even in this framework, there are decisions that remain firmly in the realm of the designer.

We see potential application of our work as an interactive planning tool. Ultimately, the deliverable would be not a 2D drawing or 3D model, but an interactive solver, which guides development while maintaining strategic relations and is adaptable to changing urban conditions. The tool is not complete, of course, but we believe it will be enriched by experimental deployment in a variety of contexts and territories.

Much work remains in the tailoring of a diverse catalog of inputs for adaptation to new environments and in the growth/phasing strategy. How do you seed a new city? And how do you change the "plan" according to the actual growth that materializes and the unexpected changes that arise? Some of these changes may be due to changing climate, population and cultural changes, changes in the flows of people and materials between neighboring cities, and new technologies in agriculture and energy production.

A primary obstacle to implementation of such a system is the current political-economic value system, which prioritizes land speculation and private development and downplays the actual cost of natural resources. This kind of myopic thinking has long driven the separation of our cities and farmlands, and has only been accelerated by industrial technologies.

It will take visionary municipalities to question the value of their land as it is currently framed, repositioning it as a vital energy source worth harnessing and managing. We have demonstrated one prototype for how this aim might be achieved. We hope we have shown that it is not only feasible, but a novel and provocative future for cities and city dwellers.

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A WEB-BASED GEOGRAPHIC VIRTUAL ENVIRONMENT FOR THE DELIBERATION OF URBAN PROJECTS FOR BRUSSELS

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ABSTRACT

In this paper, we discuss the potentials of affordable GeoWeb 2.0 applications to support the deliberation of urban projects. We first introduce the conceptual design of a web-based geographic virtual environment specifically developed for the Brussels–Capital Region in the framework of a long-term postdoctoral research project. Then, we present two alternative open-source prototypes for the implementation of this conceptual design and compare their usability with experts. Furthermore, we share our experiences from two field applications in the form of a brief case study and discuss the potentials of the proposed prototypes with a focus on their usability and supported forms of design empowerment.

1 INTRODUCTION

This paper provides a brief overview of our research efforts between 2009 and 2012, which were supported by the Brussels Institute for the Encouragement of Scientific Research. During this period, we focused on the design and development of a web-based geographic environment for the deliberation of the existing alternative urban development projects prepared for Brussels.

The motivations for our study were:

The need for integrated planning environments for deliberation and participation due to the problematic urban situation in Brussels: During the last century, a combination of urban policies caused the destruction of architectural heritage and the nature of the city, with a compromising collaboration of the public sector (also known as Brusselization) (Lagrou 2003). This trauma created a protectionist attitude among the citizens and strangled large-scale developments.

Potentials of alternative urban development projects as a reflective resource: Alternative urban development projects (AUDPs) simultaneously cover representations of the existing urban environment and imaginations of different realities. Thus they provide different frameworks for the discussion of the contemporary situation of the urban context (Pak and Kuhk 2009).

Potentials of Web 2.0: Web 2.0-based geographic technologies (GeoWeb 2.0) stand as strong alternatives to the traditional, linear, and hierarchical knowledge production methods. They are well positioned as a medium for facilitating dialogue and learning as well as communicative action (Roche et al. 2012; Hudson-Smith et al. 2009).

Based on the motivations above, we directed our efforts toward developing and testing GeoWeb 2.0 environments. We started our research with an in-depth review of the alternative approaches, AUDPs, and technological applications developed around the world. Based on this analysis, we created a conceptual design. Then, we implemented two GeoWeb 2.0 prototypes and rated their usability and fitness-for-purpose with experts and nongovernmental environmental organizations. Since it is impossible to include all of these in this paper, we will focus on the following questions:

- Can affordable GeoWeb 2.0 applications contribute to the creation and deliberation of urban projects?
- If they can, to what extent?

In this context, we will start our paper by situating our efforts within a bigger frame and relate them to the existing literature (Section 2). Afterwards, we will share the conceptual design of our web-based geographic virtual environment (Section 3). Next, we will present two alternative GeoWeb 2.0 prototypes as alternative affordable technological frameworks for the implementation of the conceptual design (Section 4). This section will also include the results of the usability evaluations of these prototypes.

In the next part of our study, we will share our experiences from our preliminary field tests in the form of a case study (Sections 5 and 6). In conclusion (Section 7), we will provide an overview of our findings and draw up future prospects.

2 SITUATING PARTICIPATION AND GEOWEB 2.0 IN A BIGGER CONTEXT

Urban planning and design are complex processes in which the decision makers are not often fully knowledgeable about the range of factors involved as well as the implications of their decisions (Simao et al. 2009). Therefore, in these practices it is necessary to promote *participation* and *mutual learning,* which require constructive conversation and coproduction (van der Veen and Altes 2011).

A significant number of studies have been dedicated to these topics, especially *public participation.* Among those, the most well-known classic is "the ladder of citizen participation" by Arnstein (1969). In her study, she identified eight participation levels through the lens of citizen power: *manipulation, therapy, informing, consultation, placation, partnership, delegated power, and citizen control.*

Connor, Dorcey et al., and Rocha have proposed their updated versions of the participation ladder, each focusing on slightly different aspects. Conner's point of view (1988) was oriented more toward *conflict resolution*, whereas Dorcey et al. (1994) proposed *ongoing involvement* and *consensus building* as the highest level of participation. Rocha (1997) placed political *empowerment* at the top and *atomic empowerment* at the bottom of her version of the participation ladder.

Overall, starting with Arnstein's ladder proposed in the spirit of 1968, it is possible to track a shift in the understanding of participation, toward democratization and greater empowerment and involvement of citizens. This shift is, of course, closely related to the theoretical shift or the "communicative turn" from rational planning to communicative and deliberative planning.

Senbel and Church (2011), in a relatively new study, stressed the importance of design empowerment and proposed a more "enabling" version of Arnstein's ladder. They proposed six "instances" of *design empowerment:* information, inspiration, ideation, inclusion, integration, and independence. The highest level of empowerment is independent design, when residents gain the capacity to create their own plans and visions and thus reach autonomy. This is followed by integration, which involves the coproduction of plans and proposals. Inclusion of the ideas and thoughts of the participants among other priorities, ideation (ability to generate and express ideas) about the future, inspiration triggering response to an alternative, and informing are the relatively lower instances of design empowerment.

In this study, we will use Senbel and Church's design empowerment (2011) as the key concept for discussing the supported participation levels.

2.1 Neogeography and WikiGIS

From the perspective of geospatial participatory technologies, it is possible to track similar layers of transformation regarding the production and dissemination of geographic information from top-down to bottom-up—referring to public participation GIS (PPGIS), from "requested production" to "voluntary production" (geocrowdsourcing), and finally toward the wikification of GIS and GeoWeb 2.0 technologies (also called neogeography) (Roche et al. 2012).

Relying on a combination of social software and information aggregation services, GeoWeb 2.0 technologies stand as a strong alternative to the traditional linear and hierarchical knowledge production methods. They are loaded with constructivist learning and production principles embedded in the ways they enable social knowledge construction. In this sense, they are well positioned to act as a medium for facilitating dialogue and learning as well as communicative action.

Preliminary examples of these kinds of initiatives are the Copenhagen municipality's *Indre By Lokaludvalg* web application; *Aloitekanava*, by the city of Turku, Finland; Bristol rising, by the city of Bristol, Connecticut; Civic Crowd, sponsored by the British Design Council; *Change by Us*, by the cities of New York and Philadelphia; spacehive, by multiple actors in London; *Lighter Quicker Cheaper*, in San Antonio, Texas; *MyCityLab* in Brussels; *Fix Your Street* in Dublin; Neighborland, SeeClickFix, *OpenPlans* (covering multiple cities), and the companies with the same names which are used for collecting ideas from citizens.

The real power of GeoWeb 2.0 emerges when it is utilized for the inclusion of knowledge acquired through lived experience, which had been granted less legitimacy in the past (Elwood 2006). Through technologies such as WikiGIS, alternative maps can be created by the public in an asynchronous and distributed manner to represent abstract forces shaping urban life—urban dynamics which are not usually accessible to designers and planning authorities (Amoroso 2010). In this way, multiple perspectives of social groups can be dynamically represented and (re)constructed. Therefore, GeoWeb 2.0 is more than just a repository of maps, images, and text. It is a strong and sustainable empowering mechanism, which invites people to decide on their future and reflect their individual points of view.

In this context, we have directed our research efforts toward the empowerment of the related actors by promoting the coproduction of plans and projects through alternative GeoWeb 2.0 environments.

In the next section, we will introduce our ideations of a web-based geographic virtual environment specifically tailored for analysis and evaluation of AUDPs for Brussels. By our conceptual design, we intend to support multiple levels of design empowerment (Senbel and Church 2011) such as independent design, integration, and inclusion as well as informing.

3 THE USE SCENARIO AND THE CONCEPTUAL DESIGN

During the development of our conceptual design, we have arranged various focus group meetings with the Brussels Development Agency (ATO), Environment Council (BRAL), and the Center for Informatics (CIRB). Together with these institutions, we have developed a use scenario considering the context provided in Section 2 and their specific needs.

In this scenario, the web-based environment is situated as an interface through which civil society and professionals can learn, exchange ideas, and shape future strategies. Besides containing AUDPs, this interface facilitates communication by allowing professionals to publish information on their development projects in a multimodal format. In this way, it encourages civil society to discuss, create ideas, and give feedback in reflective manner (Figure 1).

In parallel with the scenario development process, we have also made an in-depth analysis of AUDPs prepared for Brussels to determine their characteristics and collect the types of information they contain. The results of the analysis showed that urban development projects include:

- Textual information (i.e., objectives, definitions, and decisions)
- Two-dimensional design data (i.e., maps, plans, schemes, and photos)
- Physical and virtual 3D models (3D data)
- Temporal information (i.e., schedules and timelines)
- Location-based information (in the form of addresses)

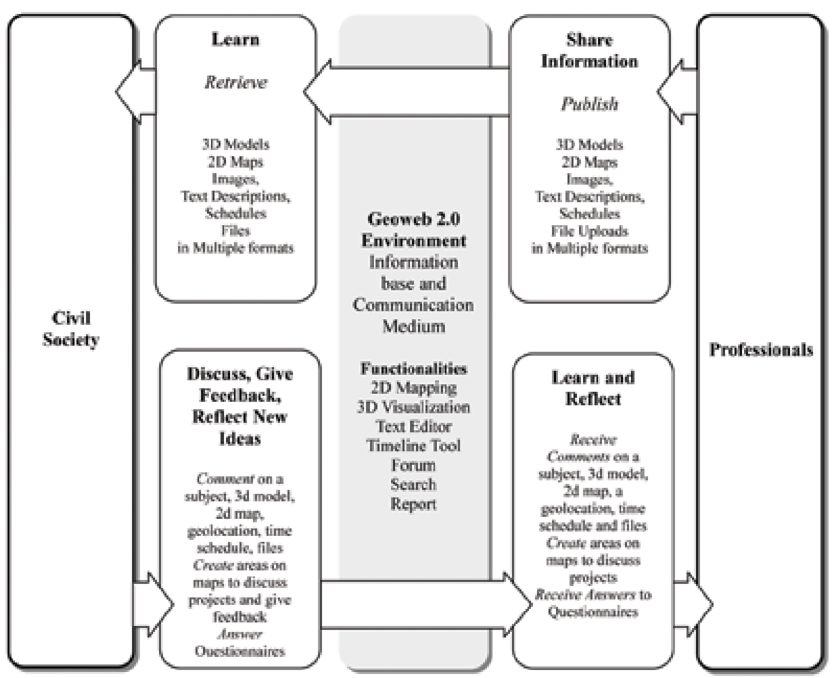

figure 1

figure 1

The primary use scenario, actions, and functions: reflection in action.

Considering these observations, the use scenario, and the feedback of the institutional actors (including a requirements analysis questionnaire), we have developed a conceptual design. This design is a web application hybrid, a "mashup" based on a combination of different representations and organized in two parts (Figure 2).

The interface on the left offers a 3/4D visualization window and an integrated time-based map, specifically addressing the geographic location. The built-in timeline below enables virtual time travel. Change of the environment through time can be observed through a variety of aerial photos and user-created/existing 3D models (when applicable). In this sense, the design can be considered as an open and developable 4D GIS interface.

The interface on the right foresees an interactive concept map and a hypertext window that serves textual data and images with search functionality. Concept maps are utilized to represent the conceptual attributes of AUDPs, revealing the complex relationships between different topics or tags defined by the users. Tagging function supports bottom-up collaborative ontology, building and establishing semantic relations between notions, which allows user-based interpretation of heterogeneous information. A text window with search capability is also available for the retrieval and visualization of long texts, such as strategic plans.

figure 2

3.1 Two Affordable GeoWeb 2.0 Prototypes for Preliminary Testing

As stressed in Section 1, for preliminary testing purposes we have created two prototypes (P1 and P2) supporting the functions described in the conceptual design phase.

Both of the prototypes employ the Google Earth/Maps Application Interface (API) as their primary visualization medium. The reason for this choice was that at the time of development, Google provided high-resolution aerial imagery and 3D city models to an unrivalled extent, including beyond the borders of Brussels.

Another rationale for relying on the Google API was the possibility of involving time as an additional dimension of representation and analysis.

Furthermore, using Google Earth/Maps API, it is possible to divide a large body of text into individual place-based strategies and geolocate them on a map as interrelated placemarks with explanations (Figure 3). As most of the information related to the AUDPs is location specific, geolocation can serve as the key integration tool for representation and discussion of the projects, including uniquely text-based plans.

3.2 GeoWeb 2.0 Prototype P1 (2009)

In this setup, the MediaWiki application is used a backbone for content management. It was preferred because it uses an extensible lightweight wiki markup language and contains a variety of functionalities including rich content, an editing interface, search function, media library, and application-programming interface. The system and the modules are based on free and open source software (except Google API).

figure 3

figure 2

The interface of the proposed web-based geographic virtual environment.

figure 3

The geolocated representations of the master plans for Tour and Taxis (on the left) and the EU Quarter (Ombudsplanmediater) (on the right).

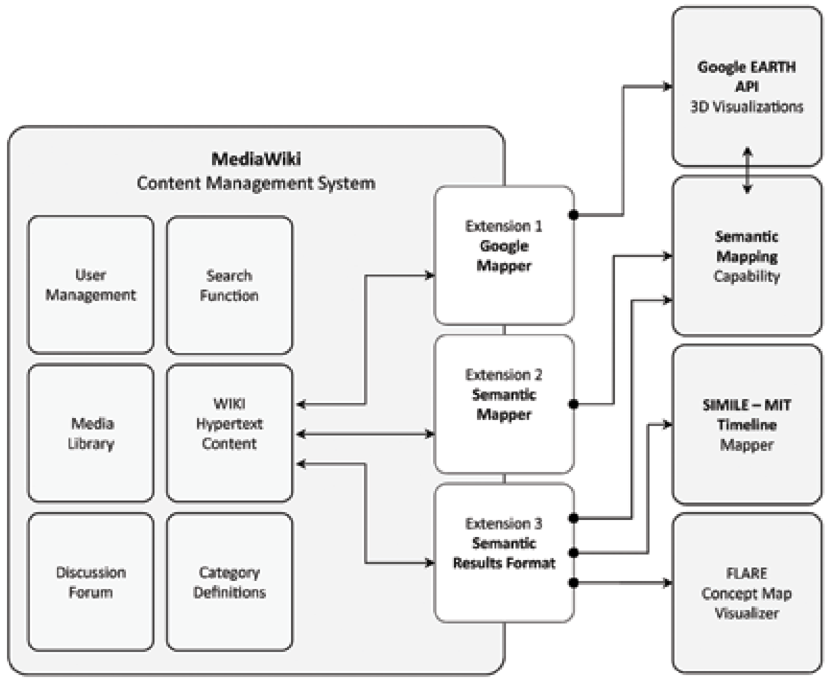

figure 4

Google API has been embedded in this system via the Google MediaWiki Extension developed by Evan Miller (2009), and Google Earth API has been included via JavaScript.

Semantic mapping functionality has been made available through the Semantic Maps Extension developed by de Dauw et al. (2009).

The timelines and concept maps have been connected to related SIMILE and Flare visualization libraries by the Semantic Results Formats Extension by Dengler et al. (2010). As an initial study, the proposed prototype has been tested in the Tour and Taxis and EU Quarter zones (Figure 5).

3.3 GeoWeb 2.0 Prototype P2 (2011)

Prototype P2 is based on more than 20 open source content management modules and other custom applications (Figure 6). OpenLayers serves as the key library and the content management module for creating location-based information as well as complex geocoding and visualization. It provides the ability to connect to any mapping API available, including Google Maps, Bing Maps, and OpenStreetMap.

figure 5

figure 4

Schematic description of the GeoWeb 2.0 Prototype P1 (Pak and Verbeke 2012 forthcoming).

figure 5

Preliminary implementation of Prototype P1.

In this setup, jQuery and its user interface (UI) library provide abstractions for low-level interactions as well as advanced effects and themeable widgets. Geotaxonomy is used to attach geo information (latitude, longitude, bounding boxes, etc.) to taxonomy terms. Similar to the first prototype, the Flare library has been integrated into the system, this time through jQuery.

4 TESTING THE USABILITY OF PROTOTYPES 1 AND 2 (DIAGNOSTIC EVALUATION)

Before testing the prototypes in the field, we wanted to evaluate their usability. With this purpose, we have conducted tests with six experts who actively work in the planning field. The first prototype (P1) was tested in 2010, and these results have been considered during the design and implementation phases of the second prototype in 2011.

In both tests, we chose to follow the diagnostic usability evaluation method that has been offered by the UsabilityNET (2010) to identify usability problems and gain an understanding of the difficulties that users face. In this context, we have chosen the following quality measures and metrics (which also relate to ISO/IEC 25062 (2006)):

- unassisted task effectiveness
- number of user errors
- number of system errors
- number of assists

Afterwards, we defined a task scenario and asked the participants to perform 14 tasks that represent basic interactions related to the task scenario. These included basic tasks such as log in and search, retrieve an AUDP topic, edit and format it, add a map to the discussion, add a placemark and mark an area on the map, place multiple maps on top of each other, and log out.

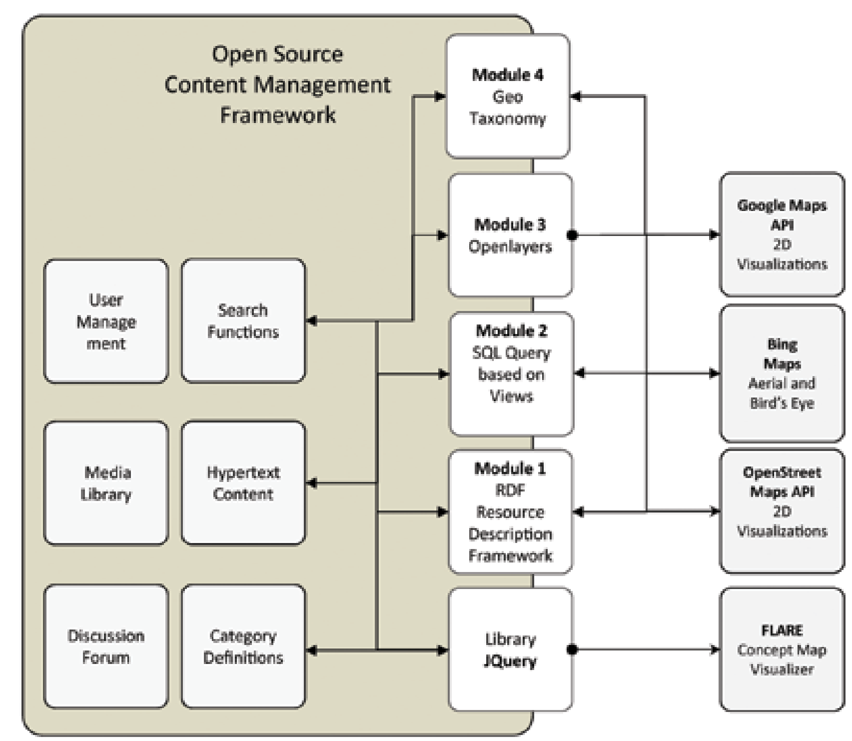

figure 6

figure 6

Schematic description of the GeoWeb 2.0 Prototype P2.

Table 1: Observation results for the task scenario for Prototypes P1 and P2

	Total Task Completion Time		Task Accomplishment Rate		User Errors		System Errors		Help Requests	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Participant 01	9' 05"	5' 30"	85.71%	100%	2	0	1	1	3	2
Participant 02	10' 27"	4' 55"	100%	100%	1	1	1	1	0	1
Participant 03	12' 34"	5' 38"	100%	100%	2	0	1	1	4	1
Participant 04	14' 21"	7' 53"	100%	100%	2	0	2	1	2	5
Participant 05	9' 53"	3' 41"	100%	100%	1	0	1	1	0	1
Participant 06	15' 41"	8' 26"	100%	100%	5	0	1	1	5	1
Averages	**12' 16"**	**6'01"**	**97.61%**	**100%**	**2.17**	**0.16**	**1.16**	**1**	**2.33**	**1.83**

According to the analysis results, using the first prototype (P1), five out of six participants successfully completed all of the tasks, which led to an average task accomplishment rate of 97.61 percent. An average of 1.16 user errors were observed for each task set. In this test, a majority of the errors were made during the execution of two specific tasks: import a map and place multiple maps on top of each other. Copying and pasting map codes were difficult for the users. This problem significantly contributed to the average number of help requests made by the users (2.33) and the average task completion time (12 minutes 16 seconds).

During the Prototype P2 testing, all of the participants successfully completed the tasks. The average number of user errors was 0.16, significantly lower than the average of the P1 tests. In line with this observation, the average number of help requests (1.83) and average task completion time (6 minutes 1 second) were lower than the first (P1) test.

In both of the usability tests, at least one system error was detected. These were invisible to the users (they did not lead to a freeze, crash, or denial of service) but had a negative effect on task completion times.

After the task observations, the participants were given an after-scenario questionnaire (ASQ). In this survey, the participants were asked three questions related to ease of completion, time spent to complete the tasks, and overall support information.

In Prototype P1 testing, the participants' overall satisfaction with ease of completion was 62 percent. They were 69 percent satisfied with the time they spent to complete the tasks. For Prototype P2, these rates were slightly higher; satisfaction with ease of completion was 79 percent, and satisfaction with time spent was 73 percent.

Besides the usability tests briefly reported above, we have evaluated the prototypes in real-life scenarios. In the next section, we will present the results of two field applications in which Prototype P1 and P2 were tested with the contributions of the Brussels Environment Council and Green Belgium organization.

5 FIELD TESTING PROTOTYPE P1: THE BRUSSELS ENVIRONMENT COUNCIL—GREEN NETWORK PLANNING

This study was specifically initiated to test the potentials of Prototype 1 as a medium for collaborative analysis and planning. The Brussels Environment Council (BRAL) used this prototype to develop an extended (unofficial and alternative) version of the Brussels Green Network Plan.

In February 2011, a specific server was set up and the web application was made available to the participants. The BRAL team, consisting of six experts, had specific requests for mapping. They wanted to be able to use previously created plans, such as the land use plan, the biological evaluation map, and the older green network plan, as a layer to work on which could be turned on and off. Moreover, they asked to be able to observe their own plans on the older plans and combine them together as they wished.

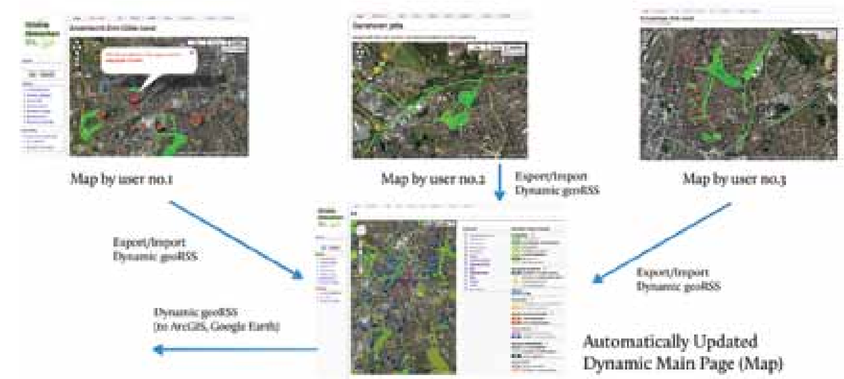

figure 7

figure 7

Field testing Prototype 1: BRAL green networks application.

The default open source prototype and the Google Mapper extension—in their original form—did not include this functionality, so we had to develop custom applications and modify the extension to enable layering and create an "input-output" flow mechanism. In the modified version, when a user creates a map and saves it, it is possible to visualize it on any page using the import and export workflow (Figure 7). This system operates as a geo-RSS feed engine and allows the dynamic representation of user maps. This means that the exported maps can be imported and organized into layers.

One of the most interesting aspects of this study was the inclusion of crowdsourced information into the planning process. Specific maps created by gardeners were made available and used as a basis to discuss the planning of future green networks. As a result of three months of collaborative work, a collective map was created (Figure 8). Two alternative views of the study were exported in both ArcGIS and raster image formats, which can be printed one meter high and one meter wide.

At the end of May 2011, the final plan was presented and handed over to the Environmental Management Institute study office responsible for the preparation of the green networks section of the sustainable regional development plan. In this context, the knowledge that has been created through Prototype P1 was officially transferred to planning authorities. This case can be considered an example of a simple "independent design" (level 6) in the design empowerment scale of Senbel and Church (2011).

6 FIELD TESTING PROTOTYPE 2: ANALYSIS AND DISCUSSION OF THE GREEN AREAS WITH THE GREEN BELGIUM ENVIRONMENTAL ORGANIZATION

This initiative was taken in January 2012 together with the Green Belgium organization, which manages an educational network of 20,000 youngsters who are members of environmental clubs.

In this study, Prototype P2 has been used as an instrument of dialogue between the youth movement of Brussels and green area managers. Establishing such a dialogue was essential because of the age and power differences between the related parties. In this setup, youngsters in Brussels are invited to represent their opinions and ideas using maps (geotags and polygonal zones), images, and text. Moreover, the managers of green spaces (including the park wardens and gardeners) also express their ideas and the problems they face in a similar format. These two kinds of participants

figure 8

can monitor what others think and write their own reviews.

Due to the incredible variety of user profiles, the scope and content of the user contributions are channeled toward three major lines: favorite places, dreams, and improvements. All types of content are aggregated and overlaid on the main page (Figure 5). On the map, individual categories are represented as icons and clustered when needed to promote ease of use.

An important quality is the multilingual nature of the contributions, which have intentionally been harvested together to encourage communication between French-speaking and Dutch-speaking youngsters as well as managers.

Using Prototype P2, it was possible to dynamically generate maps through an import/export flow mechanism provided as default with the OpenLayers library. In this way, it was possible to create easy-to-understand thematic maps such as "dream maps," "favorite maps," and "problem/improvement maps." These dynamic maps are seen by the Green Belgium organization as a basis for establishing a sustainable reflective dialogue between youngsters and managers. Overall, this case relates to levels 1–4, "information, inspiration, ideation, and inclusion," in the design empowerment scale of Senbel and Church (2011). It is still in progress, and we will reveal more details and findings during the conference presentation.

7 CONCLUSIONS AND FUTURE DIRECTIONS

In this study, we have introduced a conceptual design for a web-based geographic virtual environment and presented two alternative GeoWeb 2.0 prototypes as alternative affordable technological frameworks for its implementation. Furthermore, we have shared the results of usability tests for each prototype and experiences from two field applications in the form of a case study.

These two cases were different in terms of the user profiles, predesignated contribution types, and consequently, the level of design empowerment (Table 2). In the first case, Prototype P1 was used by the NGO BRAL for the analysis and planning of green networks. This study illustrates a type of participation in which experts from an NGO collaboratively develop a plan considering the informal maps created by gardeners as well as various official plans. The final product was a serious and independently produced plan that included analysis results and specified zones.

Table 2: Comparison of two field applications.

	Case Study Prototype 1 BRAL / Green Networks	Case Study Prototype 2 Green Belgium
User Profiles	Expert planners working for an NGO	Youngsters and city managers
User Contribution	Analysis, zoning, and zlternative plan development	Ideas, problem consultation, and preferences
Participation/ Design Empowerment	Independent design (level 6)	Information, inspiration, ideation, and inclusion (levels 1-4)

In Case 2, we have tested Prototype P2 with the Green Belgium organization. This field study was based on a different participation strategy. The users were neither designers nor planners. Their contributions were in the form of ideas, problems, and/or preferences. These were intended to be used to improve the quality of management and policy making through information, inspiration, and inclusion as well as for monitoring the effects of plans/policies.

Overall, in terms of functionality, both prototypes allowed customized communication and adjustment of access rules and communication levels to the user profile. On the other hand, the prototypes were found to be significantly different in terms of usability, Prototype 2 being far more usable (Section 4).

Using Prototype P1, the experts were able to complete an independent collaborative planning task.

figure 8

The final green networks plan overlaid on the green layer of the land use plan, including the crowdsourced data.

figure 9

figure 9

Field testing Prototype 2: Green Belgium Jeunes Natuurlijk! study.

However, due to the lack of an efficient native what-you-see-is-what-you-get editing interface, and the (relative) complexity of the Wiki platform and the integrated mapping interface, it was not efficient. For this reason, in its current form, Prototype 1 cannot be considered suitable to be used by laypeople at design empowerment levels that require relatively higher levels of interactivity such as inspiration, ideation, and inclusion.

Unlike Prototype P1, Prototype P2 provided a highly compatible, customizable interface with rich mapping support. Therefore, it may be considered to be better fit-for-purpose at all design empowerment levels, from information to independent design.

In conclusion, the two cases presented in our study can be seen as preliminary examples of giving a voice to nongovernmental organizations, accepting user-created data as a valid resource, and including this data in planning practices. The proposed prototypes successfully supported the subsequent communicative processes, and the initial outcomes conformed to the intentions of our studies.

In the future, considering the multimodal nature of planning processes, creating a new framework for combining face-to-face activities with computer-mediated activities to form an integrated planning process may significantly improve similar practices. Overall, the ultimate success indicator for similar future GeoWeb 2.0 applications will be the extent to which the plans and messages of the participants are taken on board by the authorities.

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WORK IN PROGRESS

EMERGENT CONSTRUCTIONS:

EXPERIMENTS TOWARD GENERATIVE ON-SITE DESIGN AND BUILD STRATEGIES USING CUSTOMIZED DIGITAL DEVICES

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ABSTRACT

This paper presents ongoing research investigating integrated design-and-build workflows using generative design strategies and custom-built fabrication devices.

The aim of the research, which is being developed through a series of experiments and workshops, is to explore scenarios in which these workflows can produce emergent architectural structures that are highly adapted toward the intended performance within their specific context and site.

The research has produced a number of installations and prototypical structures that test the practical and theoretical dimensions of the methodology explored. It introduces intriguing new scenarios in which the architect's role is focused on an indirect control of the process of design, allowing for a more open-ended method of negotiation between structure, users, and environment.