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ORIGINAL PAPER

Developing a web-based, collaborative PPGIS prototype to support public participation

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Abstract Web-based Public Participation Geographic Information System (PPGIS) tools, among others, have now been widely recognized as an efficient integral of sound planning processes to support the public involvement. However, Geographical Information System (GIS) alone cannot make the planning process more participative. Demands for web-based PPGIS tools, integrated with other information and computer-supported cooperative work (CSCW) tools, have rapidly become increasingly important for supporting public participation. This paper discusses a prototype development based on a research project that looks into integrating CSCW principles and groupware tools with web-based GIS. The study has been put into the context of public participation in municipal planning and development. A discussion of key design and implementation issues concludes the paper.

Keywords Web-based · Public participation · Geographical information system · Collaboration · Municipal planning

Introduction

A growing number of web-based public participation GIS tools and planning support systems have been developed to support public participation and decision-making in various planning processes. Many of these tools have been combined or integrated, to some extent, with some collaboration or decision-making tools. In most cases, these systems are based on existing commercial and proprietary software tools, and some are still in the research prototype stage. More recent developments have shown an increasing adoption of open source solutions.

Planning support systems (PSS) are designed for planners and primarily focus on coupling computer analytical tools and simulation models with visual displays for land use and transportation development options and environmental consequences of the choices (Brail and Klosterman 2001). By-laws, in many municipalities and local governments, require public participation in their decision-making processes for municipal planning and development activities, and it is expected that the wide use of these PSS by the public will be seen in the next decade.

An examination of existing practices of getting the public input in municipal development projects reveals that insufficient prior access to information required for public input and a lack of effective, innovative communication channels other than attending public meetings still remain to be the major huddles (Li et al. 2004). Web-based PPGIS tools, among others, have now been recognized as an efficient integral of sound planning processes. However, any planning support system cannot consist of GIS alone (Klosterman 2001). Solving these problems and challenges therefore requires that PPGIS be integrated with other information technologies into existing, if not reengineered, participation and decision making processes of municipal development.

This paper presents an effort towards developing an integrated solution that facilitates online public participation in municipal planning processes. Special attention has been paid to the integration of different web-based information and groupware technologies with GIS functions to provide tools for (1) efficient participation mediation and feedback, (2) automated participation and decision-making procedures,

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and (3) synchronous and asynchronous collaboration between participants for better understanding and communications. A research prototype has been developed based on the GIS-enabled Virtual Public Meeting Space (GeoVPMS) model/framework introduced by Li et al. (2007). Comparing with other similar works, some of the unique features include support of synchronous collaboration and participation, design for seamless integration of online public meeting space, and better access to the information required for informed participation.

The next section describes the shift from traditional public participation approach to e-participation and briefly reviews the development of PPGIS in the context of this research. After summarizing some of the key results from the preliminary designs and studies, the authors discuss the prototype implementation in terms of available functions, limitations, and opportunities for future research.

Background

The shift to electronic participation

Public participation in the traditional planning process has long been realized through an iterative process of public meetings and reviews, of which the public and the interested parties are notified via public notices. The process provides opportunities for public input, gathered through public meetings, telephone inquiries, letters, email, and faxes (Kingston 2002). Although public meetings are still one of the mostly used forms of public participation (Lowndes et al. 2001; Wiedemann and Femers 1993), they are often criticized and are considered as the least understood methods (McComas 2001). According to Baker et al. (2005), the success of public meetings depends on some critical factors, such as effectively notifying and educating the public before the hearing; carefully planning the meeting; giving a clear, media-rich presentation of the issues; properly facilitating the meeting; and conducting appropriate follow-up.

Macintosh (2004) states that the advancement of information technology, especially the Internet and the World Wide Web, the use of Information and Communication Technologies (ICT) to broaden and deepen political participation by enabling citizens to connect with one another and with their elected representatives is becoming ever prevalent. This new e-participation paradigm uses a number of tools and models to realize equivalent e-processes of the traditional participation activities, such as open houses, public hearings, opinion surveys, and notification mails (see Fig. 1). For instance, voice conference, e-newsletter, emails, online polling and feedback, video chatting, online notification, and discussion forums are new forms of open houses, neighborhood notification, fax, opinion surveys, awareness campaigns, telephone interviews, etc. While groupware tools, such as email, electronic meeting systems, online audio/video conference, listserv, discussion forum, and white boarding, are among early adoptions in e-participation, Web 2.0 tools such as wiki, blogging, and social networks have recently been explored (Haklay et al. 2008; Antunes et al. 2009; Abdalla and Li 2010; Boulos et al. 2010; Boroushaki and Malczewski 2010). Under this new paradigm, traditional participation processes need to

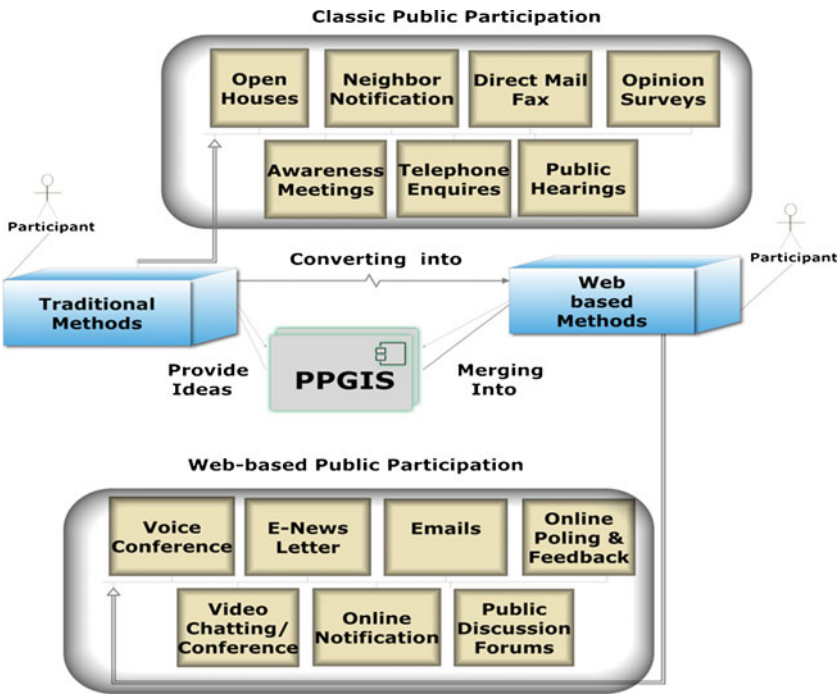

Fig. 1 Traditional and web-based participatory processes

be reexamined, and some may have at least been extended, if not redesigned.

The shift to e-participation happened at about the same time when GIS was greatly explored as a potential data exploration and decision-making tool for supporting public participation. Traditional desktop GIS, however, does not have "right-to-the-point" tools to support interactions among group members, such as shared graphics, group modeling, and group consensus building tools, and lacks the capability to support collaborative spatial decision making and public participation. To address this issue, efforts have been made under the umbrella term Public Participation GIS to study how GIS could support public participation for different application processes that require public input [see Craig et al. (2002) and Sieber (2006) for recent summaries of these efforts].

Web-based public-participation GIS

Since 1992, a growing body of research has emerged in the use of geographic information systems, collaborative spatial decision-making systems, and web-based mapping and GIS systems to encourage and promote more informed citizen involvement in government policy formulation and decision making (Obermeyer 1998). While early efforts focused on using GIS under controlled conditions to facilitate group decision making (Jankowski and Nyerges 2001; Jankowski and Nyerges 2003), more recent developments have employed Web mapping with feedback (e.g., "geo-referenced" annotations) as a means of engaging citizens (Kingston et al. 2000; Voss et al. 2004; Tang 2006; Sidlar and Rinner 2007; Rinner et al. 2008; Sidlar and Rinner 2009; Rinner and Bird 2009; Abdalla and Li 2010; Sani and Rinner 2011).

Laurini (2004) defines the web-based application as a medium for exchanging information, ideas, and maps between all participants. Web-based participatory methods are more convenient (in the sense of time, location, and information), and can be either uni-or bidirectional. The unidirectional approach is also known as traditional web participatory approach (Bryant and Wilcox 2006; Lemos 2006). In this approach, web pages are designed with only static contents and therefore supported only one-to-many interaction. Bidirectional or two-way directional web participatory approach supports many-to-many interaction. Web-based collaborative GIS and GIS-enabled discussion forums are the examples of bidirectional participatory approach and have many-to-many interactions (Tang 2006). Apparently, the bidirectional participation requires a more collaborative participation process with the support of properly designed collaboration tools.

PPGIS research used to be focused on asynchronous use of maps in the participation processes. More recently, the importance of incorporating capabilities of synchronous sharing and exploration of spatially enabled alternatives and feedback has been discussed (Laurini 1998; MacEachren et al. 2001; Li and Ma 2006; Li et al. 2007; Chang 2010). A key component of such capability is to enable participants to collaborate on a shared map view in real time while discussing the planning scenarios and their impact. When combined with other groupware tools such as chat, whiteboard, and audio/video conference, its benefits of enhancing public participation can then be realized.

Examination of selected web-based PPGIS applications

Table 1 shows a list of online PPGIS applications selected for the evaluation. Five PPGIS applications out of nine are considered/selected (see Appendix 1 for the complete list of applications examined) for the evaluation purposes. The selection (see applications 1–5 in Appendix 1) was made in consideration of their contribution to the field, relevance to the proposed research, and whether or not they were available online and functional with GIS functions integrated for better participation and decision making.

Selected online PPGIS applications have been examined based on a number of criteria, including intended use, sharing of documents, exchanging of information (participation), real-time messaging with collaborative map support, GIS functionalities (mapping functionalities), effective communication of spatial context with or without forum-based support, security implementation, collaborative decision making support, and interactivity of the user interface.

The evaluation and selection criteria are somewhat similar to the criteria that were adopted by the different researchers such as Chang (2010), Tang (2006), Zhao and Coleman (2006), Rinner (2006), and Ma (2006). Bevan (1995) stated that comparing usability of systems that have similar main functions should be considered as a part of successful (quality) implementation of the system design. The examination of the existing PPGIS applications allowed us to learn what the limitations of the current practices and applications frameworks are. It also helped to decide what kind of communication channels/functionalities and participatory approaches should be included in the proposed research work.

Table 1 presents a comparison chart constructed based on the above evaluation criteria. All GIS-based systems were designed to enhance the public participatory approach in the planning and development related discussions. Intended use of these systems is to facilitate the nonprofessionals and the general public. Except for Virtual Slaithwaite, which supports vector-based maps, other applications use raster image maps. In Interactive landscape, GIS-enabled online discussion forum (GeoDF) and Orange County (mapping) systems maps are produced using map servers (ESRI ArcIMS and University of Minnesota Map-Server), whereas in Virtual

Table 1 Comparison of selected PPGIS applications

Features\ Web PPGIS	Function List	Virtual Slatith	Orange County Info Map	Interactive Landscape	Argoo Map	Geo DF
Info Centre/Management						
	Document Transfer:	○	○	○	○	○
	Search Document:	○	○	○	◑ Search Discussion Contribution	◑ Manually Search
	Meeting Documents: *By laws, Meeting Minutes, Meeting Location Finder using Map, Agendas etc.*	○	○	○	○	◑ Consulted Document (PDF) Supported data
	GIS Data Download:	○	○	○	○	○
Communication/Information Delivery						
	Email:	●	●	●	●	●
	Map Attachment:	○	●	◑ Print PDF	●	●
	Newsletter:	○	○	○	○	○
	Feedback Polls:	○	○	○	○	○
	Discussion Forum:	◑ Initiate Discussion	○	◑ Initiate Discussion	○	●
	View Participants Feedback:	●	○	●	●	●
Synchronous Participation & Collaborating Decision Making						
	Real-time Messaging: *Meeting Attendees & Facilitator*	○	○	○	○	○
	Map sharing:	○	○	○	○	○
	Video Conferencing:	○	○	○	○	○
	Web Meeting:	○	○	○	○	○
	Video Chatting(IRC):	○	○	○	○	○
	E-White boarding:	○	○	○	○	○
	Screen Sharing:	○	○	○	○	○
Notification/ Scheduling						
	Meeting Event Handling:	○	○	○	○	○
	Event Notification:	○	○	○	○	○
	Calendaring:	○	○	○	○	○
	Share Scheduling:	○	○	○	○	○

Table 1 (continued)

Features\ Web PPGIS	Function List	Virtual Slatith	Orange County Info Map	Interactive Landscape	Argoo Map	Geo DF
GIS Functionalities						
	Exploring Spatial Data	Not Fully		Not Fully		
	(with Forum support):	Supported Forum activities i.e., Starting Topics, Forums etc.		Supported Forum activities i.e., Starting Topics, Forums etc.		
	Exploring Spatial Data (Non- Forum):					
	Organization of Map data: *using Spatial Database, etc.*			--	--	Geo-datbase & MySQL used for Textual Data
	Map Browsing: pan, Zoom					
	Map Printing:				--	
	Spatial Query:				--	
	Commenting Tools: *Sketches, Annotation*				Annotation	
Security Implementation						
	Login Authentication:				--	
	Forum Security:				--	--
	User Rights & Privileges:				--	--
User Friendly						
	HCI Implementation : *Strive of Consistency*					
	Informative Feedback:				--	--
	Error Prevention:				--	--
Mapping Server Support						
	Maps Generating:	Using Perl Scripts	Mapserver	ArcIMS	Scripting	ArcIMS
OSS-based Technology						
	Programing/ Scripting Modules:	Java Applet-based	Dhtml	Javascript	Javascript	PHP-based Modules
	OSS APIs:				--	--
	OSS SDK:				--	--

Table 1 (continued)

Features\ Web PPGIS	Function List	Virtual Slatith	Orange County Info Map	Interactive Landscape	Argoo Map	Geo DF
Online Site Admin (CMS)						
	Site Admin: *Meeting Documents & Location*	○	○	○	○	○
	GIS Comp. Admin: *Adding Maps Layers, tools*	○	○	○	○	○
	Feedback Admin: *Creating Voting/Poling Questions etc*	○	○	○	○	○
	Forum Admin: *User's rights & Privillages, Abusive Usage Control*	○	○	○	○	○
	Collaborative Module Admin: *Host Controling, Meeting Invitation, No of Attendees*	○	○	○	○	○
Supported Platforms						
	Unix Family	--	--	--	--	--
	Windows Family	●	●	●	●	●
Legends						
		● - Has Feature ◐ - Has Some ○ - Doesn't have -- Unidentified				

Slaithwaite and Argumentation prototype, maps are produced using PERL scripts and Java Application Programming Interfaces (APIs).

Not all the systems support two-way discussion forum framework for public participation except for GeoDF and Argumentation map prototypes, which have some forum-style functionalities, so the public can search the discussion forum for exchanging the information. Both Interactive landscape planning system and Argumentation map prototypes were designed using open source software technologies and, therefore, provide a relatively cost-effective solution as compared to others (Tang 2006). All systems' interfaces seem to be interactive (user-friendly) to some extent, e.g., the main interfaces of Argumentation map and Virtual Slaitwaite were designed using Java applets programming, but other systems' interfaces were designed using Dynamic HyperText Markup Language (DHTML) and JavaScripts.

Groupware is technical implementation of computer-supported collaborative work (Chang 2010). Interests in linking groupware with PPGIS have mainly focused on limited asynchronous collaboration, such as email and discussion forums.

Preliminary work

The proper implementation of a participatory process identifies different motivations for the decision maker to initiate participatory planning in connection with municipal development projects (Edelenbos 1999). In addition, the municipal participatory planning process is a local community-based planning process with citizen's involvement, which benefits from the insights, knowledge, and support of local residents. Successful design and implementation of any collaborating system for public participation require a thorough investigation of functional requirements, technological options, and operational constraints. The following summarizes the results of early work in the ongoing research program that addresses some of these issues and lays the foundation for the prototype development.

Conceptual framework

As mentioned in the previous section, access to the information required for public input, physical presence in public meetings, and well-designed technical presentations are among major factors affecting the efficiency and effectiveness of public meetings. A review of existing PPGIS frameworks reveals that they all focus on using GIS as a supporting tool to facilitate the public input process (Evans et al. 1999; Ventura et al. 2002), including augmented forums to support multiway communications among the participants, such as Argumentation Map (Rinner 1999).

GeoVPMS is a multifunctional GIS-enabled, collaborative participation framework, which integrates different information technology tools to support participation and collaboration activities before, during, and after public meetings. It centers on public meetings. Before public meetings, the major activities focus on information access, communication, and collaboration. During the meetings, real-time access to the meetings and their presentations, as well as interaction with the meetings, becomes major tasks. After the meetings, the focus shifts to the presentation of syntheses of public input, access to decisions, and receiving of feedbacks. GeoVPMS provides two streams of support: (1) asynchronous participation in which web-based GIS and geo-referenced forum techniques are used to support any-time public input and discussion and (2) real-time collaboration, in which synchronous collaborative GIS processes are implemented by applying CSCW or groupware applications principles and using digital multimedia tools to share comments and explore spatial data.

Figure 2 illustrates an extended framework of GeoVPMS with its three major components: project information center (including project documents and public meeting management), collaborative web meeting infrastructure, and spatially enabled exploration and discussion. The framework can be easily translated into web-based, modular designs of implementation systems.

As shown in Fig. 2, the project information center manages and provides public and interested groups with access to information related to ongoing municipal planning and development projects, i.e., notifications of the public meetings, meeting outputs, public input, and project related documents. The spatially enabled exploration and discussion allow participants to explore scenarios using the spatial data handler and to discuss issues by a GIS-based forum. The Collaborative Web Meeting Infrastructure, together with open map API's and collaborative map sharing component, provides anytime, anywhere (around-the-clock), and real-time access to the public meeting among those who are not able to attend physically.

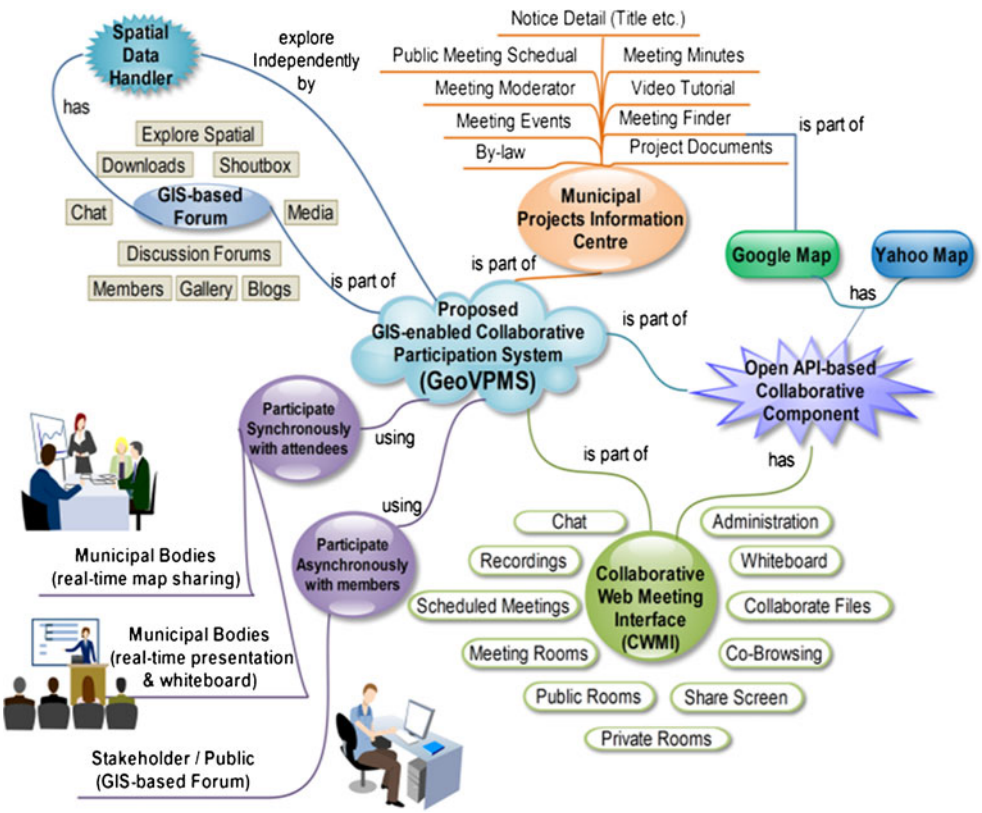

Fig. 2 Detailed conceptual framework of GeoVPMS

Functional requirements for participation and collaboration

The planning and participation process of municipal development projects normally involve project proponents, local citizens, city staff, and agency participants. Each of these groups may have different requirements in terms of information access, level of participation, and need for collaboration. Figure 3 summarizes some requirements for participants with respect to the web-based GIS-enabled virtual public meeting system.

GeoVPMS allows the municipal projects under public consultation to present, to the public through a single, consistent, and intuitive interface, all the workflows required for public participation. In order to satisfy the above requirements, major functional aspects are studied and defined as follows:

- Notice boards for public meeting information, e.g., public notices, meeting schedule, and location
- Public notification based on subscriptions and/or location-based selection of citizens affected by the project
- Participation registration and tracking facilities, if the identification of the participants is required for their input
- Electronic communication support, including email, chat rooms, online survey, and thread discussion forums linked to maps showing planning scenarios
- Video conferencing: real-time streaming of public meetings with the support of synchronous sharing of PowerPoint presentations, map displays, and chat, etc.
- Collaborative map sharing with necessary GIS functions to allow participants to collaboratively explore the planning scenarios with the required spatial contexts and to enable the public meeting presenters to share their map displays during public meetings
- Document repository and access support for all project-related materials, including regulations, planning documents, minutes, presentations, etc.

All of the above should be organized around and/or linked to individual projects under consultation.

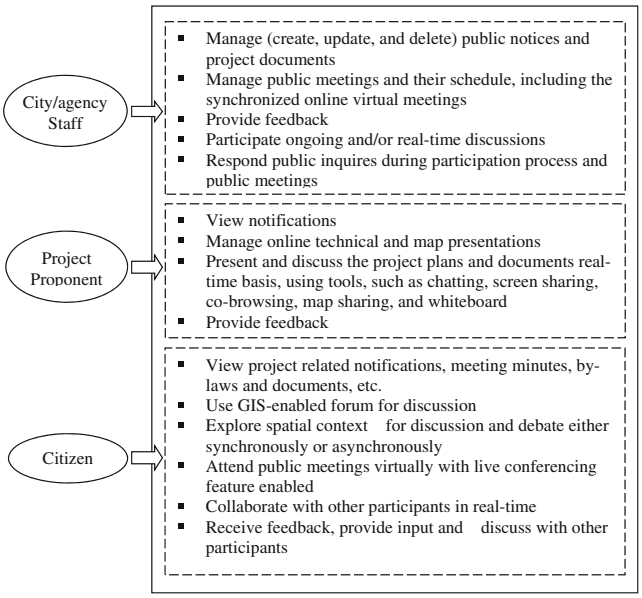

Fig. 3 Participant's requirements in relation to GeoVPMS

Prototype development

In order to develop a prototype of GeoVPMS, a generalized environmental assessment process of municipal development projects is selected. The process is a modified version of the Municipal Class Environmental Assessment process, adopted by many municipalities in the province of Ontario, Canada (OGRA 2000). Figure 4 depicts this process, which needs to be followed during the planning of each individual municipal development project.

Prototype system design

From users' point of view, the GeoVPMS can be seen as a virtual environment where they can access information, participate in the planning and decision making process, collaborate with other participants, attend public meetings, and review the outcomes of the public participation processes. A higher level architecture of the prototype is shown in Fig. 5. In this architecture, data and information stored in the database are organized by "project," and participation functions are linked to the individual project when it is set up.

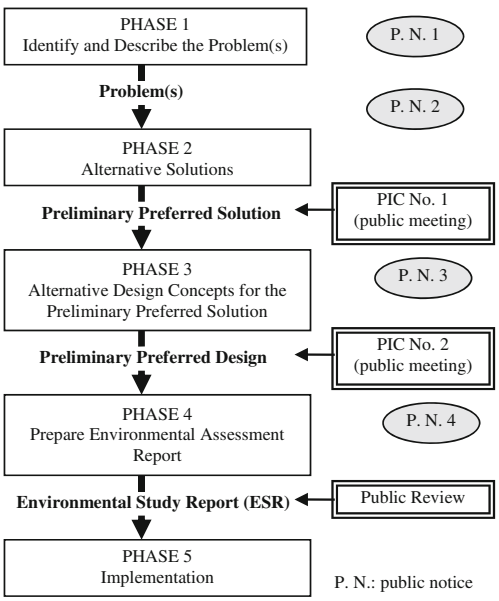

Fig. 4 Modified municipal environmental assessment process (source: Li et al. 2004)

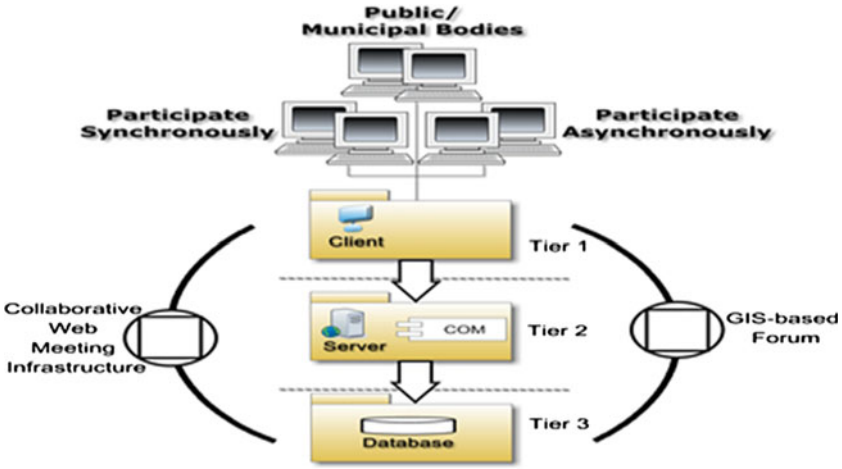

Fig. 5 Architecture of the prototype GeoVPMS

Figure 6 shows an implementation view of the prototype using various open source technologies. Presentation layer provides front end application interfaces. All client-sided web interfaces are written in Extensible HyperText Markup Language, DHTML, and JavaScript languages, whereas server-sided scripts are written in Active Server Pages, PHP Hypertext Preprocessor, PHP-HTML, and Extensible Markup Language programming languages. The application layer holds all business logics related to the proposed public participatory system, including configuration of mapping components required to handle the geospatial data, open mapping API's, and other GIS related services. The data access layer mainly contains systems' attribute database, as well as a spatial database (PostGIS) component using PostgreSQL database management system.

Implementation of participation and collaboration functions

The initial prototype is developed to demonstrate four important aspects that help improve the participation process: awareness, information access, participation, and feedback. The following describes the software implementation of some functions that support these aspects. Public notices and related information are obtained from the official website of a regional municipality in, Ontario, Canada (http://www.peelregion.ca/news/notices/) and are used for a mock-up walkthrough

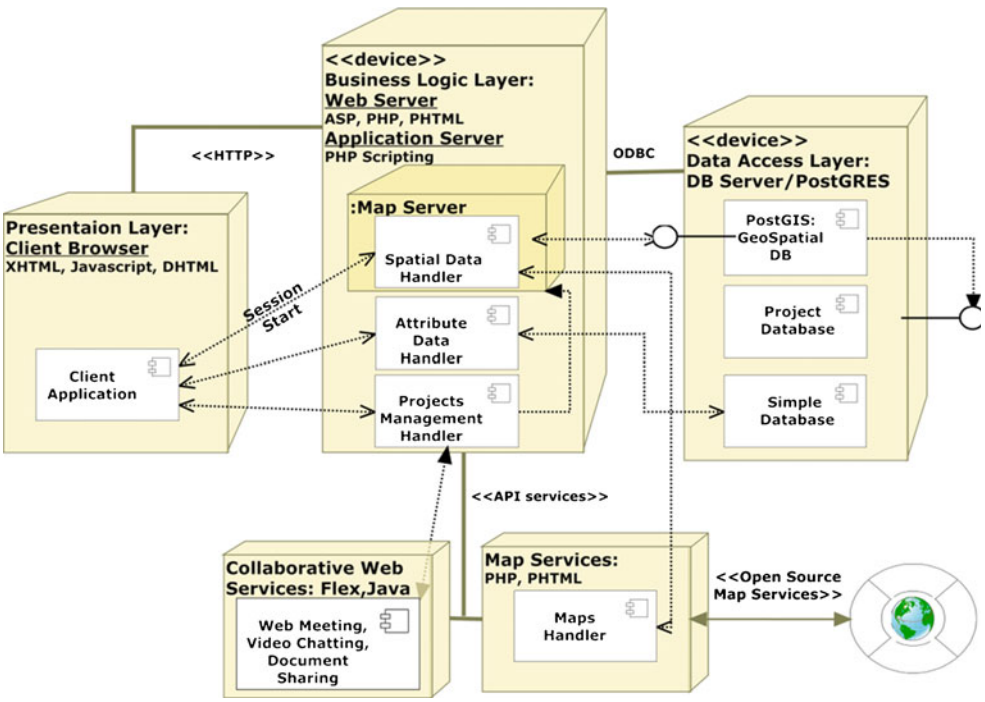

Fig. 6 Implementation view of the prototype architecture

Fig. 7 List of municipal projects under public consultation

of the prototype. A demo site of the prototype may be accessed at: http://www2.simal.ryerson.ca.

Municipal project listing

One of the requirements of this GeoVPMS is to manage multiple municipal planning new or ongoing projects that involve high level of public participation. Because all projects share the same characteristics and require the same set of functions to support collection of public input and collaboration, a common interface is designed for and applied to all projects. The interface of any project can be accessed through a project list (see Fig. 7). The project list also acts as a navigation tool to allow participants to easily switch between different project interfaces.

Info centre: documents resource centre

Access to project information enables the participants to build necessary understanding of the project under consultation and is vital to successful participation. The Web has been proven to be an excellent platform for information dissemination. The *Info Centre* component manages documents, meeting agendas and minutes, by-laws and regulation documents, and the contact information of each project in one place (see Fig. 8). The public can easily browse and view the information organized here and, if appropriate, replay public meetings or previous collaboration sessions. The contact information includes the name of the moderators or authorities, their email, phone/fax numbers, etc.

Notification: public notice system

Online public notice system, see *Notice Details*, plays two important roles: (1) notifying the registered participants of upcoming public meetings/events using newsletter function and allowing the interested citizens to explore project information and become prepared for the public meeting and (2) providing a platform for

Fig. 8 A detailed view of a municipal project interface

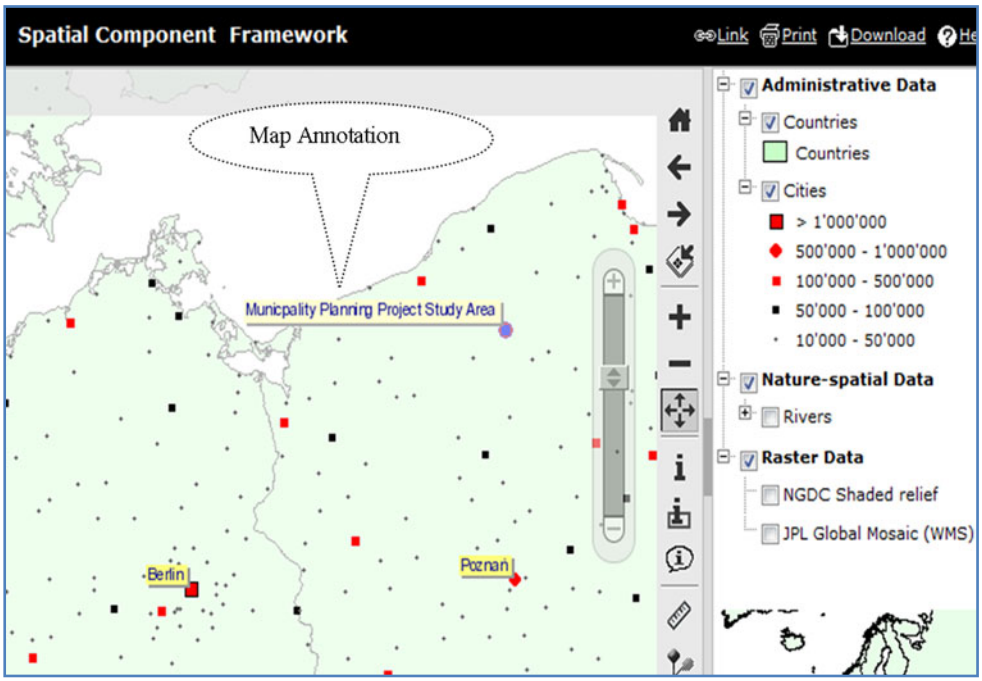

Fig. 9 Interface of the early prototype spatial component

continuous soliciting of the public input and presentation of the final results (Li et al. 2007).

The notification component currently implemented, as shown in Fig. 8, also provides location mapping function in which a participant can find his/her way or direction to the public meeting place. For this direction service, open source API's from Google Maps with a mashup of a PHP server-side scripting language were used

Spatial component

A spatial data handling component was implemented with some basic GIS functions to explore planning and development scenarios within geographical contexts of the projects. This component is especially designed for those participants who are more technically savvy and would like to examine alternatives at his/her own pace, for example, exploring "what-if" scenarios using the simple web-based GIS component. Figure 9 illustrates an earlier interface that is now under redesign to include more functions required by municipal planning.

Collaborative map sharing

A picture is worth one thousand words. For many municipal planning related discussions, having a map

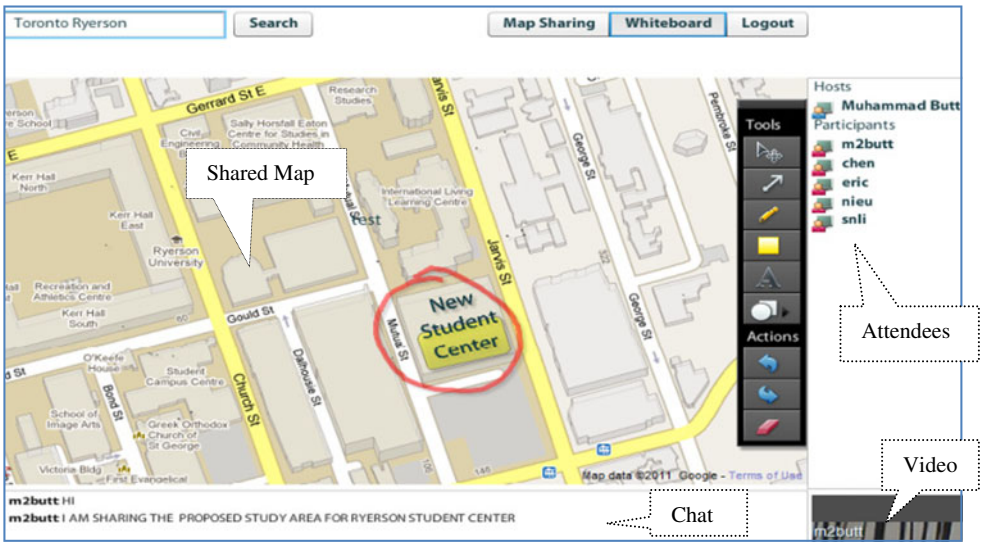

Fig. 10 Real-time collaboration using Google mapping API

or map-based displays of different scenarios shared by participants greatly facilitates their discussion on some issues. For this reason, a collaborative map-sharing component was developed to allow participants to collaboratively explore geographic context of the projects while discussing some issues. Figure 10 shows the main web interface of this component.

The component integrates a number of features, including shared map, chatting, video conferencing, and white boarding, into a single interface that can be invoked and run in a new window. It is intended to be used by a group of participants who have a common topic to discussion, which requires access to map displays to make their points clearer. Any participant can initiate a collaboration session and invite others to join. All participants who join the session are given the right to use whiteboard tools.

This synchronous (real-time) collaboration function is currently implemented using Google maps as the base map, and authors are working on how to add project-related GIS data into the display. Another issue is to record the session history so it can be replayed at a later time.

GIS-based discussion forum

As mentioned previously, GIS-enabled or augmented discussion forums have been explored in a number of studies. One of the key characteristics of these tools is to link threaded postings to a map or geo-reference the comments posted by participants. GeoVMPS also includes a GIS-based forum, as illustrated in Fig. 11, which has some unique functions. The GIS-based forum component was developed using open source solution technologies such as PHP Bulletin Board and Flexible Internet Spatial Template. Its organization of threaded postings is similar to any discussion forum found on the Internet.

The forum allows participants to share and input their ideas anywhere (anytime) using a typical web-based discussion forum, but with the extended capability to invoke a Spatial Data Handler to add their comments on the map. Alternatively, they can save or load map sessions, which can be added in discussion. A user can store the map session and attach saved session to his/her postings in the discussion forum, so to share with others. Other participants can view or alter the saved map information and repost it.

Virtual public meeting interface

The virtual public meeting is a supplement to the real public meetings in order to give those who cannot physically attend the meetings a chance to participate. The idea is to stream real public meetings online and provides facilitating tools to enable online participants to question and interac, and to allow presenters to integrate their electronic presentations and maps into the virtual meeting environment. Figure 12 shows a view of the virtual public meeting interface.

By incorporating the collaborative map sharing components, the interface allows the presenters to share map

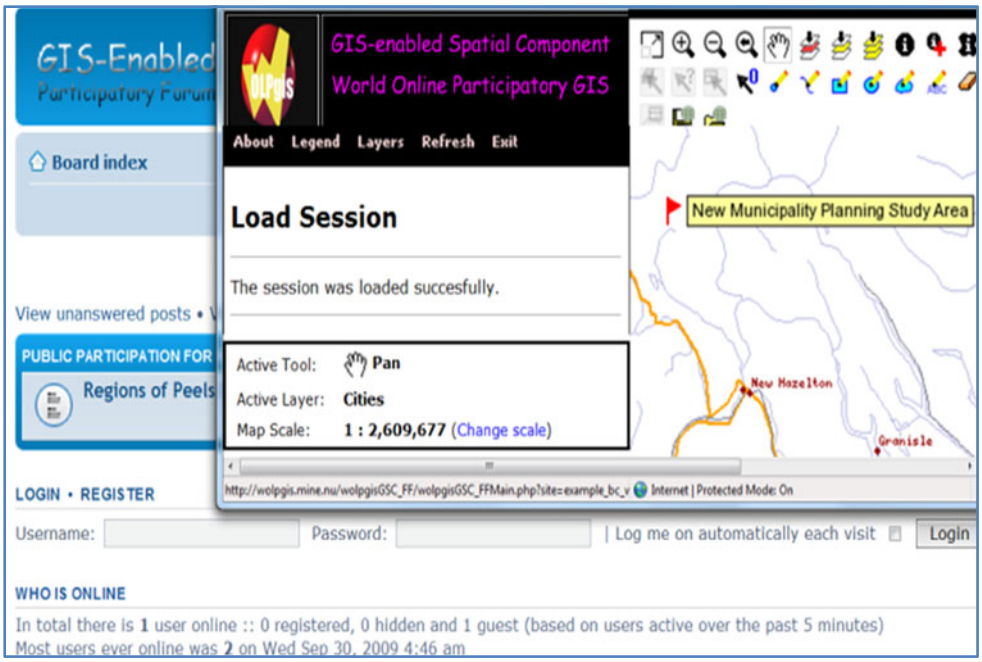

Fig. 11 Discussion forums with access to annotated maps

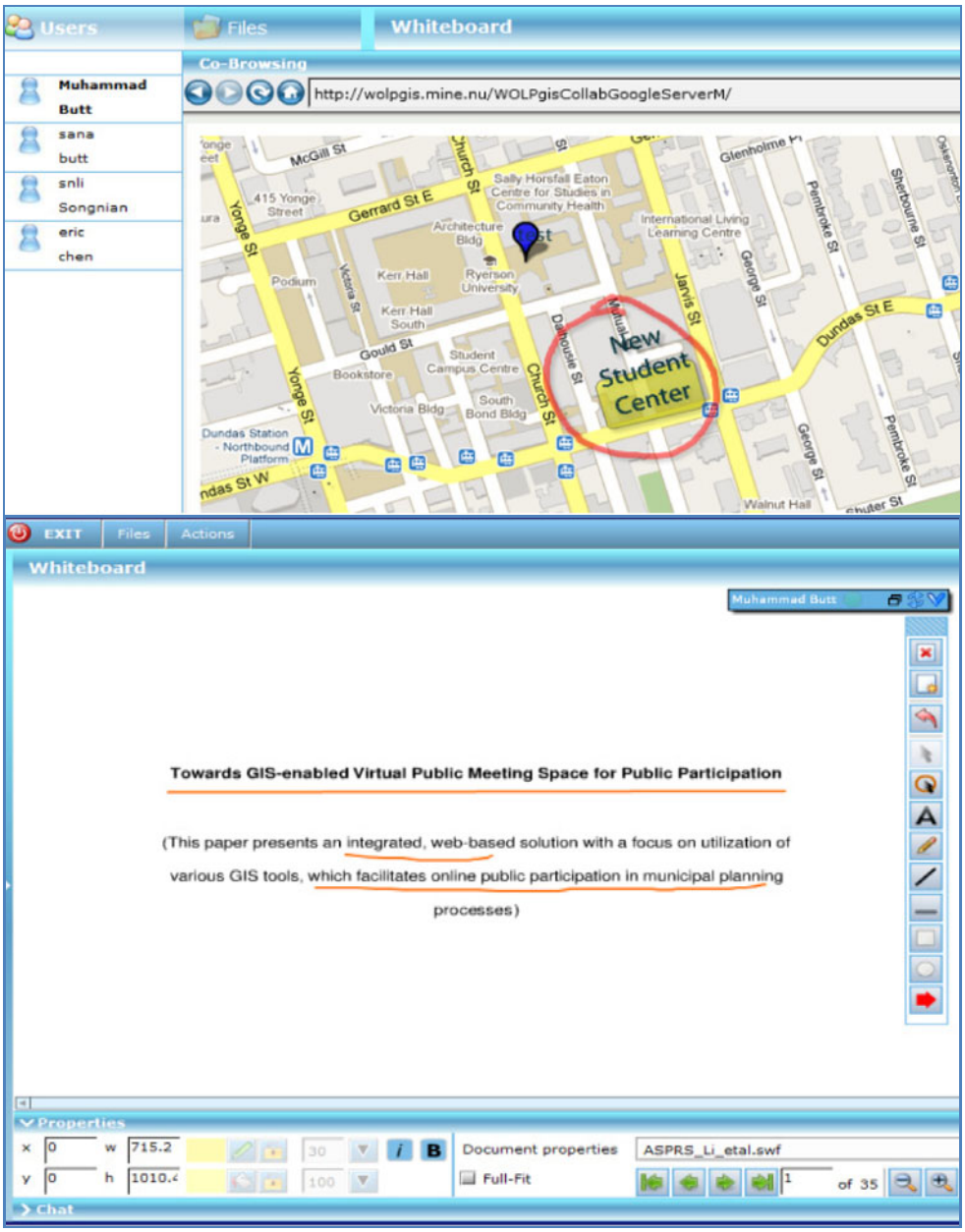

Fig. 12 Virtual public meeting interface with real public meeting streams

displays in the same way as PowerPoint slides are shared on screens in many other web conferencing systems. The presenters can also use the built-in whiteboard tools to select features, add annotations, and draw graphics. However, during the virtual meetings, only the presenters can initiate the tools and control how the map data should be displayed to facilitate their presentations.

Discussions

This study introduces collaborative methods to encourage both synchronous and asynchronous participation approaches that support public involvement during municipal planning and decision-making process. Although a prototype as a proof of concept is designed and developed based on a GeoVPMS, there are still some key design and implementation issues that need to be further studied and resolved in the next step of the ongoing research before its deployment into the real-world scenario testing (i.e., system usability and performance evaluation, etc.). Some of the social and implementation issues faced during the study and prototype preliminary development are discussed in the following paragraphs.

One of the main implementation problems authors are foreseeing will be finding/filling the role of a person/group who is going to manage (e.g., update the project info into an attribute and spatial databases, etc.) the GeoVPMS once it will be deployed to the real world project scenario. Li et al.

(2004) states, ideally, the PPGIS application should be run and maintained by the municipal government and open to the consultants to load required data and information, whereas at the same time, government agencies are responsible for broadcasting public notification for meetings. However, current research has not dealt with this issue; therefore, further investigation is required together with actively involve end-users at later stages of the study.

Authors also expect some sociological issues and forthcoming risks, which may occur after the system deployment, e.g., facing difficulties by the users (public, city staff, and project proponent, etc.) for accepting and responding to the Web GIS, multimedia, and groupware technologies in connection with traditional participatory practice. These potential hindrances also led us to use the modular/component-based design implementation (allow and support the incremental implementation of the developed methods), which may be helpful in acquainting users with the shift to new technologies. However, this issue might need further inspection at later stages of the study.

One of the organizational issues is to deal with the privacy of municipality data, which was another concern during the design and development of the prototype. It necessitates the needs for protocols to be implemented that manage the privacy of municipal project data in connection with its copyright protection law. Setting the rights and privileges of the users at the different levels of their interaction with the system may resolve this issue.

Public participation is another big issue to consider during the system development in terms of interface designs, interactivity, and quick system responsiveness. In addition, special consideration is taken while providing interactivity and user-friendly interfaces by following a common set of rules from the Human Computer Interaction (HCI) field. Authors anticipate that with the implementation of HCI principles, such as strive for consistency using Cascading Style Sheet for fonts and colors, informative feedback using Java-based dynamic effects of tooltips, and error prevention using JavaScript-based popup messages, the system can provide more efficient, interactive and user-friendly interfaces to the end-users. GeoVPMS is composed of different participation components, which require or involve some sort of GIS-based functional integration (some technical knowledge is required to better utilize the tools). Therefore, design of such interfaces by keeping in mind the expertise of the naive users or nontechnical participant can be a big challenge during development.

GeoVPMS is an effort of technology integration from a technological perspective. Some (main) key design issues related to technologies used during the development of the prototype are described as follows.

During the system development, special attention was taken during the selection of enabling technologies as it plays an important role for increasing throughput (quick response), scalability, and design/maintenance cost of the system. For example, GeoVPMS spatial data is handled by an open source PostgreSQL object relational Database Management System (DBMS) that supports broad scale interoperability with spatial data handling using PostGIS extension in relation to other open sources DBMS as well as commercial geographical database management systems, which are quite expensive (Sano et al. 2003; Wangmutitakul et al. 2003; Wangmutitakul et al. 2004; Wuttiwat et al. 2003). Although at this stage, due to the lack of availability of the spatial data related to the real projects, the prototype was not demonstrated using spatial database PostGIS.

As the spatial component was designed initially for the proof of concept, GIS mapping functionality is limited; therefore, it needs to be enhanced by embracing more carefully selected functions required by municipal planning. Moreover, the real-time (synchronous) collaborative participation component is currently developed and implemented using Google maps as the base map, whereas based on the proposed PPGIS framework, any open mapping APIs (Yahoo, Bing, MapQuest, OpenStreet, etc.) should able to be used to develop/show the prototype synchronous participatory behavior and/or function for the cobrowsing municipality spatial data during discussion. As discussed earlier, in the future, authors are working on how to add municipal project-related GIS data as a background layer into the display.

Collaborative map sharing component was initially designed for enabling "spatial" virtual meeting space for the public participation along with WebGIS support. This component was developed using Google map API, Adobe Flex, and flash collaboration service technologies. Adobe Flex platform provides and builds real-time collaboration-enabled applications rapidly as it offers a complete Software Development Kit, which contains ready-to-use components, designed with collaborative workflow. The issue at this moment is that flash collaboration service in the Adobe platform does not support screen or media sharing protocols (another design challenge, which is not considered during the initial development). The purpose of this function is to record the session history during the public meeting seminars so it can be replayed and shared at a later time. However, the issue might need further inspection at later stages of the study.

Interactive virtual public meeting component (having combined functionality of collaborative map and documents sharing) was designed and developed using JAVA and Adobe Flex platforms. Integration between two platforms was a big challenge in relation to their suitability, connectivity, and scalability in the beginning of the development. For instance, Flex code requires a flash player to run or execute, whereas Java

requires Java Virtual Machine to execute the compiled code. Other problems common to all online application developments are the compatibility of different web browsers (i.e., Internet Explorer, Mozilla, Google Chrome, etc.) and Internet connection speed. The benefit of using JAVA platform will resolve the issue related to screen and video sharing protocol of Adobe flash collaboration services. Therefore, the share/record screen module will be developed and added as a recording function along with a meeting planner component (useful to the city staff for scheduling public meeting reminders or auto-notification) using JAVA as a part of the virtual public meeting interface at later stages of the research and prototype development.

Another technical concern is related to the spatial data compatibility and availability, as both attribute and spatial data are required for the setup of GeoVPMS's municipal project listing and GIS-based forum spatial components. As the spatial component of GeoVPMS is currently tested and supported using shapefiles (*.shp, *.shx, and *.dbf) format so we assume the forthcoming concern related to the conversion if the availability of the spatial data (of municipality related projects) will be in a different format.

Finally, but not the last, the usability evaluation and performance testing for measuring the functionality of the prototype will be a major future task during the research. This will need to be performed for evaluating a number of important aspects:

1. To determine whether or not the designed framework will help in improving the public participation during the municipal planning process by maximizing public substantial input
2. To evaluate that to what extent the system will be usable and to fulfill participatory needs of the current practice
3. To deduce how public responds in adopting the ICT-based means of participation
4. To assess the amount of training required for nontechnical staff and/or participants to use the system's components efficiently
5. To find out how the city staff, higher authorities, and project proponent handle the citizen's feedback in timely fashion for the quick and/or effective decision making and determine how quickly the system responds to participant
6. To find out how citizens' access to information, communication channels, level of public participation, and the overall decision-making process may be impacted or influenced by adopting GeoVPMS, in relation to traditional participatory approaches (Li et al. 2007).

In addition, to get the proper feedback and have the answers to all the above-mentioned questions, it is necessary to implement the system in real world scenario as a case study and/or pilot project for part of the research.

Conclusions

The research reported in this paper brings together GIS, groupware, the Web, and other web-based information technologies, into an online virtual public meeting space to provide a supplementary solution for improving public participation. Craig and Elwood (1998) states, "if more people were involved in developing the plan, the more likely the plan will appropriately address issues that are important to the municipality". The prototype of GeoVPMS aims at providing a web-based virtual environment that encourages more people to get involved in municipal planning processes.

GeoVPMS subsystems are designed to provide both synchronous and asynchronous support of participation, by integrating GIS functions in all aspects of public participation, including notification, information access, participation, and feedback. Similar to other PPGIS, GeoVPMS does not make the decision itself but can help improve participation and the decision-making process.

The effectiveness of such a system in supporting public participation, especially using synchronous participatory approach that provides a virtual platform through which live public meetings/seminars, spatial data, and information can be accessed anywhere and anytime (Bailey and Grossardt 2010; Cammack 2007; Doyle et al. 1998). Furthermore, it gives meeting attendees online access to their work, convenient web-based mapping, and the ability to increase collaborative decision making via real-time participatory functions, e.g., open API-based maps cobrowsing, screen sharing, seminar recording, video streaming, and easy project documents sharing.

GeoVPMS framework is designed and implemented using Open Source Software (OSS)-based technologies to minimize potential cost (i.e., a huge early investment and high licensing cost) required to implement the system, which provides the somehow cost-effective solutions for small municipalities with limited or inadequate financial resources. There is a debate among some groups of people about the negative aspects (e.g., stability, scalability, maintenance, and reliability, etc.) of the OSS technologies, which was well considered while its selection during the development of the prototype. As the prototype development is based on object-oriented procedures (reusability), further enhancement of the prototype is practicable.

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Appendix 1

Table 2 List of selected application for evaluations

No	Application	Description	URL
1**	**Virtual Slaithwaite United Kingdom**	The Slaithwaite Public Participation Geographical Information System is redesigned using JAVA in 2003. This system was designed to accumulate citizens' ideas and comments. The users had the window (of opportunity) to write their ideas as well as thoughts on any point or location on the map using add text tool. These comments were represented with small dots (flags) and can be viewed by any user for participation (Evans et al. 1999). The user can use some other GIS mapping tools' functionalities, for example, map navigation can be performed with zoom and pan tools.	 http://www.ccg.leeds.ac.uk/slaithwaite/
2**	**INFOMAP Orange County Interactive Mapping**	The system (InfoMap) offers access to several types of property, land use, and other information for Orange County in Florida, USA (Steinmann et al. 2004). The intended use of this PPGIS application was to facilitate the citizens. The system was developed as PPGIS to identify the citizens' views or comments regarding their county. In this way, municipal government got a brief idea of their citizens' concerns (i.e., future coming plans related to municipality planning and development).	 http://ocgis1.ocfl.net/Geocortex/Essentials/Web/Viewer.aspx?Site=InfomapPublic

Table 2 (continued)

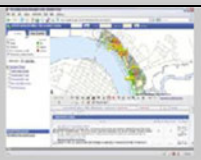
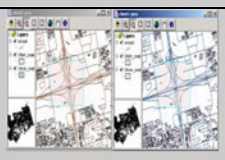
No	Application	Description	URL
3**	**Interactive Landscape Plan Königslutter am Elm (Lower Saxony, Germany)**	The interactive landscape planning system "Königslutter am Elm" is an online public participation geographic information system sponsored by the Federal Agency for Nature Protection (FANP, Lower Saxony, Germany; http://thuja.land.uni-hannover.de/). This online PPGIS provides access to the public with several types of information regarding landscape planning for the area Königslutter am Elm. It was developed to complement the traditional public participatory approach. The intended use of this PPGIS application was to facilitate the citizens as well as non-professionals. Although this GIS-based application has almost the same GIS functions as to those of the system discussed earlier (i.e., INFOMAP etc.), it still has more creditability due to its cost-effective feature. This system was designed using open source software (OOS) technologies. University of Minnesota (UMN) MapServer generates maps and simple images on the map layer and MySQL database server handles textual and spatial data.	 http://thuja.land.uni-hannover.de/ Currently, the demo is not available, last accessed in Dec 2010,
4**	**Argumentation Map (ArgooMap)**	Conceptual model of argumentation model was introduced by Rinner (1999). A prototype system to support discussion based on maps. Discussion contributions are structured to facilitate users understand the evolution of ideas. Annotations are geographically referenced and linked to geographic features.	 Downloaded at: http://sourceforge.net/projects/argoomap/ Demo is not available online http://141.117.104.183/argoomap/test/about.htm
5**	**GeoDF**	The GIS-enabled Online Discussion Forum (GeoDF) has been introduced by Tang as a prototype system for spatially-related discussions (Tang 2006). The software intends to facilitate the general public to participate in the ongoing	 http://www.vrm.ca/do

Table 2 (continued)

No	Application	Description	URL
		discussion of spatially-related issues. Discussion contributions are structured to facilitate users understand the evolution of ideas. They are geographically referenced and linked to geographic features.	cuments/ACFAS09_tang.pdf Demo is not available online; evaluation is based at available literature on the Web.
6	**GeoLink**	A synchronous approach is developed to support collaboration among users (Chang 2010); Prototype was introduced by Chang in 2005 and redesigned in 2010 with more 3d-based functionalities. GeoLink is a light-weight, object-oriented and extensible application. This application support two clients work collaboratively in one machine on real-time basis.	 http://www.simal.ryerson.ca Demo is not available online; evaluation is based at available literature on the Web.
7	**Shaping Dane's Future, U.S.**	A prototype system that allows users to use the system to visualize maps of the town of Verona and/or download GIS data onto participant's computer to create maps or further analysis of the spatial data.	http://www.lic.wisc.edu/shapingdane/resources/resources-home.htm
8	**CartoVista**	CartoVista is a flexible architecture that makes data publishing and management very simple while allowing you to produce rich mapping applications.	http://www.cartovista.com/cartovista3/Montreal.html
9	**GeoNB**	GeoNB is a collaborative project led by Service New Brunswick's Land Information Secretariat. The system objective is to facilitate the sharing of provincial geographic data and services among government departments, industry, organizations, academia, and the general public.	http://www.snb.ca/geonb2/index.html

**Applications (1-5) were selected and considered for the evaluation purposes that meet the selection criteria adopted by the authors

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