data collection is accomplished in an integrated way: The perimeter is stored as a closed polygon together with the claimed type of right combined with a photo of the face(s) of the right holder(s) or claimant(s) and a photo of his/her/their ID. A preliminary identifier is used as a linking key. In this way the names and other attributes and polygons can be

Figure 45: *Surveying by Amateurs (left). Citizens check available legal data on site (above).*

Figure 46: *The "Fit-For-Purpose" App with raw field data collected in Los Mandarinos, Apartadó, February 2018.*

linked while still in the field. Digital photos, existing documents like passports/ID, selfies, group photos of co-owners, deeds, electricity bills, boundary photos, etc., can be linked to the observed polygon.

All data may alternatively be collected offline and uploaded to the cloud, as well. Ownership of use rights to more than one parcel may be recognized by the ID. The GPS antenna may alternatively be replaced by a hand-held low-accuracy device, whenever official standards allow this.

Common boundaries of neighboring units are thus recorded twice. If those measurements are within a certain tolerance, there is an agreement between neighbors. Neighbors may not be in the field simultaneously.

Community participation is critical. Therefore, all local authorities are informed in advance to ensure commitment, awareness and involvement. The collected data can be sent with Esri's Collector App directly to a cloud-based GIS environment, enabling everyone to follow the process remotely. This allows more flexibility and transparency to the process.

This process is "fit-for-purpose" providing fast, affordable, transparent and participatory land titles to farmers in difficult rural post conflict areas, given the often relatively low value of rural land, the uncertain accuracy of boundaries and even the local methods of area calculation (Figure 46).

The experience to date shows that the used methodology provides timely integrated data collection in the field. Data are only collected once, and by trained non-professionals, while surveyors can focus on socializing, on organizing the work, the logistics, quality control in the field, and training of the participants. A minimal set of attributes should be used to keep the costs low and reduce the effort needed to maintain good quality of the data. The biggest challenges ahead have to do fit-for-purpose solutions in the legal administrative framework, as well as the institutional and IT framework. On

November 26 2018, the Dutch Prime Minister together with the Colombian Minister of Agriculture, the Director of the National Land Agency and a high level UN delegation, handed out the first land titles in one of the polit villages (Los Mandarinos, Apartadó).

The presented methodology was tested in the field in different villages in 2018 (February, June, July, August, October, November).

9.3 Prospects of Crowdsourcing

Although the terms crowdsourcing and VGI are relatively new, with both emerging less than a decade ago, the commercial and academic research that focused on them has yielded substantive and useful outcomes. There exists a significant body of knowledge of the operation of systems with and without financial compensation to participants, and some understanding of the motivations of participants, which are more complex than might seem at first sight. There are growing examples of systems that explicitly focused on geographic information and those that are implicit with some understanding of their characteristics. There are also several methods to assess information quality and reliability, which have been recently grouped to crowdsourcing, social, and geographic approaches (see Goodchild and Li, 2012). The social, economic and cultural disparities within projects and among projects is also receiving attention (e.g., Stephens 2013).

While some patterns are likely to be general and relevant to all crowdsourcing projects, for example the disparity in contribution between participants, with few contributing the most and a very long tail of those that contribute a little, the questions about how to recruit and retain high contributors and how encourage contribution remain open. It is likely that the factors that influence the success of a specific project will be a mix between aspects that are under control by the project coordinators, and those that are a mix of luck and circumstances, which are beyond their control. This should not mean that the level of risk in crowdsourcing projects is so high as to render them irrelevant, only to be aware that they need effort to make them successfully, and even with investment the success is not guaranteed.

As the framework for VGI activities emerges from an intensive and multi-disciplinary research effort, it is likely to address multiple facets, which were reviewed here. In particular, it will need to address the following elements. First, the human and societal part – from recruitment to engagement, identification of participants characteristics and methods to evaluate them, etc. Second, the construction of the socio-technical systems for data collection and organization, including the tools that are relevant for participants as well as integrating methods to ensure data quality. Third, understanding biases and patterns in data collection practices, and development of methods to address them or mitigate them. Fourth, the integration of such data sources with traditional data sources. Finally, a legal and ethical framework for such activities.

As noted across this publication, the routine use of VGI within spatial information management practices is already widespread, with some of the more visible projects reaching a decade of operation. Based on this cumulative experience, the outlines of a framework are already discernable, even if they are not fully formed.

10 OUTLOOK – RECOMMENDATIONS AND OPPORTUNITIES

1. *New technologies and citizen participation*

In conjunction with the new social involvement and technological developments, citizen activities and participation can significantly contribute and lead to successful mapping-related projects, resulting in new prospects and possibilities that were not possible until recently, namely in terms of completeness and time. These are critical in the era of information where coverage is expanding and changing, making informed knowledge and decision-making mandatory.

2. *Crowdsourcing and VGI initiatives for land administration*

Crowdsourcing and VGI initiatives can assist in acquiring missing and out-of-date land and tenure information, conditions that could be due to the lack of human, budgetary or other resources, as in developed countries. Or could provide new initiatives that replace non-existing authoritative agencies, as in developing countries. In any case, governments should adopt and promote these initiatives, which should be led by mapping and surveying agencies.

3. *Designing integrated processes and SDIs*

Crowdsourcing and VGI should not be seen as a threat and in competition with authoritative efforts. On the contrary, the two should be made alongside, making use of the community strengths. Accordingly, processes should be tailored to make use and accompany both, as well as the SDIs and data repositories that should be capable to store and analyse crowdsourced and authoritative data and information. Still, the design of these should be made with care and vision.

4. *Quality assessment and maintenance*

This is still an open issue that has been only partly dealt with. In most cases, VGI data is not equal to authoritative data in terms of quality and standardization. Accordingly, new processes and views should continue to be developed, together with new technologies and algorithms, with the aspiration that in the future both data sources will comply to the same standards and quality.

5. *The Role of the land surveyors*

In the era of crowdsourcing and VGI, the expertise of land surveyors should also include knowledge of technicalities and statistical science, alongside data and information analysis and management. Furthermore, they should be responsible for the accuracy of attributes and relationships of data; accuracy assessment; completeness and reliability of data; certification; and system design of formal and informal systems for security of land. Accordingly, land surveyors should gain broader expertise and knowledge during their training and studies, ranging from digital mapping to geospatial data processing and analysis. The academia should act accordingly to expand current practices and nurture new land surveying insights and themes.

6. *Non-technical skills of land surveying*

The profession of land surveying has always included non-technical tasks. In a working environment including actors from many different fields, non-technical skills are required for interpersonal communication, including responsibility for participation management, handling of appeal procedures, and conflict resolution.

7. *Further tasks for land surveyors*

If all necessary conditions and regulations are satisfied crowdsourcing and VGI activities have a high potential to deliver highly valuable information in the field of land administration. Land surveyors have the potential to perform high quality geospatial data and information management. Future tasks will include the integration of geospatial information into e-government and e-commerce systems.

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FIG PUBLICATIONS

The FIG publications are divided into four categories. This should assist members and other users to identify the profile and purpose of the various publications.

FIG Policy Statements

FIG Policy Statements include political declarations and recommendations endorsed by the FIG General Assembly. They are prepared to explain FIG policies on important topics to politicians, government agencies and other decision makers, as well as surveyors and other professionals.

FIG Guides

FIG Guides are technical or managerial guidelines endorsed by the Council and recorded by the General Assembly. They are prepared to deal with topical professional issues and provide guidance for the surveying profession and relevant partners.

FIG Reports

FIG Reports are technical reports representing the outcomes from scientific meetings and Commission working groups. The reports are approved by the Council and include valuable information on specific topics of relevance to the profession, members and individual surveyors.

FIG Regulations

FIG Regulations include statutes, internal rules and work plans adopted by the FIG organisation.

List of FIG publications

For an up-to-date list of publications, please visit
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ABOUT FIG

International Federation of Surveyors is the premier international organization representing the interests of surveyors worldwide. It is a federation of the national member associations and covers the whole range of professional fields within the global surveying community. It provides an international forum for discussion and development aiming to promote professional practice and standards.

FIG was founded in 1878 in Paris and was first known as the Fédération Internationale des Géomètres (FIG). This has become anglicized to the International Federation of Surveyors (FIG). It is a United Nations and World Bank Group recognized non-government organization (NGO), representing a membership from 120 plus countries throughout the world, and its aim is to ensure that the disciplines of surveying and all who practise them meet the needs of the markets and communities that they serve.

FIG PUBLICATION 73

The geographic data and knowledge collection and dissemination via authoritative professionals only – characterized as the top-down scheme – has been shifting in the past few years to the bottom-up scheme, in which citizens and laymen generate data they later use as information in various applications and services. This is a new era in the history of human mapping efforts, mainly in terms of data collection, but also for knowledge production.

FIG Commission 3 on Spatial Information Management has undertaken during the 2011-2018 period a study about the new trends in Geospatial Information in the Era of Crowdsourcing and Volunteered Geographic Information (VGI). The study was focused on the current state and practices within the land surveying, mapping and geo-science communities, on practical as well as theoretical levels.

This FIG publication is the output of this study collecting present knowledge related to Crowdsourcing and Volunteered Geographic Information and the Land Surveying activities. It is organized in seven coherent chapters:

- Geospatial data infrastructures
- Crowdsourcing of geospatial data collection
- Quality of geospatial data
- Implementation of geospatial crowdsourcing
- National Mapping Agencies and geospatial crowdsourcing
- VGI practices in developed countries
- Crowdsourcing in developing regions

Five case studies from different countries describing projects which combine VGI and crowdsourced data collection on the one hand and geospatial, mapping and cadastral applications on the other hand are presented as typical examples of the new era of the bottom-up surveying methods. Conclusions, recommendations and outlook summarize the publication.

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