International Journal of
Geo-Information

MDPI

Article

Volunteered Geographic Information System Design: Project and Participation Guidelines

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Academic Editors: Linda See, Vyron Antoniou, David Jonietz and Wolfgang Kainz
Received: 14 March 2016; Accepted: 20 June 2016; Published: 5 July 2016

Abstract: This article sets forth the early phases of a methodological proposal for designing and developing Volunteered Geographic Information (VGI) initiatives based on a system perspective analysis in which the components depend and interact dynamically among each other. First, it focuses on those characteristics of VGI projects that present different goals and modes of organization, while using a crowdsourcing strategy to manage participants and contributions. Next, a tool is developed in order to design the *central crowdsourced processing unit* that is best suited for a specific project definition, associating it with a trend towards *crowd-based* or *community-driven approaches*. The design is structured around the characterization of different ways of participating, and the task cognitive demand of working on geo-information management, spatial problem solving and ideation, or knowledge acquisition. Then, the crowdsourcing process design helps to identify what kind of participants are needed and outline subsequent engagement strategies. This is based on an analysis of differences among volunteers' participatory behaviors and the associated set of factors motivating them to contribute, whether on a crowd or community-sourced basis. From a VGI system perspective, this paper presents a set of guidelines and methodological steps in order to align project goals, processes and volunteers and thus successfully attract participation. This methodology helps establish the initial requirements for a VGI system, and, in its current state, it mainly focuses on two components of the system: project and participants.

Keywords: volunteered geographic information; crowdsourcing; community; public participation; collaboration; motivation; system design; methodology

1. Introduction

Web 2.0 [1] technologies, such as wikis, blogs and mashups, make it possible for people to become decentralized content producers over the Internet, and this is also the case for the generation and massive dissemination of geographic data online. The interactivity, interoperability and service-oriented characteristics of the Web 2.0, together with the use of dynamic web mapping technologies, geography-related web services and location-based services, has given rise to the development of the Geoweb 2.0 [2]. In the Geoweb, the Internet is used to deliver geographic information (GI) and maps [3], acting as a platform for gathering, analyzing and sharing geo-data. This platform can be used by distributed networks of individuals, and can also serve the needs of the collaborative efforts and collective intelligence of online communities working voluntarily to further shared goals. The handling and production of GI over the Geoweb has also benefited from the development of affordable personal GPS receivers with increased positional accuracy, broadband communications and geo-enabled mobile devices. This web-based and people-centered manipulation of GI has been described by such concepts as the Wikification of GIS (Geographic

Information Systems) [4], Neogeography [5] and Maps 2.0 [6]. However, probably the term most often used is Volunteered Geographic Information (VGI) [7]. In the domain of GI, these terms define and analyze the phenomenon of people's widespread engagement in the creation of user-generated geographic content and knowledge-sharing experiences, and the accompanying social and political implications. In particular, VGI differs from professional GI in that it is usually created by largely untrained volunteers [7] and its specific theme or domain covers a wide range of valuable data in which space and time are sometimes the only contextual unifiers [8–10]. However, as an organized activity that produces a consensus-building process that makes it possible to combine the data provided by individuals [11], VGI is closely related to what is known as crowdsourcing. VGI can be considered GI that has been crowdsourced from a wide range of heterogeneous participants [12]. The term crowdsourcing was first introduced by Howe [13] and refers to a web-based model for acquiring data and knowledge from an undefined and, usually, large network of online contributors from among the general public in order to solve specific problems or produce content. Crowdsourcing uses the "wisdom of the crowds" [14] in order to harness creative solutions [13] and may entail an exercise in collective intelligence [15].

Since the potential uses and value of the local data, knowledge and experiences of individuals who are specialized in their own local environment, and the online organized communities are gaining increased recognition, there is a constant growth in the number of new geographic open-participation projects being created. VGI projects employ a distributed and collective intelligence approach to crowdsourced GI. These projects are implemented by commercial and private organizations as well as social movements and citizen-driven initiatives. There are also examples of governmental initiatives carried out by national cartographic agencies that rely on participatory mapping as an efficient solution in contrast to the difficulties associated with traditional data collection and maintenance, such as the cost of resources, types of information required and the complexity of logistical management. For instance, the Spatial Data Infrastructure for the autonomous community of La Rioja, Spain (IDE Rioja) [16] has implemented a crowd-mapping collaborative project using *Github*, (a web-based *Git* repository service) for controlling distributed versions and managing source code and data, thus creating a workspace for producing GI collected by citizens.

In addition to the type of data required and personal contributions necessary in order to collect and manipulate it, the main differences to consider between VGI projects are the sorts of organization and cognitive engagement required from volunteers in order for them to contribute. It is key to define the goals and nature of a VGI project so as to determine the level of participation, cooperation strategies and crowdsourcing processes required. Also, the latter determine what abilities are required from volunteers as well as the characteristics of the necessary technological resources. These interconnected aspects highlight that it is essential to look at VGI from a holistic system approach in order to understand the parts of an environment that lead to obtaining different crowdsourced information products. As Fast and Rinner [17] remark, most current research analyzes the implications of VGI as a final information product or dataset, without making a clear distinction of existing processes and components from the perspective of VGI as a system that influences the production of GI and, hence, the outcomes of projects.

The purpose of this article is to elaborate a flexible methodology for designing and developing VGI systems. In the context of this methodology, we aim to define a set of general principles, guidelines and processes to follow in a structured and planned manner so as to solve a specific problem or demand related to GI or knowledge management by volunteers. In this article, we characterize a system for analyzing and supporting the socio-technical production of VGI, describing its components and attributes as well as the relationships between them in order to facilitate their understanding and ultimately their design. In analyzing the system, we begin by paying special attention to proposing practical steps for planning and designing a VGI project by introducing certain guidelines and methods that will help to identify the community, personal and informational requirements of the system. Similarly, the initial definition of the organizational aspects of a VGI project provides considerations on how to plan and work through the crowdsourcing process with a crowd or community of volunteers. The technical infrastructure, on which the crowdsourcing strategy and the whole system rely, is beyond the scope of the initial methodological phases presented in this paper. These early phases of the methodology focus on project design and the initial planning details of the participation structure rather than on the project implementation or the planning, design and development phases of a particular VGI web application or digital platform.

The paper is structured as follows. In Section 2, we characterize a VGI system, analyzing how it works and describing its components. In Section 3 we introduce a proposal for a design methodology and development process for VGI systems that includes nine general phases; only the first four are explained in detail in this article. The actual progression of the methodology presented at this stage begins by setting up a project, establishing how it is to be managed within an online organization, defining its goals and deciding the crowdsourcing strategy. These aspects of the project determine the planning of participants' contributions, while only giving a general indication as to the implications for the use of participation engagement strategies and technologies, leaving their detailed analysis for subsequent phases. Afterward, Section 4 briefly illustrates two case studies including several examples of existing VGI projects. In Case Study 1, one of the main criteria for designing a crowdsourcing process is analyzed and in Case Study 2, the first four phases of the proposed methodology are explored. Then, Section 5 introduces several conclusions on the overall methodological proposal and its ultimate implications for the design and development of VGI systems. Finally, Section 6 presents future lines of work with respect to the remaining phases. In addition, we have considered it more relevant to include the literature review within the various individual sections of this paper and analyze existing works in order to support the construction of the VGI system design and development methodology.

2. VGI System Characterization

The general study of a system consists of identifying its parts and interactions. The production of Volunteered Geographic Information may be analyzed as an ICT-mediated system (Information and Communication Technologies) that makes it possible to collect, manage, analyze and share GI, as well as work on spatial knowledge acquisition, spatial problem-solving and ideation through the online participation of a distributed network of volunteers. A VGI system is a specific type of Information System (IS). IS are defined as a combination of three core parts: technology, people and business (organizational) processes. They are defined as a set of procedures used to capture, transmit, store, retrieve, manipulate and display information [18–20]. Consequently, the main interdependent components of VGI systems are the technology, the people who act as participants and the set of actions and processes required to accomplish organizational goals. The activities executed by a group of people purposely working on specific tasks in order to produce VGI are normally encompassed within a project's implementation; therefore, in this paper we use the term *project* as the third component of VGI systems.

Looking at VGI as a system implies taking a holistic approach to goal seeking, which is useful as it helps to keep the focus on the processes executed among system components and to clearly see their interdependencies, which are usually not perceived when the parts of the whole are studied separately. This also makes it easier to translate processes into strategies and methods for achieving a project goal. Specifically, the crowdsourcing model is used to gather and manipulate geographic data and the inputs from personal and community online participation in order to obtain GI and knowledge. Figure 1 presents the general scheme of a VGI system.

Characterizing VGI system components and interactions reveals their design variables, thus helping to more easily identify specific requirements. It may seem logical that the most important component is the initial design parameter: the project goal associated with a final informational product (information and technical requirements). But, seen as a whole information system that relies on the organization of volunteers, VGI prioritizes the social and personal requirements of volunteers in order to participate. If a VGI system has problems obtaining and managing online participation, the overall system performance will suffer. Thus, a systematic approach to VGI becomes more important and necessary. Finally, the crowdsourcing model plays a central role in the design of VGI systems as a process that links the project objectives and organization, participation structure and technological tools in order to facilitate the expected contribution and system outputs. In the next section, we present an in-progress methodology to design VGI systems.

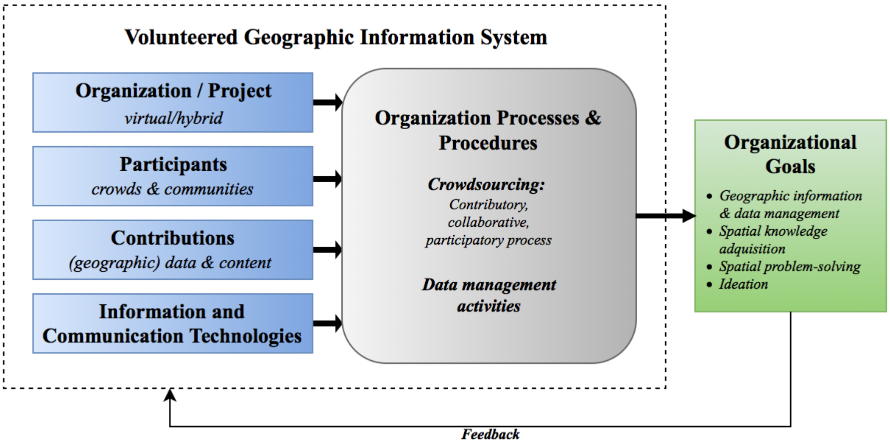

Figure 1. A General VGI (Volunteered Geographic Information) System.

3. VGI System Design: A Methodological Approach and Development Process

VGI systems are composed of two distinct technical levels that enable their development: hardware (mobile devices, PC's, sensors, etc.) and software, mainly GeoWeb, computer-supported cooperative work and social computing technologies and tools used to manipulate and assimilate geographic data and contributions and facilitate the necessary actions on behalf of participants. These systems also comprise two distinct social levels: individuals (personal level) and the community level, driven by a virtual collaborative environment enabled by an organization and by social interactions. Defining the components of a VGI system and their related social and technical levels makes it easier to identify the system requirements involved in producing geo-information and, subsequently, analyze and use them to design and develop the system, for example, requirements with respect to actions and interactions—such as functionality, usability, sociability, etc.—that are necessary in order to meet user or group task goals, or, more specifically with regards to software, identifying ways of processing and manipulating data and its interoperability characteristics, among other holistic system requirements that cannot be regarded separately.

Based on the VGI system components, we have identified a set of methodological steps to help design the system. This methodology is founded on the principle of reducing gaps between a project's outcomes and requirements with regards to its organizational approach and the personal requirements in order to facilitate participation and promote the use of the technology needed to process data. Applying each step is useful in order to align the design and development of the three VGI system components and achieve GI production or value creation goals. In addition, different requirements at the community, personal and technical levels should be recognized as an output of following the steps. The next list illustrates the methodological steps that are currently defined as useful in designing a VGI system. We have followed a top-down process, first detecting a problem or an opportunity to improve an area of interest (service, product, process, etc.) or a need for information, and translating the problem, opportunity or need into clear objectives. Then, we began working within an organizational structure in order to design the best possible solution. Finally, earlier steps in the design process serve as input in developing and testing the solution, looking for opportunities to improve the VGI system in case of low performance or in the case that, as the system evolves, certain capabilities become obsolete, thus requiring adaptation.

(1) Detecting problem/opportunity.
(2) Organizing (Virtual/Hybrid).
(3) Defining goal.
(4) Exploring crowdsourcing model strategies.
(5) Linking organizational/goal needs to the right crowdsourcing strategy.
(6) Defining crowdsourced data and content characteristics.
(7) Identify motivational factors for contributing to the crowdsourcing strategy.
(8) Linking the crowdsourcing strategy to the right collaborative environment and participation engagement strategy.
(9) Linking the collaborative environment and participation engagement strategy to the right technical infrastructure and tools.
(10) Developing the VGI system based on previous steps, testing and refining the solution (*design–development feedback loops*).

From a holistic approach to the system components, the aim of this general design process—regardless of any particular case of use—is to determine what a VGI system must do in order to meet the specified purpose of geo-information or knowledge production. Using this design methodology makes it possible to identify initial processes and performance requirements that affect the information production goal in advance and find potential difficulties or constraints early on, thus accelerating the development, implementation and deployment of the system. For example, those associated with the tools and strategies for building a network of participants or consolidating a community, which is necessary before any information product output can be obtained.

VGI systems, and the crowdsourcing model itself, are goal-oriented and focused on obtaining a unique product, value or result. This makes it easier to implement solutions based on the usual planning, definition, design and execution activities involved in project management. By focusing on this approach, it is possible to build a development process for VGI systems by applying project management workflows to each system component, while maintaining the close relationship among them, as required by the holistic nature of a particular system. The design stage for each system component can be carried out using the previously proposed methodology based on the linkage and design dependency among components. Project management brings a unique focus to the definition of objectives, identification of requirements and design activities, while applying different tools and techniques to direct a project with ease. Its practice has also proven to be of great value when executing different types of real projects within diverse domain areas, and it can be useful to focus on a VGI system's practical implementation when directing and developing it.

It is also useful to clearly define the project's nature and scope in order to continue implementing the design methodology with participants and the technological system components, and ultimately focus on the system's execution and monitoring. This approach provides a strategic operational tool for developing VGI systems: going from definition to design, and from design to development and monitoring, steps used for the VGI system as a whole, but also for each component. Following this sequential procedure, the principal approach applied to VGI system management and development process is the *waterfall* model. This model begins with the project's organizational management, whose definition and requirements become inputs in managing participation. It then continues with the necessary requirements for facilitating participation and cooperation towards the project goal, which serve as inputs in planning and designing the technological component. Finally, after all system components have been designed, it is then possible to implement the project and the technology (development and deployment).

This traditional project management approach may also benefit from being combined with other management methodologies. Using an agile approach, VGI system development can work in iterative design–develop–deploy cycles so as to rapidly obtain feedback and learn from the system's performance and results in order to improve it. This is especially useful, for instance, when validating the design of a participation engagement strategy or the usability of a web tool for processing data. Also, an iterative VGI system development approach makes it easier to adapt a project and make it more tolerant to changes in its organization and scope throughout the life cycle of more open and community-led projects. Accordingly, this helps improve the community's identity and engagement with project goals and maximizes value creation by improving participation and collaborative synergies adapted to change over time. Figure 2 represents these ideas as a VGI system design and development process. This integrated framework takes the use of the design methodology into account, adhering to a project management approach in order to focus on achieving goals and planned results. Finally, the framework follows agile and adaptive principles that should be applied in the implementation phases in response to changes in demands for participation and technological tools. It consists of nine phases, but this paper covers only the first four: three associated with initiation, planning and design of the project component of the VGI system, and the last, which begins to present some basic insights for planning the participants' component.

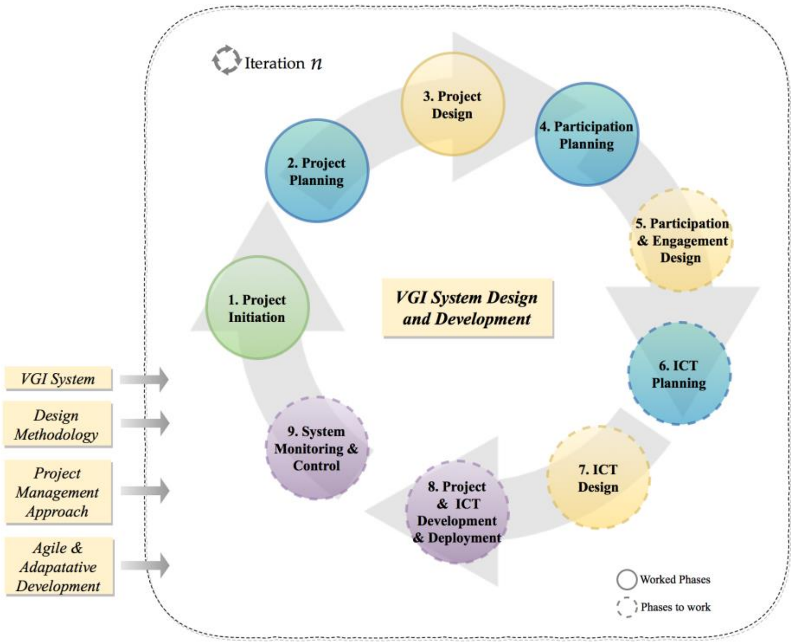

Figure 2. VGI System Design and Development Process, and its Phases.

The early phases of VGI project planning and design determine the following subsections, connecting certain information that is useful in order to address participation requirements. These initial stages employ and focus especially on the process of crowdsourcing as a linking structure that links system components and acts as the core interface for managing system inputs, obtaining system outputs and directing the overall VGI system design and development.

3.1. Project Initiation: Defining the Nature and Scope of a VGI System

Organization. VGI systems are organized and executed through a project. It is around the project definition that the initiators (an individual, an institution, non-profit organizations, companies or governments) build a virtual organization in order to plan, design and implement a VGI system. Initially, the other two system components (participants and technology) will be governed by the overall goal, objectives and set of activities designed to accomplish organizational aims. Establishing a temporary organization also implies defining an initial vision, mission, rules and processes as well as the tasks to direct the project's operation. The organization also has to coordinate the interaction and enable cooperation between stakeholders, the community and people with different types of expertise, various skills levels (education, knowledge, etc.) and different motives for contributing.

The organizational practices established while the project is being defined are critical to its success and acceptance. In order to solve a problem or obtain a desired transformation of everyday life in society, the organization must create value by making the information, knowledge or creativity of an online community useful, and achieving this requires getting people to participate. However, before securing participation, the organization must: (i) define and ensure people´s understanding and knowledge of what to do and why; (ii) define procedures and instructions on how to do it; (iii) and, since participation is voluntary, it is also necessary to create an engagement plan in order to obtain an emotional commitment from participants that is expressed through actions. These organizational practices determine how the online community is managed and establish the collaborative workplace that should facilitate and lower barriers to participation. A strong organizational plan helps ensure that the project's conceptualization and its architecture of cooperation will be adopted, and also enables the participation processes that affect the evolution of the project and the community. In addition, facilitating participation serves to establish relationships that develop into new implementation agreements, forming new actors and rules, and ultimately generating the trust and identification that define the online community. These concerns affect a project's adoption and the decision as to whether or not to participate in it. Also of key importance is having a vision of what the organization needs to do in order to succeed in the future and of its core values, top priorities and the driving forces that provide inspiration and direction to the project objectives and the online community. If the vision and values of the project match those of the participants, it is easier to build trust and obtain commitment to the project. To sum up, in order to clarify and manage the expectations of the people involved in a VGI project and advance towards its success, the organization has to define desired results, parameters and guidelines, and decide how to manage human capital in order to achieve those results. In addition, in order to promote the project's success, it is important to establish accountability within the project by tracking its progress and performance. In this sense, some of the best practices in crowdsourcing projects proposed by Braham [21] include committing to communicating the impact of contributions to the online community, being transparent, honest and responsive, and also acknowledging participants. Subsequently, in order to foster motivation and trust, it can be helpful for the project to define a way to give back to the online community, such as publishing open databases, results, statistics, maps, services and tools, or giving credit and other types of benefits like awards or privileges for being part of the community.

The above-mentioned organizational aspects, together with regulations and legal issues such as conditions for licensing data, are more likely to restrict VGI projects than is technology or concerns about the data's quality, accuracy or completeness [12], so it is important to contemplate and discuss these aspects carefully from the start. Moreover, the project has to be aware of constraining factors such as the execution time frame, duration, costs and resources available for the project, in order to plan and optimize these factors. Furthermore, VGI projects are sometimes inadequately funded. Thus, financial stability and sustainability are significant issues that must be taken into consideration from the beginning [12].

With regards to the drivers that favor establishing an organization, there are several examples of VGI projects [22–25] that emerged from grass-roots movements or bottom-up processes motivated by citizens' problems or needs that were not covered by private or government services or information products. However, as a top-down process, private companies have also been using crowdsourcing in order to improve their business strategies; similarly, VGI is now gaining interest from governments as a tool for civic engagement in public policies and improvement of services, spatial planning and participatory mapping [12,21,26]. Regardless of the starting point, crowdsourcing involves both a top-down hierarchical management process and a bottom-up open process, and the locus of control must reside between the organization and the online community, not in one part or the other [21]. Project initiators usually have to establish the balance of control between the organization and the community. The type of crowdsourcing method utilized, the mode of participation and the flexibility intrinsic to the project's start determine these levels of control, which can also be readjusted as the project evolves.

Goal Definition. VGI project definition starts with a high-level goal with regards to a problem that has been detected and needs to be solved, or regarding a production-related information management process that might benefit from individuals in the crowd or from an organized group. The goal must be clear and it must answer the question "*Why?*" In other words, it must respond to the initiators' intended purpose in creating a temporary organization in which people will be engaging in a particular activity or task. Descriptions or considerations of the project's strategic goals are usually involved and associated with one or more of these typical crowdsourcing functionalities: *collective knowledge*, *collective creativity*, *open innovation*, *crowdfunding*, *cloud labor* (or distributed tasking), *community building* and *civic engagement* [27]. While specific to the geo-information management domain, the VGI project goals are commonly defined in order to update, complement or replace traditional/professional production of current GI and official government databases, but also in order to create new forms of knowledge production, GI and content [10]. Table 1 presents the most representative VGI project goals and a list of more specific related objectives. These proposed goals present a renovated categorization with a broader general approach based on the report entitled "Crowdsourced Geographic Information Use in Government" [12]. Table 2 presents some VGI project examples associated with these general goals. Several projects fall into more than one category, however, they were located only within their primary or most important goal.

Table 1. Examples of VGI General Project Goals and Related Objectives.

VGI Goals	VGI Objectives (Scope)
Basic cartography	Long-term creation of topographic base maps or basic thematic maps including land cover, natural resources or environmental information, etc.
Updating spatial data sets	Tasks aimed at keeping authoritative, public or open data sets up-to-date. Updating national geographical databases, commercial and public geo-data, etc.
Upgrading public sector services	Policy advocacy, policymaking, e-government, e-democracy, e-planning, improving public health and educational services, spatial planning, participatory budgeting, popular consultations, participatory monitoring, evaluation and reporting, ideation and problem solving processes, etc. (based on a location or geographical reference)
Upgrading private sector products and services	Participatory monitoring, evaluation and reporting to improve products and services, ideation, innovation and collective solution of business problems, etc. (based on a location or geographical reference)
Creating or collecting location/place-based features or attributes	Obtaining or creating new spatial locations/places and geo-referenced attributes for particular themes of interest to an individual or group, etc.
Emergency reporting and humanitarian aid	Crisis mapping, crisis management, crisis or disaster response, tactical mapping, natural disaster preparedness, tracking and reporting on or coordinating relief efforts in civil conflicts and natural disasters, tracking human rights abuses and violence, etc.
Scientific research practices using geographic crowdsourced data or Citizen Science approach	Weather, climate and hydrological data gathering and modeling, ecosystems and environmental monitoring, fauna tracking, flora and species identification, conservation and biodiversity studies, public health research, social and human behavior and interactions, sociopolitical processes, etc.

Table 2. VGI Project Examples Related to its Primarily Goal.

VGI Goals	Examples of VGI Projects:
Basic cartography	OpenStreepMap (http://www.openstreetmap.org/); USGS The National Map Corps (http://nationalmap.gov/TheNationalMapCorps/); Wikimapia (http://wikimapia.org); Land-Cover Geo-Wiki (http://www.geo-wiki.org/branches/land-cover/); Forest Geo-Wiki (http://www.geo-wiki.org/branches/forest/); Argus (http://argus.survice.com); Map Kibera (http://mapkibera.org/)
Updating of spatial data sets	Waze (https://www.waze.com/); NAVTEQ Map Reporter (http://mapreporter.navteq.com/mapreporter/_templates/home); TomTom Map Share (https://www.tomtom.com/mapshare/tools/); National Biodiversity Data Center (http://www.biodiversityireland.ie/record-biodiversity/); Playgrounds For Everyone (http://www.playgroundsforeveryone.com/); Wheelmap (http://wheelmap.org); Mapillary (http://www.mapillary.com)
Upgrading public sector services	MiraMap (http://www.miramap.it/); GeoCitizen Platform (http://geocitizen.org/); FixMyStreet (https://www.fixmystreet.com/); NYC City DOT's station suggestion portal (http://nycbikeshare.herokuapp.com/); SeeClickFix (https://gov.seeclickfix.com); Helsinki city plan 2050 (http://yleiskaava.maptionnaire.com/en/); Moonee Ponds Creek Master Plan (http://ourcreek.com.au/)
Upgrading private sector products and services	HERE Map Creator (https://mapcreator.here.com); Google Map Maker (https://www.google.com/mapmaker); EMPORIS (http://www.emporis.com/community/); OpenSignal (http://opensignal.com/); RootMetrics (http://www.rootmetrics.com); Yelp (http://www.yelp.com)
Creating or collecting location/place-based features or attributes	TagZania (http://www.tagzania.com/); Community Maps (https://communitymaps.org.uk) MapStory (http://www.mapstory.org/); InfoAmazonia (http://infoamazonia.org); Wikiloc (http://www.wikiloc.com); Litterati: A litter free world (www.litterati.org)
Emergency reporting and humanitarian aid	Humanitarian OpenStreetMap (http://tasks.hotosm.org/); Ushahidi (https://www.ushahidi.com/); GeoTag-X (http://geotagx.org/); Tomnod (http://www.tomnod.com); Standby Task Force (http://www.standbytaskforce.org/); Sahana (http://eden.sahanafoundation.org/)
Scientific research practices using geographic crowdsourced data or Citizen Science approach	YardMap Network (http://content.yardmap.org); Monarch Larva Monitoring Project (http://www.mlmp.org/); E-Flora BC (http://ibis.geog.ubc.ca/biodiversity/eflora/CitizenSciencePhotoMapping.html); Did you feel it? (http://earthquake.usgs.gov/data/dyfi/); RinkWatch (http://www.rinkwatch.org/); NoiseTube (http://noisetube.net); Citclops (http://www.citclops.eu/)

The initiators' organizational approach to the project as well as the definition of goals and objectives, are the first inputs for planning and recognizing the social, personal and technical requirements for the project. These elements also help to identify the specifications, types of data and contributions needed from online community members and how these will be managed through the execution of different tasks, for example, whether content is objective or subjective, whether data are quantitative or qualitative, or their relative level of structure and normalization, and how the data collection, management and analysis will be carried out. Furthermore, this can determine the construction of participant networks and the way in which the community emerges, their involvement and the cognitive capacities—the "*Who?*"—required in order to contribute to the project's objectives; also "*How?*" the inputs will be obtained and assimilated, in summary, the types of crowdsourced contributions and the approach to the crowdsourcing process when initiating project planning and design.

3.2. Project Planning: Setting the Direction of a VGI System

A VGI project depends on the scale of crowd and community participation. In order to guarantee involvement, people's reasons for contributing must be aligned with the project's long-term goal. Also, participants must accept the use of a specific crowdsourcing technology [28] and accept the characteristics of the crowdsourcing process employed. In order to succeed, a crowdsourcing project must attain a level of participation that allows it to achieve the project's goal. Sharma [28] identifies five peripheral factors in order to ensure that the motives of crowd participation converge with the project's aim. These main factors affect people's acceptance, enrollment and participation, and must be taken into consideration when planning the direction of a VGI project:

- Vision and Strategy: coherence between participants' expectations and the project's vision and crowdsourcing strategy ensures that the crowd is willing to participate.
- Human Capital: the knowledge, skills and abilities participants must have in order to make a meaningful contribution to the project.
- Infrastructure: technology needed in order to ensure participation.
- Connections and Trust: it is critical to develop trust in the project. In this sense, formal connections with other organizations and external groups for project support increases trust.
- External Environment: geographic context and determinants such as the political situation, business environment and economic and social contexts that affect crowd participation.

Projects that consider people, and their driving force behind participation, as the most important variable are more likely to be successful, and these factors should be used to involve and motivate them. Nevertheless, the project's vision, organization and goal are just as important as implementing an organized crowdsourcing strategy.

Crowdsourcing Strategies. Next, we will focus on analyzing the crowdsourcing model that helps characterize, plan and design the *central crowdsourced processing unit* of a VGI system. Crowdsourcing is a process that involves task disaggregation and open participation. The process is driven by the use of the perceptual and cognitive abilities of a large distributed group of individuals who participate (especially online) in problem-solving and data management tasks. In addition, crowdsourcing makes it possible to acquire and share people's local knowledge, improving and facilitating collaborative networks by working as an online community. Brabham [29] proposed a crowdsourcing typology consisting of four methods based on the problems that crowdsourcing is best suited to solve: (i) *knowledge discovery and management*, which consists of finding or collecting data and information in a common format, for example, reporting urban infrastructure problems; (ii) *distributed human intelligence tasking*, suitable for processing data and making analysis; (iii) *broadcast search*, ideal for solving problems with empirically provable solutions, such as scientific challenges; lastly, (iv) *peer-vetted creative production*, used to generate and select creative ideas. This classification points to certain differences in terms of the intellectual involvement required for solving the problem, being more demanding as we get closer to the latter method. This last point is examined in Haklay's study on (geographic) Citizen Science as a VGI activity [30]. This work presents a typology based on four levels of participation, where the use of contributors' cognitive abilities can be considered a main variable. The first level, identified as *Crowdsourcing*, makes minimal cognitive demands and focuses on citizens as sensors and volunteered computing. The second is called *Distributed Intelligence* and is associated with volunteered thinking, which involves citizens as basic interpreters and in which participants' cognitive abilities are required in order to offer simple interpretations. The next level falls within the scope of community/civic science and requires increased cognitive engagement from participants, hence, it is described using the term "*Participatory science*" where people involved participate in the problem and in defining collection methods, as they would in a collaborative analysis among scientists. Finally, there is "*Extreme Citizen Science*", which is a completely integrated participatory activity that consists of defining the problem, collecting and analyzing data with both professional and non-professional scientists in the role of experts, and which is also open to the possibility of doing community work without professional scientists. As we move up in this typology, projects require higher levels of participation and greater use of cognitive abilities, and their success depends on a strong and well-organized interdependent community.

Crowdsourcing processes integrate different types of tasks executed by participants and draw upon different cognitive demands, skills and interactions. In general, projects that focus exclusively on collecting data require lower cognitive engagement and less or no collaboration at all among volunteers, particularly when these projects rely on passive crowdsourcing that takes advantage of the instrumental resources of mobile digital devices without significant human intervention. By contrast, projects based on community interaction, aimed at generating knowledge or ideas, register higher levels of participation and require greater cognitive abilities, which are necessary in order to analyze and interpret data and generate data-driven knowledge. These projects also rely on a more collaborative environment.

In broad terms, we propose differentiating crowdsourcing methods by classifying them into different modes of organizing people. The organizational setup can be based on a contributory, collaborative or participatory process, and these differ in the volunteer's level of involvement and engagement, with the levels also corresponding to different sets of motives for contributing. The proposed differentiation can be modeled as a continuum from relative passivity to increasingly high levels of active contribution, and beyond, when there is a need for proactive action. The first extreme includes *contributory* projects with basic participation, mostly autonomous activity and tasks done independently of other volunteers' work. Obtaining major complex contributions requires fostering communication and relationships within the group of individuals so that projects begin to operate *collaboratively*. Finally, the most active level of crowdsourcing engagement is through projects that facilitate *participatory processes*, offering individuals the opportunity to become more involved in deciding how the project will be conducted and defining necessary outcomes. All these crowdsourcing strategies are based on the crowd's contribution, but they do not all necessarily require collaboration or a participatory approach. Figure 3 illustrates these three main levels and their related processes or modes of organization: Contributory (or Non-Collaborative Participation), Collaborative (Collaboration) and Participatory (Co-Creation) processes.

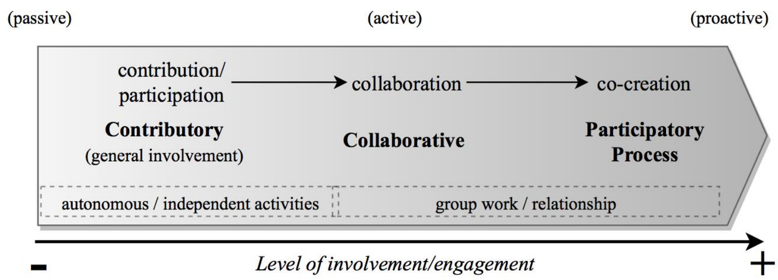

Figure 3. Volunteers' Level of Involvement/Engagement and Related Modes of Organization.

These levels of participation imply a rising degree of interaction among participants and with the established project organization, as we move from passive to more active involvement. Thus, these different types of organization with increasing levels of collaboration make it possible to build more complex and demanding tasks, and this classification must be taken into account when designing these tasks.

The different typologies introduced earlier can be useful in analyzing and planning the types of crowdsourcing methods that can be used in a VGI project from the perspective of the problem to be solved, to the use of cognitive abilities and, finally, the operational modes of crowdsourcing. All related terms used to define a crowdsourcing segmentation share start and end points (points closest to crowdsourced-driven methods vs. community-driven methods).

Crowd-Based and Community-Driven Approaches to a VGI Project. After analyzing the crowdsourcing typologies described earlier in this section, we found that there is a greater tendency for VGI projects to use a crowd-based or a community-driven strategy, although, they can also present a mixed arrangement simultaneously. Similarly, this tendency may vary over time at different stages of a project. These opposite crowdsourcing strategies differ as to the type of participation and demand different rationales from the volunteers who become involved in a project. Taking these differences into account is essential for the VGI project because they are key factors in designing the cooperative environment, the participation structure and the engagement methods used to attract volunteers. The VGI project's approach to crowdsourcing, together with its vision and specific objectives, determines the design of a contribution structure and the means of obtaining contributions. Table 3 presents the main features of online participation as they relate to these two extremes of the continuum of crowdsourcing strategies. It acts as a summary guide to assist in designing the crowdsourcing process and related participation characteristics within a VGI project.

Table 3. Crowd-Based/Community-Driven Online Participation Characteristics.

Crowd-Based	Community-Driven
Large numbers of independent contributions	Core and repeated contributions
No or low interaction among participants	High interaction among participants
Focus on contributions and data	Focus on contributions and analysis
Participants do not know each other	Participants know each other
Contributory	Collaborative or Participatory
Individuals/autonomous	Associations/relationships
Low participation commitment	High participation commitment
More passive involvement	More active involvement
Low/medium engagement	High engagement
Low use of cognitive ability	High use of cognitive ability
Less complex tasks	More complex tasks
Less advanced knowledge, learning or training	More advanced knowledge, learning or training

3.3. Project Design: Setting the Course for a VGI System

With the input obtained through the previous project steps, in this phase, we will work on building a tool to help design a crowdsourcing process. This design tool takes the participation structure and the characteristics of the task to be carried out into consideration.

Linking VGI Project Needs to the Right Crowdsourcing Strategy. A project's objectives are achieved by obtaining information or knowledge and the contributions needed from volunteers. To this end, it is necessary to build a particular mode of organization adapted to people's workflow requirements and also to design the necessary tasks that enable people to engage in the required activity. All this is framed within a crowdsourcing process. In the section above, we analyzed different crowdsourcing typologies that are intrinsically connected by the prevailing level of participation involvement. The different characteristics of the crowdsourcing methods have led us to identify an operational spectrum, from a crowd-based to a community-driven approach, to use in designing the processes for managing contributions. We have observed that, as the level of participation increases, which translates into greater involvement and engagement on behalf of volunteers, the project's mode of operation tends to rise from routine contributions towards collaboration and co-creation. Correspondingly, higher levels of participation, as Haklay's typology illustrates, are also correlated with the increasing use of participants' cognitive abilities, which enables them to solve more complex problems and tasks.

Based on the above, once a project characterization is finished, we propose identifying and designing the *central crowdsourced processing unit* required by a VGI system, using two criteria: (a) *level of participation* (involvement/engagement) *by* contributory, collaborative or participatory *mode of organization*; and (b) *task-cognitive engagement* of the participants, which we propose characterizing according to the cognitive demands of the task and the background skills it requires.

The first criterion involved in designing the most suitable type of crowdsourcing process is the *level of participation by mode of organization* (contributory, collaborative, participatory process), as presented above. These different kinds of involvement and engagement on behalf of volunteers may also correspond to the degree of interaction among participants, as well as between participants and the type of organization established for the project. Moreover, these ways of organizing how a VGI project operates also influence the complexity of the tasks, and this complexity may either depend on the subtasks carried out by other participants or else be totally independent.

The second criterion is related to the amount of mental effort and skills required to work on a crowdsourcing task. Based on research and literature on educational practices, cognitive demand is an intrinsic characteristic of tasks and consists of the kind and level of thinking required to work on the task and solve it [31]. "Low cognitive demand tasks involve stating facts, following known procedures and solving routine problems", while requiring minimum thinking, mainly focused on providing concrete answers and using prior knowledge without making connections [32]. By contrast, "high cognitive demand tasks involve making connections, analyzing information, and drawing conclusions" [33]. Moreover, following Erickson et al. [34], we may classify the background skills necessary in order to complete a task as general/common skills, required in routine tasks; specialized or advanced skills; and skills specifically related to a given scientific or technological domain. Finally, in order to characterize the overall *task-cognitive engagement* from lower to higher use of participants' cognitive abilities, we propose taking into account both the cognitive demand (classified as low, medium and high cognitive demand) and the background skills required to perform the task (common, specialized and domain-related skills). By combining both, we consider the lowest level of *task-cognitive engagement* to be one that requires low cognitive demand and the use of a common skill; by contrast, the highest level corresponds to a task that requires high cognitive demand and the use of domain-related skills.

The two criteria proposed with regards to designing the crowdsourcing process must lead us to formulate and answer different design questions, such as: What level of complexity, cognitive demands and participants' skills are needed to perform a task or solve a problem? What participation dynamic is required while the tasks are being performed and during the overall execution of the VGI project? Is an interdependent collaborative or participatory interaction necessary? Or, is it possible to solve the geographic crowdsourced task or problem with independent individual contributions? In Figure 4, we follow the above-mentioned design criteria so as to characterize crowdsourcing strategies in order to present a diagram that aims to explain the type of crowdsourcing process required for a VGI project visually and identify whether this type of process is closer to a crowd-based or community-driven method within the crowd–community continuum. We have also located an extended crowdsourcing typology that combines diverse existing crowdsourcing methods (some of which have been analyzed above) as a broad reference in order to identify the most related or closest match to serve as a guide for a particular VGI project's crowdsourcing strategy. Finally, in addition to the aforementioned main cognitive engagement items, the diagram shows a taxonomy of thinking skills [35] as additional support when designing and understanding a data management or problem-solving task and its cognitive demand (see Appendix).

Additionally, within a VGI project, it is possible to design a general crowdsourcing process subdivided into smaller functions and implemented through various sub-processes (simultaneously or complementarily) that control different stages of geographic data management, spatial problem solving or knowledge generation activities. Each sub-process may be characterized by different items of the proposed crowdsourcing design criteria, identifying the best method in each case. One advantage of this design model is that it is based on continuous variables that make it possible to apply thresholds in order to discretize them into sections of processes, thus facilitating a modular crowdsourcing strategy design. This enables the creation of semi-independent sub-processes that can be used in different areas or stages of a VGI project. Such sub-processes can work in parallel or linearly, in which case subsequent sub-processes utilize an output from a previous sub-process as input, while a required type of group of volunteers in each module can work on distinct tasks. Furthermore, a participant's typology, by motivations for contributing, abilities and behavior, or familiarity with working in groups or collaborative scenarios, can be used to segment and funnel the crowd into different sub-processes that are best suited to them, and also make it possible to use differentiated engagement strategies for each segment. For instance, data gathered autonomously by a general group of volunteers with common skills and low cognitive demands can then go to a second crowd segment with expert knowledge in a domain involving higher cognitive demand and working in a collaborative environment to analyze and assure data quality. This example relies on different crowdsourcing methods that involve different types of volunteers and technical tools. Finally, a modular crowdsourcing design facilitates scaling and reusing crowd participation and technology while also simplifying their development.

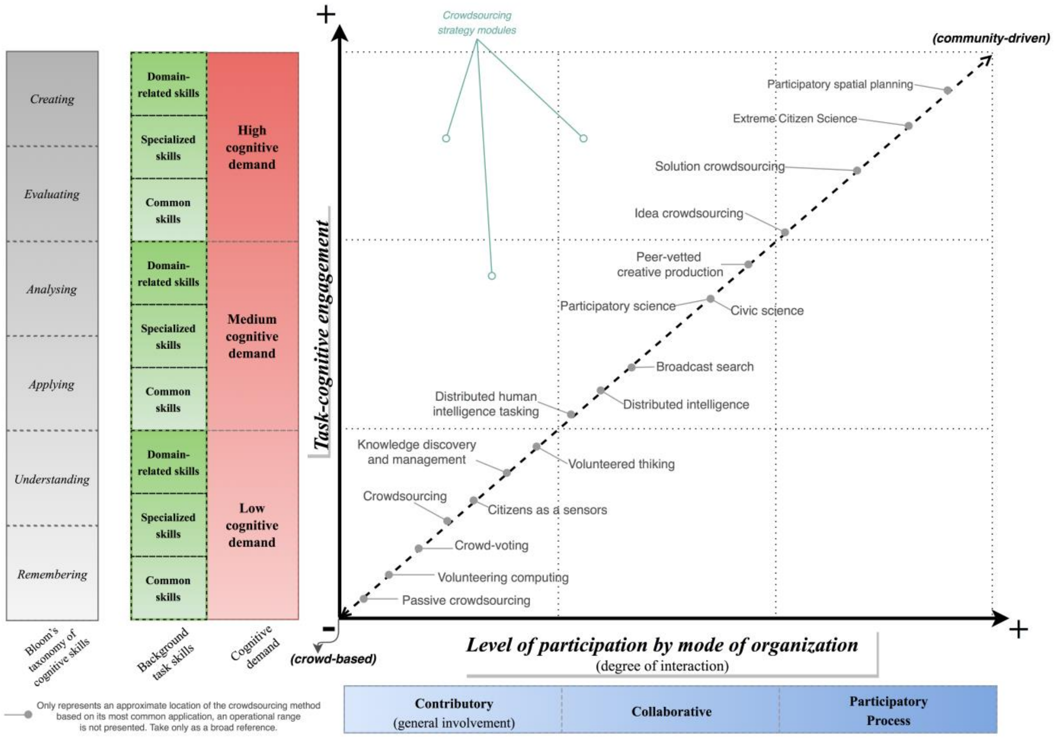

Figure 4. Design Criteria of the *Central Crowdsourced Processing Unit* and Strategy of a VGI Project.

Moreover, the type of data and content that will be managed affects the way the crowdsourcing processes for the project are designed. The crowdsourcing process and the nature of the contributions are strongly related between them and cannot be approached independently in VGI and knowledge production.

Data and Content as a Design Principle. Another variable to consider in a VGI project and its crowdsourcing process design is the type of contributions (data or content) that must be obtained from or managed by the crowd or community. However, first, it is more important to clearly identify how these contributions are going to be used, since this determines the type of data or content: the spatial working area and time period; the need for quality controls; and how the contributions are managed and the key factor in VGI—who contributes. Next, the crowdsourcing process design must take into account the types of contributions required, which also influence the degree of involvement on behalf of participants, and the use of technological resources and tools development. In order to analyze the VGI system data and content inputs throughout a crowdsourcing process, typically, a distinction is made between spatial and attribute dimensions. With regards to the spatial dimension, we propose differentiating it by *location-based* or *place-based*. Locations are normally represented by coordinates using a common geographic reference framework and depend on positioning technologies, such as GNSS (Global Navigation Satellite System), particularly GPS (Global Position System), network or infrastructure-based technologies like cell-ID, cell tower triangulation and Wi-Fi (IP address), as well as hybrid technologies, such as A-GPS (assisted GPS). In VGI projects, locations are usually associated with physical or environmental data measurements or observations gathered with the assistance of sensors enabled on mobile devices, such as GPS navigators, tablets or smartphones. However, geo-tagging processes are also used to insert a location into digital media content such as photos, audio, video, microblogging text, comments or other text-based contributions. Projects may also utilize a geocoding process to get an approximate (interpolated) location (geographic coordinates) based on a reference to a place name or geographic landmark. However, place-based contributions rely more on human or social attributes to characterize a space by giving it a meaning or an interpretation. More than just a location, a place can be described as a location created by human experiences [36] with associated physical and human characteristics. Place-based contributions rely on geographic features normally represented by or associated with a linear or polygon area. Some examples are real-world objects, such as a restaurant, street, neighborhood or national park, in which cases gazetteers and topographic databases with inventoried places may be helpful as references; but, also, new geographic places may be created as defined by contributors wherever they may decide to attach an experience or human-related attribute of interest. For example, VGI projects involved in participatory spatial planning gather more subjective place-based contributions rather than objective data tied to a coordinate. The technologies or actions used to collect place-based contributions in VGI projects typically are: inverse geocoding in order to automatically match a contributor's position with a particular place; navigating on a digital map in order to identify or select a geographic feature and make a contribution about it; matching—digital or social—media content to a place name using gazetteers; and digitizing a geographic feature on a web map or by drawing on paper maps in order to identify objects and make contributions and then uploading these maps onto a digital platform.

In addition, by analyzing VGI, Deparday [37] worked on a useful review of data characteristics. Regarding the spatial dimension, he presents the mode of capture and type of geographic feature (point, line or polygon). Concerning the attribute dimension, he starts by distinguishing the flexibility of the data structure, categorized as *structured* or *unstructured*. The first one refers to attributes that employ a range of values on nominal, ordinal, interval or ratio scales, and the second is associated with participants' spontaneous comments or opinions and any digital media generated in connection with a spatial dimension. This structured/unstructured classification may be associated with the terms (attribute) *data* or *content*. Finally, another distinction presented, with reference to Tulloch [38] where contributions are differentiated as facts and opinions, is between *objective* and *subjective* contributions. Furthermore, regarding VGI data management, Deparday [37] also identifies a degree of interaction characterized as *one-way*, *two-way* and *n-way* data flows, the latter referring to its use in tools that allow participants to comment on and edit each other's contributions.

It is essential to take the characteristics and types of data presented into consideration, as well as their related technologies and the procedures used to gather, create and manage them. These factors determine the use of different (geospatial) web tools and infrastructure and demand a different *task-cognitive engagement* of the participants in addition to requiring differing *levels of participation by mode of organization*. As stated earlier, these two criteria have a significant impact on the design of a particular crowdsourcing process. The crowdsourcing strategy is going to determine how volunteers interact and what participation structure is required, while its scale limits the success of a VGI project. Consequently, the participation component of a VGI system must be planned and designed when the motivation to contribute plays a primary role.

3.4. Participation Planning

This fourth phase in designing and developing a VGI system is related to its second component—participants. Several studies have identified an unequal participation in online communities and VGI projects such as *OpenStreetMap* (*OSM*) [39–42]. Most online communities follow the general rule that 1% of users are active members, 9% are casual users and occasional contributors and 90% of users passively consume information and content but never contribute [39]. For instance, Neis and Zipf [40] analyzed the activity of contributors to *OSM* in 2011, and concluded that only 5% of all members actively contributed in a productive way. Furthermore, another case study of participation in *OSM* within the Greater London Area [42] found that there was a problem with commitment among highly productive contributors, who generally do not go back and update the geographic features they have created. Similarly, a major difference was discovered between the accumulated percentages of features that had been created and updated, this being considered a problem with updating the database. Lastly, by analyzing the contrast between high and low mapping activity areas, a clustering problem was identified.

These kinds of recognized biased contribution issues can be caused by a lack of sustained motivation. They alert us of the necessity of analyzing the rationale and needs of participants in order to engage them and manage the contribution flow required by a VGI project. Said analysis will help plan and design appropriate incentive systems (recognition-based, reward-based, career improvement, *gamification*, etc.) with the aim of attracting and maintaining volunteers' contributions. Furthermore, in order to facilitate and elicit participation, it is important to use compensation schemes, trust-building systems (to assess the credibility of contributors) and voting and commenting mechanisms so as to valuate contributors [43]. Thus, it is necessary to plan for recognizing participants' motivations and the using these type of tools, and this must be included in the VGI system's design and development.

The participation behavior of volunteers is determined by three dimensions: (i) the knowledge of what to do and why; (ii) the capabilities required to complete a task or collaborate; and (iii) the desire to perform a task or collaborate—motivation. These three dimensions are directly affected by the organizational aspects of a VGI project—particularly the vision, mission and goal—as well as the designed crowdsourcing strategy to be followed and its operational characteristics. The crowdsourcing process defines how participants' contributions are to be obtained, what capabilities are required of people and what their interactions and way of organizing collaborative actions will be like. Moreover, the proximity to a crowd-based or community-driven strategy or a resulting combination thereof is associated with different motivations for contributing. Designing a particular crowdsourcing process entails specifying the use of different motivational factors. As one of the variables of participation behavior in VGI projects, this reliance on different motivations can be planned, as can the design of engagement strategies that foster commitment among participants. In the next subsection, we will analyze the motivational aspect of participation in order to identify general requirements based on people´s needs to be motivated.

Motivational Factors for Contributing to VGI Projects. There are two forms of participation in open online collaborative projects, such as wikis. These kinds of projects present, first, a generalized independent contribution and, second, a contribution based on community interaction that allows members to debate, recognize each other and discuss information. This dual aspect of participation suggests different motivations for contributing as members of a crowd or as members of a community [44]. In terms of the motivations associated with participants in these two kinds of contributions, Haythornthwaite [45] articulates a model in which online crowds and communities are seen as two ends of a lightweight-to-heavyweight continuum with overlapping forms of online participation. The first entails using crowdsourcing to gather a large number of easy-to-submit contributions from unconnected participants and having a centralized control organizational model, while the second involves collaborations sourced from an interrelated community that depends on social interaction and norms and follows a consensual control organizational model. The requirements as far as participation commitment and engagement are a key property of this continuum of contributory behavior and are correlated with a set of motivational factors. The principal motivators on the first end of this continuum—the crowd—are related with personal interests or needs, but with a clear altruist aspect with respect to a wider societal good. At the other end of the spectrum, in addition to the above-mentioned factors, other motivators emerge related to community interaction factors and relationship networks [44].

For crowdsourcing initiatives, some of the motivations identified for participating include developing one's current skills and having the possibility to express them, the opportunity to make friends and develop networks of people with similar interests and, finally, doing something that is perceived as fun, enjoyable and even sometimes described as addictive [14,46–48]. Furthermore, Brabham [47,48] found that other significant incentives include the joy of solving a problem and having free time available to work on scientific challenges, as well as developing creative skills and improving one's professional reputation.

Moreover, specifically in relation to participation in VGI projects, Budhathoki et al. [49] reviewed relevant literature in the fields of volunteerism, leisure studies and social production of knowledge in order to identify and characterize intrinsic and extrinsic motivations for participating that could potentially be useful to foster contribution. Subsequently, Budhathoki and Haythornthwaite [44] used those motivators to design a 39-item survey suitable for measuring 22 of these motivating factors in the context of *OpenStreetMap*. Each item on the survey was associated with a motivating factor. The survey makes a distinction between answers given by casual and serious mappers, associating them with the lightweight and heavyweight end of the continuum, respectively, and identifying the associated type of participation as crowd versus community. Based on their published data, we developed Figure 5 that summarizes the mean scores for each motivational factor on a 7-point Likert-type scale, where the maximum score of 7 represents strong agreement (and 1 is strong disagreement) with a given statement about a specific factor. In addition, with the aim of facilitating participation planning by prioritizing and optimizing the use of different participant motivations, in this figure the motivational factors are presented in decreasing order of importance in fostering contribution, taking the sum of the scores of both types of mappers into consideration.

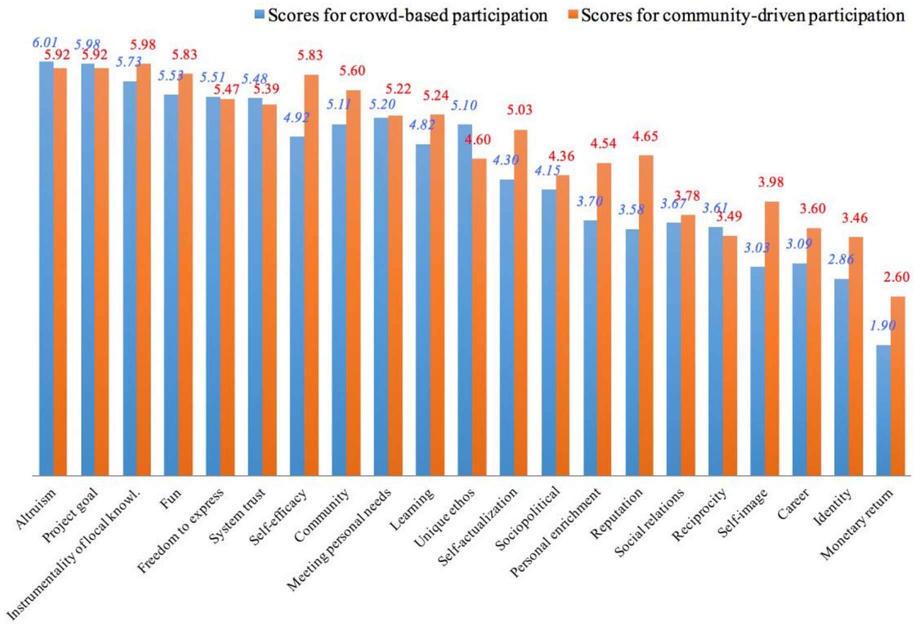

Figure 5. Mean Scores of Motivational Factors for Contributing to *OSM* Participating as a Crowd versus Community-Type User. Figure created based on published data in Budhathoki and Haythornthwaite [44].

In practical terms, there are certain insights that may be obtained based on these motivational factors as inputs to participation planning.

Altruism, the perceived significance of a *project goal* to be achieved for a common good, and the belief in the high value of people's *local knowledge* contributions are the prime motivating factors to rely on to inspire involvement and participation. These motivators are followed by the *fun* factor: thus, engaging and modern user interfaces, easy-to-use and attractive mapping platforms and *gamification* methods are important and helpful in motivating the participants. Also, the possibility of choosing tasks and thematic or geographic areas of interest (*freedom to express*) and a *trustworthy system* to manage contributions and efforts are central considerations in designing and developing a VGI system in order to engage participation. In addition, being involved in supporting an organization or *community*, especially when it is aimed at developing a product or service that meets a *personal need*, is also a representative motivator for both types of participants. Moreover, Figure 5 also synthetizes the importance attributed to each type of participation (crowd vs. community). The scores serve as a reference tool to facilitate the planning and design of a motivational engagement strategy in relation to a particular crowdsourcing process. These scores can determine the usage trend of a motivation associated with a VGI project's crowdsourcing approach (crowd-based, community-driven or a combination thereof) in order to encourage, obtain or segment different types of participants. Furthermore, by analyzing the graph, it is possible to identify some factors with wider score gaps between the crowd and community aspects of participation. This gap as a potential score achievement helps in designing methods to boost community-based participation from individuals by offering and developing targeted motivations. For instance, a project strategy whose objective is to gradually evolve an existing crowd-based initiative into a community-driven project can design methods for acknowledging personal knowledge and skills and developing participants' confidence by encouraging them to learn, test and practice. The latter helps to increase *self-efficacy*, *self-actualization* and *self-image* with respect to participants' abilities as members of a crowd, thus motivating a change in the contribution behavior towards a collaborative participation in developing the *community*. Then, visibility, feedback, relationships and interactions with other community members facilitate *personal enrichment* and *learning*. Similarly, other extrinsic motivational factors, such as participant's interest in *reputation*, *career* and *identity*, also emerge.

Finally, in [44], the authors identify the results—from higher to lower importance—of a factor analysis of 444 survey responses from *OSM*, grouping them into seven main motivational clusters for contributing to VGI projects: (1) *Project goal*; (2) *Altruism*; (3) *Self-efficacy regarding local knowledge*; (4) *Learning*; (5) *Personal need*; (6) *Personal promotion*; (7) *Monetary reward*.

In conclusion, it is crucial to examine and harness these seven motivational constructs together with the preceding specific factors in order to determine the system requirements with regards to the participation behavior of volunteers. These must be taken into consideration from the beginning in relation with defining the nature, goal and scope of the VGI project, and also within the crowdsourcing process design, with the aim of better applying these motivators when planning and designing the expected types of participation, together with the other components of the VGI system.

4. Case Studies of VGI Projects

This section presents an analysis of two case studies including several existing VGI projects. The first study focuses on one of the criteria defined previously in this article in order to design a crowdsourcing process. This design criterion is one of the most important, not only for the crowdsourcing process, but also for the entire VGI system, because it affects the way that volunteers are organized and the tools used to achieve a desired level of participation. Thus, it is one of the core considerations when designing and implementing a VGI project; in this brief study, we work on a rapid identification of the largest possible number of projects in order to see the differences between them with respect to their modes of organizing participation.

The second study addresses a more detailed analysis of just four VGI projects. Here, some characteristics of the four phases currently developed for designing and developing a VGI system are used to analyze these projects as a first theoretical validation.

4.1. Case Study 1. VGI Project Examples: What Is the Level of Participation by Mode of Organization?

This subsection presents a brief analysis of several VGI projects in order to differentiate and locate them within a continuum associated with the first proposed criterion for designing and characterizing a crowdsourcing process. The result of this analysis is presented in Figure 6. This figure offers an approximate illustration of the level of participation (involvement/engagement) by a contributory, collaborative or participatory mode of organization of each project. The cooperation of volunteers within a project may actually present a range of type of participation or may enable one level of participation more than another. Thus, a project can allow for varying degrees of interaction and, under different scenarios or during different time periods, it can operate according to one mode of organization or another. Figure 6 does not consider an operational range for each project; it merely provides a reference for comparing and understanding the differences among some VGI projects.

At the first end are located the projects whose primary mode of participation is based on individual and more independent actions, such as enabling the execution of a software to collect data automatically, as in the case of *Argus* and *OpenSignal* projects. Also, by sending data to a centralized platform by filling out web-based forms, as in the case of the *Did you feel it?* and *Citclops* projects. Towards the second and third sector of the diagram are located the projects whose participation is based on a greater degree of communication and interaction with other volunteers and some of the tasks may be performed in groups. *Google Map Maker* or *Waze* are examples of projects that enable processes that are mainly based on collaborative participation. Finally, tending towards the latter end are located the projects that enable more room for participatory processes where it is possible that the whole community can get involved in decision-making activities regarding the information management and use, as in cases of participatory urban planning (e.g., *Miramap*, *Helsinki City Plan 2005* projects), or working proactively in order to improve a geographical area (e.g., *YardMap Network*, *Map Kibera* projects).

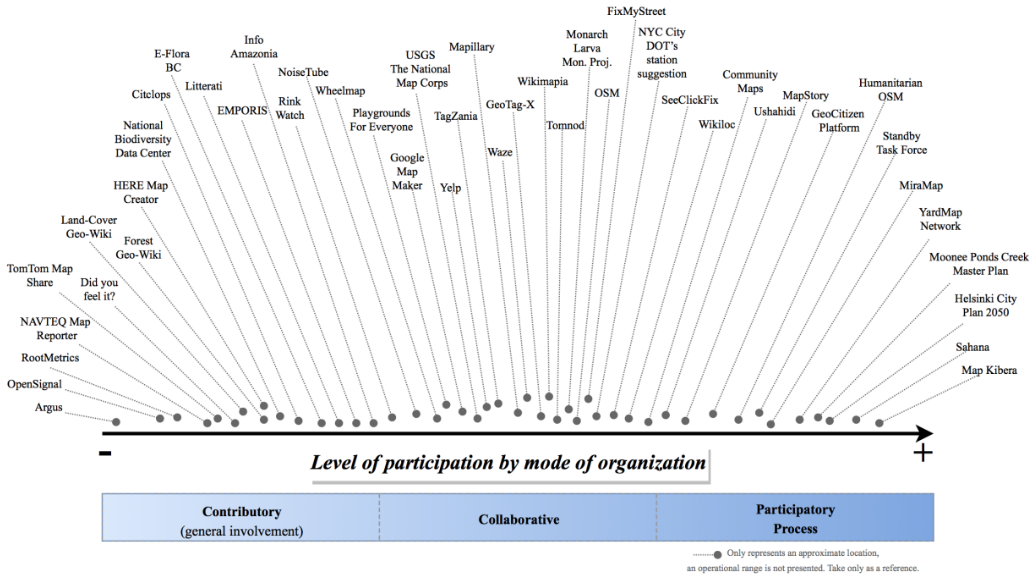

Figure 6. VGI Projects by Approximate Level of Participation by Mode of Organization.

Moreover, unlike crowd-based projects, community-led projects usually have a point of convergence in a local and offline environment, thus creating an organization that works in a hybrid manner and not only within an online or virtual community. In particular, VGI projects that operate under participatory processes tend to be local projects with a hybrid organization that includes both an online community and face-to-face meetings and tasks within the local geographical area. In these types of projects, the advantage of widespread participation across a distributed network is not the main focus, in contrast to projects that have a contributory or collaborative process that benefits from online participation and thus enables it; but this has other implications, such as the possible lack of a local and geographical context for some volunteers. Depending on its objectives, purpose and final use of the information output, the crowdsourcing process and design of ITC tools for a VGI project may have to consider a participant's geographic context and location in order to manage local or zonal contributions distinctly.

Furthermore, it is also possible that, within a VGI project initially designed with a mainly crowd-based strategy seeking a wider participation and geographic extension, some more collaborative communities may also emerge when groups of participants meet physically in a given location. These groups collaborate locally to gather data and may follow a participatory process among members in order to define objectives, identify interests and decide on the actions to be taken based on the precise local need for information, which may differ from the needs of the main project as a whole. Or ultimately, they may create an independent new community-led project that takes advantage of some of the technological tools designed for the initial project. For example, *OpenStreetMap* and *NoiseTube* both have a global reach, but their platforms may serve to implement local mapping projects in order to solve specific local problems operating under a participatory process scheme, such as in the case of the *Map Kibera* project.

4.2. Case Study 2. A Characterization of Four VGI Projects Using the First Phases of the System Design and Development Process

This subsection describes four VGI projects: (a) *Climateprediction.net* [50]; (b) *Mappiness* [51]; (c) *AtrapaelTigre.com* [52]; and (d) *New York City Council Participatory Budgeting* [53]. The projects were selected as useful examples of the different modes of organization presented above, with increasing levels of active participation, task-cognitive engagement and use of cognitive abilities that modify a VGI system in different ways. First, using the project initiation guidelines, we offer a structured description of some of the most important factors in establishing a VGI project's organization. Also, in addition to describing the project goal for each case, we focus on defining the VGI project goals and objectives in following the crowdsourcing characterization developed and VGI functionalities and goals, and establishing the rationale behind the project's organization and scope. Defining a project adequately with these two initial steps makes it easier to figure out how to achieve the higher goal by identifying project priorities, specifications and requirements as inputs to planning its operation and crowdsourcing processes. Next, we go on to analyze the crowdsourcing strategy and particular processing characterization and general crowdsourcing approach tendency for each case, applying the procedure explained in previous sections. These steps are necessary in the project planning and design phases in order to associate the requirements identified earlier with the right type of crowdsourcing process and crowd contributions. Subsequently, to conclude the project-related phases, we will examine crowdsourced contributions, focusing on the characteristics of the data and content as design principles that also condition the tools to be implemented and the participants' involvement. The overall project planning and design phases determine the structure of participation and the motivational factors for contributing; consequently, the participation planning phase based on these motivators is the guide and input for designing additional participation engagement strategies. Therefore, we finish this section presenting the motivational factors used and possibly associated motives for contributing in each case.

4.2.1. Organization: Project Initiation

(1) Climateprediction.net

Vision/Mission. To discover evidence of how our climate is changing is vital in order to encourage reduction of greenhouse gas emissions and manage this change. To use distributed computing to run climate models in order to acquire data more efficiently.

Coordination (Actors/Organization/Connections). (i) Oxford University's Environmental Change Institute; (ii) The Oxford e-Research Centre and Atmospheric Oceanic and Planetary Physics; (iii) Volunteers and Coordinators; (iv) Natural Environment Research Council; (v) BOINC project.

Start and Type of Establishment. The project was started with Oxford University's open call to run climate models on their participants' computers. The establishment is a top-down process, so participants' involvement is minimal. **Shared Control.** The project's developers have complete control over the implementation and running of climate models ensembles and of the analysis and use of the computer data generated by volunteers. **Norms/Rules.** The models can only be run on computers over which participants have complete control, and must accept data and project policies. **Regulations.** The project has several regulations concerning intellectual property, data and software usage. **Limiting Factors.** Failing models (several models failed while being run). **Process.** Volunteers are requested to download the software, applications and input files; then the software itself computes the desired task and participants upload and report the results obtained or any possible eventualities.

(2) Mappiness

Vision/Mission. To identify the external local environment, context and situations in which people are happier to provide insights in areas of interest for human psychology, health and public policies for better living.

Coordination (Actors/Organization/Connections). (i) Dr. George MacKerron and Dr. Susana Mourato; (ii) The Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science (LSE); (iii) United Kingdom's Economic & Social Research Council; (iv) Volunteers.

Start and Type of Establishment. The project follows a top-down process design and implementation in order to gather crowd data from volunteers. **Shared Control.** Coordinators manage the overall process; nevertheless, the webpage features a forum where anyone interested in the project can submit ideas and provide feedback. **Norms/Rules.** Volunteers must agree with the project's nature and purpose of the research, and they have to be at least 18 years old. **Regulations.** The project operates under the United Kingdom's data disclosure principles. **Limiting Factors.** Technology: the app is only available for iOS. Budget for increasing the project's exposure and divulgation (it is a relatively low-profile project). **Process.** Volunteers use the mobile app to answer a few personal questions and sign up for the project; they are then asked to report on their feelings and current situation once a day or more. The project's coordinators analyze the data submitted with the subjects' approximate location and noise-level measurement.

(3) AtrapaelTigre.com

Vision/Mission. To create a citizen science initiative and alert system for studying, tracking and monitoring the expansion of the tiger mosquito (*Aedes albopictus*). To improve species management and minimize the risk of disease transmission. Citizen participation makes it possible to precisely identify the mosquito's real distribution in order to control its expansion, since it normally reproduces on private property and quickly expands throughout the territory with help from human transports.

Coordination (Actors/Organization/Connections). (i) ICREA Movement Ecology Lab (CEAB-CSIC, CREAF); (ii) Spanish Foundation for Science and Technology (FECYT) and the Ministry of Economy and Competitiveness; (iii) La Caixa (RecerCaixa); (iv) Lokímica; (v) Entities monitoring and preventing the spread of the tiger mosquito (Public health agencies, Research labs, Universities); (vi) Entomological experts; (vii) Volunteers/Citizens.

Start and Type of Establishment. The project and crowdsourcing process were initiated and designed by ICREA Movement Ecology Lab researches and developers, while citizens are an integral part in the scientific bottom-top process, being conscious of the importance of their role in mosquito identification, prevention and control. **Shared Control.** The project presents a centralized coordination, having a strong collaboration with public and private entities, universities and a community of citizens with support from a large number of professionals and experts involved in the project's improvement. **Norms/Rules.** Volunteers must be adults or supervised by adults. They must agree to the *AtrapaelTigre* privacy policy. **Regulations.** The data shared is ceded to the members of the research team for perpetual, royalty-free, non-exclusive, sub-licensable license use, reproduction, modification, publication, creation and distribution of derivative works in any media, and the research team reserves all publicity and copyrights. **Limiting Factors.** Volunteers' learning and knowledge in order to better recognize a tiger mosquito. **Process.** Citizens using the *Tigatrapp* mobile app report their discovery of tiger mosquitoes and potential breeding sites, including location and response to a questionnaire, photos and notes. The data sent are shown on the project website map with different levels of confirmation. Reports with available photos go through an expert validation process. Also, a citizen validation process is used on the *Tigafotos* platform at *crowdcrafting.org*. After validation, some reports are marked as confirmed on the map.

(4) New York City Council Participatory Budgeting (PB)

Vision/Mission. To enable a grassroots democratic process that promotes transparency and allows community members to participate directly in public budgeting. To give real power to people who have never before been involved in the political process, resulting in better budgeting decisions in a community because the people who live there know their needs better than anyone.

Coordination (Actors/Organization/Connections). (i) Council members from each NYC district; (ii) Community members (Neighborhoods from each district); (iii) Budget Delegates (Volunteers from each district); (iv) District committee; (v) City departments and agencies; (vi) Facilitators, volunteers and technical assistances; (vii) Participatory Budgeting Project; (viii) OpenPlans (*Shareabouts* project).

Start and Type of Establishment. The project starts with an open call from Council members, then, with help from facilitators, the community follows a bottom-up process in order to directly decide how to spend the public budget, adhering to certain rules. **Shared Control.** A Council staff member manages logistics and planning of the overall process, but the community has full control of idea collection, project development, voting and evaluations. **Norms/Rules.** The project follows a timeline according to specific dates. It features project eligibility rules: anyone can post ideas, but ideas must be submitted before a certain date, they must be one-time expenditures capital infrastructure projects within given categories and must benefit the public; and process-stage rules, community roles with eligibility rules and responsibilities. **Regulations.** Projects must be feasible within city guidelines and regulations. **Limiting Factors.** Duration of each stage. The total amount of money allocated for PB funding. **Process.** The project follows an online/face-to-face participatory process for idea collection, proposal development, exposition, voting and monitoring. Citizens share ideas on a map and provide feedback before in-person workshops. After the *Idea Collection Map* [54], ideas go to Budget Delegates who turn them into proposals to be voted on with input from city agencies. Proposals are used in online/in-person community-wide polls.

4.2.2. Goal Definition: Project Initiation

(1) Climateprediction.net

Goal Description. To investigate and reduce uncertainties about climate change and its immediate and long-term effects. To simulate the climate for the next century, producing predictions of temperature, rainfall and the probability of extreme weather events. Also, the problem the initiative must solve is that, given the large amount of state-of-the-art climate models developed, the researchers from the *climateprediction.net* project are unable to run all the models they need on the supercomputers currently available and must thus turn to distributed computing resources with help from volunteers.

(2) Mappiness

Goal Description. To collect data about how volunteers feel (happy, relaxed and level of wakefulness) in order to discover links between momentary subjective wellbeing and immediate environmental factors within the UK. To publish the results in academic journals and elsewhere.

(3) AtrapaelTigre.com

Goal Description. To involve the general public in scientific research aimed at detecting, tracking and controlling adult tiger mosquitoes and their breeding sites. To help divulge and fight against this vector of diseases and obtain a participatory mapping of their distribution in Spain.

(4) New York City Council Participatory Budgeting (PB)

Goal Description. To get the whole community to participate in decision making on how to spend the public budget in council districts in order to meet local needs, increase and diversify civic participation and develop new community leaders.

Linked to the organizational characteristics and description for each VGI project presented above, Table 4 shows their goal definition that follows the different general aims previously developed in relation to crowdsourced and volunteered GI.

Table 4. VGI Project Goal Definition.

	Project:	(a)	(b)	(c)	(d)
	Collective Knowledge			✓	✓
	Collective Creativity				✓
	Open Innovation				✓
	Cloud Labor (or Distributed Tasking)	✓	✓	✓	
	Community Building			✓	✓
	Civic Engagement			✓	✓
Crowdsourced (Geo) Information General Goal	*(Geographic) Information Management*	✓		✓	
	(Spatial) Knowledge Acquisition	✓	✓	✓	✓
	(Spatial) Problem-solving			✓	
	Ideation (with a geographic reference)				✓
VGI General Functionality [10]	*Update, complement or replace the traditional production of GI and existing official databases*			✓	
	Create a new form of spatial knowledge production, GI and content	✓	✓	✓	✓
VGI Project Goal Type	*Basic cartography*			✓	
	Update of spatial data sets				
	Upgrade public sector services			✓	✓
	Upgrade private sector products and services				
	Location-based/Place-based features creation or attributes collection	✓	✓	✓	✓
	Emergency reporting and humanitarian aid				
	Scientific research practices using geographic crowdsourced data or Citizen Science approach	✓	✓	✓	
VGI Project Objectives		Produce info. about extreme weather events (where/what)	Distribute data on well-being and its geographic correlation	Environmental monitoring, species tracking and identification. Species location, breeding sites and distribution map	E-democracy, participatory budgeting, popular consultations, spatial ideation and planning, new spatial places with geo-referenced project idea proposals

4.2.3. Crowdsourcing: Project Planning and Design

With regard to the VGI project planning and design phases, the crowdsourcing strategy characterization for each project is shown in Table 5, then, in Table 6 is presented the *Central Crowdsourcing Processing Unit* design following the criteria proposed for this undertaking.

Table 5. VGI Project Planning—Crowdsourcing Strategy.

	Project:	**(a)**	**(b)**	**(c)**		**(d)**	
				Tigatrapp App	***Tigafotos Platform***	***Idea Collection Map***	***Online Voting***
Best-suited problem-to-solve CS typology [29]	*Knowledge discovery and management*	✓	✓	✓			
	Distributed human intelligence tasking				✓		✓
	Broadcast search			✓		✓	
	Peer-vetted creative production					✓	
Crowd organization mode	*Passive contribution*	✓					
	Active contribution		✓		✓		✓
	Collaboration			✓		✓	
	Co-creation					✓	
Use of cognitive abilities CS typology [30]	*Low use of cognitive abilities*	Crowdsourcing/ Volunteered computing	Crowdsourcing/ Citizens as a sensors		Crowdsourcing		Crowdsourcing
	Medium use of cognitive abilities			Participatory science/Civic science	Distributed intelligence/ Volunteered thinking	✓	Distributed intelligence
	High use of cognitive abilities					✓	

Table 6. VGI Project Design—*Central Crowdsourced Processing Unit*.

	Project:		**(a)**	**(b)**	**(c)**		**(d)**	
					Tigatrapp App	***Tigafotos Platform***	***Idea Collection Map***	***Online Voting***
Level of participation by mode of organization	*Contributory*		✓	✓		✓		✓
	Collaborative				✓		✓	
	Participatory process						✓	
Task-cognitive engagement	***Cognitive demand***	*Low*	✓	✓	✓	✓		✓
		Medium			✓	✓	✓	✓
		High					✓	✓
	Cognitive skills (related)		Understanding	Understanding	Remembering, Understanding, Applying	Remembering, Understanding, Analyzing	Applying, Creating	Understanding, Analyzing Evaluating
	Background skills	*Common*	✓	✓	✓	✓	✓	✓
		Specialized				✓		
		Domain-related						
Crowdsourcing approach tendency	*Crowd-based*		✓	✓		✓		✓
	Community-driven				✓		✓	
	Modularity?		No	No	Yes		Yes	

4.2.4. Data and Content as a Design Principle: Project Design

The proposed items to consider—that are linked to the design of a crowdsourcing process—in relation to the crowdsourced data and content contributions are shown in Table 7.

Table 7. VGI Project Design—Crowdsourced Contribution.

Project:	How Is Data/Content Used?	Where? Region or Geographic Area . . .	When? Time Period, Season . . .	Quality Controls or Assurance?	Spatial Dimension	Attributes Dimension
(a)	To run climate simulations in order to obtain different scenarios	Worldwide	• Models running during inactive use of a personal computer. • Long-term initiative.	• Model results validation. • Data gathering for reporting problems while participants are running the software.	• Both location and place-based	• Structured • Objective • One-way data flow
(b)	Location data are used to estimate environmental characteristics of the places covered by the overall crowd monitoring and its effects on people's perceived impressions.	United Kingdom	• 1 or more beeps per day, which users can control using app settings. • Long-term initiative.	• No available info.	• Location-based	• Structured (levels/scores) • Subjective (sense of happiness) • One-way data flow
(c)	To identify and map tiger mosquitoes and their breeding sites	Spain	• User decides when to issue a report • Long-term initiative	• Expert validation • Citizen (crowd) validation	• Location-based	• Structured (Yes/No answers) • Unstructured (Photos, notes) • Objective • One-way data flow
(d)	*Idea Collection Map*: Project proposal development Online voting: Selecting projects to be funded	27 NYC districts in Bronx, Brooklyn, Manhattan and Queens	*Idea Collection Map*: • October to November 16, 2015 *Online voting:* • May, 2016	• Restricted choice of categories • Identification if an idea is outside the PB district's boundaries	*Idea Collection Map*: • Placed-based *Online voting:* • Placed-based	*Idea Collection Map*: • Unstructured (Ideas, comments, stories) • Subjective (Opinions, comments, support button,) • N-way data flow *Online voting:* • Structured (scores) • Subjective • One-way data flow

4.2.5. Motivational Factors for Contributing: Participation Planning

Table 8 shows the different motivational factors that can be associated to each project in order to encourage participation.

Table 8. VGI Participation Planning.

Project:	Use of Incentive System?	Use of Trust-Building System?	Motivational Factors		Motivational Construct
			Intrinsic	*Extrinsic*	
(a)	• General use of regular motivational factors	No	• Altruism • Unique ethos	• Project goal • System trust	• Project goal • Altruism
(b)	• General use of regular motivational factors	No	• Learning • Meeting personal needs • Unique ethos	• Project goal • Reciprocity	• Project goal • Learning • Personal need
(c)	• General use of regular motivational factors • *Gamification*: use of special missions for *android* users	No	• Meeting personal needs • Altruism • Learning • Instrumentality of local knowledge • Fun	• Project goal • Reciprocity • System trust	• Project goal • Personal need • Altruism • Learning • Self-efficacy regarding local knowledge
(d)	• General use of regular motivational factors	No	• Meeting personal needs • Freedom to express • Instrumentality of local knowledge • Self-efficacy • Unique ethos	• Community • Sociopolitical • Project goal • Reciprocity • Social relations • Identity	• Project goal • Personal need • Self-efficacy regarding local knowledge

5. Conclusions

In this paper, we studied the domain of VGI with a focus on the general processes that support and enable the social and technical production of GI and knowledge by volunteers. By reflecting on these processes it is possible to analyze and characterize the three components implied in this particular type of information system: technology, people and organization; the latter, in the case of VGI systems, is usually implemented by a project pursuing a defined goal. The characterization of VGI systems helped us understand the individual components and their attributes as well as the existing relationships and interdependency among them, as determined by the system as a whole. Understanding how changes in one component of the VGI system can, as a consequence of its interactions, cascade into changes that drastically alter all parts of the system has important implications for the system's design and offers opportunities to better develop VGI projects. Identifying variables and features that affect a VGI system's performance is helpful when planning its design or making improvements to it once it is in operation.

With regards to these ideas, this work presents a methodological proposal with some preliminary results, considerations and tools, as well as a description of steps to follow for designing a VGI system. This organized design methodology is practically oriented to the development of VGI projects. The value of these design steps is that they follow a strategy of aligning the three components of a VGI system, seeking to reduce gaps between project, participant and technological requirements. The VGI system design process is triggered by a problem or the detection of an opportunity for improvement, and then sets out to create an organization following an integrated design flow: from a clear goal, to the right crowdsourcing process and crowdsourced contributions, up to and including the right collaborative environment and participation engagement strategy based on the motivational factors identified and the right technical infrastructure and tools to support a particular collaborative environment. By following the guidelines and design steps presented here, this proposal aims to reduce friction in the VGI production flow, from the objectives to the final system outcomes, thus facilitating the design of various aspects of participation and technology. If the steady flow of information fails, decreases or becomes "turbulent" due to friction in the components' aligned "pipeline," the final step contemplates refining the solution using *design–development feedback loops*, examining each previous step in order to work on improvement actions. Then, as illustrated in Figure 2, we propose the use of these design steps as part of the process of developing and building a VGI project, based on a project management (plan–design–implement) approach and agile/adaptive development concepts. The latter facilitate continuous improvement by monitoring the evolution and new requirements of any given component of the system. In the proposed methodology, the goal-oriented characteristic of VGI systems, the crowdsourcing model and the project management process converge, bringing a unique focus to the definition of objectives, identification of requirements and design and development activities. We decided to follow this workflow approach because it has proven to be of great value in executing various types of professional projects within different domain areas. It is also generally known and applied in the professional/commercial world, where it is already a common practice. Thus, implementing a VGI system based on project management can make it easier to incorporate non-professional GI into the routine operations of professional GI production, hence benefiting from the crowdsourced and volunteered GI in order to improve a product or service, but also from the advances and theories of a growing academic research area. The design methodological approach and development process presented in this paper can serve as a linking point between academic insights and professional practices and help increase the capacity for closer collaboration with other VGI practitioners in society.

Although this paper proposes all the steps to follow, it only covers half of the design and development flow of a VGI system. During the research stage, we worked on the conceptualization of VGI and the applicability of certain ideas. In particular, we identified that VGI projects are clearly differentiated by: (i) the way people interact within a network or virtual community enabling different types of cooperation (see Figure 3 and Case Study 1) and (ii) the cognitive abilities required in order to make a contribution. Within the methodology, they were considered as major planning variables when designing and developing a VGI system. Both variables govern the characteristics of crowdsourced contributions as well as processing strategies and use of technology. Additionally, they determine the collaborative environment necessary, which affects volunteers' readiness to participate in terms of their motivation, knowledge and capabilities.

First, the VGI system design methodology focused on the organization created in order to direct a VGI project. Within the organization, where the communication and interactions take place, are determined the conditions that must be created in order to allow participants to work on producing VGI. These conditions should facilitate participation and orient the actions expected from the participants. In addition, the VGI project organization defines the initial goal, objectives and principles that determine the project's identity, people´s understanding and commitment and the procedures and capabilities necessary in order to achieve its objectives. Then, in order to put these organizational aspects in action and enable people´s cooperation, we found that a crowdsourcing strategy based on the VGI project goal serves to bind the VGI system components together, as its design enables different types of arenas of participation where crowd and community technology-based contribution inputs are managed in order to obtain specific desired outputs. Thus, as a fundamental input of the methodology, we analyzed diverse crowdsourcing strategies so as to build a classification of crowdsourcing methods into different modes of organizing people.

In this paper, we introduced the first insights obtained from the methodological proposal with regards to the project's initiation, planning and design, as well as some ideas on how to connect the project organization with planning the necessary participation, focusing mainly on analyzing one variable—motivation. Within the three initial phases of the integrated framework we built an organized scheme, proposing central considerations and methods to: define the organization, goal and scope; set a strategic direction; and guide the design of a VGI project based on a crowdsourcing strategy. Next, we developed a quite useful tool for designing a crowdsourcing process in relation to VGI production. The proposed multi-criteria design tool presents a procedure for characterizing and designing the required *central crowdsourced processing unit* for a particular stage of a VGI project. Based on, first, an earlier developed crowdsourcing classification of the *level of participation by mode of organization* (contributory, collaborative, participatory process); and, second, a proposed characterization of the *task-cognitive engagement* relying on the task-cognitive demand and on identifying the necessary background skills in order to work on a task. We propose to apply these criteria as a design guide in order to analyze the necessary environment for cooperation, help define the task (complexity, cognitive demands, skills, etc.) for a project and, finally, identify the crowdsourcing method within a crowd–community continuum approach to implementing participation strategies that differ depending on participants' motivations for contributing. In Figure 4, we developed a diagram reflecting this design tool in order to clarify the links between the needs of the VGI project and the right crowdsourcing strategy. Next, we highlighted an advantage of this design approach, which is that it enables a modular crowdsourcing process, thus facilitating disaggregation so that different types of contributions and contributors may be funneled to selected project areas or stages as needed. Furthermore, in order to associate the dependency among processes, technology and contributions, we performed an analysis of data and content as a design principle.

Similarly, from the early stages of the VGI project-planning phase, we recognized that without participants there are no project outcomes. Thus, we found that it is crucial to align people´s rationale for participating with the project's goal, vision and a well-suited crowdsourcing strategy in order to increment the likelihood of success, while the human capital, ICT infrastructure and external context also have an influence. So, once a crowdsourcing process is designed, a certain technological and operational level is required in order to control its core processing characteristics through specific functionalities, and also with regards to user interaction in order to enable the actions required from participants. We analyzed the participants' component of VGI, which requires and operates throughout this level, while its contribution must correspond to the VGI project's planning and design as a whole.

We examined and synthesized a set of motivators for contributing to VGI projects in order to attract and manage the required participants for a crowdsourcing process. The motivational factors reviewed tend to be more present in either crowd-based or community-driven participation, which serves to associate their use with a specific crowdsourcing approach. We presented some insights on how these factors serve as inputs to help plan the participation, design the engagement strategies and technology necessary in order to support the required participation dynamic and workflow of a VGI project. Also, we proposed the use of the participants' perceived importance in order to foster different kinds of contributions, to plan a crowdsourcing strategy using different motivators at different stages in the project depending on how participation is expected to evolve.

This paper presents our first partial results of a long-term research study on the design of VGI systems. Until all the proposed phases have been completed, the practical use of our methodological approach in designing and developing a VGI project from the start will serve as additional empirical validation. Nevertheless, at this stage in our work, in Subsection 4.2, we applied some of the currently proposed guidelines and tools from the initial phases of the methodology. We tested whether the core items of the project planning and design presented were useful in analyzing and characterizing the essential modus operandi of four existing VGI projects. We found that, as these projects followed some of the proposed considerations, the features defined in these phases satisfactorily described the organizational component of a VGI project as well as the crowdsourcing design criteria and their alignment with the use of motivational factors as an input for participation planning. In addition, it was noticed that these projects can also be planned following the initially proposed guidelines to help design and manage the system components.

Furthermore, using this methodological proposal makes it easier to identify some of the general requirements of a VGI system. With regards to information requirements, it helps to identify features related to the functionality, flexibility, modularity or connectivity. Similarly, with respect to personal requirements, it helps to recognize such factors as the necessary capabilities, interaction, communication, credibility, privacy, freedom, fun and ease of use in order to reduce cognitive overload during a crowdsourcing task, etc. And, at the community level, related requirements include identity, order, trust, transparency, accountability, openness and synergy. We also observed a correlation between some of the VGI system design requirements and the analyzed motivational factors for contributing. So, the proposed methodology definitely helps integrate different requirements, improving system performance at every level.

In the diagram that follows (Figure 7) we present a summary of the basic interdependent aspects that we found, throughout this research, must be analyzed and taken into consideration in order to successfully design and implement a VGI system: the organization, participation, crowdsourcing process and crowdsourced contributions. Each item is listed along with the three main dimensions required in order to work on it and develop it when designing a VGI system. The organization defines a project goal and the processes required to work towards achieving it. Then, the processes are implemented using a crowdsourcing strategy that includes the design of a task with particular levels of participation, levels of thinking and skills, as well as the characteristics of the data and content that must be obtained. The organizational processes and crowdsourcing tasks are mediated by the use of ICT and enable personal and community participation. Participation is determined by an understanding of the value of a project's goal and of why it is important for people to cooperate, the knowledge of what to do and how to do it, and the type of contribution and capabilities needed in order to work on a crowdsourcing task; but, also, the motivation to take valuable action. The motivation to participate is determined by the way the organization operates (goal, vision and crowdsourcing strategy being the most important aspects in this sense); but, also, in order to increase motivation within a VGI project, it is possible to design engagement strategies to inspire participation and get people involved, increasing their capabilities, learning and other aspects required in order to participate, or that might act as constraints to participation.

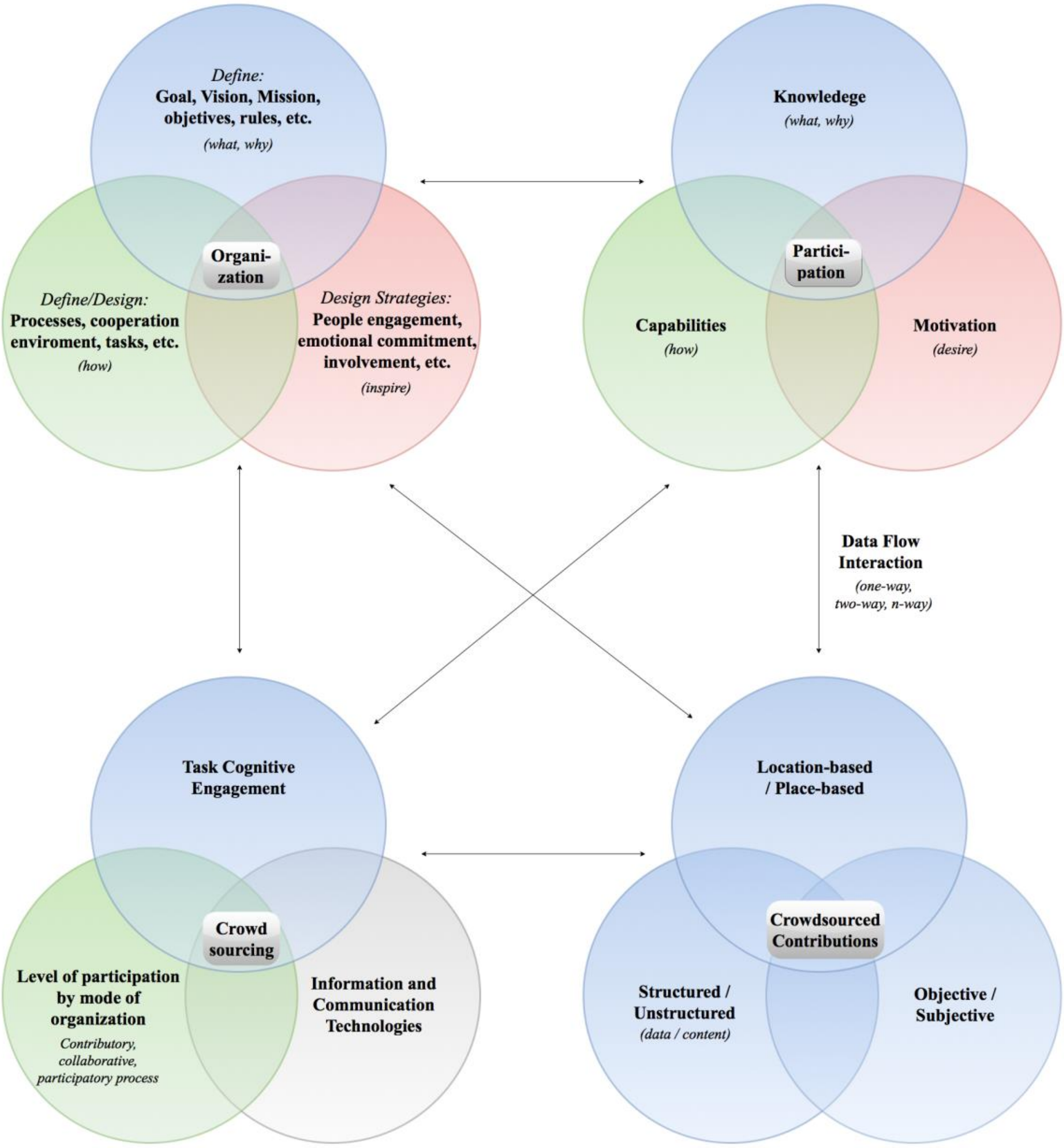

Figure 7. Interdependent Aspects in VGI Management and Production.

Finally, we learnt that in some cases, the bi-directional condition of the crowdsourcing model implies that, based on their expressed participation behavior and shared vision, the crowd and community will generate different outcomes than expected—perhaps more related to the needs of participants or the group, or more "democratic" needs. This flexibility of control over the project can result in changes in its definition, processing methods and technological implementation. The holistic characteristic of a VGI system implies that as one VGI system component evolves and changes over time, the other components will be adjusted or rearranged accordingly. Thus, any component may operate as a design and experimental variable, although the structure of participation, crowdsourcing strategy and technology might be more flexible, dynamic and apt for experimentation, than the project itself. The goal and project definition are normally considered more static, particularly on VGI projects that rely more on crowd-based participation, where volunteers should be more closely directed. By contrast, in community-driven participation it is easy to adjust the project definition to account for new needs in terms of information or findings made through community collaboration. Therefore, we suggest that initiators who require greater control in order to ensure they will attain their intended outcomes should adopt a crowdsourcing strategy design with limited implementation of participatory processes and low flexibility with respect to the type of participation behavior. In addition, the opposite is true for VGI projects that require greater flexibility, collaboration and open co-creation functionalities; this should offer the community higher shared participation and greater control.

6. Future Work

Continuing with the methodological design steps, and with relation to the phases already worked on, we will work to determine practical steps that may be used to engage participants based on a design approached from the perspective of motivational factors in combination with further criteria yet to be developed. In addition, we will address the planning and design of the technology component, based on the development of tools and principles in order to support the decision of what type of technology is right in order to facilitate the necessary contributions and the implementation of the required crowdsourcing process. This is because, while the structure of participation—associated with a set of motivators—is determined by the approach to the crowdsourcing process—with a particular characterization—corresponding to the project's definition, its technological implementation must also be aligned.

In addition, as a final result of the proposed VGI system design and development process, we would like to develop an organized set of design patterns for web components and tools, as well as tools for participation engagement. These design patterns will synthetize the theoretical insights developed in pre-designed reusable and modular components to be implement upon prior characterization of the project and crowdsourcing process, and will also be useful if a project changes over time, being more flexible in its adaptation. Among other uses, we believe this will facilitate the design and development of the VGI project, its testing and improvements. It will also help projects that, regardless of their unique goals, have certain requirements in common, by comparing their use of design patterns and helping solve problems specific to each project that were previously successfully addressed in similar scenarios. Having a set of methodological steps and clearly identified components for designing VGI systems, it is possible to have a common base for the comparison of the solutions used between similar projects and to benefit from the experience and success stories of others VGI practitioners.

Ultimately, as a consequence of a VGI project's condition of uncertainty due to its dependence on the response of dispersed participation, the strong interdependency of VGI system components and its rapid changes in terms of both technological development and community demands over time, we propose exploring the use of *Agile* and *Lean* software development principles [55,56]. This will help to reduce the risk inherent in the project by enabling a faster adaptation. In the future, we will work on the VGI project and technical infrastructure implementation phases, based on flexibility and focusing on participants, stakeholders and feedback cycles in order to develop, test, measure and learn. Based on making incremental design iterations that adjust to changes in the system and the uncertainty with regards to participation, this approach can facilitate continuous improvement of the VGI project and its information product. Also, developing metrics to monitor, evaluate and control the performance of a VGI project and taking the entire system into consideration is a study area that needs improvement and will have to be addressed.

Acknowledgments: We must thank the COST ENERGIC Action IC1203 for providing a funding grant to participate in their Training Schools ("VGI and Citizen Science: Engaging, Creating and Understanding"—2014; "GIS, Crowdsourced Geographical Information and Citizen Science"—2015), for the learning experience and exchange of ideas that facilitated this work and served to inspire it.

Author Contributions: José-Pablo Gómez-Barrón and Miguel-Ángel Manso-Callejo conceived the general idea of a VGI system design and development process to guide and facilitate the implementation of VGI projects. José-Pablo Gómez-Barrón developed the overall conceptualization of the methodological proposal; worked on the first phases and wrote the manuscript with the advice, input and review from Miguel-Ángel Manso-Callejo, Ramón Alcarria and Teresa Iturrioz.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix

The revision of Bloom's taxonomy of thinking skills made by Anderson and Krathwohl [35] presents six categories of cognitive skills in order of increasing cognitive demand. The lower order thinking skills are: remembering, associated with actions such as identifying, listing, recognizing and describing something; understanding, related with actions such as explaining, classifying, interpreting and summarizing information; and applying, which entails implementing, calculating, using and applying prior information. Then, the higher order thinking skills are: analyzing, associated with comparing, contrasting and inferring; evaluating, related with deduction and actions such as prioritizing, rating, judging and testing; and, lastly, creating, which involves inductive thinking associated with actions such as creating, producing, designing and planning.

References

1. O'Reilly, T. What is Web 2.0. Available online: http://oreilly.com/web2/archive/what-is-web-20.html (accessed on 15 January 2016).
2. Maguire, D. Geoweb 2.0 implications for ESDI. In Proceedings of the 12th EC-GIGIS Workshop, Innsbruck, Austria, 14–16 February 2006.
3. Haklay, M.; Singleton, A.; Parker, C. Web mapping 2.0: The neogeography of the GeoWeb. *Geogr. Compass* **2008**, *2*, 2011–2039. [CrossRef]
4. Sui, D.Z. The wikification of GIS and its consequences: Or Angelina Jolie's new tattoo and the future of GIS. *Comput. Environ. Urban Syst.* **2008**, *32*, 1–5. [CrossRef]
5. Turner, A. *Introduction to Neogeography*; O'Reilly Media, Inc.: Sebastopol, CA, USA, 2006.
6. Crampton, J.W. Cartography: Maps 2.0. *Prog. Hum. Geogr.* **2009**, *33*, 91–100. [CrossRef]
7. Goodchild, M.F. Citizens as sensors: The world of volunteered geography. *GeoJournal* **2007**, *69*, 211–221. [CrossRef]
8. Elwood, S. Volunteered geographic information: Key questions, concepts and methods to guide emerging research and practice. *GeoJournal* **2008**, *72*, 133–135. [CrossRef]
9. Goodchild, M.F. Citizens as voluntary sensors: Spatial data infrastructure in the world of Web 2.0. *Int. J. Spat. Data Infrastruct. Res.* **2007**, *2*, 24–42.
10. Elwood, S. Volunteered geographic information: Future research directions motivated by critical, participatory, and feminist GIS. *GeoJournal* **2008**, *72*, 173–183. [CrossRef]
11. Schuurman, N. An interview with Michael Goodchild. *Environ. Plan. D Abstr.* **2009**, *27*, 573–580. [CrossRef]
12. Haklay, M.; Antoniou, V.; Basiouka, S.; Soden, R.; Mooney, P. *Crowdsourced Geographic Information Use in Government*; Global Facility for Disaster Reduction & Recovery (GFDRR), World Bank: London, UK, 2014; p. 76.
13. Howe, J. The rise of crowdsourcing. *Wired Mag.* **2006**, *14*, 1–4.
14. Surowiecki, J. *The Wisdom of Crowds*; Doubleday: New York, NY, USA, 2004.
15. Brabham, D.C. Crowdsourcing as a model for problem solving. *Converg. Int. J. Res. New Media Technol.* **2008**, *14*, 75–90. [CrossRef]
16. IDE Rioja. IDE Rioja Cartografia Colaborativa. Available online: https://github.com/iderioja/cartografia_colaborativa (accessed on 10 February 2016).
17. Fast, V.; Rinner, C. A systems perspective on volunteered geographic information. *ISPRS Int. J. Geo-Inf.* **2014**, *3*, 1278–1292. [CrossRef]
18. Avison, D.; Wood-Harper, A.; Antill, L. *Multiview: An Exploration in Information Systems Development*; Alfred Waller Ltd.: Oxon, UK, 1990.
19. Averweg, U.R. An intranet within a knowledge management strategy. In *Encyclopedia of Information Science and Technology*, 2nd ed.; IGI Global: Hershey, PA, USA, 2009; Volume 25, pp. 2221–2223.
20. Ruffin, T.R. Health information technology and business process reengineering. In *Encyclopedia of Information Science and Technology*, 3rd ed.; IGI Global: Hershey, PA, USA, 2015; Volume 45, pp. 3355–3365.
21. Brabham, D. *Using Crowdsourcing in Government*; IBM Center for The Businnes of Government: Washington, DC, USA, 2013.

22. Haklay, M.; Weber, P. OpenStreet map: User-generated street maps. *IEEE Pervasive Comput.* **2008**, *7*, 12–18. [CrossRef]
23. Greenough, P.G.; Chan, J.L.; Meier, P.; Bateman, L.; Dutta, S. Applied technologies in humanitarian assistance: Report of the 2009 Applied Technology Working Group. *Prehosp. Disaster Med.* **2009**, *24* (Suppl. 2), s206–s209. [PubMed]
24. Hagen, E. Putting Nairobi's slums on the map. *Dev. Outreach* **2010**, *12*, 41–43. [CrossRef]
25. Radjawali, I.; Pye, O. Counter-mapping land grabs with community drones in Indonesia. In Proceedings of the Land Grabbing, Conflict and Agrarian—Environmental Transformations: Perspectives from East and Southeast Asia, Chiang Mai, Thailand, 5–6 June 2015.
26. McCartney, E.A.; Craun, K.J.; Korris, E.; Brostuen, D.A.; Moore, L.R. Crowdsourcing the national map. *Cartogr. Geogr. Inf. Sci.* **2015**, *42* (Suppl. 1), 54–57. [CrossRef]
27. Carl Esposti; Crowdsourcing.org. Crowdsourcing Industry Taxonomy Definitions (V2). Available online: http://www.crowdsourcing.org/document/crowdsourcing-industry-taxonomy-definitions-v2/2935 (accessed on 15 January 2016).
28. Sharma, A. Crowdsourcing Critical Success Factor Model Strategies to Harness the Collective Intelligence of the Crowd. Available online: https://irevolution.files.wordpress.com/2010/05/working-paper1.pdf (accessed on 10 February 2016).
29. Brabham, D.C. *Crowdsourcing*; MIT Press: Cambridge, MA, USA, 2013.
30. Haklay, M. Citizen science and volunteered geographic information: Overview and typology of participation. In *Crowdsourcing Geographic Knowledge*; Sui, D., Elwood, S., Goodchild, M., Eds.; Springer: Houten, The Netherlands, 2013; pp. 105–122.
31. Stein, M.K.; Smith, M.S.; Henningsen, M.A.; Silver, E.A. *Implementing Standards-Based Mathematics Instruction: A Casebook For Professional Development*; Duschl, R., Ed.; Teachers College Press: New York, NY, USA, 2000.
32. Van De Walle, J.; Karp, K.; Bay-Williams, J. *Elementary and Middle School Mathematics: Teaching Developmentally*, 8th ed.; Pearson: Upper Saddle River, NJ, USA, 2012.
33. Smith, M.S.; Stein, M.K. Selecting and creating mathematical tasks: From research to practice. *Math. Teach. Middle Sch.* **1998**, *3*, 344–350.
34. Erickson, L.; Petrick, I.; Trauth, E.; Erickson, L.B. Hanging with the right crowd: Matching crowdsourcing need to crowd characteristics. In Proceedings of the AMCIS 2012, Seattle, WA, USA, 9–12 August 2012; pp. 1–9.
35. Anderson, L.W.; Krathwohl, D.R. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*; Pearson: Upper Saddle River, NJ, USA, 2001.
36. Tuan, Y.F. *Space and Place: The Perspective of Experience*; University of Minnesota Press: Minneapolis, MN, USA, 1977.
37. Deparday, V. Enhancing Volunteered Geographical Information (VGI) Visualization with Open Source Web-Based Software. Master's Thesis, University of Waterloo, Waterloo, ON, USA, 2010.
38. Tulloch, D.L. Is VGI participation? From vernal pools to video games. *GeoJournal* **2008**, *72*, 161–171. [CrossRef]
39. Nielsen, J. Participation Inequality: The 90-9-1 Rule for Social Features. Available online: http://www.nngroup.com/articles/participation-inequality/ (accessed on 19 September 2015).
40. Neis, P.; Zipf, A. Analyzing the contributor activity of a volunteered geographic information project—The case of OpenStreetMap. *ISPRS Int. J. Geo-Inf.* **2012**, *1*, 146–165. [CrossRef]
41. Neis, P.; Zielstra, D.; Zipf, A. Comparison of volunteered geographic information data contributions and community development for selected world regions. *Future Int.* **2013**, *5*, 282–300. [CrossRef]
42. Antoniou, V.; Schlieder, C. Participation patterns, VGI and gamification. In Proceedings of the Agile 2014, Castellón, Spain, 3–6 June 2014.
43. Saxton, G.D.; Oh, O.; Kishore, R. Rules of crowdsourcing: Models, issues, and systems of control. *Inf. Syst. Manag.* **2013**, *30*, 2–20. [CrossRef]
44. Budhathoki, N.R.; Haythornthwaite, C. Motivation for open collaboration: Crowd and community models and the case of OpenStreetMap. *Am. Behav. Sci.* **2012**, *57*, 548–575. [CrossRef]
45. Haythornthwaite, C. Crowds and communities: Light and heavyweight models of peer production. In Proceedings of the 42nd Annual Hawaii International Conference on System Sciences, Big Island, HI, USA, 5–8 January 2009.

46. Lakhani, K.R.; Lohse, P.A.; Panetta, J.A.; Jeppesen, L.B. The value of openness in scientific problem solving. *Biotech Bus.* **2007**, *18S*, 5533–5464.
47. Brabham, D.C. Moving the crowed at iStockphoto: The composition of the crowd and motivations for participation in a crowdsourcing application. *First Monday* **2008**, *13*, 1–19. [CrossRef]
48. Brabham, D.C. Moving the crowd at threadless. *Inf. Commun. Soc.* **2010**, *13*, 1122–1145. [CrossRef]
49. Budhathoki, N.R.; Nedović-Budić, Z.; Bruce, B.C. An interdisciplinary frame for understanding Volunteered Geographic information. *Geomatica* **2010**, *64*, 11–26.
50. Climateprediction.net. The World's Largest Climate Modelling Experiment for the 21st Century. Available online: http://www.climateprediction.net/ (accessed on 15 January 2016).
51. Mappiness.org.uk. Mappiness, the Happiness Mapping App. Available online: http://www.mappiness.org.uk/ (accessed on 15 January 2016).
52. AtrapaelTigre.com. Available online: http://tigaserver.atrapaeltigre.com/en/ (accessed on 5 February 2016).
53. Participatory Budgeting NYC. Available online: http://council.nyc.gov/html/pb/home.shtml (accessed on 10 February 2016).
54. Participatory Budgeting NYC—Idea Collection Map. Available online: http://ideas.pbnyc.org/page/about (accessed on 10 February 2016).
55. Dingsøyr, T.; Nerur, S.; Balijepally, V.; Moe, N.B. A decade of agile methodologies: Towards explaining agile software development. *J. Syst. Softw.* **2012**, *85*, 1213–1221. [CrossRef]
56. Wang, X.; Conboy, K.; Cawley, O. "Leagile" software development: An experience report analysis of the application of lean approaches in agile software development. *J. Syst. Softw.* **2012**, *85*, 1287–1299. [CrossRef]