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Analysis and design of a GIS-enabled virtual public meeting space using UML for participatory municipal planning

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ANALYSIS AND DESIGN OF A GIS-ENABLED VIRTUAL PUBLIC MEETING SPACE USING UML FOR PARTICIPATORY MUNICIPAL PLANNING

by

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A thesis presented to Ryerson University
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ABSTRACT

The main aim of this research is to develop and test Web-based Public Participation Geographical Information Systems (WebPPGIS) to enhance public involvement and participation in municipal planning and decision making. The objective is based on the belief that by providing citizens with access to information and data in the form of maps and visualisations they can make better informed decisions and it can immerse them into the spatial decision making process.

This thesis presents a prototype implementation serving for spatially related discussions which is based on the GeoVPMS (GIS-based Virtual Public Meeting Space) model introduced by (Li et al., 2007). Moreover, a prototype has been analysed, designed and implemented using UML (Unified Model Language) approach to demonstrate a Web GIS-based architecture with utilization of various open source GIS and other OSS (Open Source Software) tools. In addition, it depicts a cost effective model of n-tier (multi-tier) Web integrated application prototype that can facilitate online public participation in municipal planning and development processes. Its components include online GIS-based participation forum as well as notification system enhance communication during spatially-related discussions in municipal planning and manage all kinds of notices among members as well as general public participants. Furthermore, the spatial data handling components used in this prototype is designed to help the public to explore the spatial contexts related to the issues under planning with and without accessing the forum, whereas this contribution makes the prototype more effective and successful. In addition, the prototype is demonstrated with a scenario of public participation in spatial planning using Region of Peel's data.

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LIST OF ABBREVIATION AND ACRONYMS

AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
AWT	Abstract Windows Toolkit
CORBA	Common Object Request Broker Architecture
COM	Common Object Model
CSCW	Computer Supported Cooperative Work
DBMS	Database Management System
DBF	Database Format
DFM	Data Flow Model
ESRI	Environment Source Research Institute
EOC	Emergency Operations Center
GeoVPMS	GIS-enabled Virtual Public Participation Meeting Space
GIF	Graphics Interchange Format
GIT	Geographic Information Technologies
GIS	Geographic Information System
GUI	Graphical User Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
ICTs	Information and Communications Technologies
IFM	Informational Flow Model
IIS	Internet Information Services
JPEG	Joint Photographic Experts Group
LAN	Local Area network
NCGIA	National Center for Geographic Information and Analysis
OCX	OLE Control Extension
OGC	OpenGIS Consortium
PDF	Portable Document Format
PHP	PHP Hypertext Preprocessor

PPGIS	Public Participation Geographic Information Systems
PDA	Personal Digital Assistant
RPC	Remote Procedure Calls
QA	Quality Assurance
RDBMS	Rational Database Management System
SDSS	Spatial Decision Support System
SDK	Software Development Kit
SQL	Structured Query language
TCP/IP	Transmission Control Protocol/Internet Protocol
WCS	Web Coverage Services
WFS	Web Feature Services
WYSIWIS	What You See Is What I See
XML	Extensible Markup Language
XHTML	Extensible Hypertext Markup Language

CHAPTER 1 INTRODUCTION

1.1 Background

Municipal planning and development is an important and complex decision making practice for every local/municipal government. By laws, public participation in planning and development related issues, are major concerns nowadays. These issues may be resolved with Web-based participatory planning approach. According to Huxhold (1991), "good decisions are the best composition of good information". Based on a survey (Lowndes et al., 2001), public meeting is one of the major means of improving public participation. It's undoubtedly true that public participation relies on efficient notification, participation and feedback. In the fast and rapid age of this modern technology world, holding public meetings or establishing public information centres virtually, with the help of Geographic Information System (GIS) and Web technology (World Wide Web), would recognize as the enhanced ways of gathering public input for the planning and development of a municipality (Tang, 2006).

It has been well perceived that the recent advancement in the communication technologies of the technological global village, World Wide Web (WWW) and GIS have changed many facets of the traditional way of public participation (Allen et al., 2003). As stated in Meredith (2000), appropriate gathering of data and information, robust connection to decision-making process and better tools for getting input into decision-making process can play vital role in public participation.

In the last few years, we have seen a growing number of Public Participation Geographic Information Systems (PPGIS) applications to facilitate municipality groups and individuals. PPGIS provides a virtual space for spatial analyses during municipality planning and development with public input (Wong and Chua, 2001). Nowadays, several online PPGIS are available to enable all of the citizens to explore geospatial data related to municipality over the WWW (Evans et al., 1999; Hackney's GIS Team, 2004; Orlando GIS, 2004).

1.2 Problems

First of all, based on observations Evans et al. (1999) and Ventura et al. (2002), a few PPGIS frameworks allow the general public participants to post their comments and exchange views with each other effectively. Moreover, providing the access to the information only is not enough for the public to get involved in the complete planning process. In addition, a few online PPGIS specimens/frameworks such as Argumentation Map (Rinner, 1999; Keßler, 2004) and WebPolis (Xie, 2003) have included participation forums to support multi-way communication among the participants until now. It is important to prepare an application framework that will be useful for sharing views, letting participants understand each other's positions and ideas. Furthermore, design and implementation of a spatial data handling component, GIS-based discussion forum, and notification system with the feedback support will be helpful as well as effective approaches for the public to explore the spatial contexts related issues under planning. Moreover, the individual accessibility for the exploration of under planning municipality

areas using spatial component will give choice to the public participants to initiate their discussion, by providing comments or inputs on the map, without accessing GIS-based forums.

Secondly, the implementation of WebPPGIS in the small municipalities is too costly for the local bodies. Therefore, the small budget becomes one of the major hindrances in the design and implementation of GIS-based public discussion forums (Ma, 2006). A prototype has been analysed, designed and implemented using UML approach to demonstrate a GIS-based architecture with utilization of various open source GIS and other OSS tools.

Lastly, based on the survey done by Ma (2006), a few "WebPPGIS does not have a user-friendly interface for the general public" whereas I anticipate with the implementation of the following attributes the proposed prototype provides efficient, interactive as well as user-friendly interface to the general public.

- Ease of use (visualization)
- User-friendly Interface (interactivity)
- Platform independent (any operating system)
- Good response time (client's perspective)
- Maximum throughput (system's perspective)

Each attribute will be the key input function during the prototype development life cycle and helpful in evaluation of the successful design output in the end.

1.3 Research Objective

The objective of this research is to present a prototype (GIS-based participation forum, spatial data handling component, notification system and feedback support) design and implementation based on the GeoVPMS model introduced by Li et al. (2007) serving for spatially-related discussions in planning of municipality.

The research objective will try to achieve by tackling the following questions:

- What are the participation requirements for the discussions related to spatial contexts in participatory planning after detailed analysis of the municipal planning process and review of existing applications?
- To what extent proposed prototype fulfilled those needs by integrating the Web-based GIS with online participation forum component?
- Does the design of a spatial data-handling component help the public to explore the spatial contexts related issues under planning with and without accessing the forum?
- How does the usage of open source solutions end up with a cost-effective solution?
- Does the prototype provide user-friendly, fast and accurate GIS-enabled public participation platform as well as notification component?

- Does the prototype provide knowledge-based resources with spatial context for new and expert users?

It is necessary to point out that this research mainly comprises of several workings of GeoVPMS that are going to be tackled by different researchers in a certain timeframe. My research objective in this thesis is related to analysis and design of GIS-based discussion forum, spatial data handling component as well as notification system using Unified Modeling Language (UML). In short, the perfect implementation of previously mentioned points provides the way to get an effective prototype application (solution) with its integrated components (GIS-based participation forum, spatial data handling component and notification system).

1.4 Approaches to the Research

In this thesis, the following approaches have been adopted to achieve the research objective:

- **Review of relevant literatures:** This part of the thesis organizes around relevant literature review for this research on Web-based Public Participation Geographic Information System (Web-based PPGIS). Firstly, the section discusses the abstractions of participatory planning and necessity of the public participation in municipal planning process and development. Secondly, the benefits of Web

OSS (Open Source Software) technologies to date for solving the research questions are discussed.

- **Evaluation of existing online PPGIS applications:** Existing PPGIS applications are evaluated for complying the approach used in second chapter of Bennett's Object-Oriented System Analysis and Design (OOSAD) using UML book, "better the system analysis/evaluation, end up with better the system design".

- **Analysis and design using UML of the proposed prototype:** This part of the thesis induces all the Unified Modeling Language (UML) building blocks for the object-oriented analysis, design and implementation of the proposed prototype. UML as an Object-oriented Software Engineering (OOSE) model and Rational Unified Process (RUP) life cycle approach were followed to capture all analysis and design requirements for the system (prototype). Core workflows requirements, analysis, design, implementation and testing of a proposed prototype were captured and implemented during inception, elaboration, construction and transition phases respectively (the unified process life cycle phases).

- **Implementation and evaluation of the prototype:** The prototype is evaluated to determine to which extent the participation needs can be fulfilled during the spatial contexts related discussions.

Figure 1.1 depicts the synopsis of the research methodology used in this thesis with relation of the OOSE model that is comprised of five building blocks, namely requirement, analysis, design/coding, implementation, testing/evaluation and conclusion.

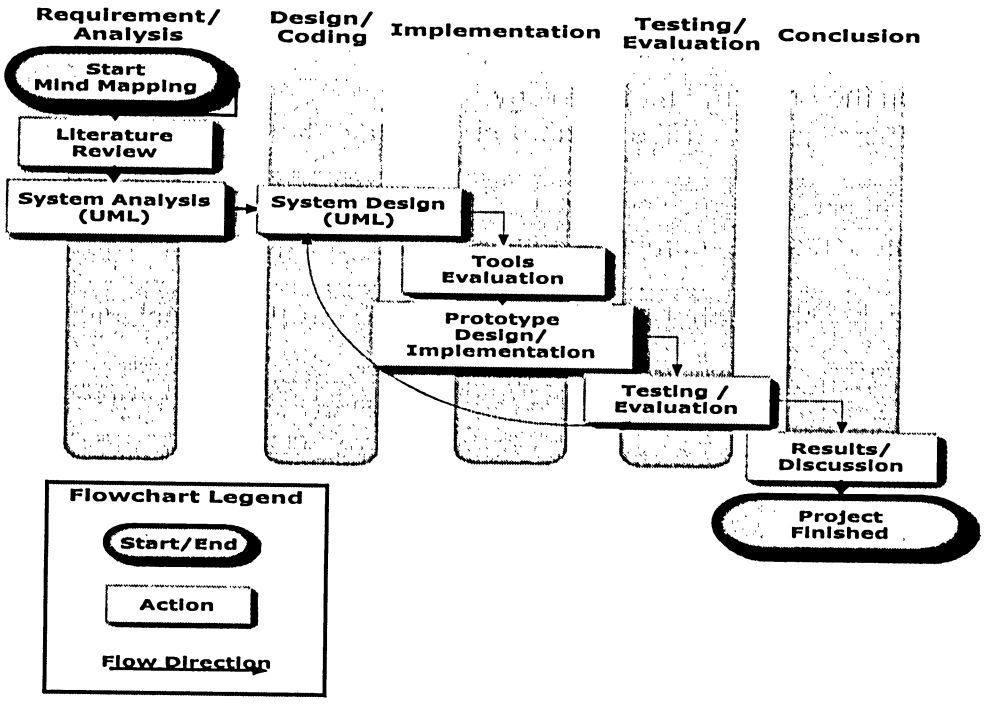


Figure1.1: An overview of the research methodology

1.5 Thesis Organization

This thesis is organized into six chapters. Chapter 1 provides an overview of the present research. It describes the objectives and approaches of the research. The significance and contributions of the research and its scope will also be discussed. Chapter 2 discusses the related theories and principles of public participation in the contexts of municipality planning decision-making. It provides the background

knowledge to the present research followed by the discussion related to the usage and benefits of the open source software technologies. Chapter 3 discusses the existing online PPGIS applications and conducts an evaluation from a technological perspective on selected online PPGIS applications to assess whether they can fulfill the communication requirements for participatory planning. The strengths and limitations (comparative summary) of those PPGIS applications will also be identified, followed by the discussion on the preferred methodology.

Chapter 4 presents the complete analysis and design using the object-oriented modeling approach with rational unified process life cycle (UML) including the intended use, target user group, user requirements. It depicts the design methodology using CASE (Computer-Aided Software Engineering) tool Rational Rose™ as well as key design considerations for the prototype including the enabling technologies as well as the system architecture. The details about the implementation and demonstration of the prototype will be discussed in the Chapter 5. Moreover, the second half of this chapter evaluates the prototype implementation based on the criteria selected followed by the brief discussion on usability approach for the prototype testing.

Finally, Chapter 6 concludes and summarizes work completed in this research and then suggestions are given by summarizing the opportunities for future research.

CHAPTER 2 REVIEW OF RELEVANT LITERATURES

This chapter organizes around relevant literature review for this research. The first part of this chapter discusses the concepts and requirements of participatory approach in municipal planning process and development. The second half discusses degrees of public participation with reference of the well-known ladder of participation from Arnstein's (1969) and Wiedemann and Femers (1993). In Section 2.2, methods of participation in planning and decision-making process are discussed and finally, the benefits of OSS technologies to date, in the context of research questions, are discussed.

2.1 Concepts of Public Participation

2.1.1 Public Participation in Municipal Planning Process

An efficient municipal planning process demands public participation and good teamwork, initiated by the municipality, with government agencies, councils (county) and local bodies, at the determinative stage. In addition, each planning process itself comprises of some certain steps for instance, problem initiation or identification, a planning process analysis, define alternatives, develop evaluation criteria to asses the alternative and deploy a perfect solution or a successful plan with its implementation. For better understanding, the steps shown in a self-explanatory flow chart (see Figure 2.1) portrays an example of how municipality planning process, along with the public participation as an input, goes through a series of steps to become more adoptive.

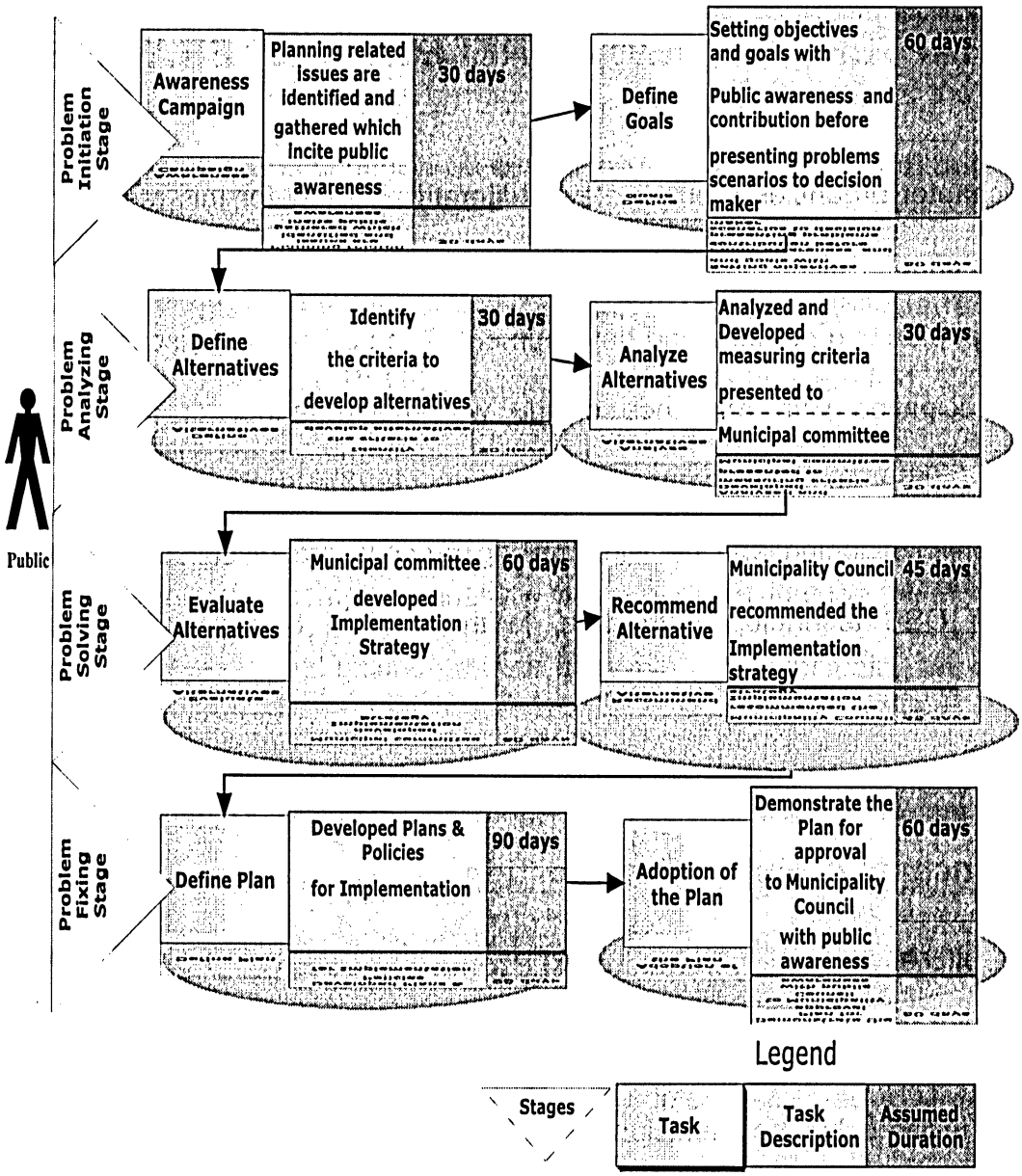


Figure 2.1: Steps in municipality planning process (source: http://halifax.ca/regionalplanning)

Figure 2.1 depicts how the public are encouraged to involve in each stage (from initiation of a problem to finalizing a solution) of municipal planning process in order to achieve the desired and optimal outcome.

2.1.2 Public Participation in E-Government

E-Government is defined (see Figure 2.2) with such a stunning participation concept which is designed to make it easier for citizens, business mates, municipalities, other authorities (agencies) and government entities to access government information and services. It is the use of information and communication technologies (ICTs), such as Wide Area Networks (WAN) and the Internet, particularly Web-based participatory applications, that improves the activities of public division organizations (McClure, 2000).

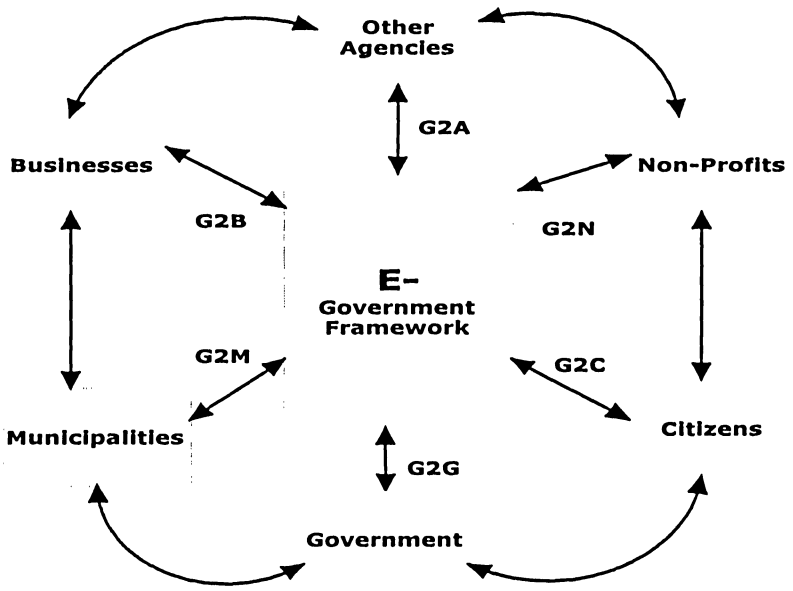


Figure 2.2: Conceptualization diagram of E-government framework (McClure, 2000)

Figure 2.2 illustrates the implementation of a conceptual framework of e-government that depicts the interaction between government and citizens (G2C), government and businesses (G2B), government to government (G2G), government to municipalities

and/or communities (G2M), government to other agencies (G2A), and government to non-profit organization (G2O) more friendly, convenient, transparent, inexpensive and citizen-centered (Pacific, 2002).

2.1.3 Citizen Involvement Advisory Committee Reasons (CIAC) for Public Participation

Oregon state citizen involvement advisory committee gives reasons how municipality planning process increases its versatility along with the public participation as an input (Sadagorpan, 2000). Moreover, Figure 2.3 portrays the five reasons of CIAC in a brief and self-explanatory way.

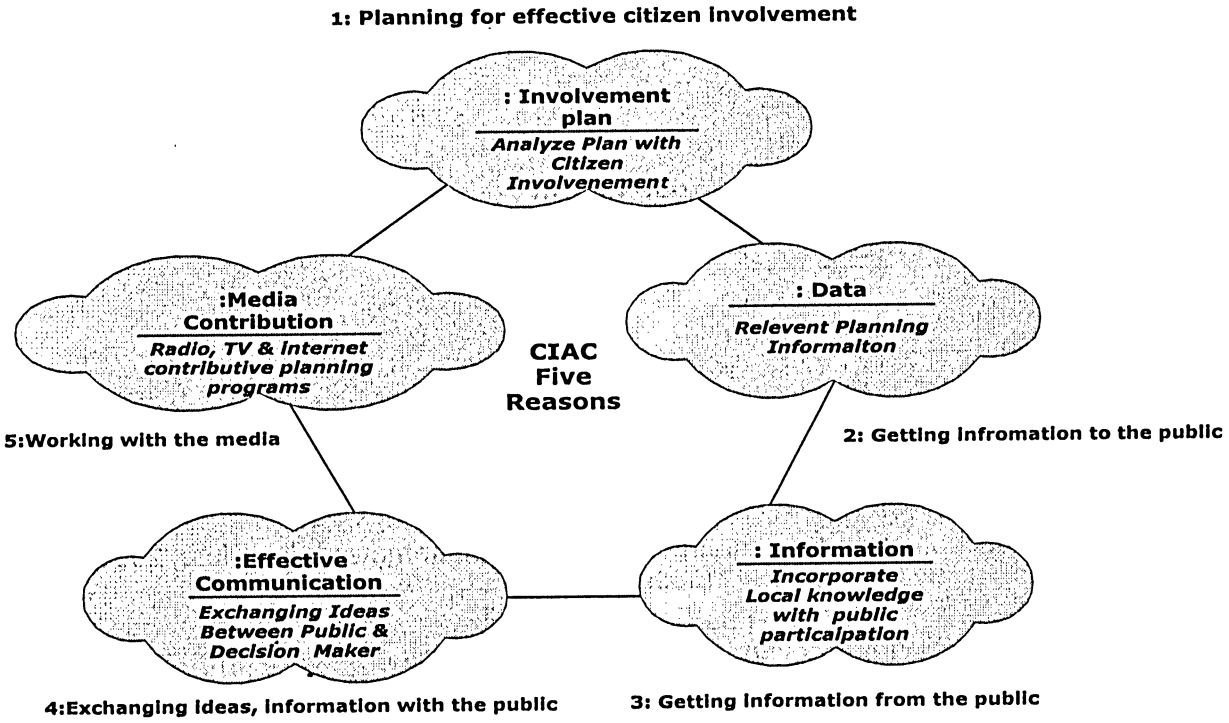


Figure 2.3: Five reasons of participation by CIAC (source: http://www.oregon.gov)

Figure 2.3 states that the planning for citizen involvement, getting information to and from the public as well as exchanging ideas with them and media contribution originate the path or course of leading to have strong citizen participation. The ultimate synopsis of the Sadagorpan (2000) reasons is the public participation (as input), number of alternative scenarios (after effective communication among public and with media contribution) and final recommended solution are directly proportional to each other. In simple words, the more we increase the public participation input, more we will come up with alternative scenarios that bring forth in a better outcome.

2.1.4 Ladder of Participation - Arnstein, Wiedemann and Femers

To portray the degree of public participation the public participation ladder has been extensively used nowadays. As shown in Figure 2.4, the bottom rungs of the ladder (manipulation and therapy) represent non-participative status of the citizen that they can not participate in planning and decision making process at this level, whereas the top rungs of the ladder (delegate power and citizen control) represent full citizen control and the public have got the responsibilities for final planning and decision-making at this stage (Carver, 2001). In addition, Arnstein (1969) claims that how power is in fact redistributed between citizens and power holders using pubic participation/involvement strategy in planning and decision-making process. In one of the classic articles of Arnstein (1969), related to public participatory approach, "Arnstein uses a ladder to depict the different levels of power given to the citizen in affecting the outcome of the participation process" (Tang, 2006). For the ease of orientation and better

understanding, the characteristics of important rungs of Arnstein's ladder are shown briefly in Figure 2.4.

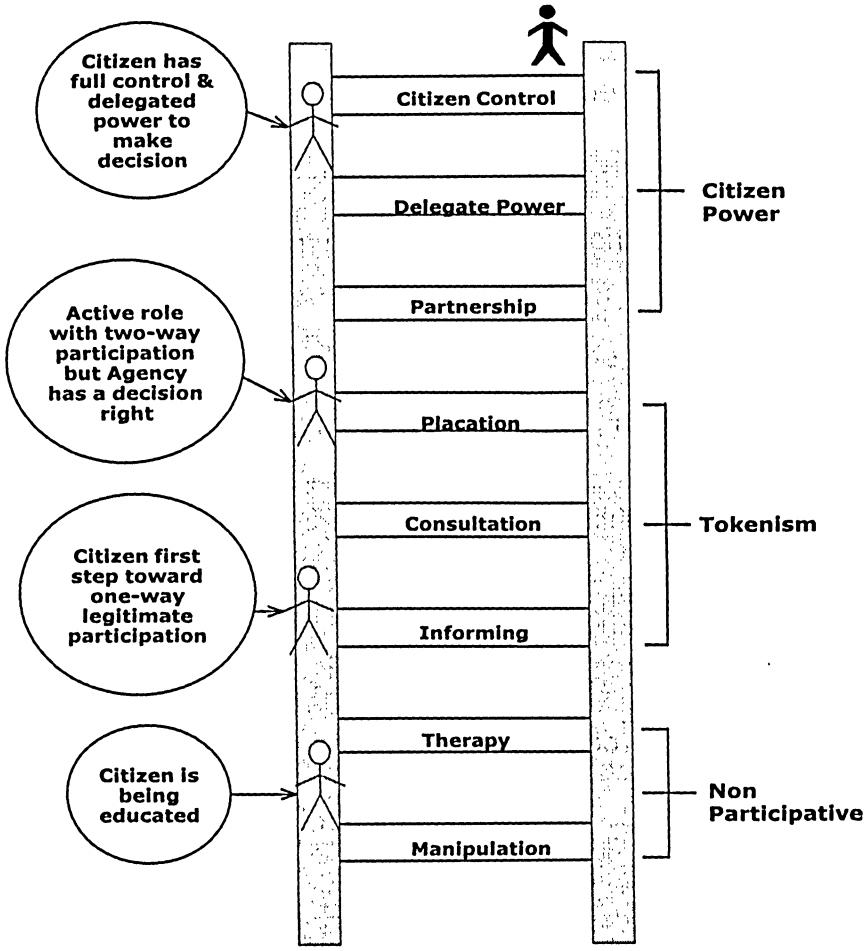


Figure 2.4: Ladder of public participation (Arnstein, 1969)

In addition to above discussion, Weidemann and Fermers (1993) adopted the sam theory from Arnstein (1969), further contributed their knowledge and reproduced a si rung ladder (see Figure 2.5) of public participation which is based on the people' right and authorities.

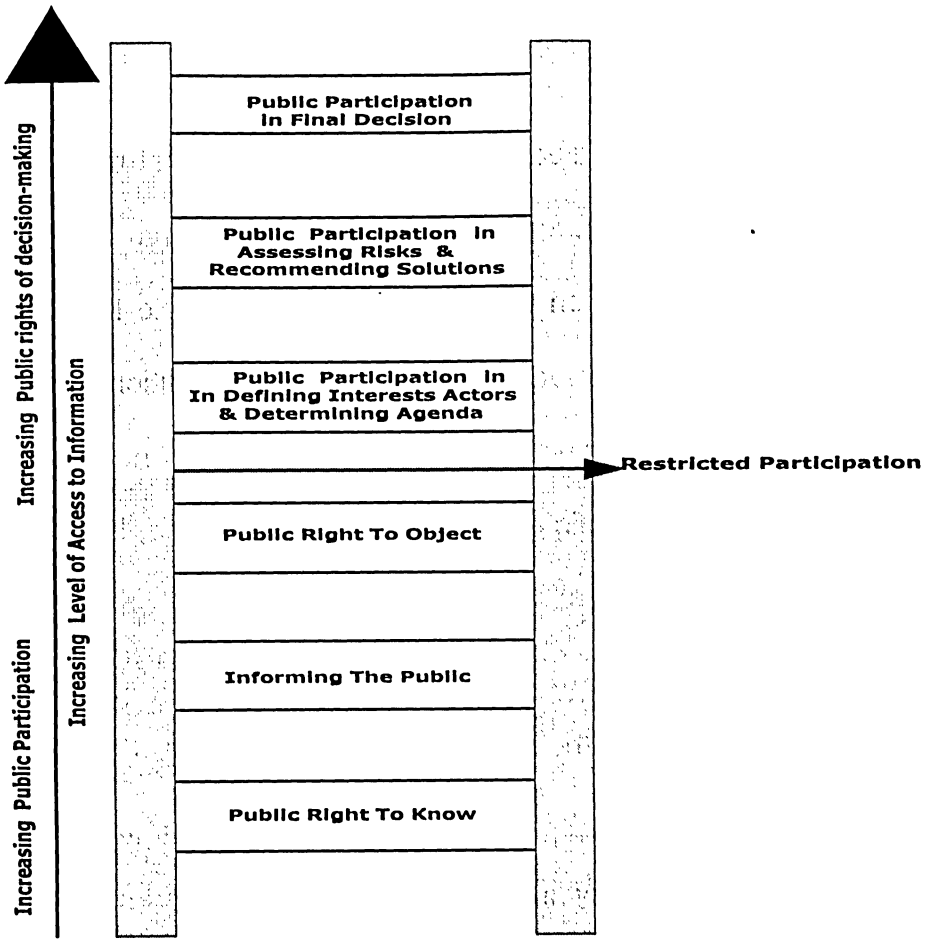


Figure 2.5: Public participation ladder (Wiedemann and Fermers, 1993)

In a nutshell, knowing these degrees as well as gradations of public participation make it possible to cut through the hyperbole or extravagant exaggeration to understand the increasingly strident demands for participation from the have-nots as well as the gamut of confusing responses from the power holders (Wiedemann and Fermers, 1993). Public involvement therefore should be considered as a continuous (input) process that feeds important information into all processes related to municipal planning.

2.2 Web-based Participation in Planning Process

There is a variety of public participation methods available that main objective is to get the public input (participation) for the municipal planning related issues. It is undoubtedly true that the participation trends are changing due to the rapid growth ir the Web-based technologies in this modern era. According to traditional methods, public participation in the customary planning process are ranged from neighbor notification, exhibitions, public meeting, and public enquires through telephone, letters, mails fax or public hearing (Kingston, 2002; Li et al., 2004).

On the contrary, Web-based methods are categorized in two types and are named as unidirectional and bi-directional Web participatory approach. Lemos (2006) and Bryant and Wilcox (2006) states unidirectional approach is also known as traditional Web participatory approach. In this approach, Web pages are designed with only static contents and therefore supported only one-to-many interaction. Bi-directional or two-way directional Web participatory approach is supported many-to-many interaction. Web-based collaborative GIS and GIS-enabled discussion forums are the examples of bi-directional participatory approach and have many-to-many interaction (Tang, 2006). Figure 2.6 demonstrates a simple comparison between traditional and Web-based participatory approaches.

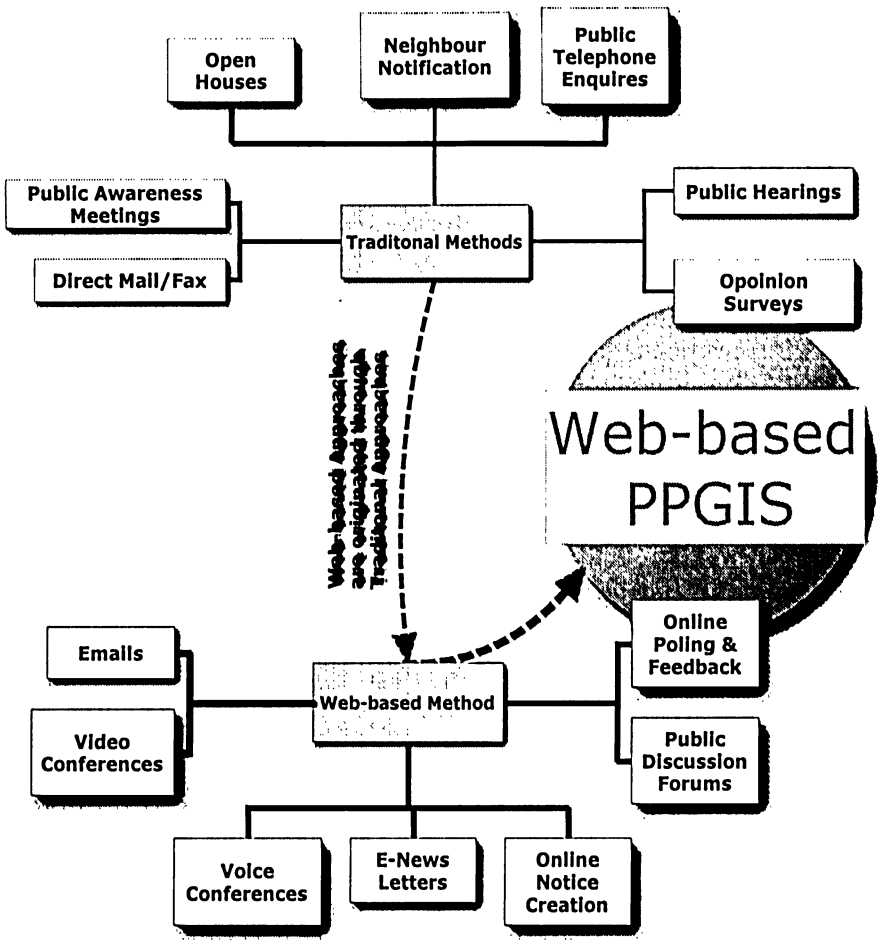


Figure 2.6: Comparison between traditional and Web-based participatory approach

There is no doubt Web-based PPGIS applications have some advantages over the traditional approaches of participation. Laurini (2004) defines the Internet-based application "as a medium for exchanging information, ideas, maps between all actors". Web-based participatory methods are more convenient (in the sense of time, location and information). For instance, it is more expedient to use the GIS-based online applications (i.e. discussion forums etc.) that can be accessible from any location without any time limitation for sharing opinions, knowledge and information among different groups of people (Tang, 2006).

The objective of PPGIS applications is to provide the informative as well as user-friendly interface to the public with collaboration of GIS technologies and tools. Robustness of PPGIS application is based on ICTs as Kingston (2002) states that power of PPGIS application increases as the power of ICTs increases.

Web-based GIS functions like zooming (to some map extents), panning, switching between active layers, measuring (e.g., area etc.), making annotation on map, and select querying functions allow user to participate interactively in spatial context related discussions on municipal planning. Peng and Tsou (2003, p.161) define spatial server-based Web mapping as "making maps, managing or conducting queries to find information and display it as output as well as doing some limited spatial analyses in the server".

In a nutshell, the GIS-based discussion forums, world-widely available twenty-four hours a day, seven days a week over the Internet, make a participatory approach more interactive, functional and convenient than the conventional (customary) participatory approach.

2.3 Open Source Technologies

The requirement of the high budget during analysis, design and implementation of the GIS-based participation framework is one of the main impedance among small municipalities from deploying their geospatial data over the World Wide Web. An

alternative solution, which is considered as cost effective for the implementation of GIS-based application nowadays, is the use of Open Source Software (OSS) technologies.

2.3.1 Open Source Software (OSS)

Use of open source software technologies in any system analysis and design provides a number of benefits. There are several OSS-based technologies which are successfully implemented and used nowadays, i.e., Linux (operating system), Apache Web server, Firefox (Web browser) and database management systems (MySQL and PostGRESQL) Bitzer and Philipp (2004). Nowadays organizations are recognizing the ultimate benefit of merging OSS as an essential part of their business (Mapserver, 2004). OSS has some merits and demerits, which are briefly discussed as follow:

- ***Cost:*** The primary goals of OSS Technologies are to provide cost effective solutions. Most current OSS projects are available free of charge and royalty.

- ***Reliability:*** Broadly speaking, in computer science language, we can measure software reliability with the absence of defects which cause data loss or sudden failures. The software is more reliable if it has fewer bugs (defects). On the contrary, some people also argue about the potential of lack of reliability because open source software is not properly documented, and nobody takes the responsibility to maintain it.

- ***Auditability:*** for OSS projects, the source code is open to inspection by and contributions from any interested individual. Therefore, users can also be auditors.

- ***Support of Active User's Mailing List:*** The OSS community represents a nexus of exchanges in which members of the community report problems expecting that other members will identify or fix them and deliver the solution free.

- ***Freedom:*** Open source software can be tailored with full of liberty. Usually the smaller organizations (as they have less resources) modify the open source project according to their needs.

- ***Availability***: Some of the software developer's communities are also working as the part of the OSS communities so the OSS user/member gets the benefit of having tools available from both communities.

- **Security/Stability:** Debatably, the OSS is demonstrated to be more secure due to fast tailoring and examining of open source code with the help of big community of OSS users.

Open software solution also has some drawbacks similar to other commercial software. The most common problem of using open source software is that nobody

takes the responsibility if the software does not work. Moreover, OSS version conflict is another common problem that occurs due to involvement of different groups in its development.

Even though an open source software solution has some disadvantages, its good reputation is due to its advantages. As in recent times, most of the GIS communities and IT industries are considering the integration of OSS technologies during the development of GIS-based programs and tools (Mapserver, 2004).

2.4 Summary

This chapter began with the concept and requirement of participatory approach in municipal planning process and development followed by the brief discussion about the importance of public participatory approach and stages that were comprised of some certain criteria, which helped in assessing and implementing the successful plan.

Subsequently, the chapter discussed degree of public participation with reference to the ladder of participation from Arnstein's (1969) and Wiedemann and Femers (1993). These ladders provided a picture and a conceptual model to help in clarifying the important role of the public and other types of participants in the building blocks of planning process. Then various participatory approaches were discussed with focus on Web-based PPGIS applications and its advantages over the traditional approaches. In the end, this chapter reviewed the OSS technologies with emphasis on its merits for

solving the research question. In fourth chapter, the proposed prototype for public participation is analyzed and designed based on OSS, OOSE (Object Oriented Software Engineering) process life cycle after identifying problems (see Chapter 3) in existing online GIS-based participation systems.

CHAPTER 3 EVALUATIONS OF SELECTED ONLINE PPGIS APPLICATIONS AND DESIGN METHODOLOGY

The first part of this chapter evaluates some existing Web-based PPGIS applications which assess whether or not the current PPGISs have fulfilled the public participation needs. Subsequently the design methodology of the proposed prototype is discussed.

3.1 Evaluation of Selected Online PPGIS Applications

This section evaluates some selected online PPGIS applications based on a number of evaluation criteria including: intended use, exchanging of information (participation), GIS functionalities (mapping functionalities), and interactivity of the user interface. Moreover, a selection criteria for the online PPGIS is based on a number of aspects including: PPGIS application must be available online and during the time of evaluation, application must be functional with GIS-based mapping functions for finding better comparative results.

This section does not aim to give a complete overview on existing PPGIS applications whereas my evaluation and selection criteria for the following public participation GIS-based applications is somewhat similar to the criteria which was adopted by different researcher such as Tang and Ma (2006). In brief, the selection and evaluation of the following PPGIS applications will help to decide what kind of GIS

(mapping) functionalities as well as participatory approaches should include in proposed prototype.

3.1.1 Virtual Slaithwaite

The Virtual Slaithwaite project was developed as PPGIS to identify the users' views regarding how they would like their municipality to develop in the future. It was initiated by Leeds school of Geography and funded by the British government. The purpose (intended use) of this system was to facilitate the non-professionals as well as citizens.

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. Furthermore, user can also perform spatial query to retrieve spatial data of the village (Slaithwaite). The user interface of the system can be assumed user-friendly as the feed back of the system was positive (Carver et al., 1999).

The digital version of the system is shown in Figure 3.1 and can also be viewed online at http://www.ccg.leeds.ac.uk/slaithwaite/.

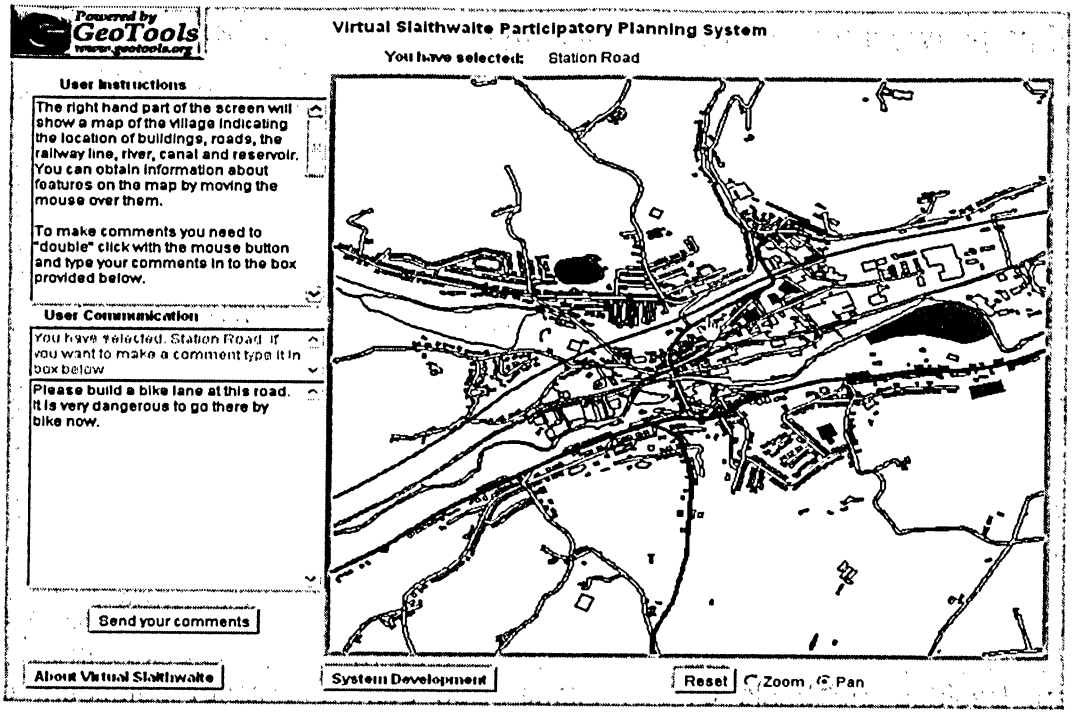


Figure 3.1: Virtual Slaithwaite project (source: http://www.ccg.leeds.ac.uk/slaithwaite/)

There are few drawbacks that affect the system's performance as well as cause framework ineffectiveness. First, the system performance was inefficient due to absence of the map server (generate maps). Moreover, maps are generated with the help of PERL scripting language modules, which is not a generic and efficient solution. Second, the annotations were not well organized; the GIS-based system does not provide option to reply of any topic so discussion among the citizens was not possible (no discussion forum support).

3.1.2 INFOMAP Orange County Interactive Mapping

The online version of Orange County's "InfoMap" interactive mapping tool can be accessed at http://www.cityoforlando.net. 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).

This PPGIS application supports more GIS functions as compare to the system (Virtual Slaithwaite) discussed earlier. User can query to find out the certain features on the map. Besides the basic GIS functions (add comment, layer selection, drawing points, polygon and rectangle etc.), an enhanced tool is provided to save the session information which can be used by the user in later time. Furthermore, user can save map as an image or PDF file to send it to other users through emails. The user interface of the system is user-friendly as well as interactive. A snapshot of the system is shown in Figure 3.2.

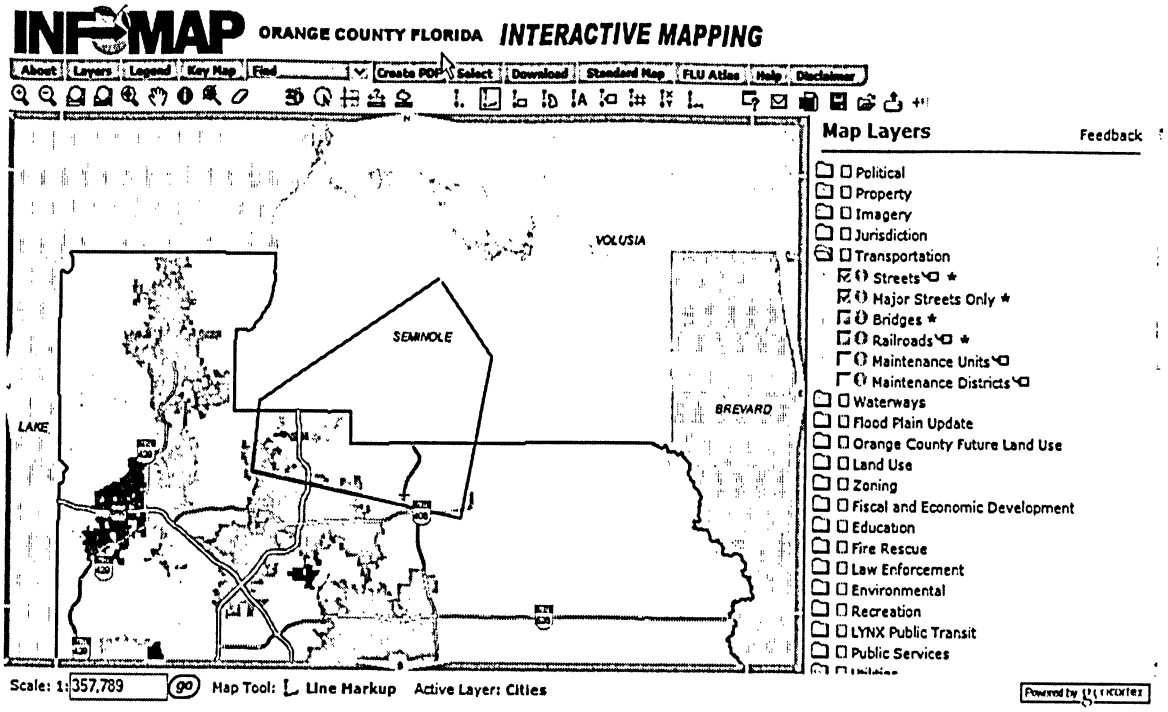


Figure 3.2: Interface of Orange County INFOMAP mapping tool (source: http://www.cityoforlando.net)

There are few drawbacks, which make the system's framework ineffective in the sense of participation. First, as the system does not have any support of discussion forum, therefore exchanging of ideas is not possible, except that the user can find or search the proper email address for exchanging the information.

Secondly, It seems that as the system was built using commercial software and technologies (i.e., ESRI ArcIMS), it was not a cost effective solution.

3.1.3 Interactive Landscape Plan Königslutter am Elm

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 (customary) public participatory approach (Tiedke and Kretzschmar, 2003).

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. Moreover, both OSS technologies are widely using nowadays. The interactive interface of the system is shown in Figure 3.3.

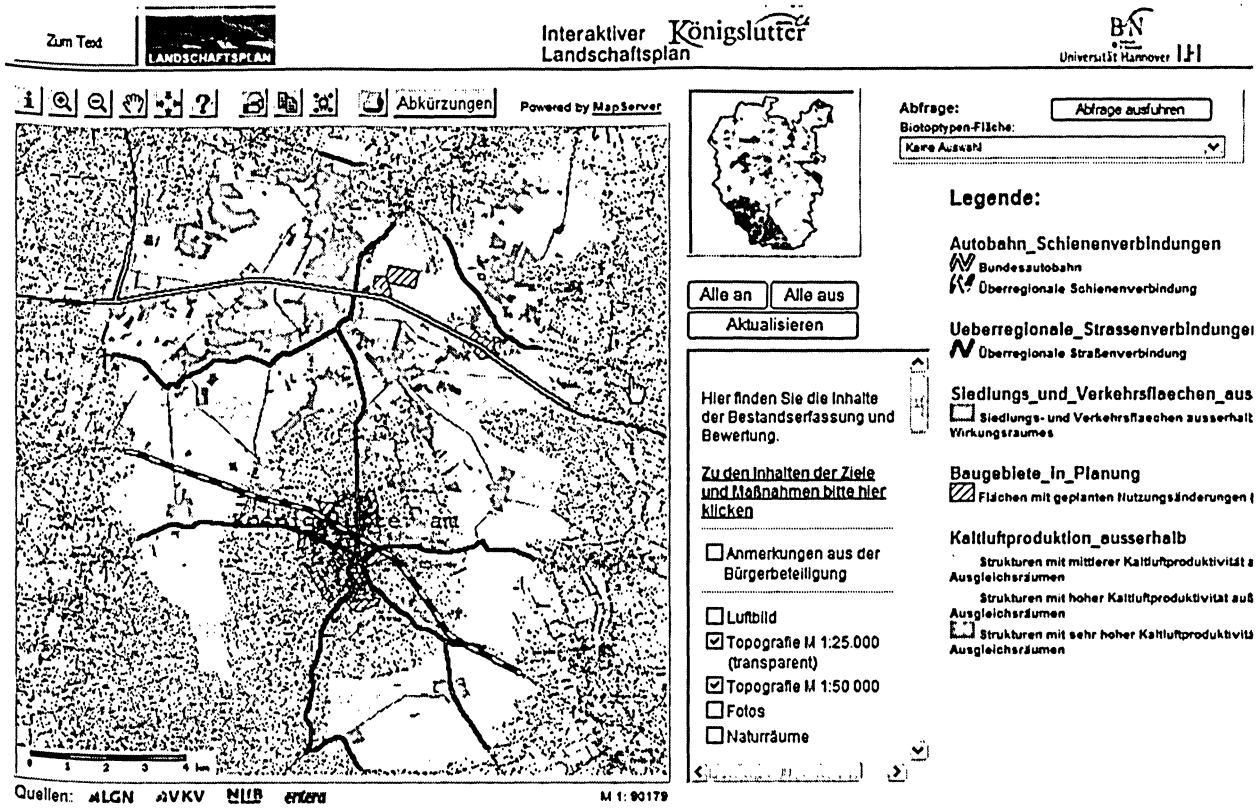


Figure 3.3: Landscape Plan Königslutter am Elm (source: http://thuja.land.uni-hannover.de/)

Although it seems obvious that the system compared to the above discussed systems is more economical because of OSS-based framework implementation but one-to-many participatory approach still makes this system ineffective. Information is streaming between the public and the authorities, but there is no participatory support among users. No doubt, a few more GIS functionalities with discussion forum support will make this system ideal.

3.2 Summary of Comparison

All three GIS-based systems were designed to enhance the public participatory approach in the municipality related discussions and issues. Intended use for these systems was to facilitate the non-professionals/general public. Both systems were supported raster-based maps except Virutal Slaithwaite (supported vector-based). Maps were produced by using map servers (ESRI ArcIMS and OSS-based UMN Map-Server) in both Interactive landscape plan and Orange County mapping systems, whereas in Virtual Slaithwaite maps were produced using PERL scripts due to which the system performance and response was slower (for participants) as compare to others.

Only Interactive landscape planning system was designed using open source software (OOS) technologies and therefore provided a cost-effective solution as compare to others. All three systems' interfaces were user-friendly as well as interactive as Virutal Slaitwaite main interface was designed using Java applets programming, whereas both other systems' interfaces were designed using DHTML and JavaScript. None of the systems supported discussion forum framework for public participation, so the public has to search the discussion forum for exchanging the information.

3.3 Methodology

Careful study on user requirements from both project analyst as well as end uses prospective is very essential and it is a key to ensure a successful design and

implementation of a system. The design and development of a GIS-based system (GeoVPMS) is based on the user-centered design methodology (see Figure 3.4), it splits the overall UML-based Rational Unified Process (RUP) life cycle of a system into four major parts: requirement gathering and analysis, data preparation, prototype design and testing or evaluation (Li et al., 2007).

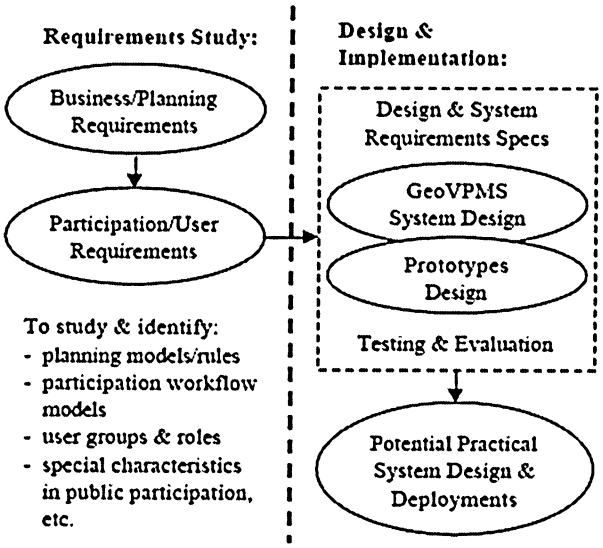
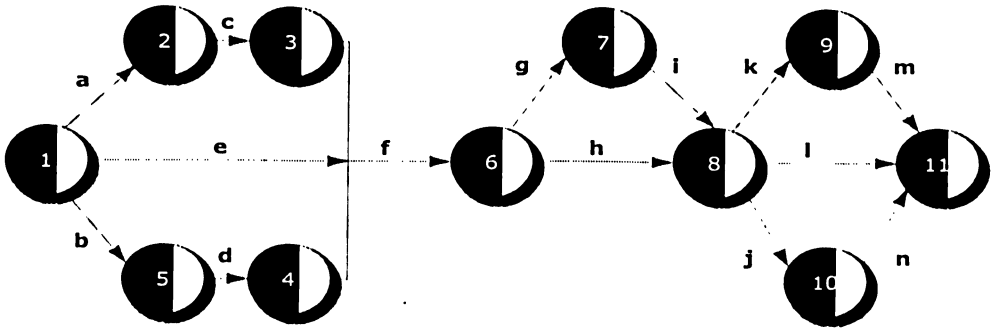


Figure 3.4: User-centered design methodology (Li et al., 2007)

The second step is to design a requirement model (requirement specification, gathering, and analyzing) using Unified Modeling Language (UML). The requirements are gathered by evaluating the existing WebPPGIS applications and by understanding the planning process discussed earlier. In short, the following actions are needed to be taken for the design of successful requirement model of a proposed prototype, as discussed in Li et al. (2007):

- Dialogs with selected municipal and, if necessary, provincial and federal government organizations responsible for auditing, regulating or conducting public consultation related to municipal planning and environmental assessment.
- Develop a critical comparison of data model/format and architecture supported by various online PPGIS and existing open source software technologies in relation to these requirements.

In the next stage, two preliminary Program Evaluation and Review Technique (PERT) charts are discussed that provide a graphical illustration of a schedule which helps to plan, coordinate, and track specific tasks in a project development life cycle. Moreover, PERT charts are typically used for projects that involve numerous stages of development due to its huge scope, where the duration times are hard to define and the relationships between tasks are complex. Each PERT chart starts with an initial point from which all tasks originate. Each subsequent task is connected to other tasks and is either coded or annotated with its name; the people assigned to it, and its best, worst, and average duration time. The chart is completed when all networked tasks come together to a completion point. Figure 3.5 describes an example of PERT chart used during project analysis and design.



ACTIVITIES	
CODE	MEANING
a	Obtain requiremnts specificaiton & data gathering
b	Acquiring background knowledge
c	Evaluating existing PPGIS applicaion
d	Evaluating OOS technologies
e	Draw up project proposal
f	Anlysis of a system using UML
g	Design of GeoVPMS
h, i	Implementaion of the Prototype
j	Testing of a prototype
k	evaluation of a prototype
l	Deployment of Information Centre
m	Deployment of Geo-Notification
n	Deployment of Geo-Participation

EVENTS	
CODE	MEANING
1	Problem Statment Made
2	background knowledge acquired
3	PPGIS Evaluated
4	OOS Technologies Selected
5	Presented project proposal
6	Anlysis Completed
7	Design Completed
8	GeoVPMS Implemented
9	Component Level Evaluation
10	Component level testing
11	GeoVPMS Deployed

Figure 3.5: PERT chart of a project (GeoVPMS)

Figure 3.6 depicts another example of time-based PERT chart used during project analysis and design.

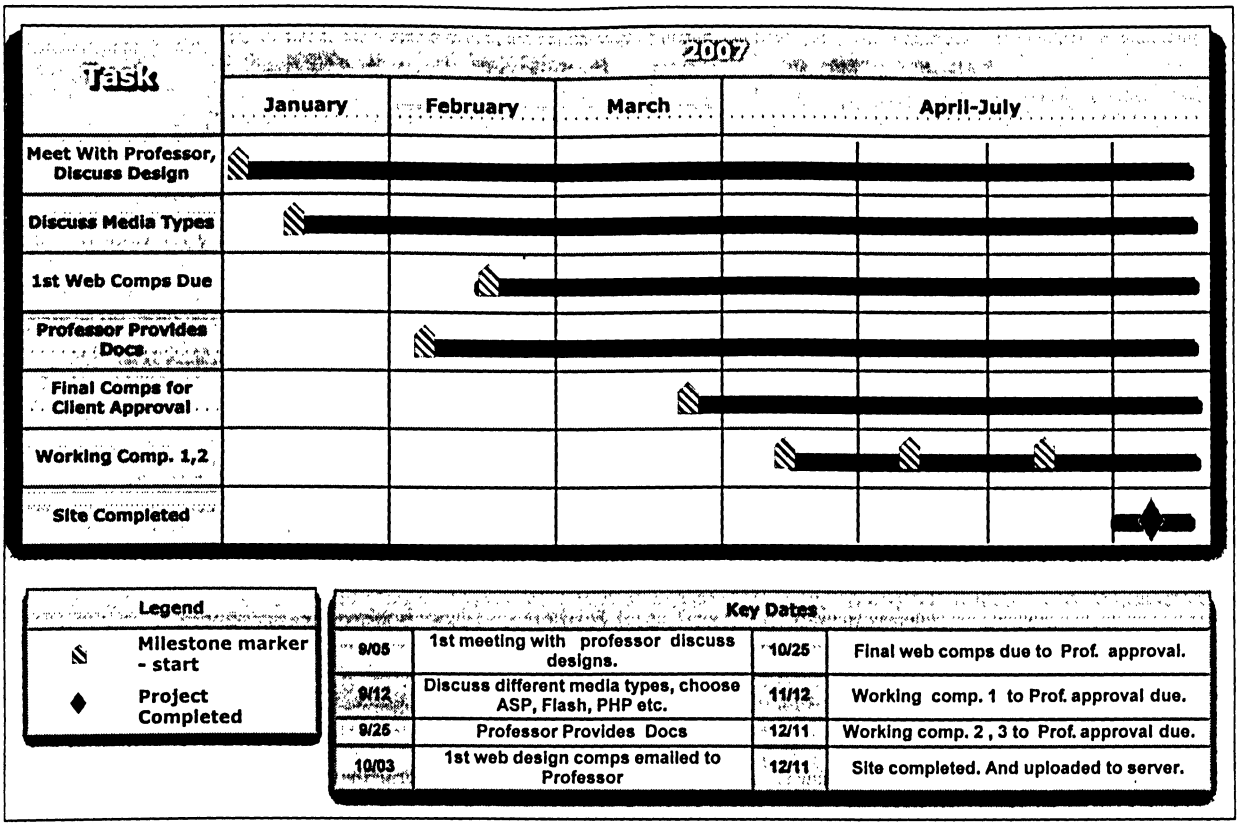


Figure 3.6: PERT chart of a prototype site design

In the next stage, a criteria rational unified process life cycle (RUP) supported by object-oriented software engineering (UML) is selected for the completion of user requirement analysis and design phases. Figure 3.7 shows rational unified process life cycle phases such as inception, elaboration, construction and transition with relation of analysis and design workflows of proposed prototype (i.e., GIS-based participation forum, spatial component and notification system based on GeoVPMS's framework).

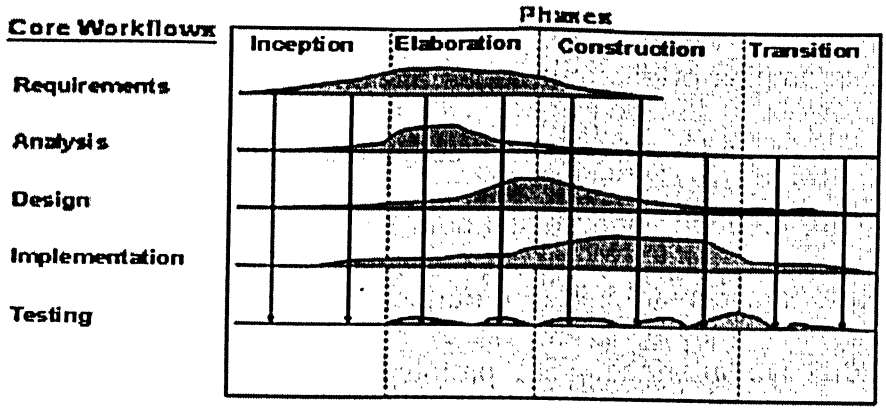


Figure 3.7: Unified process life cycle phases (source: http://www.uml.org/)

Figure 3.7 explains that a workflow requirement is at its peak level in the elaboration phase of RUP. Moreover, it depicts graphically that how many requirements are captured from inception to construction phases. In addition, there is no requirement capturing at transition stage. On the other hand, testing workflows are participated in very low but a steady ratio during all the rational unified process life cycle phases.

After completion of requirement model, the analysis model is documented in which use cases and preliminary classes are identified based on user's requirements in requirement model.

After successfully documenting analysis model, the design model is started in which UML interaction and state transition diagrams are developed. In addition, these diagrams' realization further provides help in designing the logical architecture of a proposed prototype that includes choosing the software components, Web pages organization and database schema development as well as deployment. In brief, this stage also begins with building the architecture of the prototype. Furthermore, Web

server, map server, database and server programming platform are chosen and installed. The hierarchies of different pages are determined, which includes the index page that integrates part of GeoVPMS components (GIS-based discussion forum, notification system, feedback and spatial data handler component). Other pages such as help, about etc. are constructed too. Furthermore, to come up with the successful user-friendly/interactive interfaces, the prototype designing stage is constructed by following some rules of HCI (Human Computer Interaction) which are shown as follows:

- ***Strive for consistency:*** using Cascading Style Sheets (CSS) consistent color, layout, capitalization, fonts, and, so on, will be employed throughout.
- ***Offer informative feedback:*** Using DHTML-based (Dynamic Hypertext Markup Language) visual effects (e.g., dynamically color changing of buttons and presenting extra information with tool tips) the system will be able to respond in some way to every user action.
- ***Offer error prevention and simple error handling:*** Server and client side scripts written in PHP (PHP Hypertext Preprocessor) and JavaScript languages will be used to make available this feature, for instance, JavaScript-based popup windows will be used for error handling and prevention during the user interaction (i.e., wrong password input etc.) with prototype's database.

The last stage is to evaluate and test the prototype before its real-time deployment. Further, the prototype is demonstrated with a scenario of public participation in spatial planning using Region of Peel's data.

3.4 Summary

The first section of the chapter began with an evaluation of some existing online PPGIS applications based on the some certain selected aspects (evaluation criteria). The selection and evaluation of the selected PPGIS applications were demonstrated to be very helpful, after analyzing what kind of GIS functions and communication problems existing PPGIS had. This also gave the abstraction of what communication strategies with GIS functionalities should be included in the proposed prototype.

Subsequently, the complete step by step design methodology for the proposed prototype which is based on the GeoVPMS framework introduced by Li et al. (2007) with OOSE approach using UML was discussed.

The following chapter fourth, endeavors to analyze and design a prototype (GeoVPMS) with its subcomponents. One of technical aspects of the proposed prototype is to integrate an online discussion forum with Web-based GIS technology. It is certainly true (after the evaluation of existing PPGIS applications) that a Web-based participation forum with many-to-many participatory approach and mashup with GIS functionality as well as OSS technologies is an effective solution. The proposed prototype will focus on constructing the main components (Web-based GIS online participation forum, spatial component, notification system, feedback and information centre) based on GeoVPMS framework.

CHAPTER 4 ANALYSIS AND DESIGN OF GEOVPMS USING UNIFIED MODELING LANGUAGE (UML)

This chapter begins with brief introduction of UML and CASE tool IBM Rational Rose™ and then it presents a detailed discussion about the building blocks of three GeoVPMS subsystems starting from requirement capturing to analysis and design (system architecture) using object-oriented unified modeling language approach.

4.1 Unified Modeling Language and Rational Rose ™

The Unified Modeling Language (UML) plays very important role during the analysis and development of object-oriented system. It can be used with all processes, throughout the development life cycle, and across different implementation technologies. The UML uses mostly standard graphical notations (UML diagrams) to express and document all the phases of system development life cycle (i.e., problem initiation and identification, requirement gathering, analysis, design, implementation and testing).

The classifications of UML diagrams are discussed as follow:

- **Behavior diagrams:** it depicts behavioral features of a system or business process. This includes use case, object (context) and state machine diagrams.

- **Interaction diagrams:** A subset of behavior diagrams which emphasize object interactions in a specific time. This includes sequence, collaboration and communication diagrams.
- **Structure diagrams:** A type of diagram that depicts the elements of a specification that are irrespective of time. This includes class, package, component and deployment diagrams.

The market leading CASE tool IBM Rational Rose™ is an object-oriented UML-based software design tool. Intended use of Rational Rose™ is discussed as follow:

- **Visual Modeling:** It supports all UML standard graphical notations and diagrams.
- **Component Modeling**: it provides the platform for component construction of enterprise-level software applications with forward/reverse engineering approaches that make application-programming codes ready for the system real time implementation or deployment.
- **Application Development Platform:** IBM Rational Rose™ provides an application development platform that improves the speed, reliability, quality, and predictability of complex as well as distributed framework-based software projects.

As Ma (2006) states "the municipality or city planning process is an extremely complex decision-making process whereas the UML is an effective technique to manage the complexity of system". Therefore, it is true in this regard that the usage of

UML and CASE tool Rational Rose™ during the analysis and design of a prototype will result in more effective and reliable solution. In brief, all building blocks of proposed system prototype life cycle will be documented using object-oriented software engineering (UML) as well as Rational Rose ™.

4.2 UML-based Analysis and Design of the Prototype Subsystems

OOSE-based project life cycle using UML consists of five major models i.e., requirement, analysis, design, implementation and test models, which combine the best of the best from the data and business modeling (data workflows) concepts. These OOSE-based models/phases are further specialized in UML-based standard diagrams (UML building blocks) in the Figure 4.1.

Furthermore, Figure 4.1 depicts project life cycle stages and building blocks based on UML and OOSE concepts that are adopted for the analysis and design of the proposed prototype GeoVPMS sub-systems.

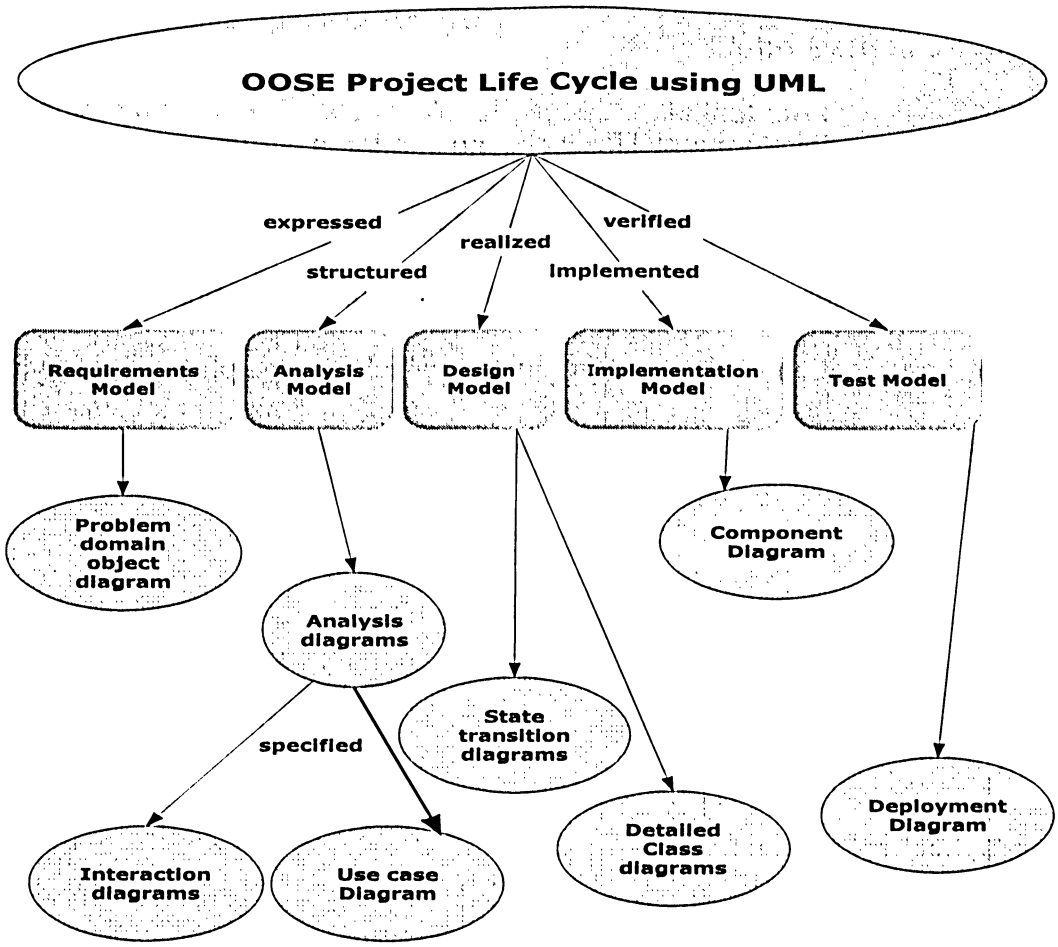


Figure 4.1: OOSE-based project life cycle using UML

Sections 4.2.1 and 4.2.2 describe the UML-based requirements and analysis models for the proposed prototype whereas some details about these models as well as other models (i.e., design, implementation and test models) shown in Figure 4.1 are presented in Appendix II, which cover each aspect of using UML and CASE tool-IBM Rational Rose™.

4.2.1 Requirements Model

In every system development life cycle, no matter a structure-oriented or object-oriented approach is selected, the requirements model plays the most important role during the system analysis and design. In addition, during this phase analyst makes a requirement specification and context diagram, which are helpful in identifying actors and use cases. Stages of requirement modeling for proposed prototype are shown in Figure 4.2:

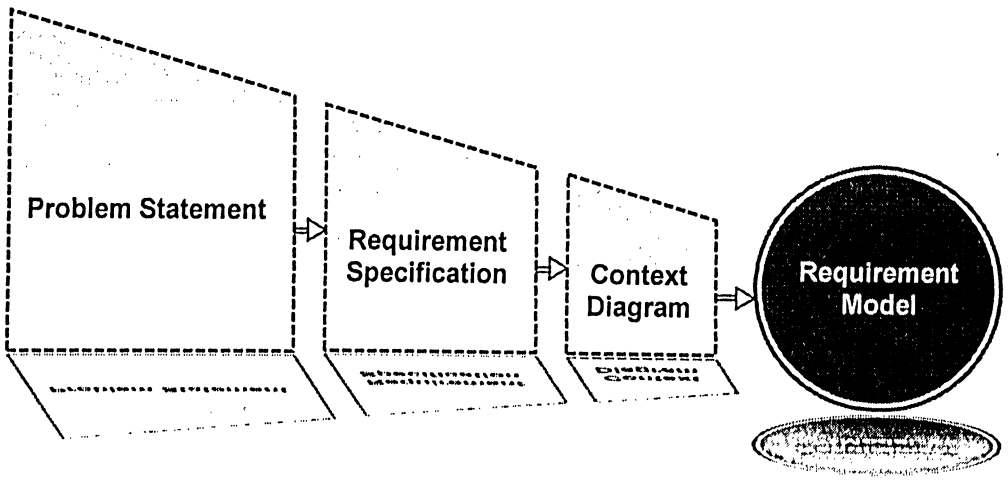


Figure 4.2: Stages of requirement model

4.2.1.1 Problem Statement/User Requirements

The first step in every system analysis and design is to identify the problem statement/user requirements, which are usually given by the end users, but in the current scenario, the statement criteria are developed by evaluating online PPGIS applications in Chapter 3 and planning processes in Chapter 2.

4.2.1.2 Requirements Specification (RS)

The requirements specification includes the artefacts that are discussed briefly in the following section. Figure 4.3 depicts the five artefacts of RS for the proposed prototype.

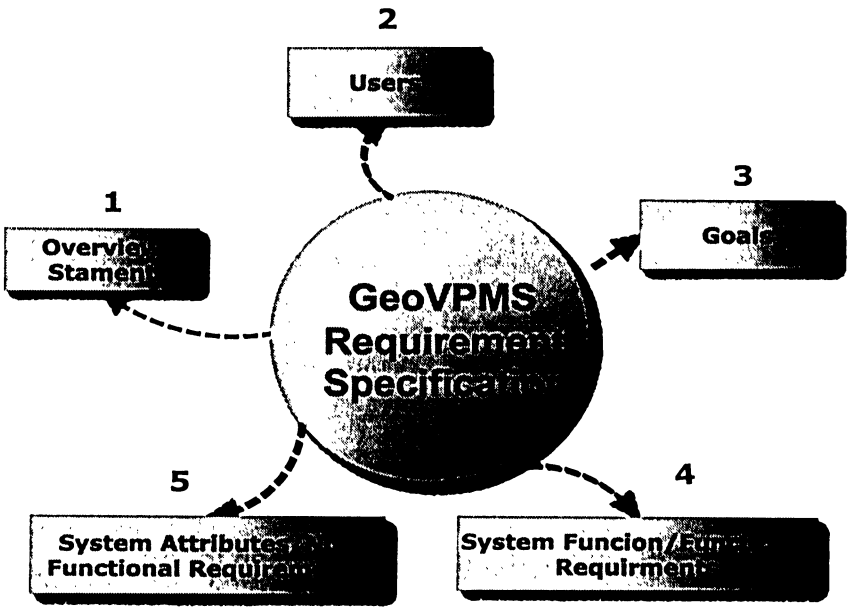


Figure 4.3: Artifacts of requirements specification

Overview Statement

The purpose of this project is to create GIS-based participation forum, notification system and feedback (voting/polling etc.) components under the general GeoVPMS framework based on OSS technologies for public participation in municipal planning and development activities.

Users

- General Public Participant (Citizens)
- City Staff Members (Municipal/Local Bodies)
- Project Proponents
- Domain Experts
- Spatial Database Administrator
- Environmental Assessment Researchers
- Project Manager

Goals

- Fast and accurate GIS-enabled public participation forum.
- Notification system for municipal planning related notices for public.
- Knowledge-based resources with spatial contexts for new and expert users.
- Address finder Application Programming Interface (API) feature enables registered users to access all meeting locations from their places.
- Feedback component for getting feedback from user.
- Newsletter feature enables users to get the latest related information posted on the forum.

System Functions/Functional Requirements

I. F1-Projects List

This will display a list of the available projects under public consultation to the registered and non-registered users.

II. F2-Project Specification

This will provide the detailed information of any selected project.

III. F3-Notification

This functional sub component enables users, according to their assigned privileges, to view notices related to different projects of municipal development.

IV. F4-Participation

User uses this sub component to explore the specific project with its spatial context and it allows user to store his/her comments that will become the future helpful idea for other participants. It is comprised of two major sub components: discussion forum and spatial data handler APIs.

V. F5-Information Centre

This function provides basic and expert knowledge of municipality planning related projects e.g., relevant by laws, regulations, public meeting minutes, videos, conference papers, power point presentation, etc. to all participants.

VI. F6-Feedback

This function is used to enable the feedback feature.

VII. F7-Location API

This function is a mashup of Google APIs and PHP scripts. It enables user to find a location of the meeting place on Google maps.

VIII. F8-Newsletter

This function is used to deliver all latest news.

IX. F9-Visit Us

This function is based on location API function and provides the user the direction to project meeting place.

X. F10-Contacts

This function is used to provide all the contacts information.

XI. F11-FAQ

This function is used for Frequently Asked Questions (FAQs).

XII. F12-Login

This function is used to login as authorized/registered user to enable some more administrative features e.g., add new topic or any informative event on the discussion forum. Moreover, login function is needed to initiate the administrative interface of each component.

XIII. F13-Logout

This function is used to logout the authorized user.

XIV. F14-Email

This function enables users to send email to the administration.

System Attributes/Non-Functional Requirements

- Ease of use
- User-friendly Interface
- Platform Independency
- Better response time (related to user's perspective)
- Maximum throughput (related to system's perspective)

4.2.1.3 Context Diagram

Context diagram depicts the external view of the system. It describes how different users interact with GeoVPMS sub components according to their primary tasks, for example, project proponent/mediator primary task is to monitor and manage the system with its sub components. In addition, they also administrate and input the data related to the municipal planning projects and notifications whereas domain experts/consultants provide assistantship in gathering important information (i.e., polling questions, contact details, project related presentations/documentation etc.) when needed. General users (Public/city staff) are the major users who most frequently interact with the system and participate in municipal planning related discussions using GeoVPMS sub components. Figure 4.4 shows a view of the context diagram for the proposed system. It is noticeable if a project proponent/municipality staff and domain experts access the GeoVPMS sub components for participation perspective then system treats them as its registered users/participants.

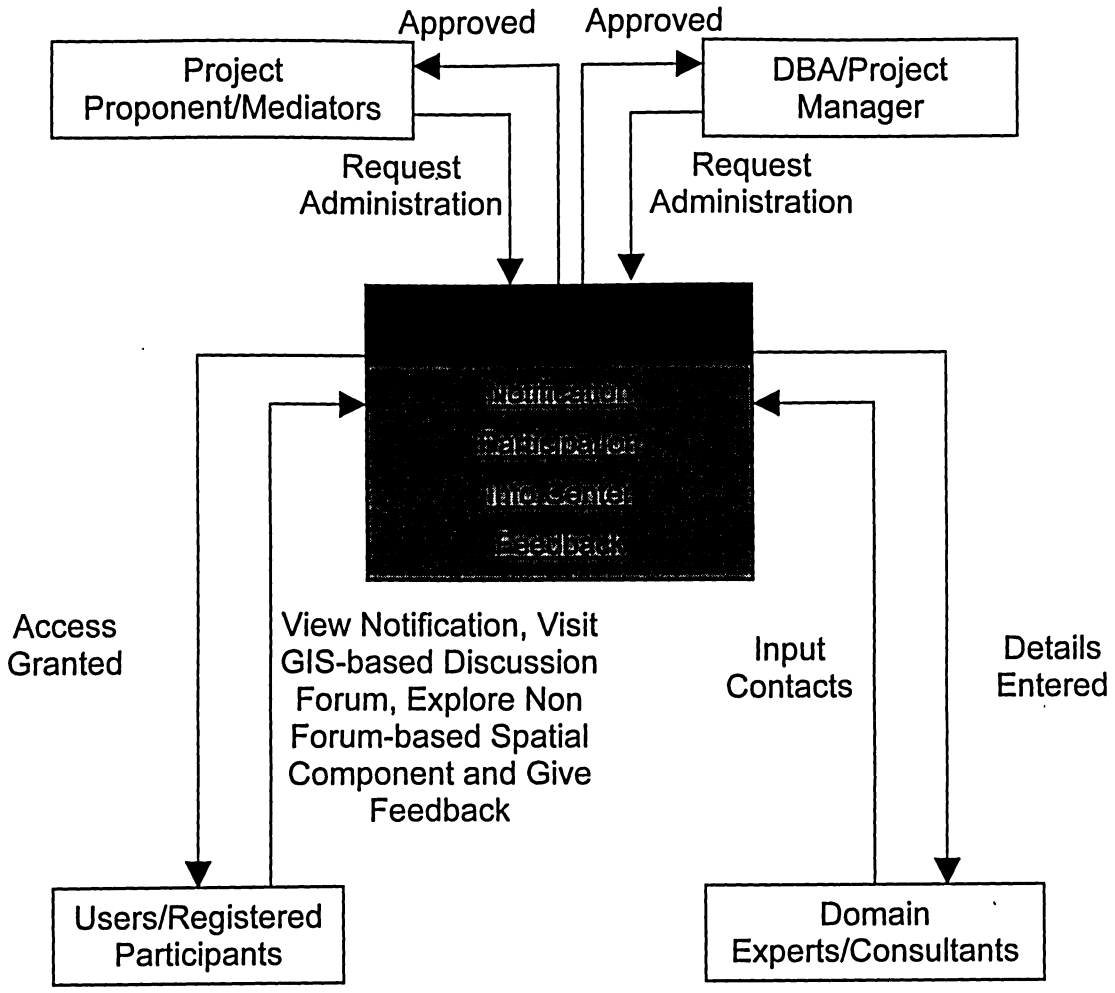


Figure 4.4: Context diagram of GeoVPMS sub systems

No doubt, context diagram will also become very useful in finding actors, use cases and analysis diagrams during analysis stage of the proposed system that are briefly discussed in Section 4.2.2.

4.2.2 Analysis Model

In an object-oriented software engineering using UML, analysis model usually consists of use case diagrams but in some scenarios behavioural and preliminary class diagrams can also be the part of this model (see Appendix II.II and II.V for behavioural and preliminary class diagrams). Figure 4.5 depicts the conceptualization of analysis model by showing interrelationship of actors, use cases and use case diagrams.

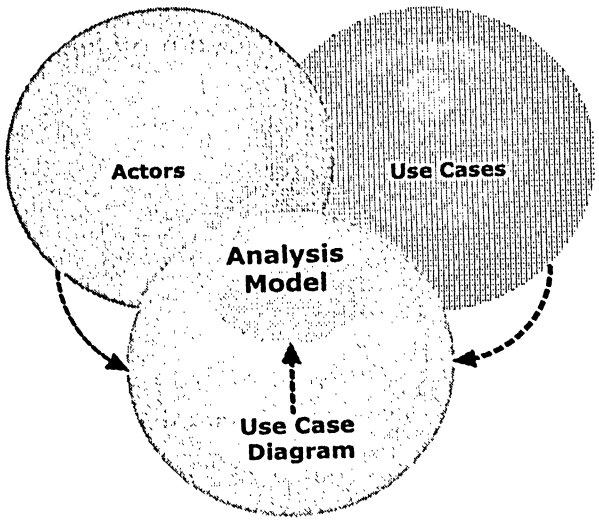


Figure 4.5: Conceptualization of analysis model

Following sections illustrate more in detail about analysis model of proposed prototype by identifying actors, use cases and use case diagrams.

4.2.2.1 Actors

An actor is a person, organization, or external system that plays a role in one or more interactions with the system. In addition, an actor is someone or some-thing that

must interact with the system under development. Major actors of the proposed system prototype are categorized as follows:

- **General Actors:** This category includes city staff members/local bodies and general public/citizen.
- **Corporate Actors:** It includes domain expert/agency participant/consultants.
- **Managerial Actors:** It includes project proponent, manager and mediators.

Figure 4.6 shows all the actors of the proposed prototype.

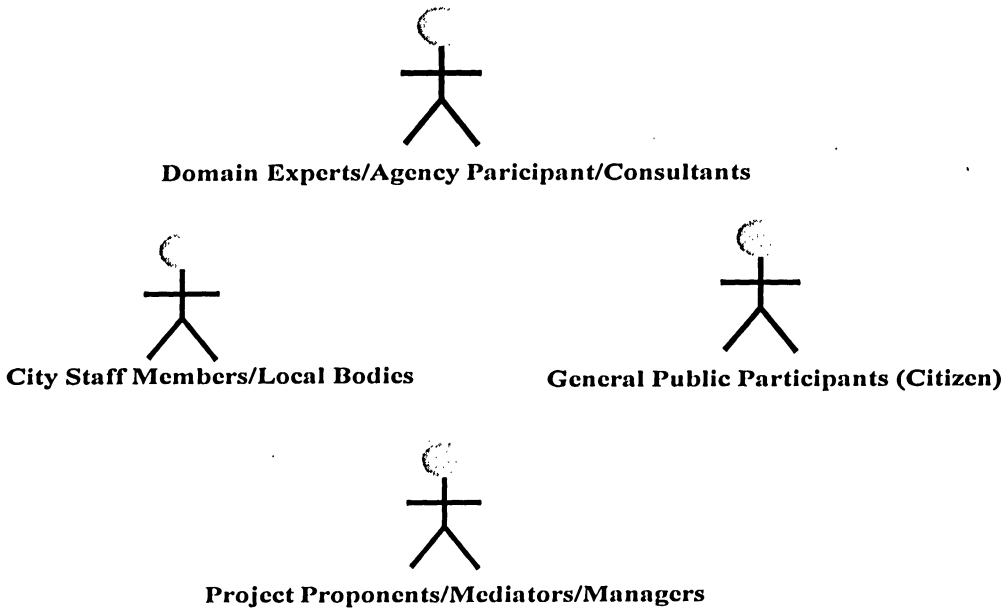


Figure 4.6: Actors of prototype (GeoVPMS)

4.2.2.2 Use Cases

A use case describes a sequence of actions that provides something of measurable value to an actor and is drawn as a horizontal ellipse. In simple words, we can say that each use case is a sequence of related transactions performed by an actor and the system in a dialogue, for example, in the dialogues "project proponent manages the project lists" and "public participant visits the online notification system". Project proponent and visitor are actors whereas manage and visit are the use-cases. Some basic examples of use-cases for the proposed prototype are shown in Figure 4.7:

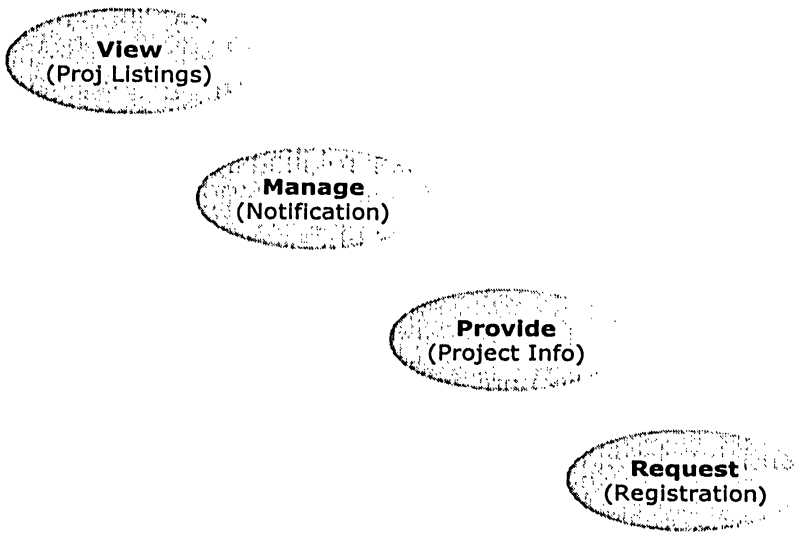


Figure 4.7: Basic use cases of prototype

According to Bittner and Spence (2002), "top/detailed level use cases, stated simply, allow description of sequences of events that, taken together, lead to a system doing something useful". Each detailed level use case provides one or more scenarios that convey how the actor will interact with the system to achieve a specific business

goal or function. Appendix I summarizes, use case relationships (uses and extends), top level and detailed level use cases for the proposed prototype.

4.2.2.3 Use Case Diagram

Use case diagrams are created to visualize the relationships between actors (users of the GeoVPMS) and use cases. Use case diagrams are constructed graphically with the combination of actors and use cases. Moreover, its purpose is to present a graphical overview of the functionality provided by a proposed system.

In addition, use case diagrams overview the usage requirements for a system as well as describe the pattern of events that occur during a certain time between the system and actors. Moreover, the use case relationship is evolved when use case interacts with another use case (see Appendix I.I).

In Figure 4.8, a user (public participant) interacts with the GeoVPMS subsystem (spatial component) by drawing a polygon (graphics) and providing comments on a given map. The system saves map states with all drawings (graphics) and annotations by pressing the save information session button to produce a composite map for later reference.

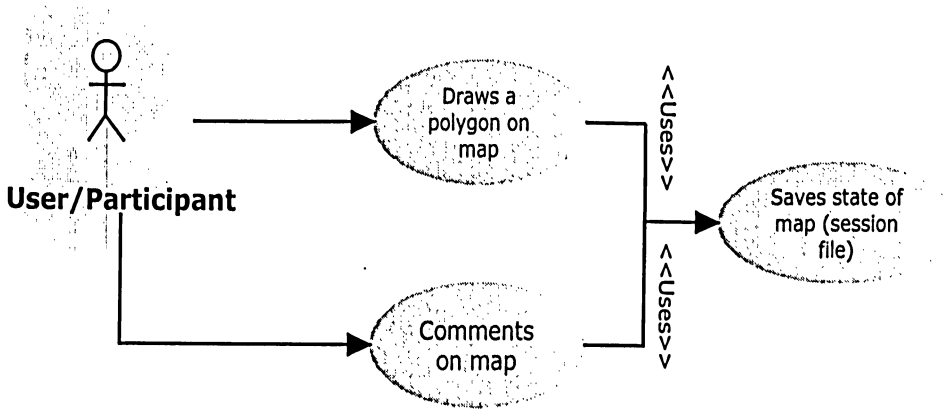


Figure 4.8: Use case diagram for showing user interaction with GIS mapping functions

Figure 4.9 depicts the use case diagram in which a user can view a previously saved session (map state) by clicking on the load session button and adding saved session file generated by the spatial component of GeoVPMS. Furthermore, user can input comments and draw new graphics on previously saved map states that can further be saved for future references.

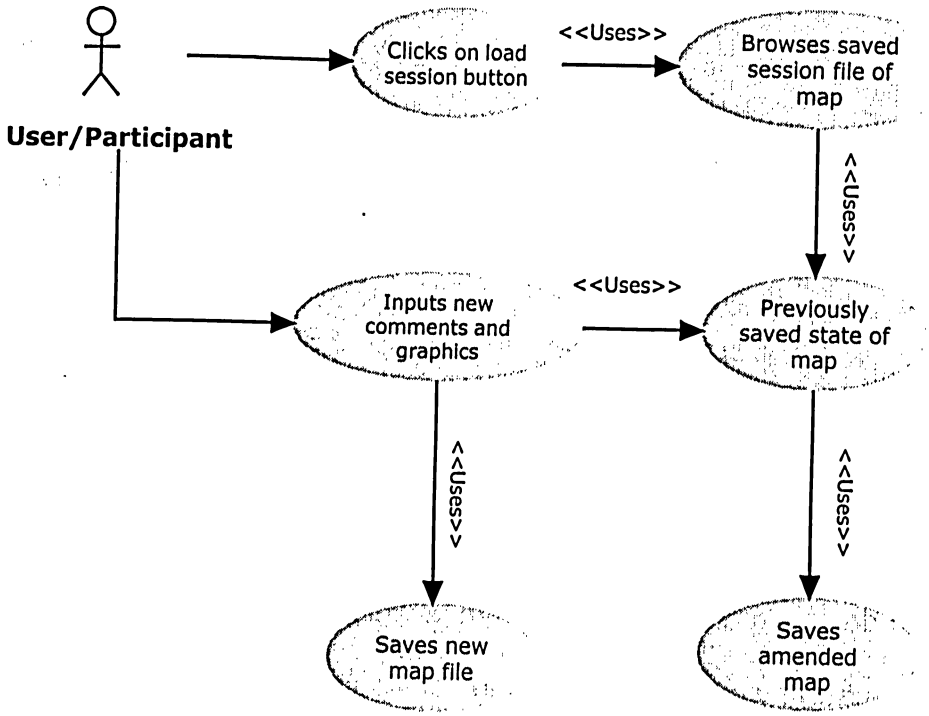


Figure 4.9: Use case diagram for showing participant interaction with GIS mapping functions

There is no doubt, to understand more clearly the functional aspects of the system, it is necessary to make a use case diagram for such a user who has more definite/obvious interaction with all of the system's sub components. In the current scenario, general users (public/citizen) will have more interaction as compare to others after deployment of the proposed system. Figure 4.10 shows how use case diagram of public participant is useful in providing overview of the usage requirements for a system's sub components.

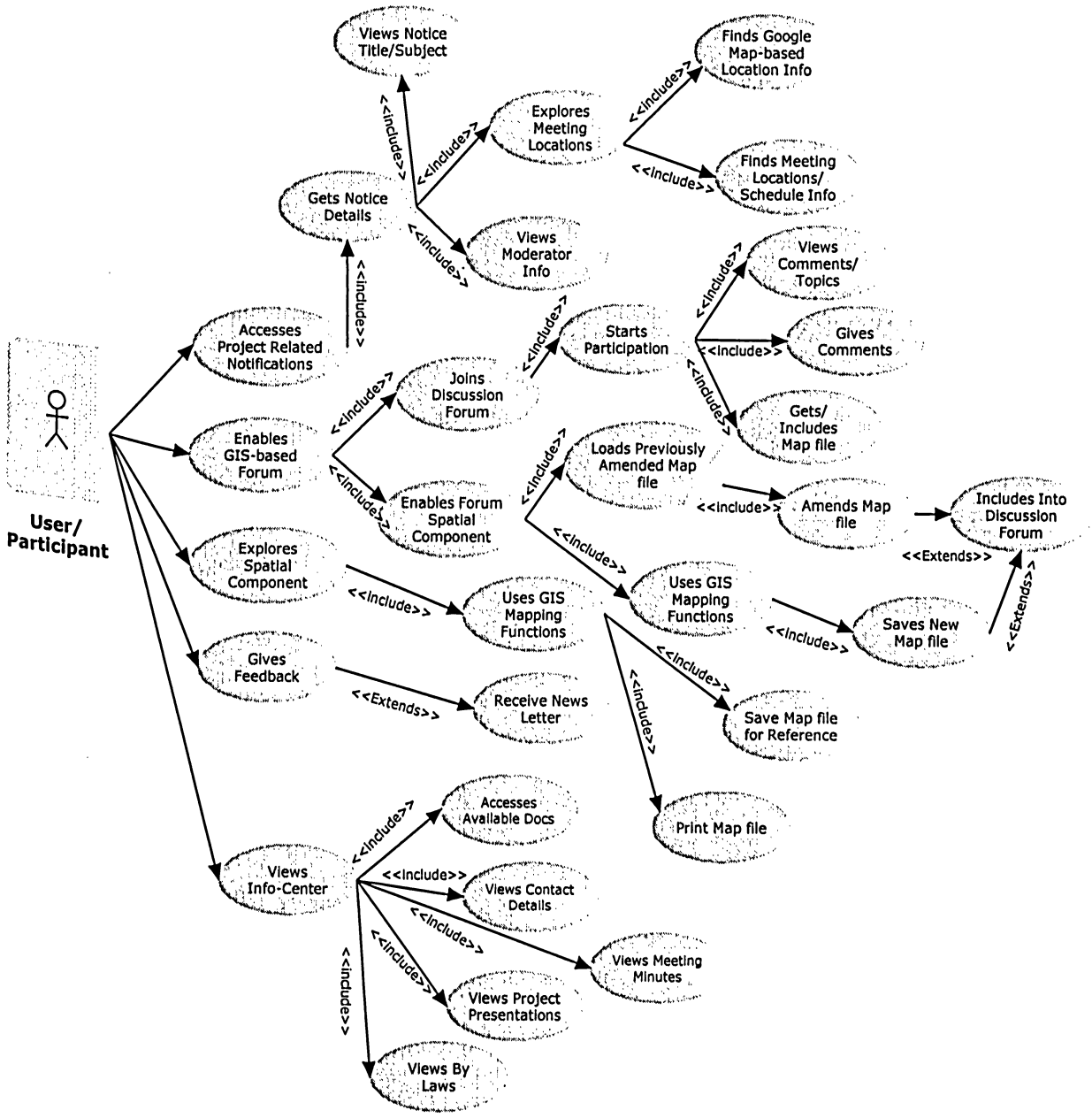


Figure 4.10: Use case diagram of public participant

Furthermore, a final use case diagram for the proposed prototype is designed for better understanding the interaction between users and GeoVPMS sub components. Figure 4.11 demonstrates the main use case diagram for the proposed prototype (a partial prototype of GeoVPMS).

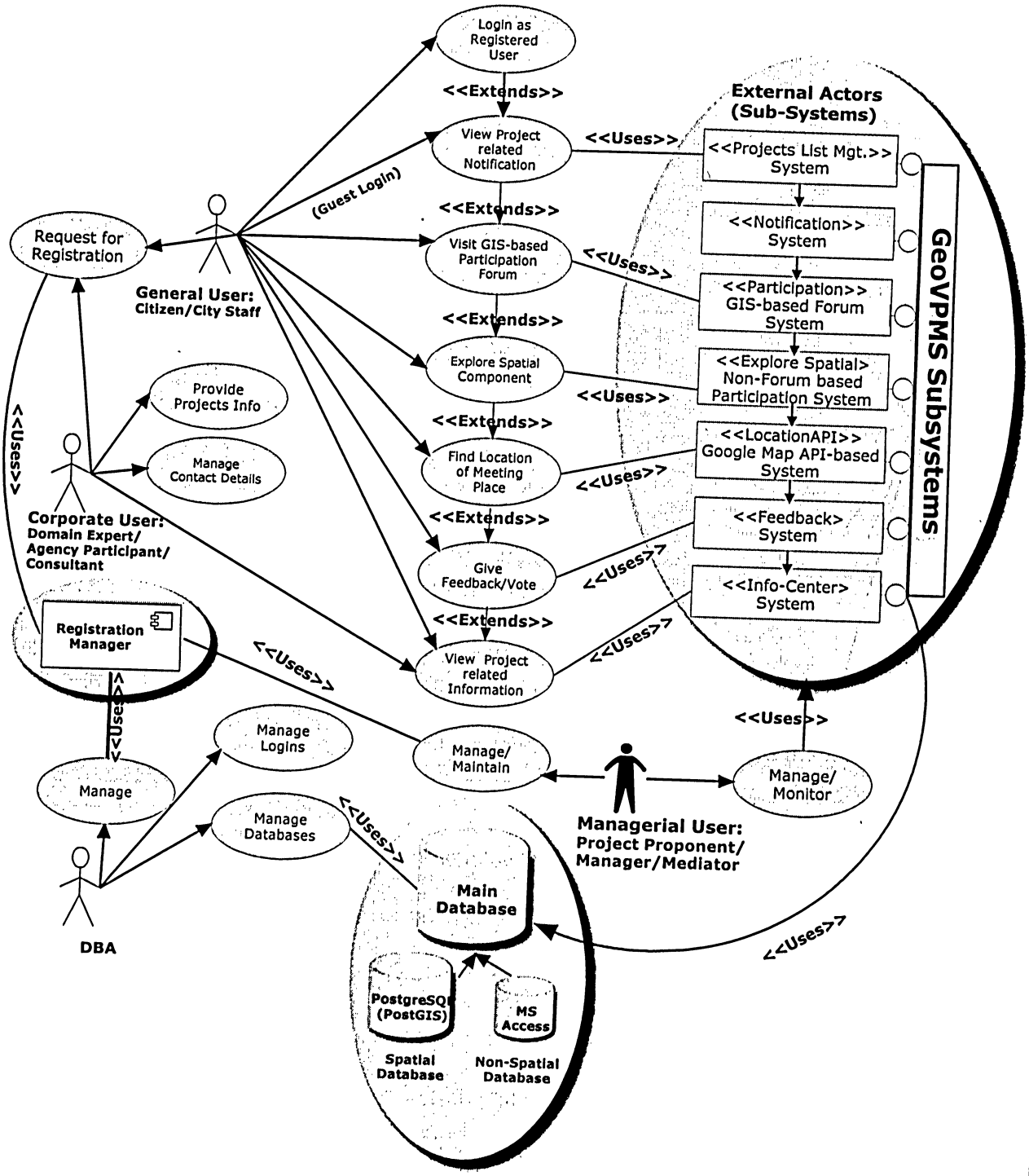


Figure 4.11: Main use case diagram of prototype

Figure 4.11 describes complete interaction between actors and the prototype's subsystems with an overview of the usage requirements for a proposed system. It clearly depicts that how general actors initialize different dialogues as well as get interaction with all GeoVPMS's subsystems according to their personal preferences/priorities. For instance, users can request to view the project lists, whereas in every project they can access notification related to that project with its detail information. Moreover, the general user can initiate discussion as a registered user or a guest by enabling GIS-enabled discussion forum or by exploring spatial component only for participation in municipal planning related issues. Moreover, managerial actors monitor and manage the system's sub components except database activities which are managed by DBA. On the other hand, corporate actors make a dialogue of managing contacts details and project information (relevant documents etc.) with the system.

In addition, the first half of the Appendix II describes more about the UML use case diagrams of the proposed prototype, which depict how these main actors/users such as the general user/citizen, managerial user/project proponent and expert user/domain expert interact or have a dialogue with the system.

4.2.3 Summary of UML-based Analysis and Design Building Blocks

In real time scenario, every system architecture and design model is dependent on requirement and analysis models (discussed previously). No doubt, more detailed gathering of requirements with deep analysis approach will provide an optimal design outcome. However, it is true to some extent that before starting construction of any real-

time system, the use of UML-based development life cycle building blocks (i.e., inception, elaboration, construction and transition) with its standard graphical notations and diagrams such as behaviour, interaction and structure diagrams provide some logical design outlook of the system. Moreover, this OOSE-based logical analysis and design model has provided close intimation with final prototype design outcome. Furthermore, UML-based logical design outcome using CASE tool-Rational Rose™ will be very helpful in analysing/identifying different sets of procedures (coding, methods or functions etc.) and enabling technologies for the proposed prototype.

As discussed earlier, UML-based analysis and design models using OOSE are classified into behaviour, structure and interaction diagrams whereas each classification contains some set of diagrams that provide several benefits during every stage of system development life cycle. For example, the context diagram (problem domain object diagram) provides the outer picture of the system's sub components and its realization in the form of use case diagrams displays interaction between users and system. In the end, both are helpful in creating effective system architecture and design which results in successful solution.

Some of the UML-based analysis and design related work with its diagrams is presented in the Appendix II. Moreover, first part of the appendix describes the UML-based interaction, behaviour diagrams followed by the discussion about structure diagrams (i.e., class, package, component and deployment diagrams) within the perspective of proposed prototype.

4.3 Prototype System Architecture and Design

The section consists of system architecture and design, which is a composition of some individual integral components that are used to develop the proposed prototype.

4.3.1 System Architecture

GIS-enabled Virtual Participation Meeting Space (GeoVPMS) is a multifunctional framework, composed with different subsystems, for supporting municipal planning and development related issues. It is a Web-based GIS framework that introduces the concept of spatial context to an online public participation, collaboration and communication with the support of a Web-based GIS and a spatial database. Figure 4.12 shows the conceptual architecture of the GeoVPMS introduced by Li et al. (2007).

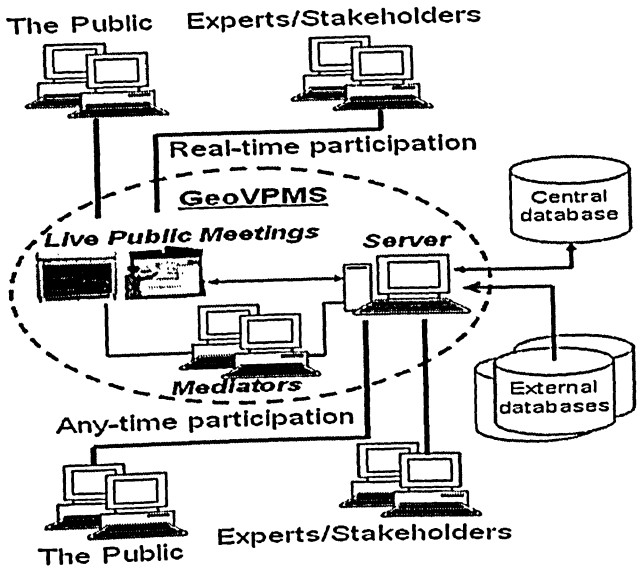


Figure 4.12: Conceptual view of the GeoVPMS (Li et al., 2007)

The prototype, simplified version of GeoVPMS with selected functional components, has been designed using modular/component based approach. Following sections are briefly described the Informational Flow Model (IFM) and some of GeoVPMS's sub components.

4.3.2 System Informational Flow Model (IFM)

The system's information flow model is developed by getting the abstraction from UML-based analysis diagrams shown earlier. It depicts an architecture view from IFM as well as Data Flow Model (DFM) perspectives. In brief, Figure 4.9 illustrates a logical architecture of GeoVPMS subsystems from IFM and implementation perspectives, induced from conceptual view (see Figure 4.12) and main use case diagram model (see Figure 4.11), of the proposed prototype.

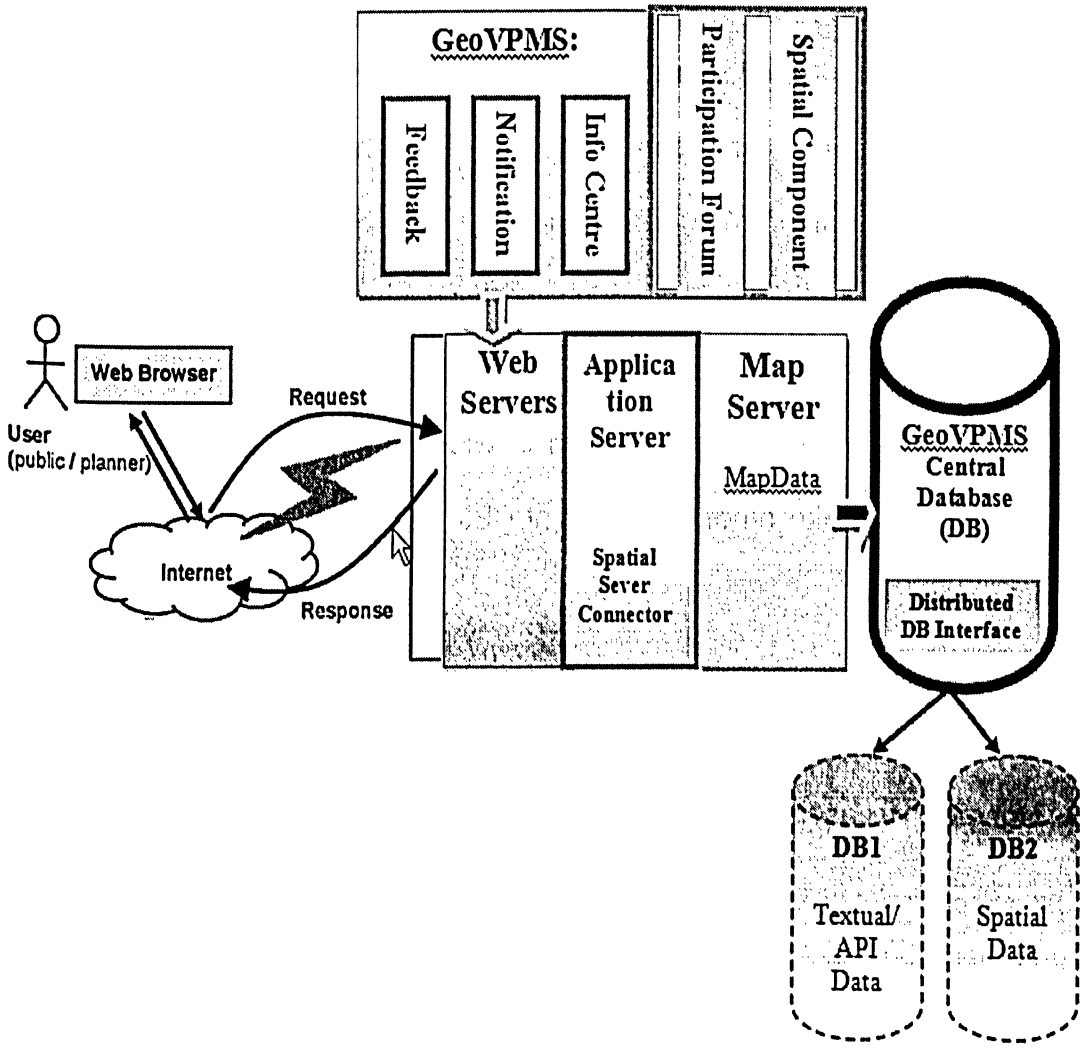


Figure 4.13: Logical architecture for the prototype IFM

The self explanatory Figure 4.13 illustrates that how the flow of data and information begins when the public send the request through HTTP protocol using client interface to IIS Web server, which holds (Active Server Pages) ASP-based programmed components (i.e. direction API and info-centre), and Apache Web server that hold PHP-based programmed components (feedback and GIS-based participation forum) of the prototype. The application server is programmed using PHP scripting modules that run on the server side to process the client request and customize the client output. If the

client requests the map information, the Web browser passes the request to application server, in order to fulfil the client request, the application server in turn communicates with the UMN map server and central database of the prototype. Moreover, some request regarding textual information is handled by Microsoft access database whereas spatial context data from the GIS-based online discussion forum is stored in PostGIS. In addition, PostGIS is a spatial extension supported by PostgreSQL/PostGRES Data Base Management System (DBMS) which is widely used OSS and has most of the similar robust features like other commercial DBMS (Oracle Spatial etc.) for managing spatial data.

Ideology of using two different databases and Web servers in the n-tier architecture of the prototype increases the stability as well as reliability (throughput) of DBMS with the better response time to the client. For instance, some simple queries related to notifications will not become the burden of spatial database management system as they are handled by a separate DBMS. In addition, all data related to address locator API are handled with Microsoft access. Moreover, all the data from the online GIS-based participation forum and feedback components are stored in a PostGRES database.

In a nutshell, using a mashup of different open source technologies will provide a more robust and reliable solution in a real-time environment. For example, the uses of two different Web servers provide the maximum advantage and support of using multiple programming languages (PHP, ASP and Java Server Pages etc.) during the design and construction phase of proposed prototype. Moreover, multiple participatory

approaches are quickly manageable by two Web servers due to increase empowerment of load balancing feature.

For rapid development, the prototype is built upon generic Web site that integrates with different sub components such as the GIS-based participation forum, non-forum based spatial component, notification, feedback and information centre. Details about prototype sub components are discussed in the next section.

4.3.3 Proposed Prototype Components

The prototype, simplified version of GeoVPMS with selected functional components, has been made using modular/component based approach. The prototype is a composition of some individual integral components, such as public notification, GIS-based participation forum, spatial component, info-centre, feedback and address locator API etc. Some of these components are briefly described in the following sections.

4.3.3.1 Notification: Public Notice System

Online GIS-enabled public notice system, called Notification, 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 continuous soliciting of the public input and presentation of the final results (Li et al., 2007).

The notification component also provides location mapping related function in which participant can find his/her way or direction to the public meeting place. For providing required direction services open source APIs from Google with a mashup of PHP server-side scripting language were used.

4.3.3.2 Info-Centre: Information Resource Centre

In this component, the public can browse arranged information related to the municipal planning and development problems. The document includes bylaws and regulation documents, project documents, meeting agendas and minutes, and the contact information. Moreover, the contact information includes the name of the moderators or authorities, email, phone/fax numbers etc. Participant can also download and view other informational resources related to incoming and existing municipality projects as well as prototype's operating manual.

4.3.3.3 Participation: GIS-enabled Discussion Forum and Spatial Component

Participation component is mainly consisted of two major sub-components that are briefly discussed as follow:

A. GIS-enabled Discussion Forum

The GIS-enabled online participation forum was designed and developed using open source solution technologies. The organization of threaded comments in participation forum component is similar to any discussion forum found on the Internet. All the forum

data is stored in PostgreSQL database. This participation forum is embedded with another module, which handles all the GIS functionalities and can be enabled at any time during spatial contexts related discussion with other participants.

An architectural model of the GIS-enabled discussion forum is somewhat similar to the system architecture that was introduced by Ma (2006, pp. 54). Its architecture is shown in Figure 4.14.

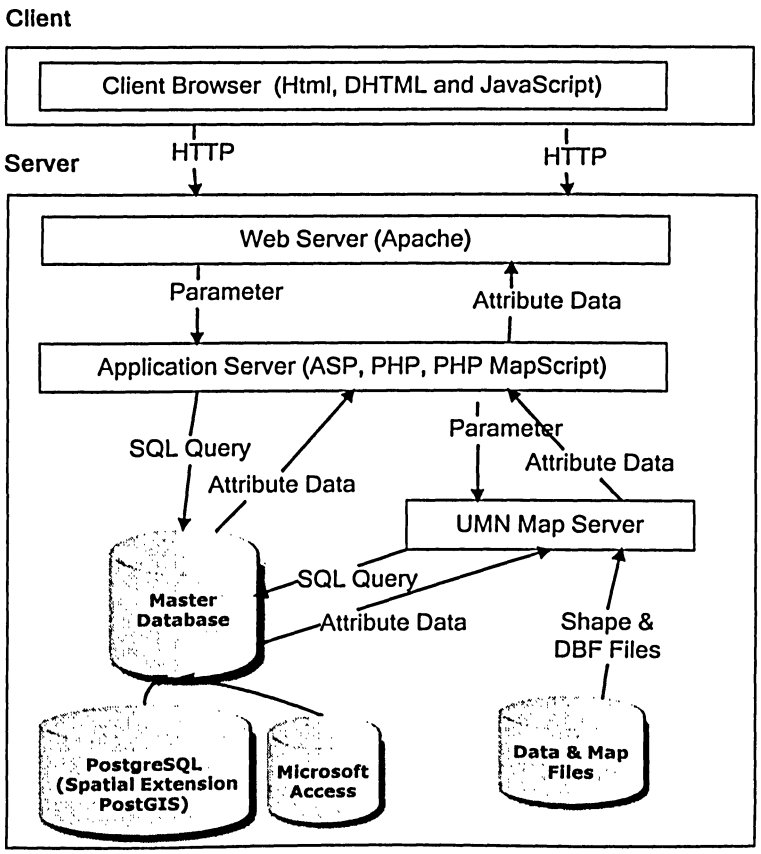


Figure 4.14: Logical architecture of GIS-based discussion forum (Modified after Ma, 2006)

The threaded forum messages are displayed in the main panel and the pop up window is used for GIS-based spatial component exploration. It initiates a concept of GIS-enabled discussion forum in which public participants can participate and share ideas of spatially-related discussion with spatial data file attachment (generated by spatial component). In this component public participant can add, modify or view their own and other participants comments. Furthermore, there is no doubt that this component enables public to participate in planning related discussion at a flexible period of time as well as according to their easiness (one of the major benefit of WebPPGIS).

The logical architecture of the spatial component with IFM perspective (used in discussion forum) is shown in Figure 4.15. It depicts how mashup of different open source technologies interact with each other and generate the final out put to the client interface.

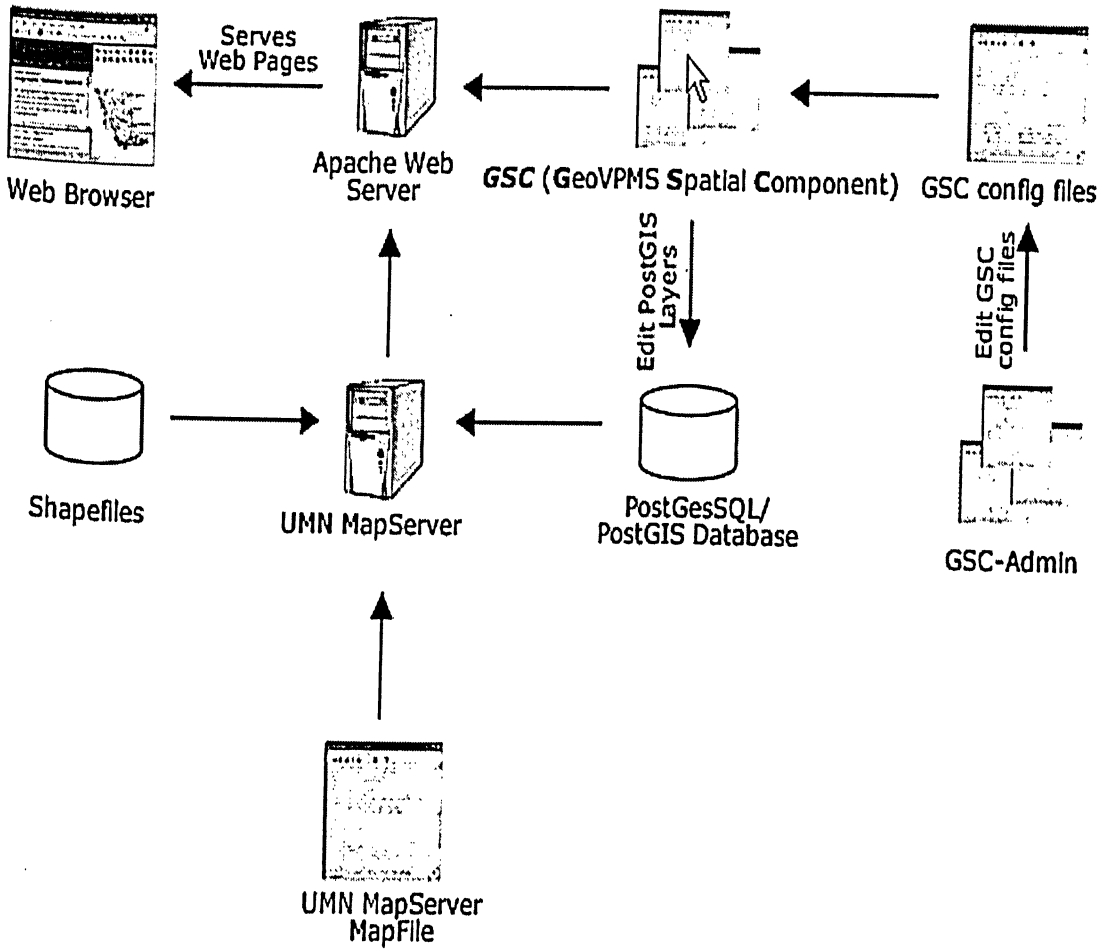


Figure 4.15: Logical architecture of spatial component with IFM perspective

B. *Non-forum based Spatial Component*

Another component is designed for those participants who want to initiate their discussion without getting into the forum. The purpose is to facilitate the user according to their mindset by providing them the access to explore only a spatial component for participation associated to municipality planning related issues. The architectural model of this component is similar to the one which is designed for GIS-enabled spatial component (shown in Figure 4.15).

4.3.3.4 Feedback: Public Feedback Component

The feedback module handles features such as newsletter, polling/voting and feedback from user. Two major ways of getting public feedback are discussed as follow:

- **Using Interactive Wizard Interface:** For getting feedback, the component provides an interactive interface to participants which include several voting/polling questions made by domain experts/consultants.
- **By Email:** It is another important as well as common way of taking feedback from all the participants.

Furthermore, except from feedback functionalities mentioned above, this sub-component is also used to generate the acknowledgement (e-messages) e.g., newsletters for all upcoming events as well as the notification of municipal planning related projects. This system feature is only available to the registered users.

4.4 Importance of UML and Rational Rose™ in Analysis and Design of GeoVPMS

It is true to some extent that use of UML and CASE tool-Rational Rose™ during the analysis and design of GeoVPMS was very effective. The lessons learned from using UML and Rational Rose™ in designing PPGIS applications is discussed as follow:

First, it is very important to gather all the requirements and do the deep analysis before design and implementation of any new system. Moreover, it is highly recommended that all the requirements and analysis stages (both user and system perspectives) should be documented in proper form by following some certain standardized criteria or set of rules before starting development stage. Rational Unified Process (RUP) life cycle supported by UML was used to capture all the stages of GeoVPMS development life cycle. As per my experience during this research, the use of RUP was an effective way of documenting all the phases of system development life cycle. It was an iterative incremental development process with more emphasis on documentation and visual modelling. The process was architecture driven, use case driven, and risk driven, in right balance.

Secondly, PPGIS systems have very complex framework due to its GIS-based functionalities, so without using any CASE tool, it's very difficult for the analyst to document each building block (phases) of the system development life cycle. Rational Rose™ is an object-oriented UML-based software analysis and design tool, which provides the multifunctional platform to both analyst and designer. For instance, in current research, the CASE tool-Rational Rose™ was very useful during the execution of all phases related to proposed prototype development life cycle. All the analysis and design related workings were documented using Rational Rose™ generated visual diagrams (UML standard graphical notations) whereas the entire coding (programming) concepts for the prototype construction and implementation were generated through its one of the best feature (function) named forward engineering. As of my knowledge, this

approach (UML) and platform (Rational Rose™) both are also good for Rapid Application Development (RAD) scenarios.

4.5 Summary

The first half of this chapter presented the introduction of the UML and CASE tool-Rational Rose ™ followed by the discussion related to the UML-based analysis and design approaches using OOSE for the proposed prototype. Then the conceptual as well as architectural model of GeoVPMS framework introduced by Li et al. (2007) was discussed followed by the debate related to the implementation/information flow model of the prototype. After that, all the proposed components of GeoVPMS framework were briefly described with their functionalities and design consideration. In the end, importance of the UML and CASE tool-Rational Rose™ during the analysis and design of online GIS-based public participation framework were discussed.

The next chapter discusses about the actual implementation and evaluation aspects of the proposed prototype.

CHAPTER 5 PROTOTYPE IMPLEMENTATION AND EVALUATION

The following sections discuss how the prototype is implemented and realized (user interfaces) in the real world. First, the prototype implementation using OSS-based technologies are discussed and then the user Web interface development and database design are examined based on the analysis and design model discussed earlier. In the end, demonstration of the prototype using the Region of Peel example project to walk through major implemented interfaces and functions followed by evaluation and usability testing of the prototype is discussed.

5.1 Software Tools and Technologies used in Prototype Implementation

The Open Source Software (OSS) technologies within the context of prototype development are discussed briefly in this sub-section. As a matter of fact, a wide variety of appropriate technologies or softwares are available in this modern hi-tech world but the benefits (discussed in Section 2.3.1) of OSS technologies are convincing developers to merge these technologies during the development of a new system. The key considerations for adopting an OSS technology for the proposed prototype development are as follows:

(i) It supports Rapid Application Development (RAD).

(ii) It is easy to learn and set up.

(iii) It is readily available and preferably free of charge.

Software and technologies that are used through out the system (prototype) analysis, design and implementation are listed as follow:

- *Web server*: Apache, Internet Information Server (IIS)
- *Web mapping tools*: UMN (University of Minnesota) MapServer
- *Database server*: PostGIS (PostGRES), Microsoft Access
- *Web server side programming*: PHP, ASP (Active Server Pages)
- *Client side programming*: XHTML, JavaScript, Dynamic HTML
- *CASE Tools, OSS Modules & Softwares*: Macromedia Dreamweaver Studio 8, Adobe CS3 Web Premium, Coldfusion, *PHPBB, Invision Power Board (IPB), Drupal, WordPress, FIST,* IBM Rational Rose ™ 2003 *Enterprise Edition*
- *Analysis Approach*: Unified Modelling Language (UML)

The following sections give a brief overview for some of the above-mentioned technologies:

5.1.1 Rational Rose ™

CASE tool IBM Rational Rose ™ enterprise edition was used during design to delivery stages of the prototype. In short, all building blocks of system life cycle were implemented using object-oriented software engineering (UML) as well as Rational Rose ™.

5.1.2 Web Server/HTTP Server

One of the major components of Internet related applications is Web server. Its purpose is to "respond to requests from Web browsers (client interface) via the HTTP (Hypertext Transfer Protocol)" (Peng and Tsou, 2003). The prototype used IIS (Version 5.1 or 6.0) and Apache Web server 2.2.4 both as the Web servers to avail the benefit of max system throughput and response time and as the development platform is a Windows operating system both are easily available for installation.

5.1.3 UMN (University of Minnesota) MapServer/Spatial Server

No doubt, to support map related applications on the World Wide Web there is a variety of Web mapping technologies available nowadays. MapServer was selected as a spatial server for handling spatial request of participation component because it is one of the most widely used open source spatial server with a large open source community of developers. Although, it is not a fully featured spatial server comparing to other commercially available servers (i.e. ESRI ArcIMS etc.), but it can handle basic Web mapping functionality efficiently.

5.1.4 Database Servers

A database server is required for storing and managing/manipulating the contents (record sets) of the online participation forum, feedback, info-centre and notification modules. The selected database servers for notification, participation, spatial component and feedback are PostGreSQL/PostGIS and Microsoft Access.

PostgreSQL/PostGRES (http://www.postgresql.org) is free open source Relational Database Management System (RDBMS). It is compatible with PHP scripting language and easy to deploy. Open source database (PostGRES) has its own well supported spatial extension which is known as PostGIS. It will be used to store the data related to spatial data handler API. At this stage, the PostgreSQL is not using its spatial extension due to the lack of availability of (real time) spatial data. Shape files and dbf files are used to show and demonstrate the functionalities of spatial data handler API.

5.1.5 Server-side Programming Language

PHP, PHPMapscript and ASP were adopted to develop dynamic Web contents of the prototype. PHP is the popular open source language. It supports all major platforms such as Linux, Windows and even Mainframes (Orzech and Zend Staff, 2001). It has good support with MySQL and PostgreSQL/PostGIS.

5.1.6 Client-side Programming Language

JavaScript (created by Netscape) is a well-known client-side scripting language. It is used extensively in all components of the developed prototype to provide interactivity with the Web pages. In particular, the menus and other dynamic behaviours will be implemented with JavaScript and Dynamic HTML (introduced in Netscape 4).

5.2 User Web Interface Design

To facilitate the textual component of individual contributions to be read alongside the corresponding spatial context, the prototype index page is made up of three major frames which are explained as follow:

- **Top frame:** As shown in Figure 5.1, the top frame is across the top of the Web page. It displays the title and the logo of GeoVPMS as well as drop down list menu of municipal development projects currently under development. Every time a user selects a particular project from the projects list, displayed at top frame, it will take the cursor to the left frame and display some more information related to the selected project.

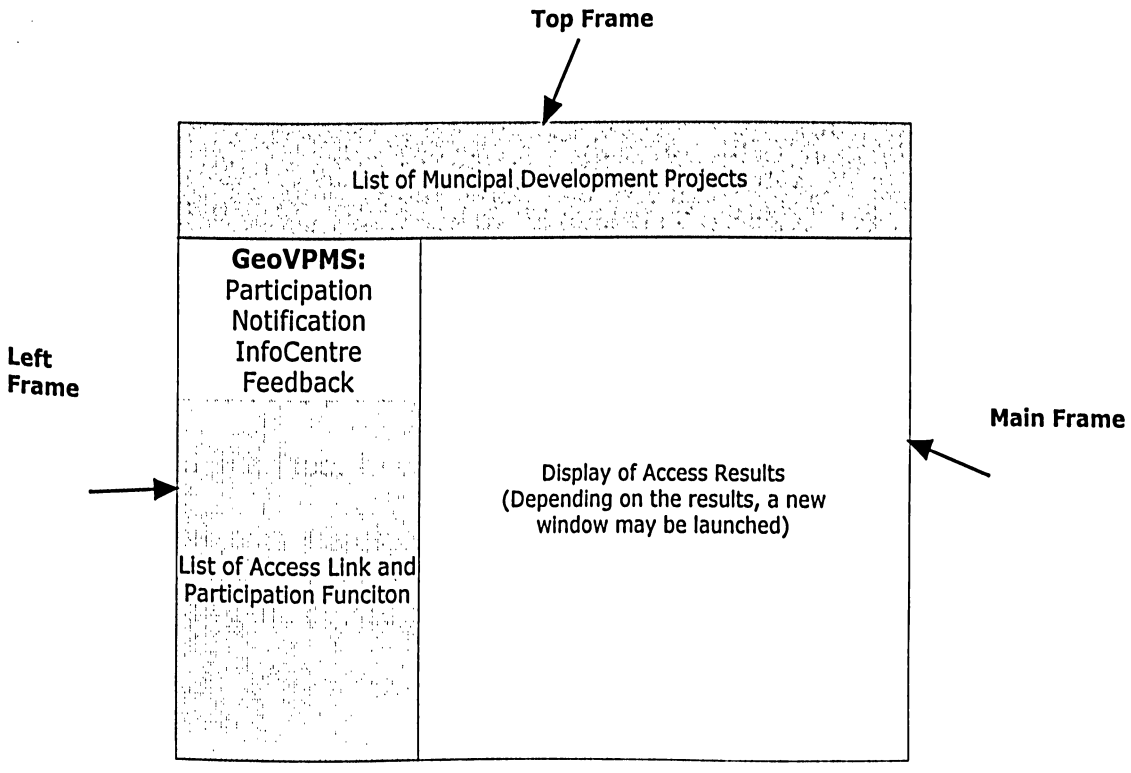


Figure 5.1: Conceptualization of the main Interface of GeoVPMS (Li et al., 2007)

- **Left frame** is also very important part of the interface; it contains information links of all the GeoVPMS's components. Furthermore, it changes its behaviour dynamically when user wants to explore any particular project information. For instance, when user clicks on project1 link displayed in the drop down menu, the further links related to the project1 components (i.e. public notification, GIS-enabled participation, feedback etc.) are provided.

- **Main frame** is the heart of the main interface which is used to display the contents (detail) of the selected project components, e.g., notification, info-centre, or participation.

Figure 5.2 is the real time snapshot of the prototype's main interface that depicts all the integral components of the prototype in the left frame (i.e. participation, notification, info-centre and feedback).

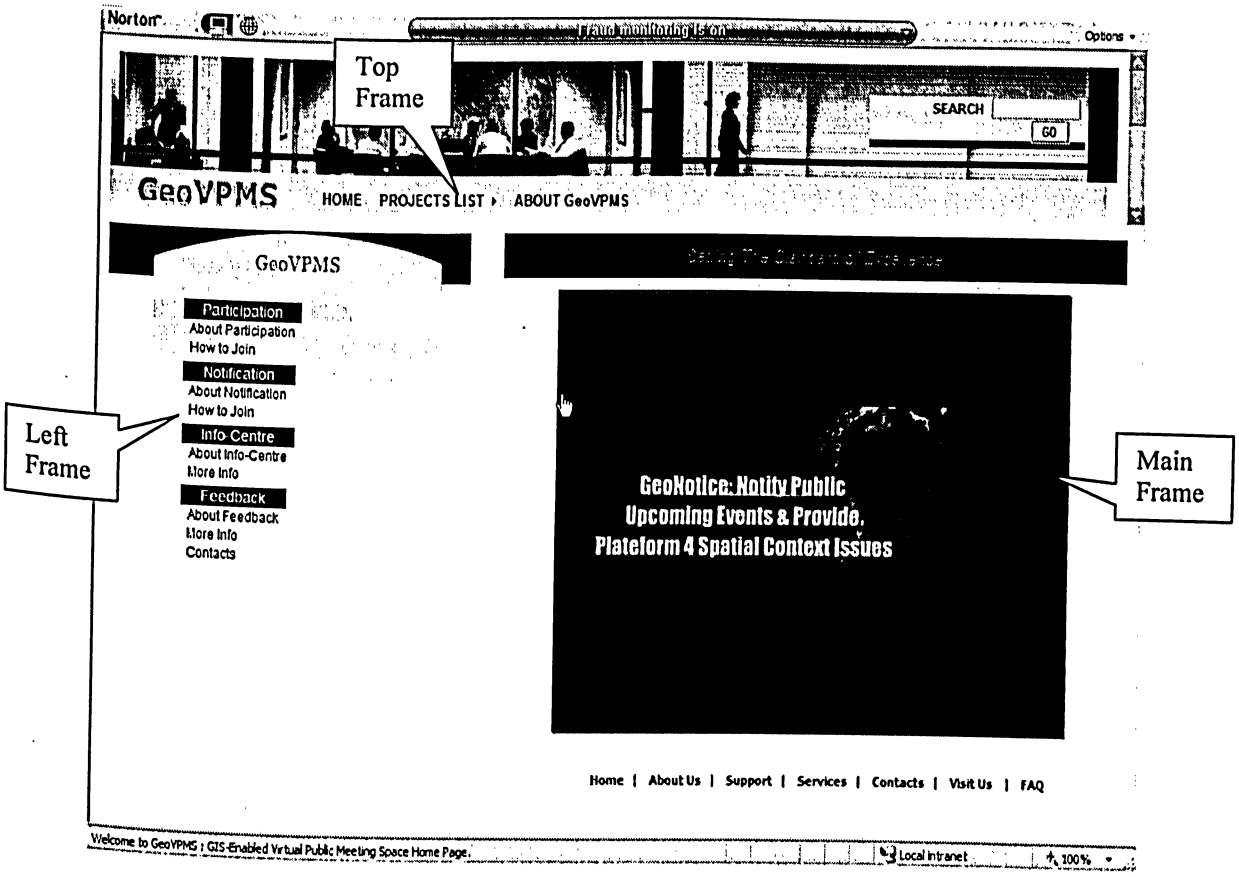


Figure 5.2: Main Interface of prototype (GeoVPMS)

5.2.1 Component Level Web Interfaces of Prototype

As discussed earlier, the prototype has some components which are integrated with the GeoVPMS main interface. Every component can only be accessed from the drop-down menu list of projects that is appeared at the top frame of the main interface. The following section shows the details of these components with their final interface design.

5.2.2.1 Participation Forum Interface

The main interface of the forum component helps registered user to login in the system or register for an account for posting contributions as well as initiating spatial context related discussion for municipality development. When a user clicks on the participation link, it opens up a Web page that contains some descriptions about active forums and topics related to spatial discussion. Figure 5.3 depicts the main interface of the participation forum.

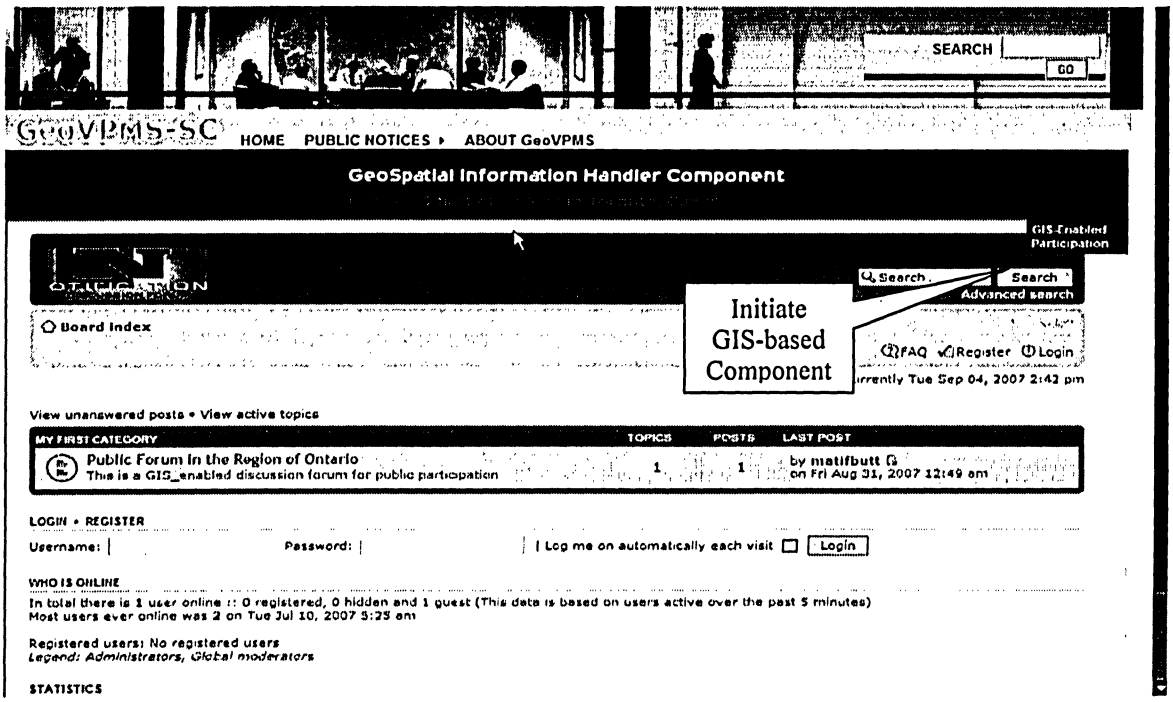


Figure 5.3: Main Interface of participation forum

5.2.2.2 Notification/ Events Interface

This interface of notification component is prompted when the user clicks on the events link (under notification details). It provides all the upcoming events information related to the municipal planning and development related projects. Figure 5.4 depicts the main interface of the notification component for displaying all upcoming events.

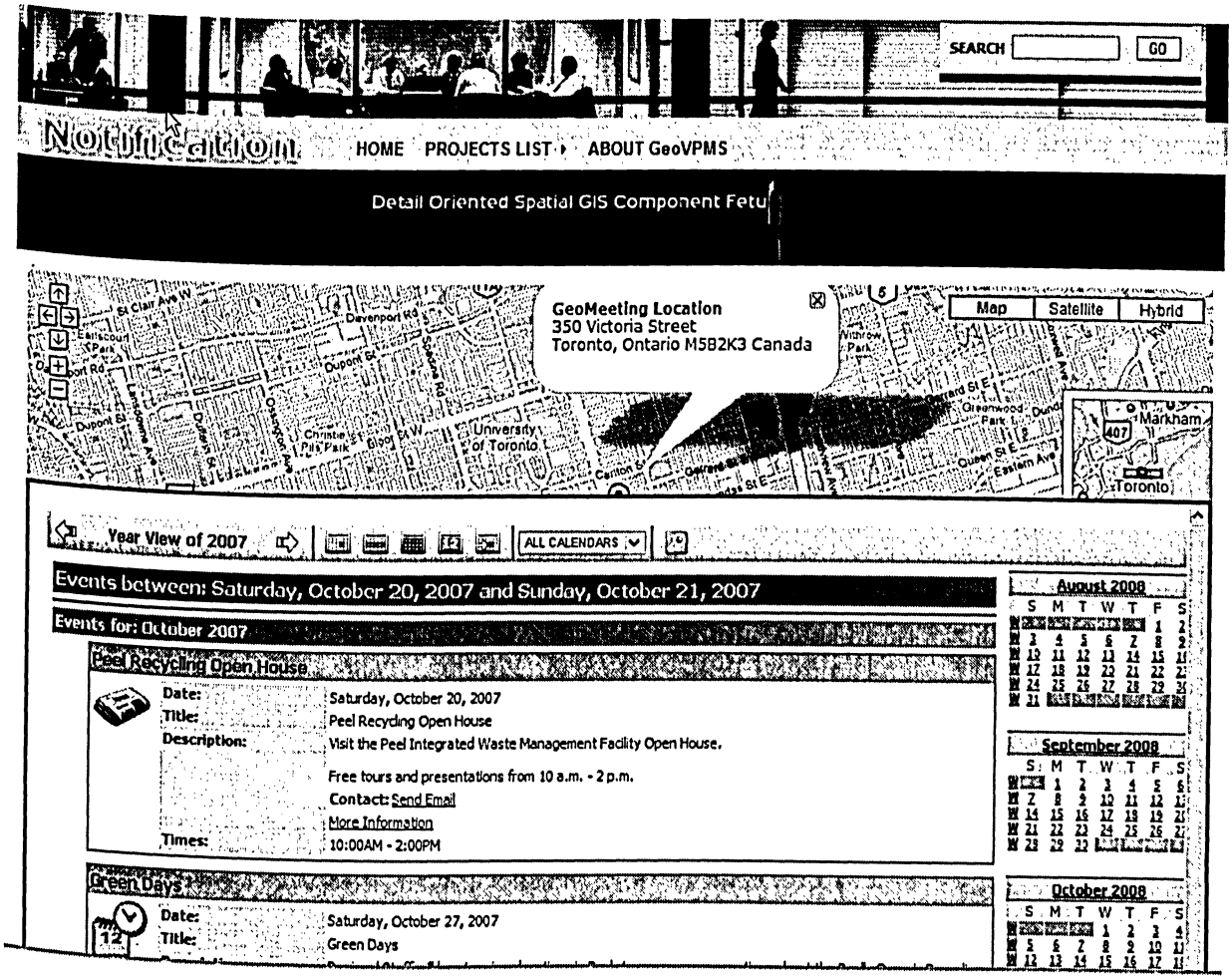


Figure 5.4: Main Interface of notification component for displaying events

5.2.2.3 Participation Spatial Component Interface

This interface provides the core GIS functionalities to the user. Using this interface, the user can add his/her comments to the map and have some drawing functions as well as some other useful GIS functions such as select query, zoom in, zoom out, query by attribute, erase graphics, identity feature, measure area and pan tools. User can store the map information session and attach saved session with discussion forum in his/her posting; whereas another user can view or alter the saved map information and repost it. This is the multi-way communication in which all participants can participate according to their area of interest. Figure 5.5 illustrates the main interface for participation spatial data handling component.

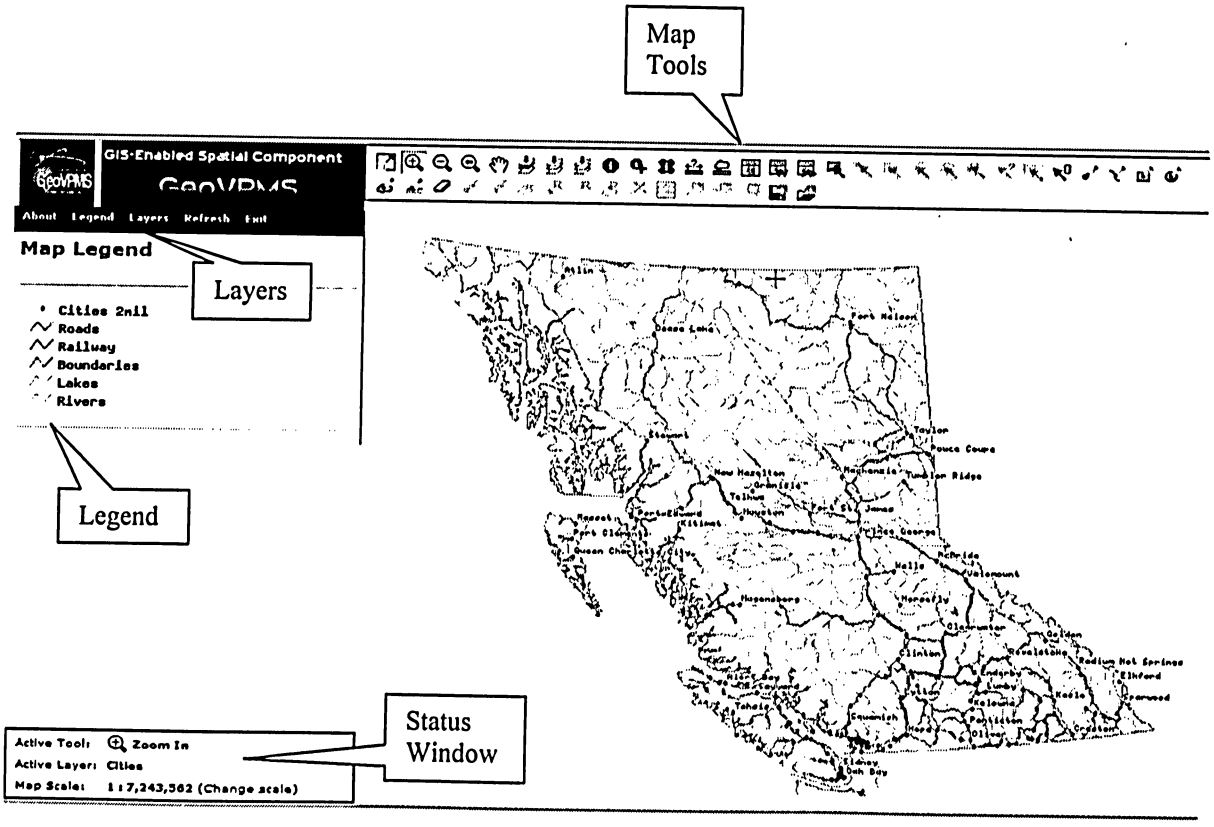


Figure 5.5: Main interface for participation spatial data handling component (with forum)

Another snapshot of spatial component is shown in Figure 5.6 which is prompted to the user only when the participants want spatial component to explore the spatial contexts related issues related to planning without accessing the forum.

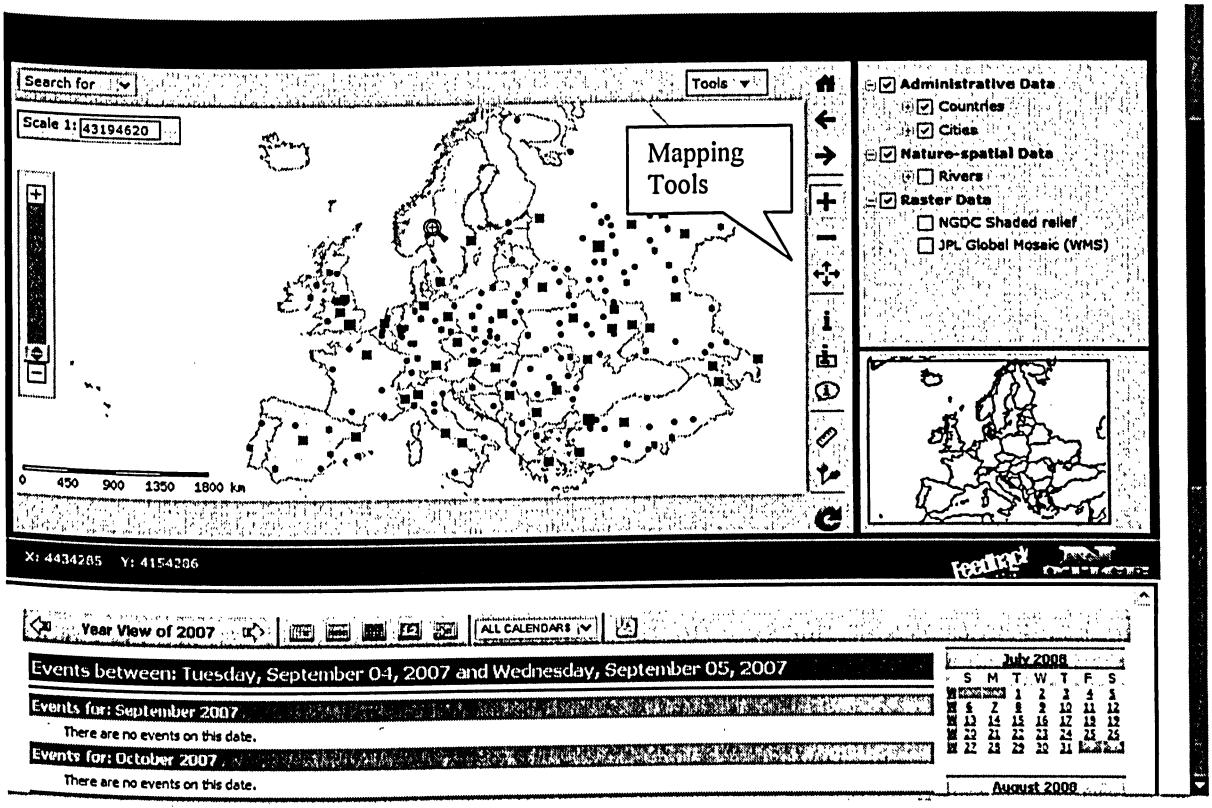


Figure 5.6: Main Interface of spatial component (non-forum based)

5.2.2.4 Information Centre Interface

The information centre interface provides information about a particular project that the user selects from the drop down menu of the project list and it also provides some relevant information, including tutorials, planning regulations, journal papers and contact information for that particular project (see Figure 5.7).

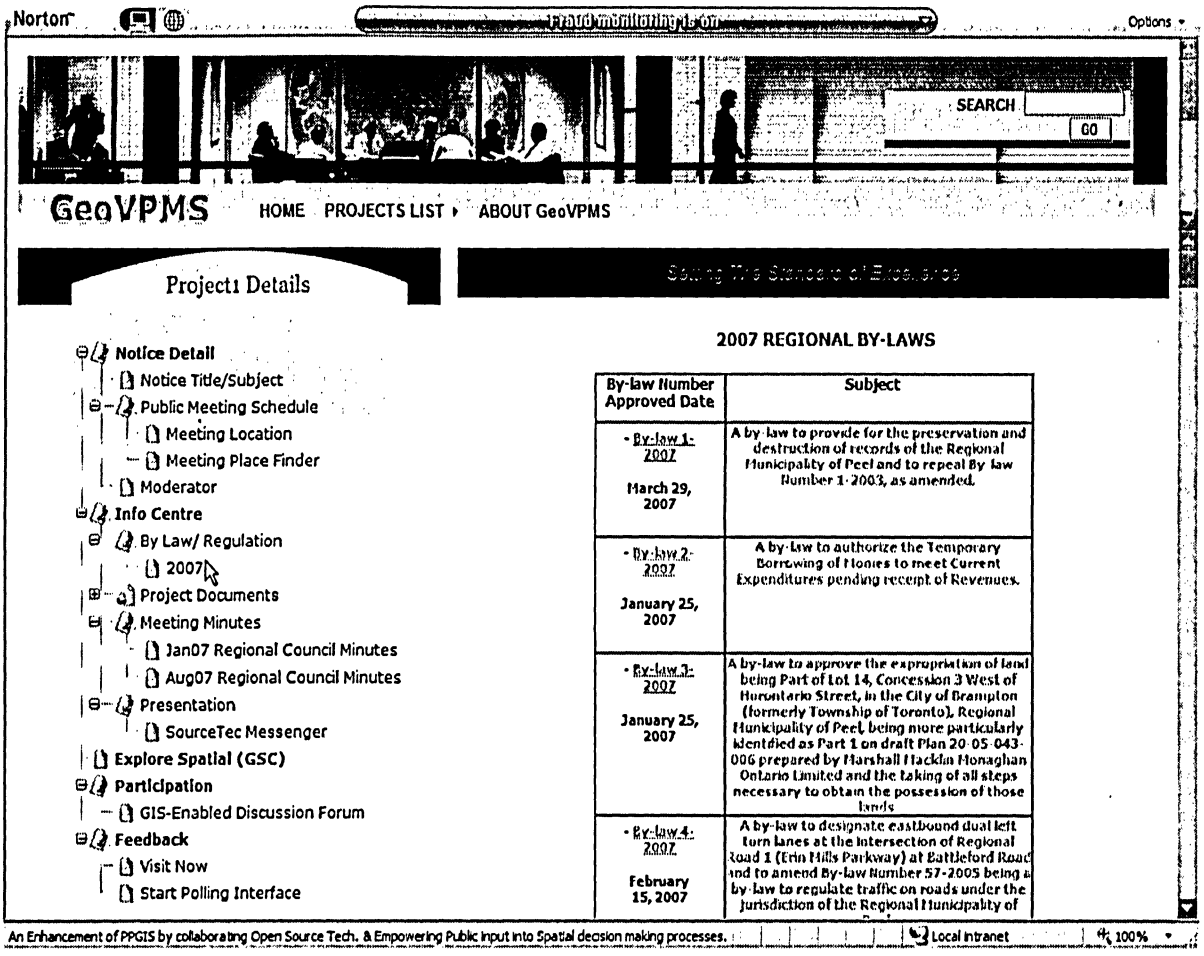


Figure 5.7: Main Interface of info centre component

5.2.2.5 Prototype Administrative Interfaces

Administrative interfaces are designed to provide a simple, quick, and powerful way to manage GeoVPMS subsystems. These interactive interfaces provide effective administrative functionalities to the managerial users (i.e., project proponents and mediators etc.) and can be initiated using valid administrative username and password.

Figure 5.8 illustrates administration control panel of the forum component, which is used by managerial users to administrate major functions e.g., formation of new forums, creation of new users and groups with different rights and privileges and setting the user or system level securities and permissions etc.

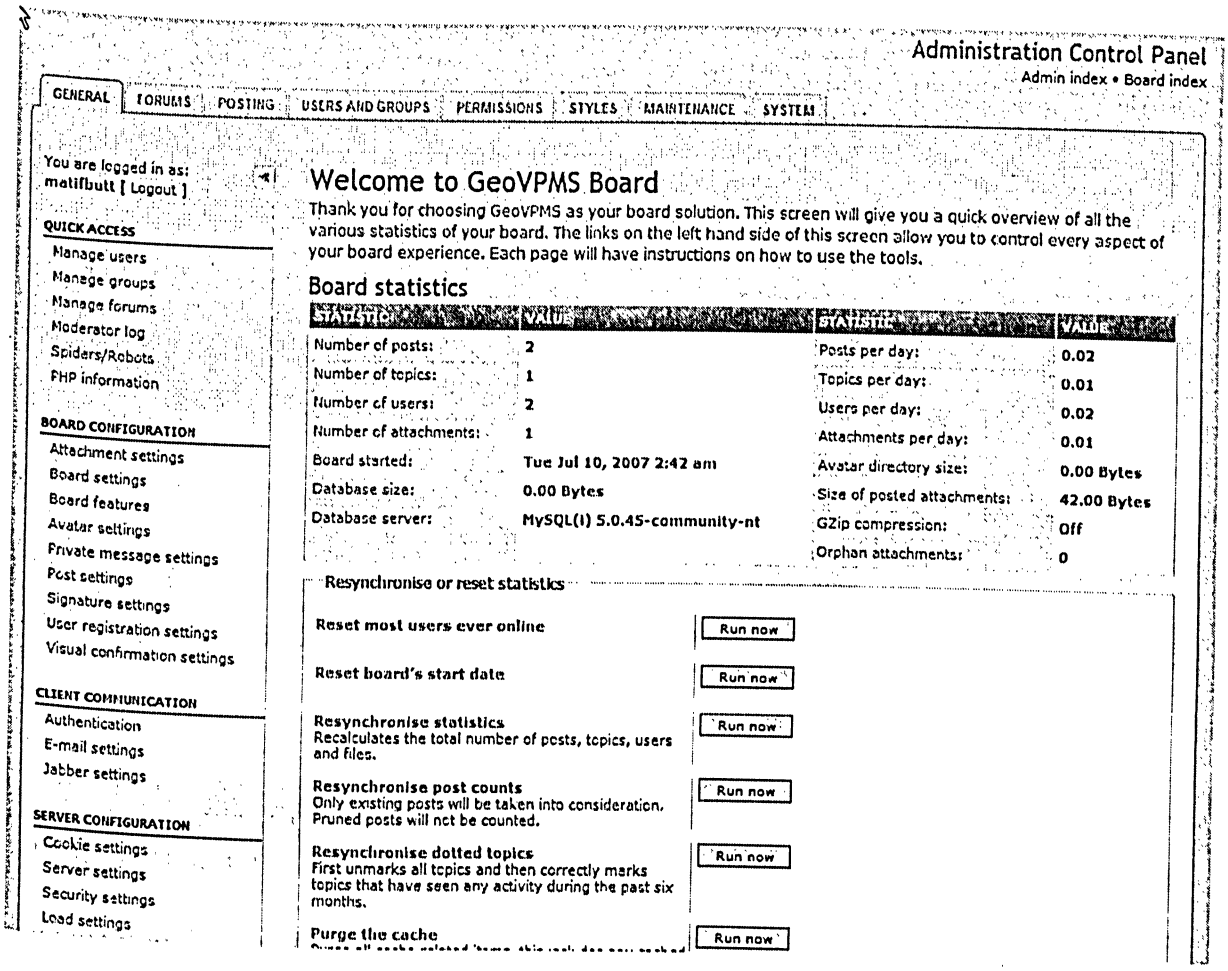


Figure 5.8: Administration control panel of the forum component

Figure 5.9 shows the administrative interface of the spatial component used in discussion forum. It's a powerful visual administration console that enables managerial users to easily administer spatial component (GSC). All the administrative tasks

including: layer, site, user and map service configurations etc. can be accessed from the spatial component administration control panel.

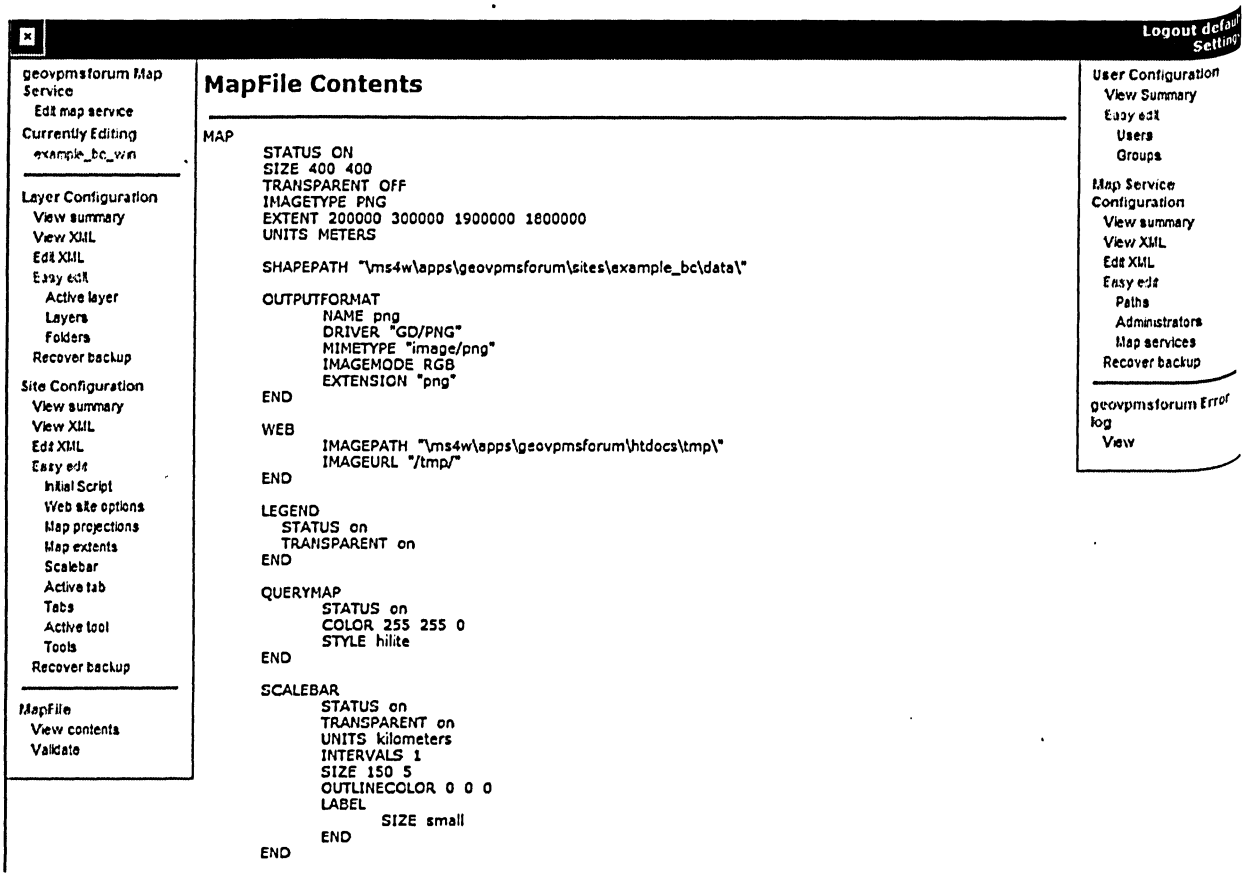


Figure 5.9: Administrative interface of the spatial component

Figure 5.10 depicts the administrative interface of feedback component which is used by admin (managerial/corporate) users to make polling/survey questions as well as adding, editing or deleting and sending the newsletters to the registered users/applicants.

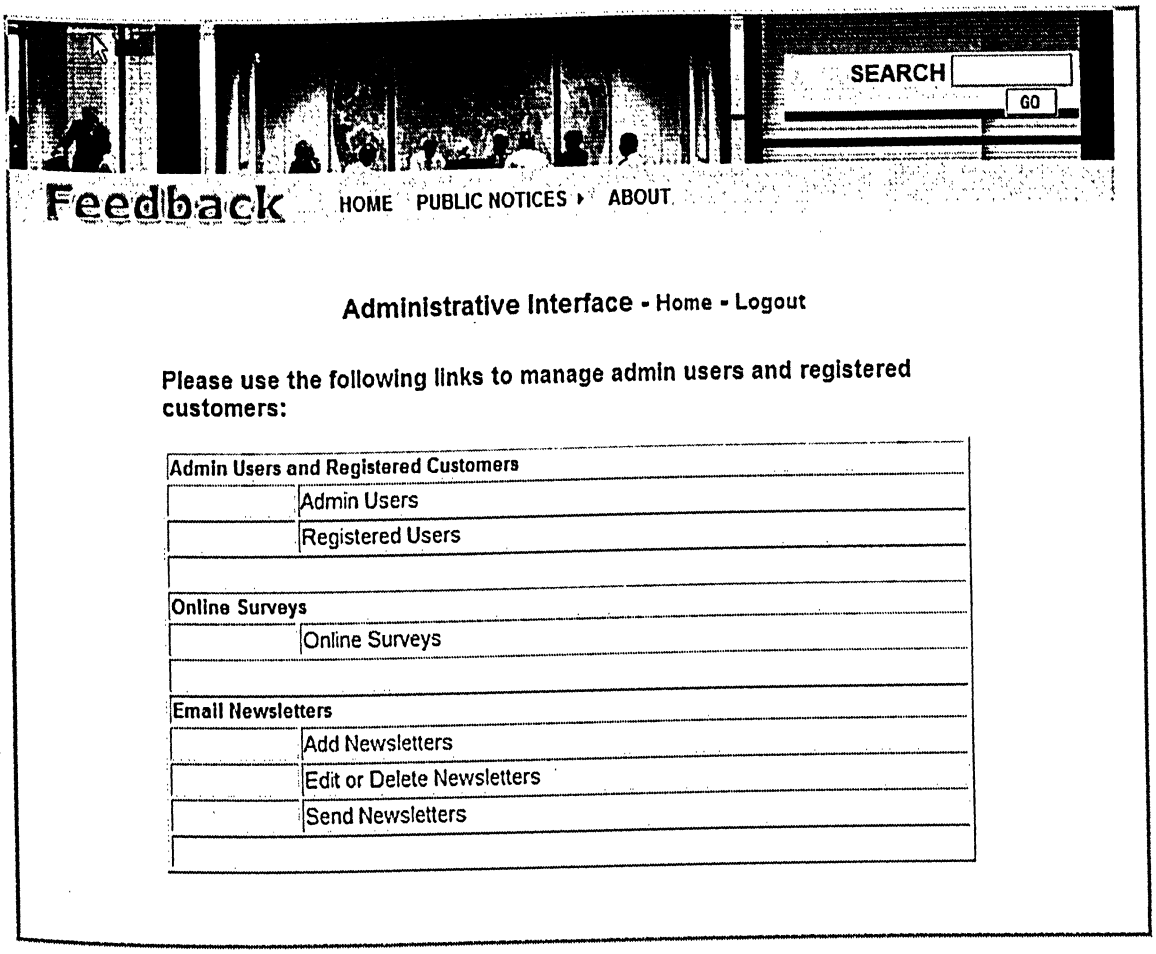


Figure 5.10: Administration control panel of feedback component

Figure 5.11 shows the interface, which prompts to corporate/managerial users (e.g., consultants, mediators and domain experts etc.) to enter password and let the authenticated user to the interface (see Figure 5.12) which allows users to manage (i.e., add, delete and modify events etc.) all the upcoming events related to municipal planning and development related projects.

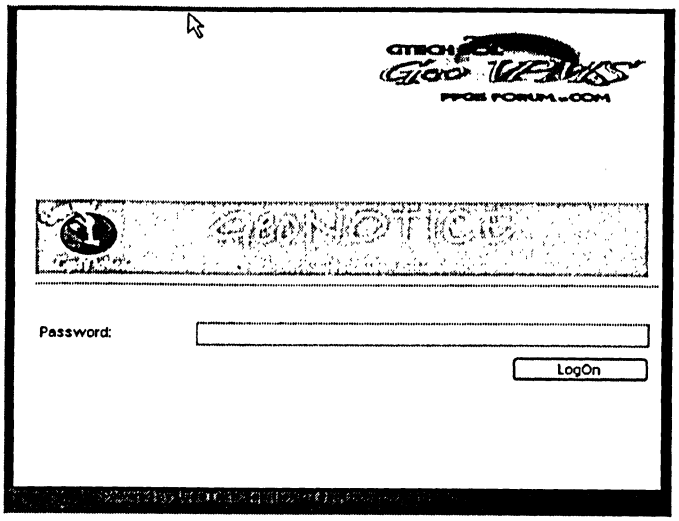


Figure 5.11: Login interface of notification component

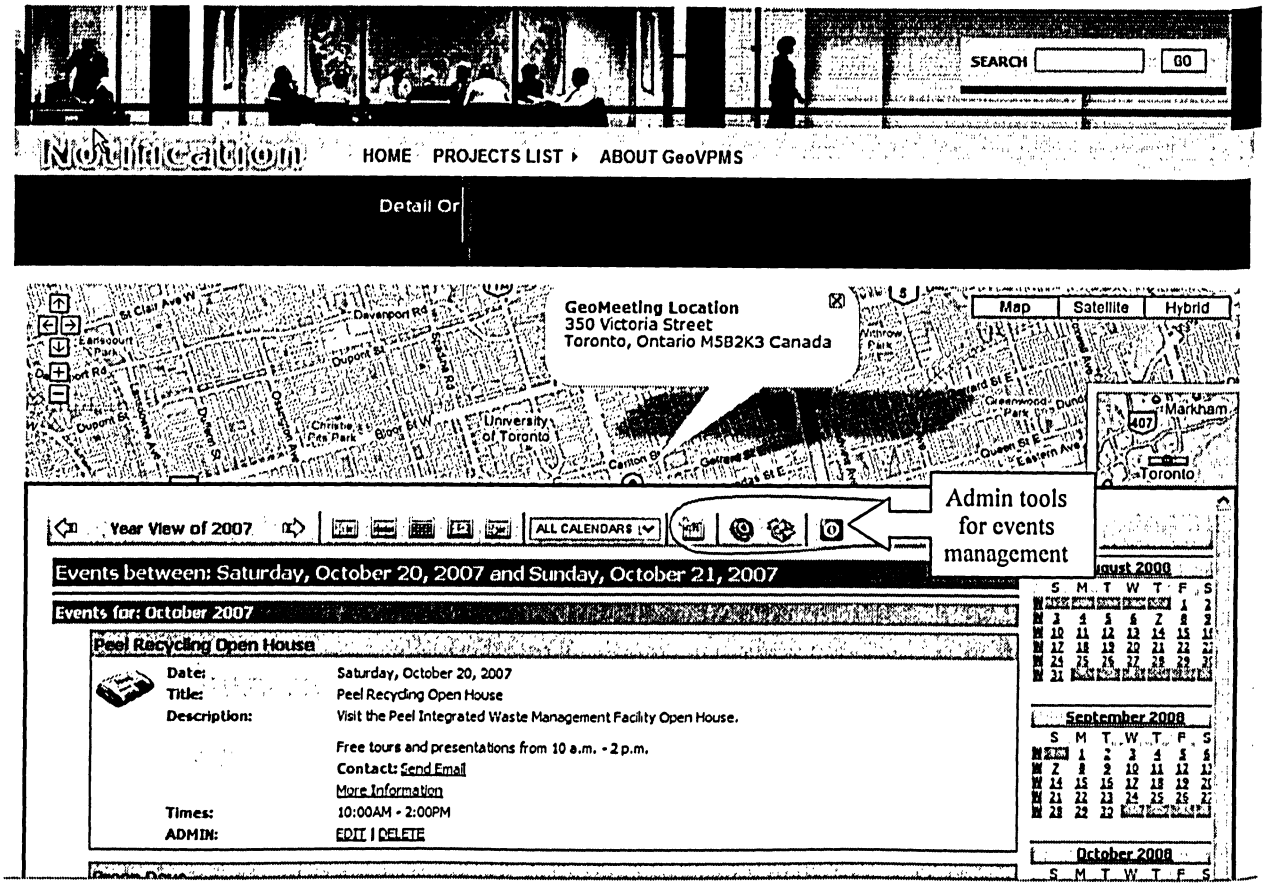


Figure 5.12: Administration tools for the events (notification) handling

5.2.2.6 Prototype Database Components

Spatial context related data is stored in PostGIS. Some basic non-spatial data is stored in MS Access. Using this concept of distributed database approach will be increased the system's efficiency and throughput. Moreover, database recovery and backup features are more robust in this way.

- **Notice Events DB (Database):** As discussed earlier, this component handles only non-spatial data and some direction APIs data. Figure 5.13 shows schema diagram (tables) used by upcoming events DB.

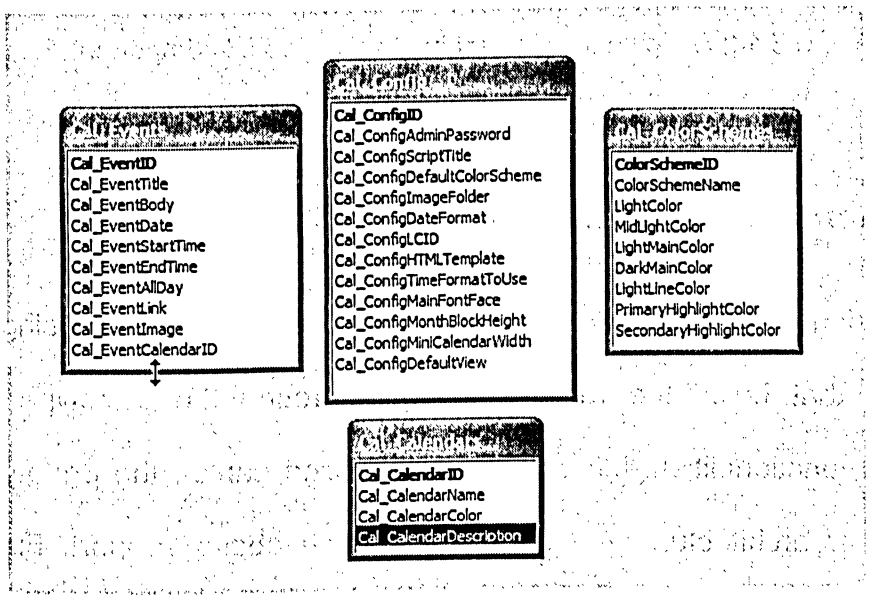


Figure 5.13: Simple schema architecture of info-centre database

Participation DB: This component uses PostgreSQL spatial extension (PostGIS) for the manipulation of spatial data. Some basic tables, which were created to test the spatial functionalities of this component, are shown in Figure 5.14.

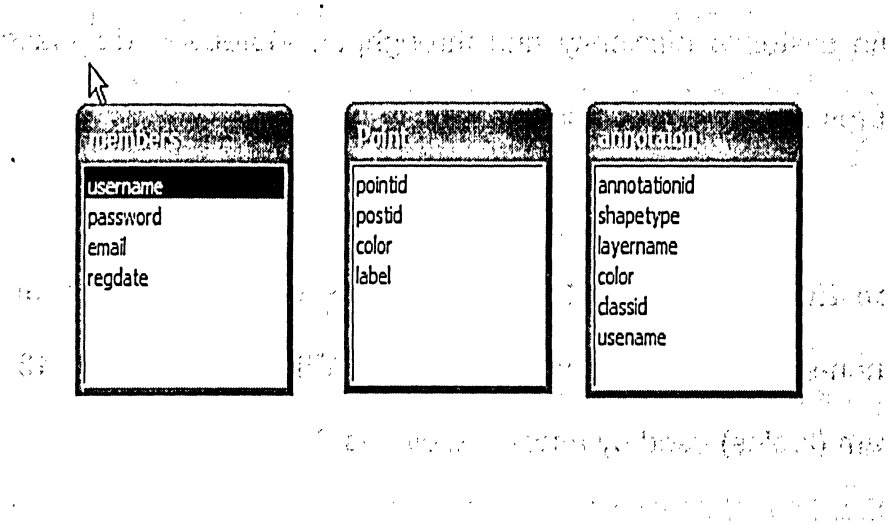


Figure 5.14: Simple schema architecture of spatial component database

5.3 Demonstration of the Prototype

This section discusses the real time scenario implementation using the Region of Peel's data that helps the readers to walk through the prototype interfaces and components functionalities. Moreover, as discussed earlier, the prototype is designed with the n-tier architecture and the distributed database support. Furthermore, with reference to database implementation, PostgreSQL (RDBMS) spatial data extension (PostGIS) is disabled due to the unavailability of the spatial data related to different projects of the Region of Peel whereas simulated fortified spatial data is used, in the form of shape (shp) and database (dbf) files for the proof of concept.

5.3.1 Case Scenario: Municipality Planning using Region of Peel's Data

5.3.1.1 Hierarchy of Planning Projects Web Pages

This section illustrates the hierarchy of the Web pages for the main interface of any Region of Peel's project. Figure 5.15 shows the detail of the main interface of Project1 with relation to its children interfaces.

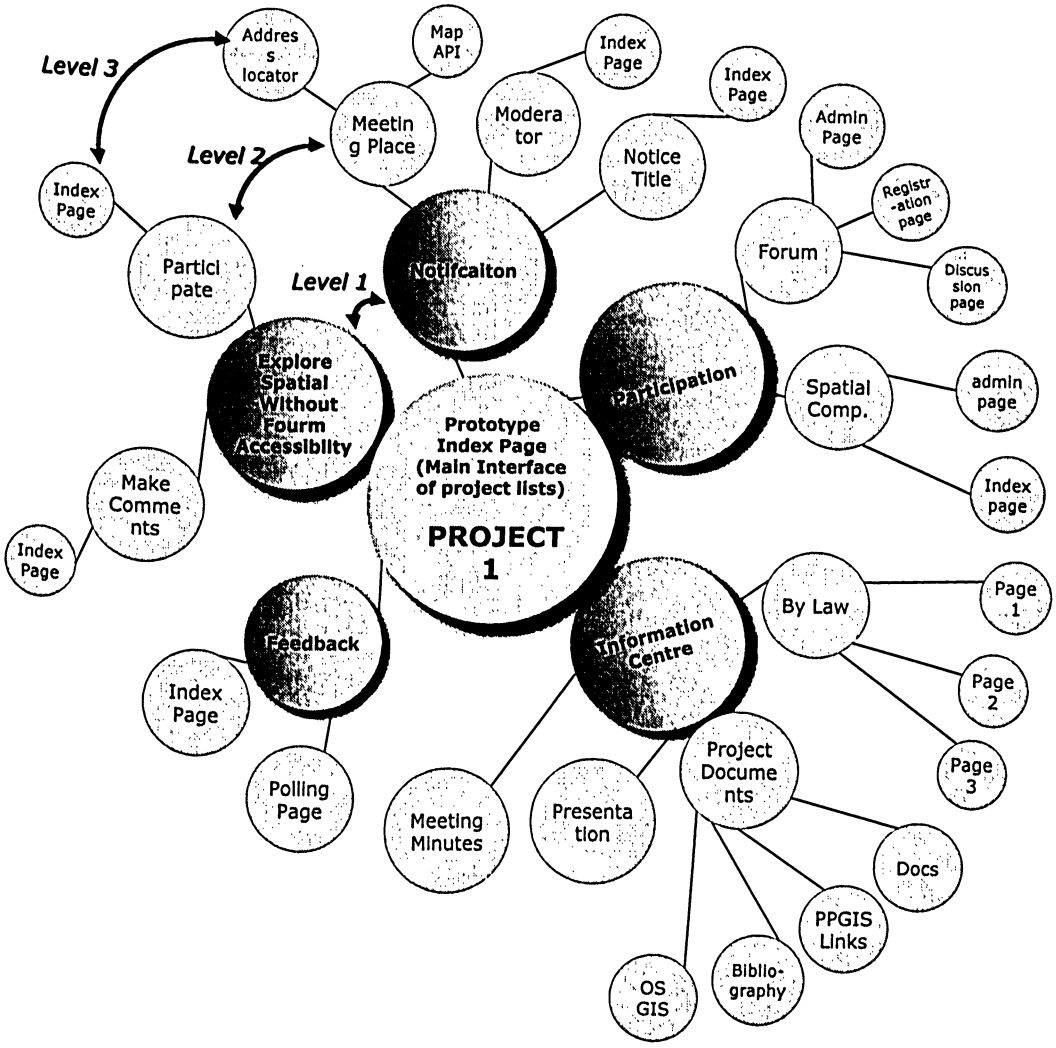


Figure 5.15: Radial tree of Project1 Web pages

Every project main interface is comprised by five major sub components level interfaces. As shown in Figure 5.15, first level circles represent the main interfaces of participation, explore spatial component, notification, info-centre and feedback components whereas these main interfaces have further set of interfaces.

5.3.1.2 Workflow Process/Activity Flowchart

A workflow process/activity flowchart for Region of Peels' projects is a graphical representation of the flow of activities based on user perspective. The diagram is composed of GeoVPMS subcomponents interfaces and connectors. Figure 5.16 depicts the graphical workflow between participant and the GeoVPMS subsystems which explains all the activities that user can participate through main interface of the GeoVPMS.

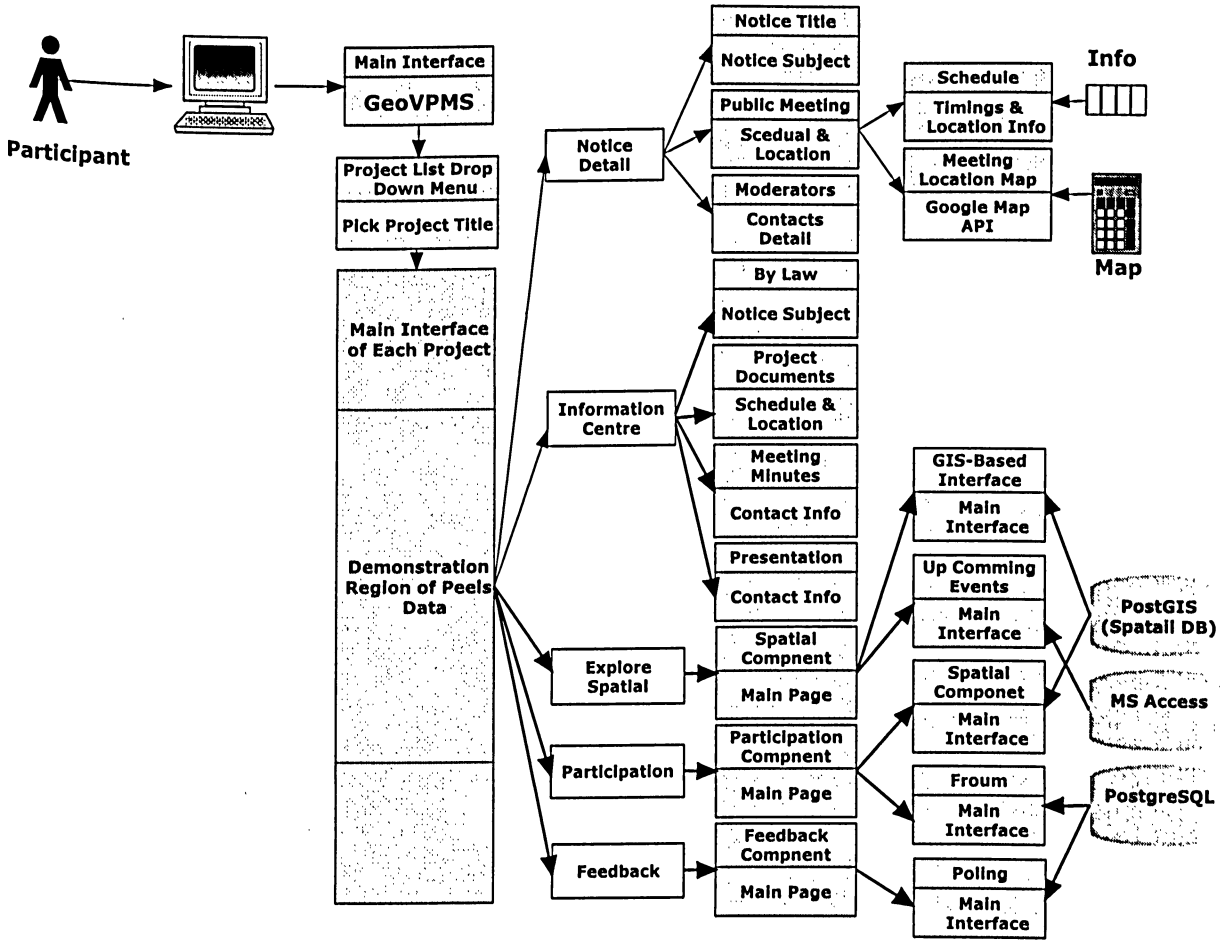


Figure 5.16: Participant activity flowchart of Project1 Web pages

The Figure 5.16 is also helpful in understanding the walkthrough related to Region of Peel example project discussed in the next section.

5.3.1.3 Walkthrough of Region of Peel's Example Project1

This section describes how the public participant input is realized during the discussion of different projects related to Regional Municipality of Peel. Following steps

try to demonstrate a walkthrough with all possible interactions between user (participant) and the GeoVPMS subsystems.

1. First, a user opens up the project list drop down menu from the top frame, and selects project's title, the detail will be revealed in the left frame of the main interface. Moreover, every project's detail will be appeared with the same description/specification (see mark A of Figure 5.17).

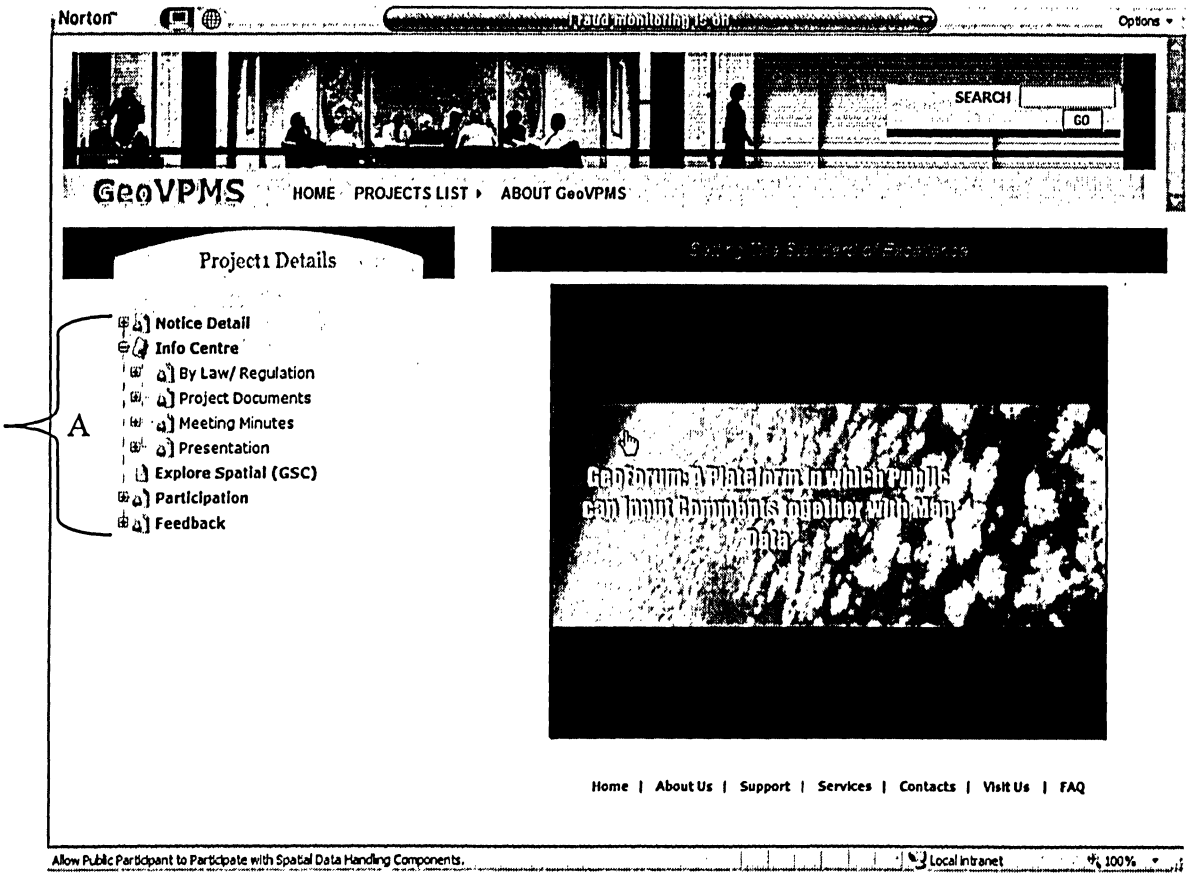


Figure 5.17: Prototype's main interface with Project1 details

2. User can view the important notice information regarding any project. For instance, when user wants to view some notification related information of

Project1 and presses the notice detail heading, it will be extended into some sub-headings i.e. notice title/subject, public meeting place and schedule information, meeting location finder API and moderators, which are all accessible from there. Figure 5.18 shows when municipality staff member press the notice title/subject heading, all information is displayed in main frame window (right side).

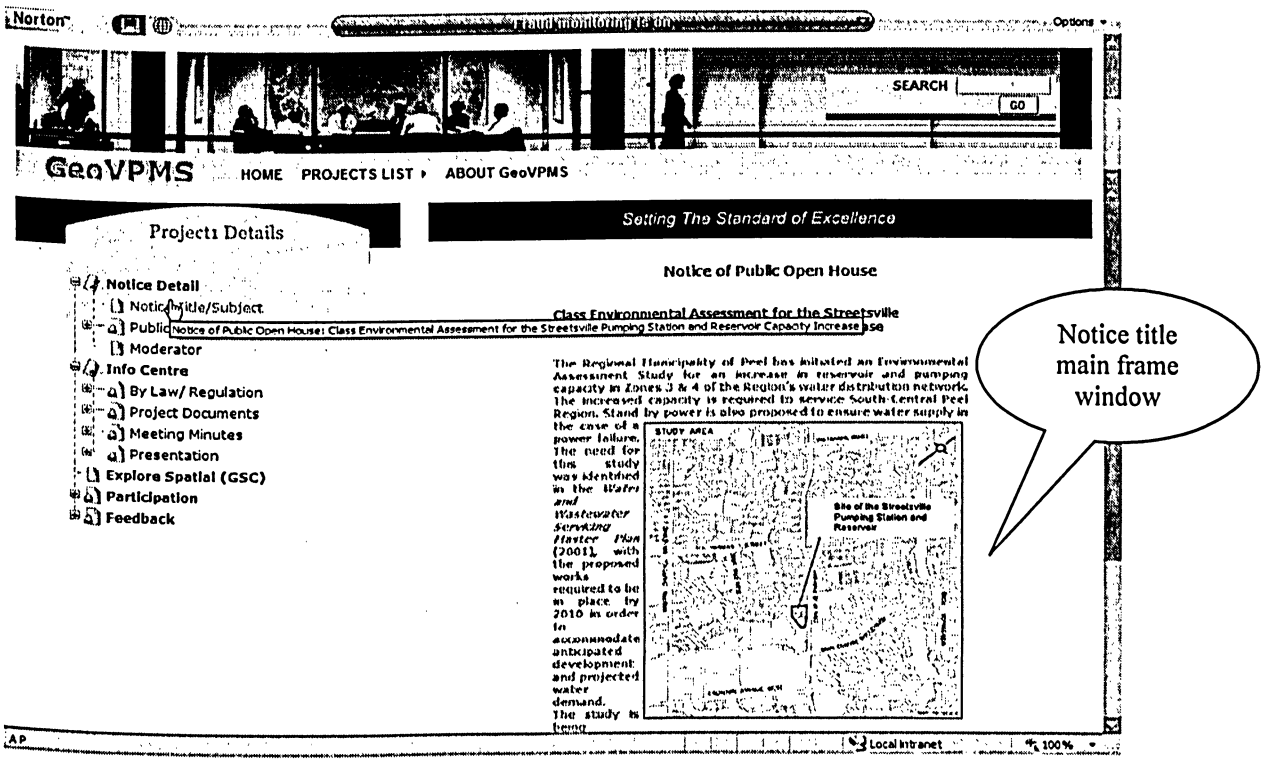


Figure 5.18: Project1 notice title/subject window

Figures 5.19 and 5.20 display the public meeting place and schedule information related to the notice (public open house). On the other hand, in Figure 5.20 meeting place is displayed using the map location finder API, which is designed with the mashup of different open source technologies, and Google map API.

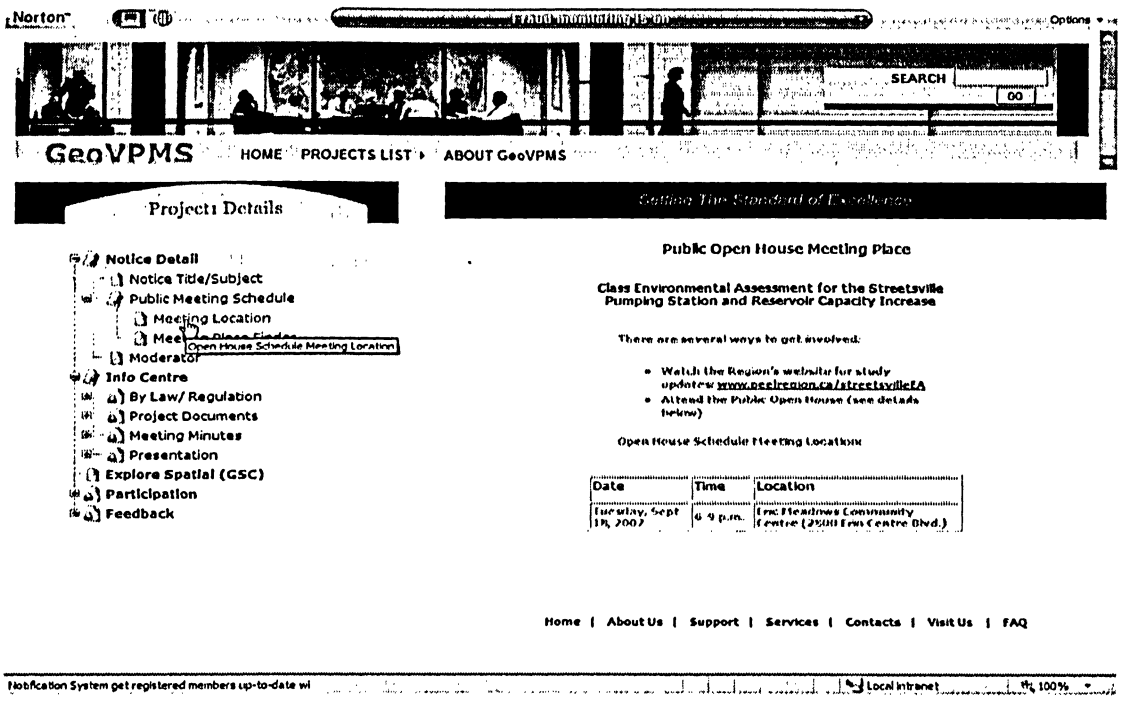


Figure 5.19: Project1 interface of meeting location

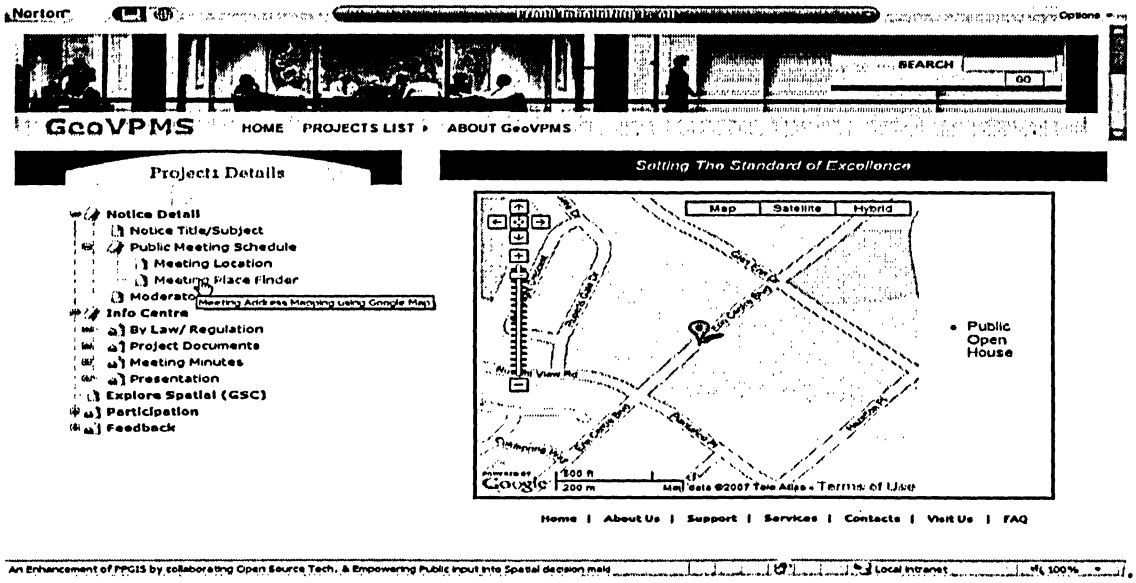


Figure 5.20: Project1 map-based interface for meeting location

3. Info-centre is another option that user can browse from this interface for gathering more information related to projects. Info-centre component will be

extended into its detailed subheadings such as by law/regulation, project documentation, meeting minutes and presentation etc. No doubt, exploration of this component with its subheading is very useful in understanding the project's description. Figures 5.21 and 5.22 depict the 2007 regional by-laws/regulation and January 2007 regional council meeting minutes.

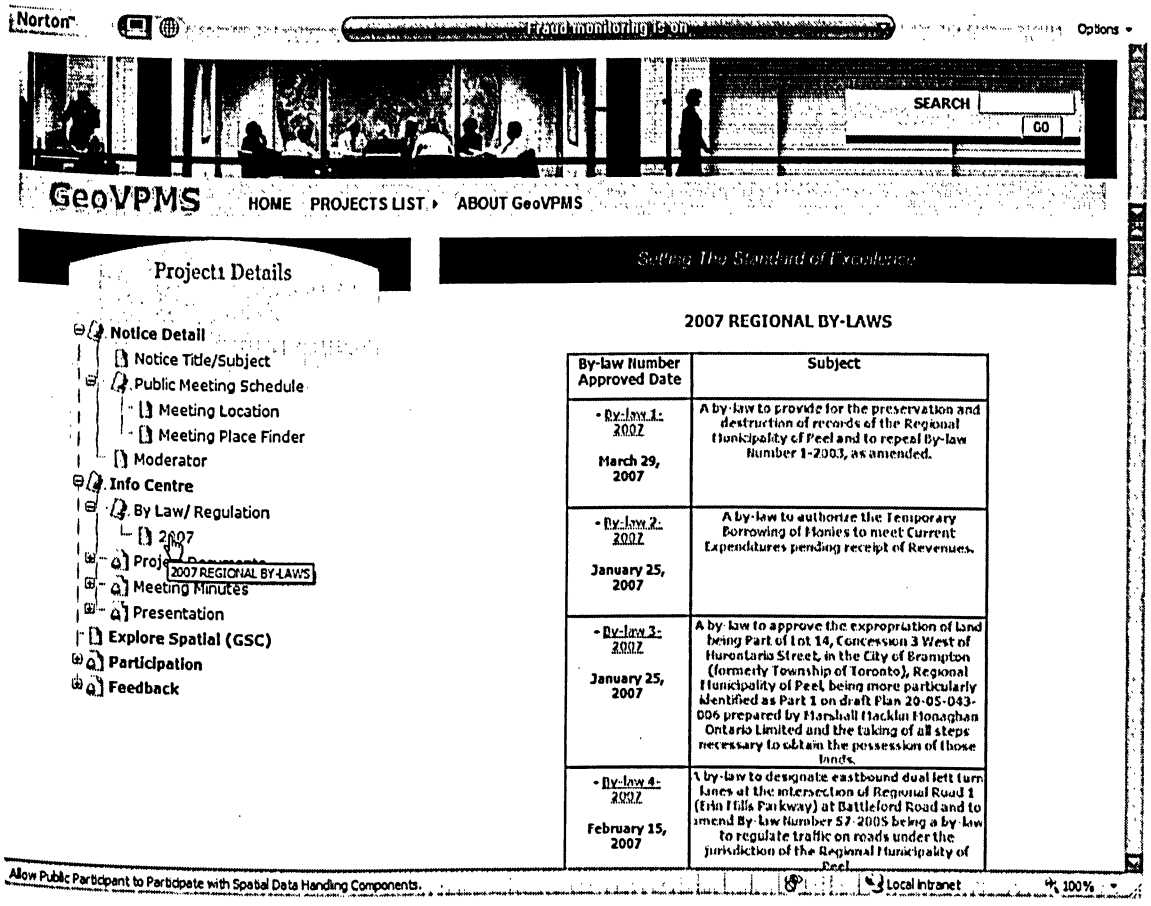


Figure 5.21: Regional by-laws/regulation for the year 2007

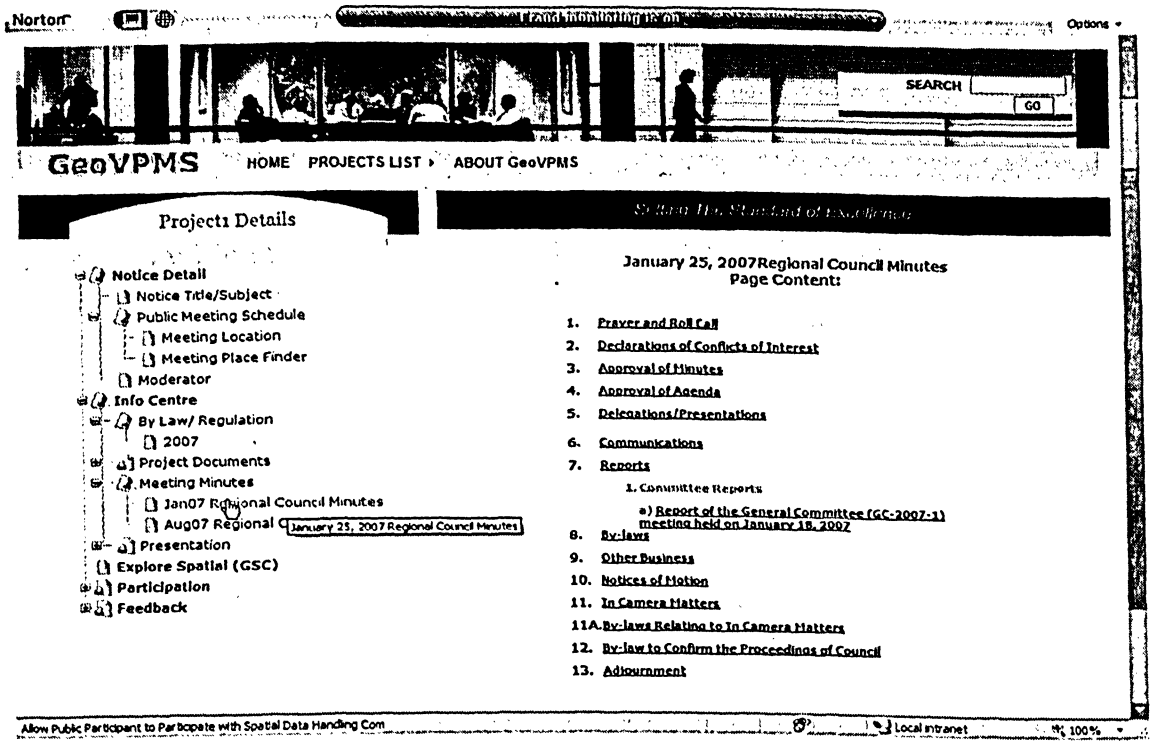


Figure 5.22: January 2007 regional council meeting minutes

4. GSC (GeoVPMS spatial component) is another important component of the prototype that is used for exploring project's spatial data related to municipality planning. The user can add annotation, draw graphics on the map, measure areas, and query to retrieve some map features. Moreover, by using this GIS-based component user can explore the spatial feature of the municipality map without initializing discussion forum activities but user can view the future coming events from the lower frame window of this interface. Figure 5.23 portrays how user initiates the spatial component whereas, Figure 5.24 shows the interface of GeoVPMS spatial component.

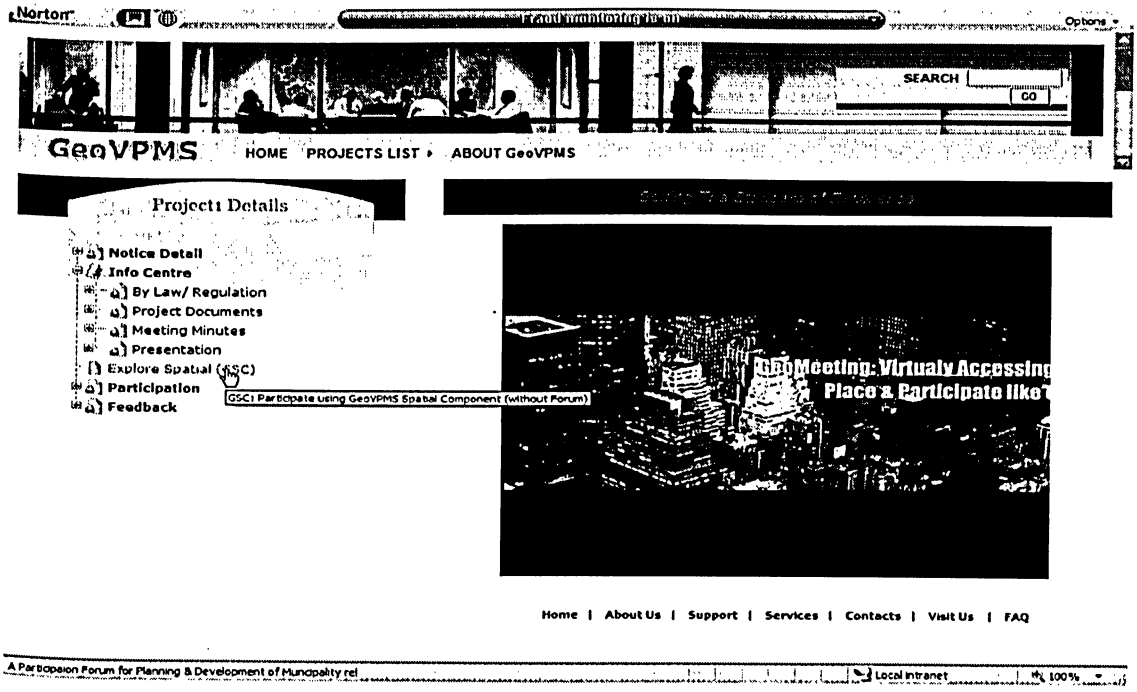


Figure 5.23: Initialization of spatial component

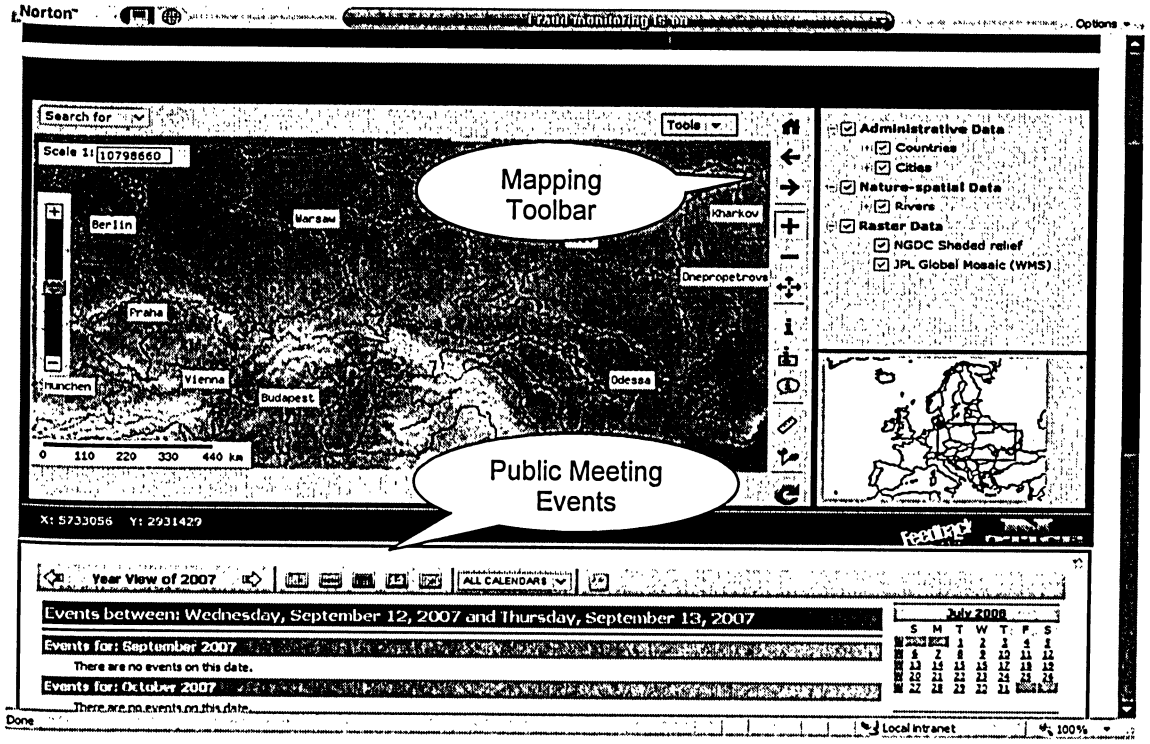


Figure 5.24: Main interface of the GSC

5. Participation is another important component of every project's interface; user can initiate the GIS-enabled participation forum from this caption (see Figure 5.25). Figure 5.26 depict the main interfaces of GIS-enabled discussion forum and spatial component.

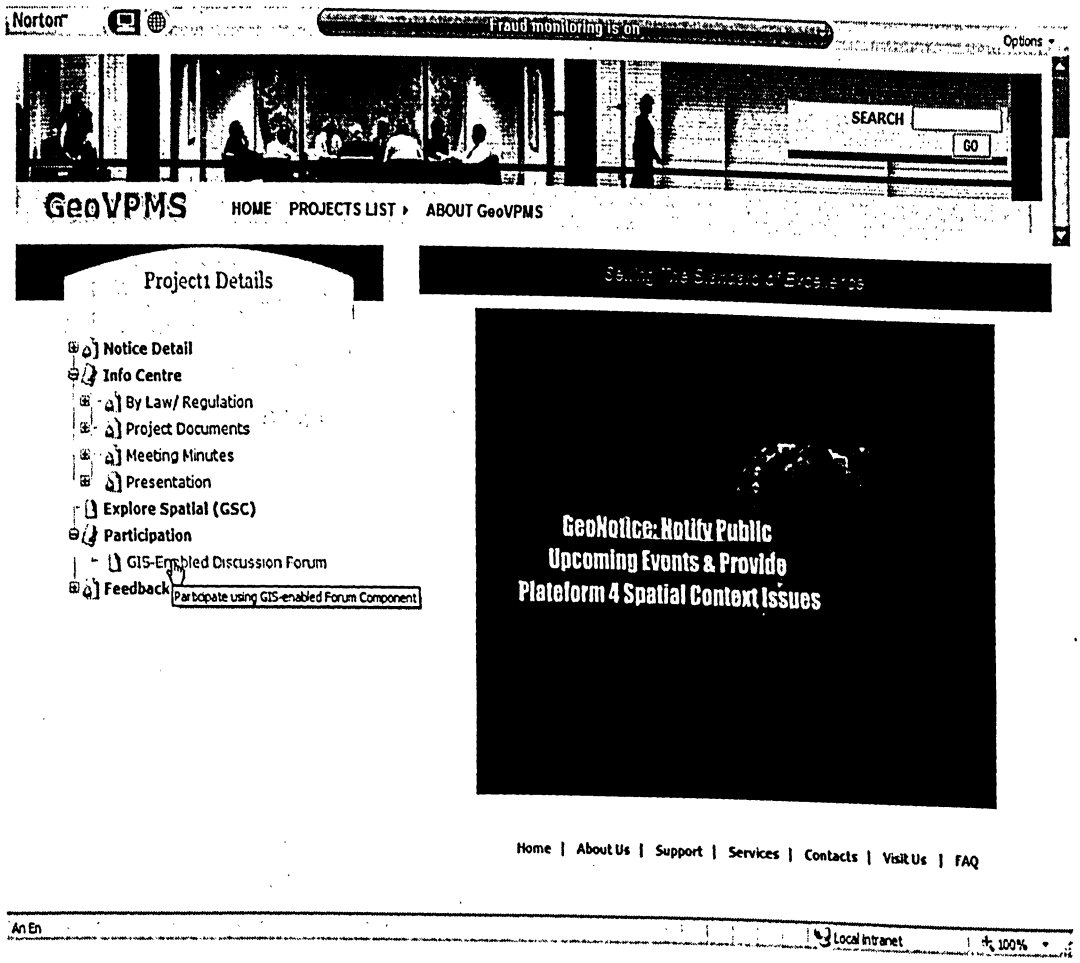


Figure 5.25: Project1 interface for initiating a GIS-enabled discussion forum

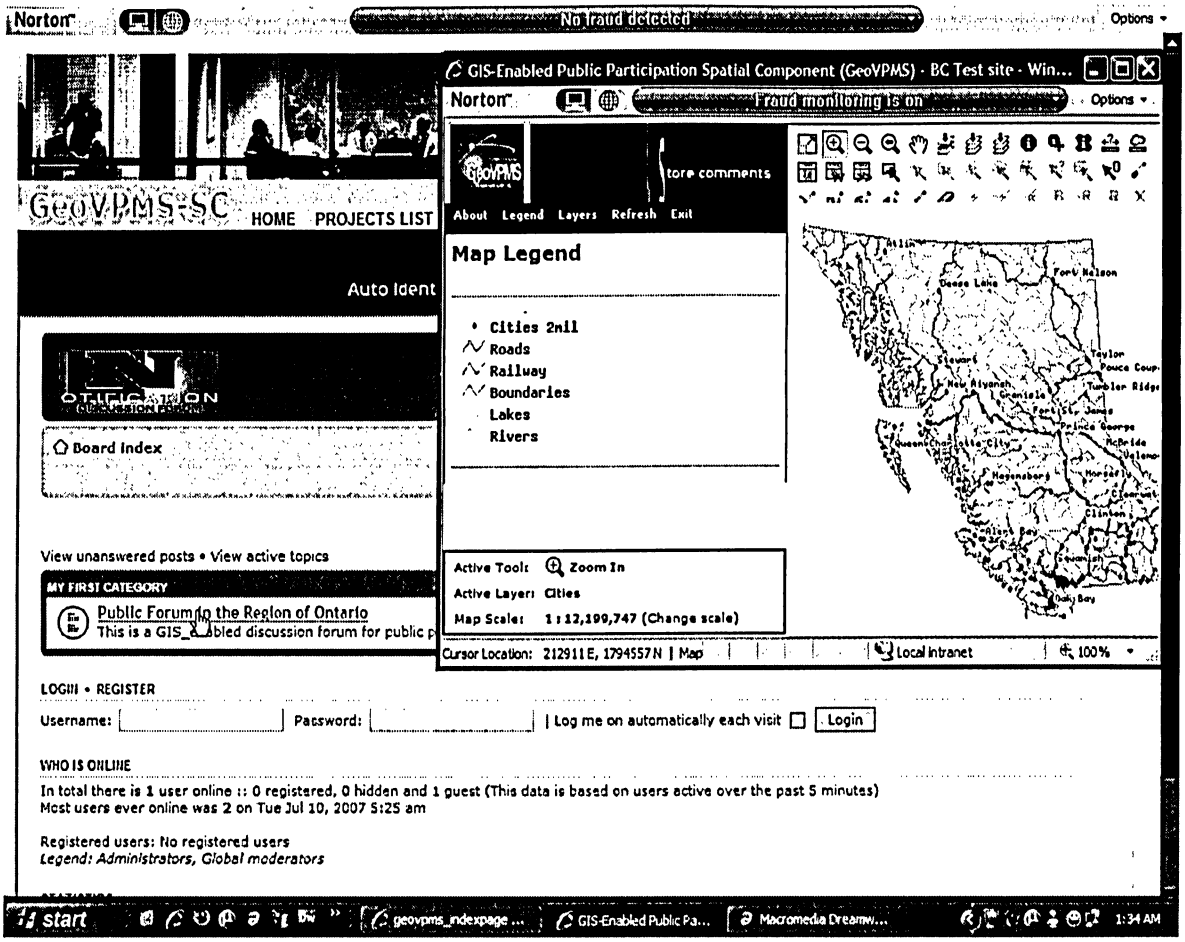


Figure 5.26: Main interface of GIS-enabled discussion forum

The user can add text as well as graphics on the map, measure areas, and queries to retrieve some particular map features. Another important feature of this component is save/load session with particular map information and includes this session to the discussion forum. Figures 5.27 to 5.29 depict the usage of add text, save session and load session tools of this component.

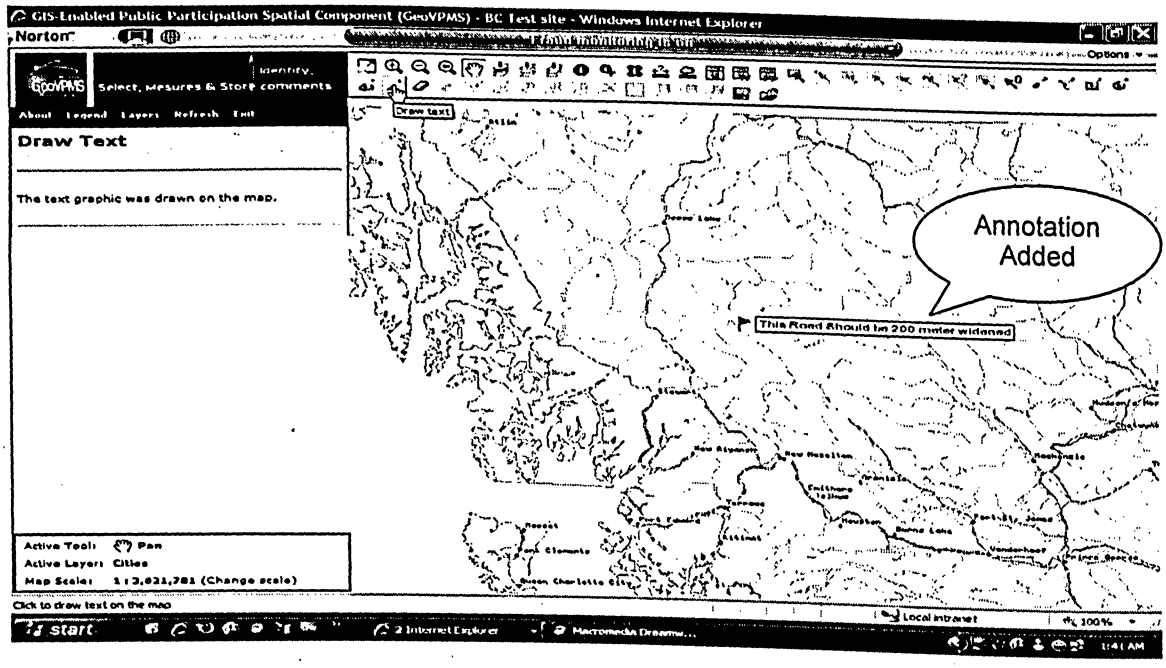


Figure 5.27: Adding the text on the map layer

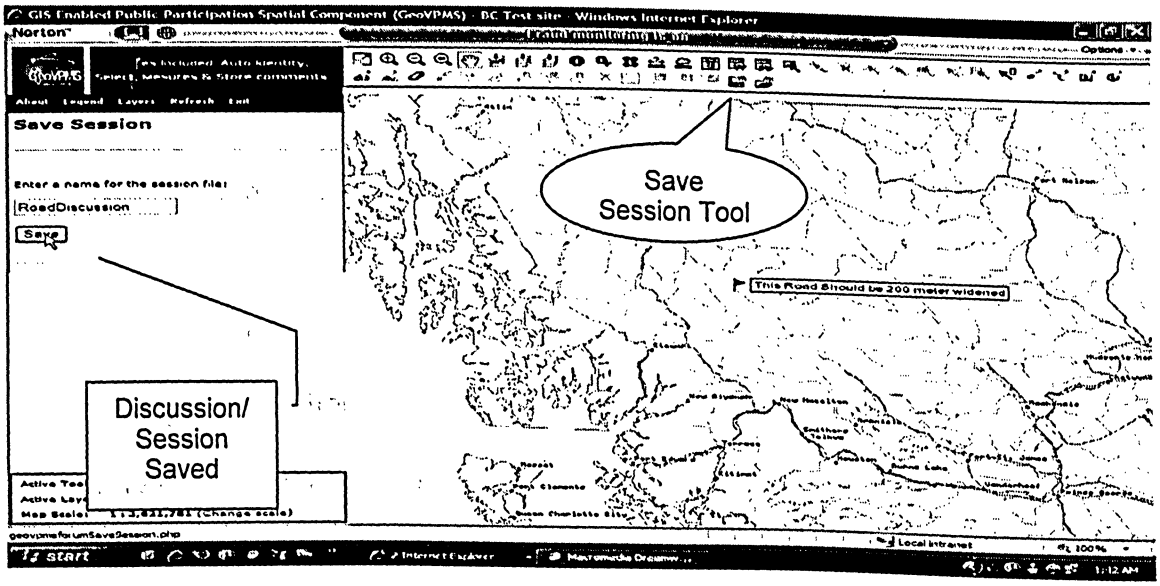


Figure 5.28: Saving session interface

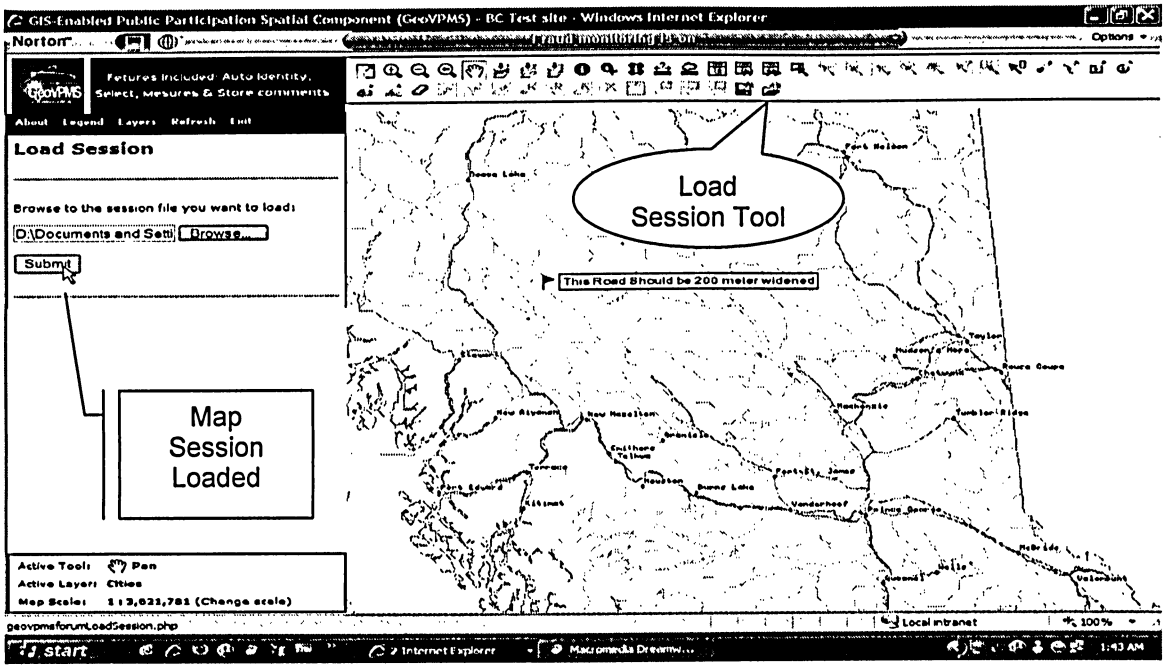


Figure 5.29: Loading session interface

6. The feedback option provide user to give the feedback to the administration in the form of voting/polling. The polling/survey interface can either directly be accessed through the project's detail window (left frame of main interface) or from the main interface of feedback. Figure 5.30 and Figure 5.31 show the main and polling/survey interface of the feedback component.

These all steps are similar to every project interface related to the Region of Peels' examples data.

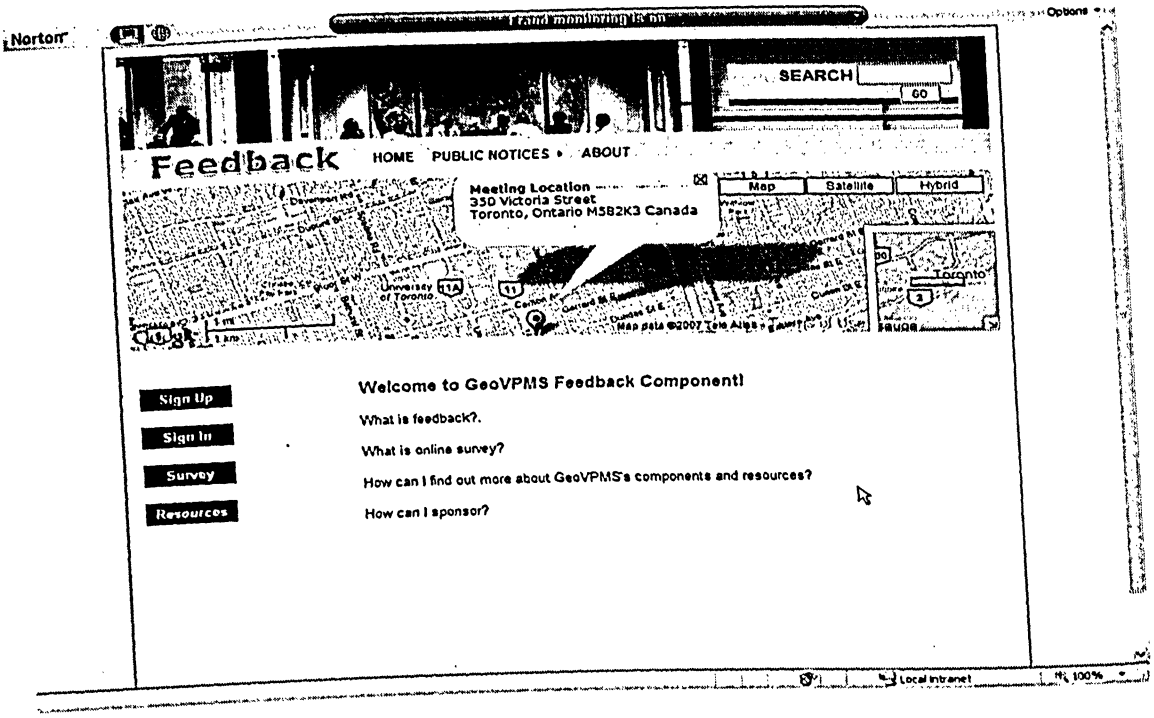


Figure 5.30: Feedback component main interface

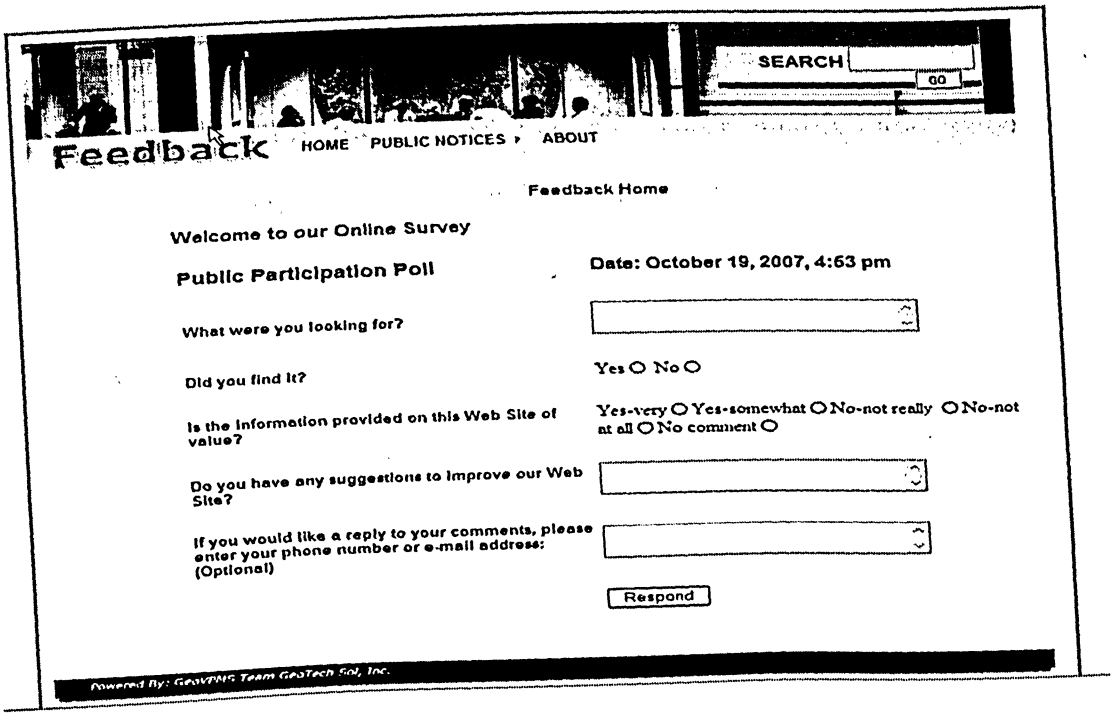


Figure 5.31: Polling/survey interface for the user

5.4 Evaluation of the Prototype Implementation

This section evaluates the prototype implementation based on number of aspects including: intended use, interactivity of user interface, exchanging of information (communication) with GIS-based mapping functionalities, educational resource, feedback support and system attribute. Moreover, the criteria for the evaluation of prototype implementation is somewhat similar to the one which is used in Chapter 3 for evaluating the existing online PPGIS applications.

The evaluation results are summarized as follow:

- **Intended Use:** System provides a platform to facilitate the non-professionals and citizens for participation during the municipal planning related discussions.

- **Interactive Visualization:** System provides user-friendly and interactive as every component of the prototype is developed by following set of rules introduced by HCI. General user has complete right to access or explore full website whereas at every level informative tool tips with dynamic effects are provided. System main page is designed using framesets (three frames) to provide user an easy to use interface. Main frame display all the information of GeoVPMS selected functional components. The objective is to deter the user from switching between different interfaces.

- **Effective Communication/Participation:** In this prototype, participants can initiate discussions just like other online available discussion forums. This requirement is fulfilled by one of the GeoVPMS component called participation, a well-designed forum as well as a GIS-enabled spatial component. Furthermore, multi way of participation is possible among users as well as municipal authorities using this OSS technology-based component. Moreover, any user can view the contributions, though only registered participants are permitted to post new postings/topics. Besides all the basic GIS mapping functions provided by spatial component attached to discussion forum, the add text tool is used to add the annotations on the map layer which can be stored as a map information session and can be uploaded to the discussion forum to commence participation related to spatial contexts. Another spatial data-handling component is designed which offers basic GIS functions such as panning, zooming, layer selection or querying on the map side and a structured discussion to those who do not want to get in (participate through) the forum-based activities.

- **Educational Resource:** The system allows participants to easily access additional information and documentation necessary to provide input to the project under consultation. As one of the components of the designed prototype, Info-center provides plenty of useful documentations, tutorials, meeting minutes, presentations, by law and other helpful multimedia resources related to the particular project of municipality. All of those materials are easily accessible from the index page of every project.

- **Feedback/Acknowledgement:** Participants can send emails to the consultants/mediators and get the response back for their queries. Frequently Asked Questions (FAQs) section is also very useful medium for getting the acquaintance with the system especially for non-professionals (new users). Newsletters are sent to the registered users regarding new postings of recent projects related to municipal planning and development. A polling interface is designed for taking the feedback from the participants which is managed by the consultants or mediators.

- **System Attribute/Non-Functional Requirements:** By using two different databases and Web servers, the system response time and throughput are better and quicker. Moreover, as programming languages i.e. PHP, ASP, Javascript, Xhtml, and XML etc. are used during the designing or construction phase, the developed prototype supports many other platforms i.e., UNIX, LINUX and Windows.

5.5 Prototype Testing

In reality, system development life cycle includes software testing phase, which is usually performed by Quality Assurance (QA) and testing department of every software development industry. Moreover, no doubt, testing before deployment protects system from so many future coming risks and disasters. Inclusion of QA approach is not achievable during phases of prototype development life cycle as system is designed and implemented only for the proof of concept due to limited resources.

Furthermore, due to lack of availability of real time datasets, the system cannot be tested with real users in a real life participation/discussion to verify the evaluation results presented in Section 5.4. On the contrary, the usability testing approach, discussed in the following section is adopted to test current prototype application by using the example projects datasets of Region of Peel.

5.5.1 Usability Testing

It is undoubtedly true that adoption of usability testing criteria for the prototype evaluation will also be helpful. It is common rather widely used criteria in object-oriented software engineering for testing computer-based software's interface design and functionalities. Moreover, this approach is useful for online GIS-based participation frameworks which are designed using complex functionalities (e.g., GIS mapping functions etc.) as compare to simple internet-based applications. In few words, extensive testing of the usability (by collecting and measuring user's point of view) before deployment of the application is one of the reliable ways to ensure that participation framework GeoVPMS designed for the public is usable. Therefore, the usability criteria have to be carefully selected. In current research, the evaluation of the prototype implementation is based on criteria discussed in Chapter 3 and Section 5.4 that is also somewhat similar to the criteria adopted by different researchers such as Ma and Tang (2006).

A group of few students (testers) with different technical backgrounds is picked out to check whether the functions of the system are implemented correctly. Furthermore,

testers attempt to walkthrough every GeoVPMS subsystems major functions to determine whether these functions meet design objectives and requirements. The self-explanatory Figure 5.32 shows the usability-testing environment (i.e., hardware, software and networks etc.) for prototype subcomponents.

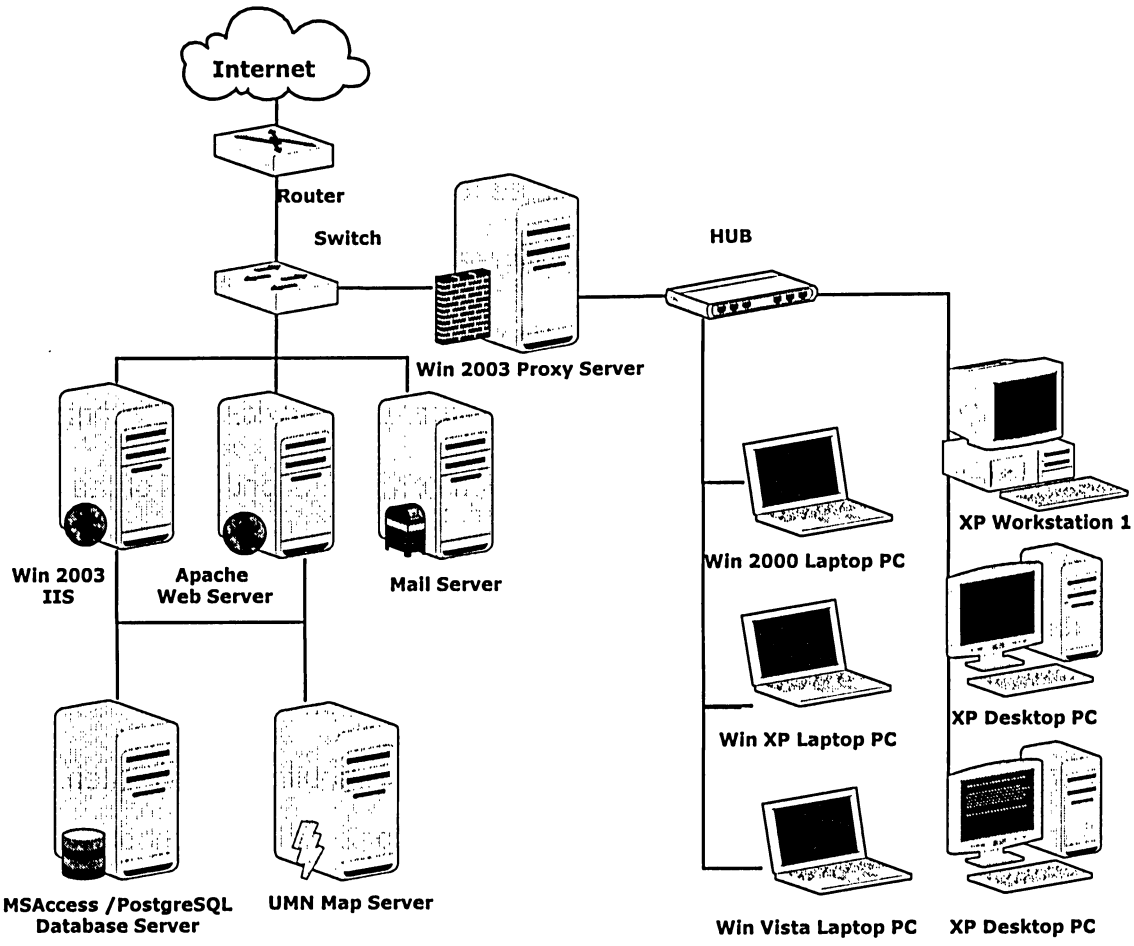


Figure 5.32: Usability testing environment for GeoVPMS subcomponents

The results met the design requirements except some testers experience performance (i.e., system response time etc.) variability when the system's GIS-enabled

components are accessed through WAN (Wide Area Network) whereas in LAN (Local Area Network) environment system response time was optimal. Moreover, server and client machines hardware configuration (i.e., low processor and memory speed etc.) also effects on the system speedability and performance.

5.6 Summary

The chapter began with the discussion related to the technological requirements for the proposed prototype. Then, prototype user Web interface designs and functionalities were implemented with OSS-based technologies due to the cost effective feature and vast developer community network that are always ready to provide the technical help and support to other members of the OSS communities. The second half of the chapter presented the demonstration of the prototype by using Region of Peel's example projects data to provide a walkthrough with major implemented interfaces and functions. The last sections depicted the evaluation of the prototype implementation based on the selected criteria followed by the discussion about software usability testing criteria.

CHAPTER 6 CONCLUSION AND DISCUSSION

This chapter consists of important aspects i.e., major achievements of the research, future research opportunities and concluding remarks.

6.1 Discussion and Conclusions

6.1.1 Contributions and Achievements

Major contribution of this research is the implementation of a prototype serving for spatially related discussions of municipality planning. Moreover, a prototype has been analyzed, designed, implemented and tested using OSS technologies as well as documented using Object-oriented Software Engineering model (UML). The achievements accomplished so far are discussed as follow:

- **GeoVPMS Components (Participation, Explore Spatial, Notification, Info-Centre and Feedback):** The contributions of this thesis are several. First, the development of the discussion forum as well as notification component handled multiway flow of information among the public participants as well as authorities. Furthermore, the forum-based spatial data-handling component was designed to help the public to explore the spatial contexts during municipal planning related discussions. Another effective feature (explore spatial) was designed which initiated the public participation by exploring the spatial data with all GIS mapping functions without initializing the forum-based activities. Feedback component was

designed to take the feedback from the participants. Moreover, documentation, video tutorials, journal papers, by laws, meeting minutes, project presentations and flash video files of conferences related to the municipality projects are the best information source provided by the information center component. Further, my contributions can be judged more fairly when the prototype is demonstrated with a scenario of public participation in spatial planning using Region of Peel's data. In the end, newsletter feature (part of feedback component) provided by the designed prototype made more up-to-date the public participants with several incoming meeting agendas and posts.

- **OOS Technologies:** There is no doubt, that the OSS technologies have several benefits comparing with the commercial technologies. First, the no license requirement for OSS decreases the prototype designing and implementation cost. Second, due to easily available open source APIs and codes, development time is lesser comparing with other commercial technologies. Finally, by being a part of a community of users and developers who have an interest in working together to support each other, problems can be identified and solved quickly.

5.1.2 Limitation of the Research

Although this research has gained some achievements as discussed earlier, there still have some limitations, which are discussed as follows:

- The prototype is not a complete communication system in the sense that the communication functions provided are still limited. The public may need more communication channels to exchange their information or suggestions, for instance, chatting and video conferencing with collaboration of the spatial component.

- Spatial components need more GIS mapping functions especially which are helpful during public discussions, for example, a pictographic reference tool for providing the snapshot of municipal planning and under developing areas.

- Finally, as at this stage, due to lack of availability of the spatial data, the prototype was not demonstrated by using spatial database PostGIS (PostgreSQL spatial extension).

6.1.3 Opportunity for Future Work

As I have built this prototype based on open source products and OOSE using UML concepts, I hope that my contributions will help other researchers during the advancement of Web-based PPGIS frameworks. Future work on the prototype will concentrate on the development of missing features that are discussed in the Section 6.1.2. Moreover, the following feature will also be considered during the future development of the prototype.

- As prototype is not designed to accommodate any kind of disability so I believe it may need the considerable enhancement especially in the participation component that should have some functionality, which deals the people with disabilities as they also have equal rights of participation to input their suggestion in the planning issues related to the city development.

5.1.4 Concluding Remarks

The thesis has demonstrated that it is possible to implement a system which has potential to involve the public during the municipal planning related matters. The concluding remarks are discussed as follow:

- This research has been established to find out a solution of public participation in the municipal planning and development related issues. It is true to the some extent that prototype's subsystems i.e., GIS-based discussion forum, explore spatial, notification, feedback and info-centre have more potential to involve the public comments as an input in municipal planning and development related issues as compare to traditional participatory approaches.

- My major contribution in this research is the formalization and implementation of the concept of spatial data handling component to help the public to explore the spatial contexts of municipal planning projects during their discussions (forum-based). Moreover, another contribution is to provide a feature of exploring the spatial context for participation without initializing forum-based activities and no

doubt, these contributions make the prototype more functional, effective and successful.

- The idea of using OSS has been demonstrated to be a cost effective or economical solution to implement prototype's subsystems, especially for small municipalities with limited resources.

- The intended use of the prototype is to provide knowledge-based resources with spatial context for new (non-professional) and expert users.

- From a user's point of view, the prototype offers easy-to-use/user-friendly, fast, accurate and self-explanatory functions with additional tool tips for interactive exploration of a geographically referenced discussion.

- Just similar to other a traditional approaches, GeoVPMS does not make the decision itself but can improve the decision-making process.

- As the prototype development is based on object-oriented procedures (i.e., UML-based analysis and design with RUP iterative life cycle etc.) so future enhancement of the prototype is practicable for resolving the above-mentioned limitations.

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APPENDIX I TOP AND DETAILED LEVEL GEOVPMS USE CASES

I.I Use Case Relationship

As the use cases are documented, other use case relationships may be discovered. There are normally of two types of relationships, "uses" and "extends". A uses relationship shows behaviour that is common to one or more use cases and an extend relationship shows optional behaviour. In Figure I.I registered participant and project proponent use cases have "uses" relation ship with login validation as both require entering their login and password before they will get the access to main interface.

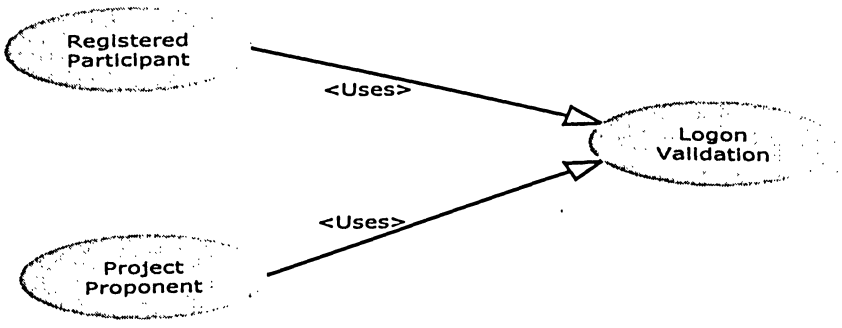

Figure I.I: Use case relationships

I.II Top Level GeoVPMS Use Cases

This section describes top level use-cases with relation to its actor which will be helpful in documenting use case in a flow of event document, explained in section I.III

i. General User: Public Participant (Citizens)/City Staff

- Request for registration.
- Modify Profile Information.
- View projects listing.
- View specific project details.
- Login to access geo-notification (sub system component of GeoVPMS).
- Login to geo-participation (sub system component of GeoVPMS).
- Visits information center for learning and gaining knowledge.
- Get direction to meeting place through direction API.
- Use chatting component.
- Use video streaming component for virtual access to meeting place.
- Login to access Collaborative system (sub system component of GeoVPMS).
- Send feedback to GeoVPMS management.
- Send email to management.
- Use searching utility for search.
- Store comment on maps.
- Preview comments of other participants placed on maps.
- Find contacts of moderators/managements.
- Logout

ii. Corporate User: Agency Participant/Domain Experts/Consultants

- Sends request of registration (with special user id and rights).
- Request for Modify/Delete agency from listing.
- Request for placing advertisement/banners.
- Modify/cancel request for occupied place.
- Place a request for their upcoming projects proposal.
- Request for adding new project in listings.
- Deleting request for the removal of an old project from listing.
- Add new meeting events related to their upcoming projects.
- Login
- Logout

iii. Managerial User: Project Proponent/Project Manager/Mediators

- Create corporate/agency listing.
- Delete/modify corporate listing.
- Create Project listing.
- Modify Project listing.
- Delete Project listing.
- Manage site.
- Create new logins.
- Revoke rights from users.
- Banned/Disabled users.
- Create logins with specific rights.

- Login
- Logout

I.III Flow of Event Document

After use case identification process, a flow of events document is created for each use cases which are normally written from an actor point of view. Furthermore, it shows a detail what the system must provide to the actor when the use-cases are executed.

Typical contents in this use-case document are as follow:

- How the use case starts and ends.
- Normal flow of events.
- Alternate flow of events.
- Exceptional flow of events.

For instance, in Notification (component of GeoVPMS), flow of event for the use case "View Upcoming Events" begins when the registered public participant logs onto the system and enters his/her password. After that, the system verifies that the password is valid and prompts the person with some more options on the same window such as add new event for meetings as well as some other configurations which allow participant to change the password etc.

In addition, if the activity selected is adding events then use case add event sub flow is performed. For instance, when the person click the add event button it will prompt you a new window asking to enter the event name, event description, time of event occurrence and an icon which describes the event type.

Following tables describe flow of event for different actor's point of view:

USE CASE: REQUEST FOR SIGN UP	
Primary Actors	Public participant, Agency participant, Domain Experts, Project Proponent
Purpose	The main purpose of this use case is to create a new registration for a participant.
Overview (flow of events)	A participant types a URL www.ryerson.ca/civil/geovpms in a browser and it will open an index page of GeoVPMS Web site. When actor presses the signup button and a window is prompted to enter information that defines the registered user/participant such as login, name, address, password, email etc. The actor can choose to save the information or cancel the operation, if actor decides to save the information, the new registered user is created and the list of user is updated.
Alternative Flow of Events	The actor attempts to add a login that already exists. The system will notify the user and cancel the operation. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered.
Type	Primary and essential, In some cases optional.
Starting point	This use case starts when the Actor requests to create a new login.

Ending point	The actor's request to create a login is either completed or canceled.
Measurable Result	A login as a registered user is added to the system.
Cross References	Functions: F1, F2, F3, F4, F5, F6, F7, F8, F14 (see Section 4.2.1.2 for functions details)

Table I: Flow of event document of a use case (request for signup)

USE CASE: MODIFY A USER'S PROFILE	
Primary Actors	Public participant, Agency participant, Geometics Eng., Students, Professors.
Purpose	The main purpose of this use case is to modify user information.
Overview (flow of events)	This use case begins when the actor request to review an existing profile for modification and the system presents the information. The actor makes a request to edit the information. The actor can edit all the information. The actor can either save the changes and return to main page or can return without any changes are saved. If the actor chooses to save the changes, the edited user information is saved and user's profile data file is updated.
Alternative Flow of Events	An improper value for one of the fields is entered. The system will not allow the update until it is corrected.
Type	Primary and essential.
Starting point	The actor must have changed his/her profile information.
Ending point	The actor's request to modify profile information is either completed or cancelled.

Measurable Result	A user's record is updated.
Cross References	Functions: F1, F2, F3, F4, F5, F6, F7, F8, F14

Table II: Flow of event document use case (modify a user's profile)

I.IV Detailed Level Use Cases

After use-case flow of events document, detailed level use cases are created for each use case which are normally resemble with flow of event document with an extra function named typical course of event. As like flow of event document, it also depicts a detail what the system must provide to the actor when the use-cases are executed. Typical contents in this use-case detail documents are as follow:

- Typical course of events.
- Normal flow of events.
- Alternate flow of events.
- Exceptional flow of events.
- How the use case starts and ends.

DETAILED LEVEL USECASES

USE CASE: REQUEST FOR REGISTRATION

Primary actors	General Users, Agency participant
External actors	Notification, Participation and Feedback
Purpose	The main purpose of this use case is to create a new login

	for a new user.
Overview (flow of events)	When actor open GeoVPMS site and system asks for sign in. The actor is prompted to enter information that defines the registered user such as login, password, name, address, etc. The actor enters the information. For agency participant/ municipality staff the availability of logins will not be checked because for agency participant the hosting corporation has made the advance booking of their user's login with reference of their corporation therefore actor just verifies the identity of the login as corporate when he arrives then the system will ask his/her information and let him enter after verification with its database. The actor can choose to save the information or cancel the operation, if actor decides save the information, the new login is created and the list of user's login is updated into a database.
Alternative flow of events	The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. If the system find some error in identification of corporate user. It will not allow him/her to enter as registered agency participant and forward to particular error page.
Starting point	The use case begins when the user arrives at GeoVPMS site and system welcomes him/her.
Ending point	The use case ends when the actors enter the information safely.
Measurable result	System has the appropriate customer information.

Type	Primary and essential for corporate actor.
Cross References	Functions: F1, F6, F7, F8, F13

SECTION: MAIN

TYPICAL COURSE OF EVENTS

Actor Action	System Response
This use case begins when the user arrives at the GeoVPMS Web site and request for sign in to become a registered user	
The actor then first checks the type of user (Web user/general user, corporate or mobile user). Types of customers: If the customer is a. General user: Geometics student, professor, engineer, EA researcher, public participant Corporate: Agency/Muncipality/Local bodies participants see section corporate user b. Managerial users	
The actor collects the personal information from the customer	System saves the user's information in its repository.

SECTION: GENERAL USER

TYPICAL COURSE OF EVENTS

Actor Action	System Response
The actor press sign in button and directs to sign up page where actor put his desire user id and press check availability button	System will determine the registered user logins list and verify the actor desired login with the list and response to the actor either with already selected user id or with suggested user's id list

Actor gets the desired user id or suggested user id and enter his/her personal information with desired password and press submit button	System will determine the login and other entered information correct and displays it to the actor for preview.
Actor previews and press submit & save button	System enter the information into repository

SECTION: DOMAIN EXPERTS/CORPORATE USER	
TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
The actor enters his/her identity to verify him given by host corporation	System will determine the user information and displays it with verification pin window to the actor
Actor enter his/her pin# and desired password and If the verification process result becomes positive then actor successfully registered	System adds the user validation information to the running transaction.

Table III: Detailed level use case (request for registration)

USE CASE: LOGIN	
Primary actors	Registered general users, corporate user
Secondary Actors	Project Manager, DBA
External actors	Notification, Participation and Feedback
Purpose	The main purpose of this use case is to Log In the Actor in the System.
Overview (flow of events)	Use case begins when the actor needs to use the system. He is prompted to enter his login and password. If his/her login and password both are correct he is allowed to use the system. And in case any information typed is incorrect

	a failure message is displayed and either he has to retype the correct information or he has to contact system administrator to get his/her rights.
Alternative flow of events	If the actor is not the right person, system will not allow entering. If the actor has entered wrong password and id, the system will prompt him to try again. One of the cases could be, actor is the right person but he has banned/disabled by the system administrator.
Starting point	The use case begins when the actor tries to login the system.
Ending point	The use case ends when the actor's try to login is either successes or fails.
Measurable result	The actor logins into the system
Type	Primary and essential for registered user
Cross References	Functions: F6

TYPICAL COURSE OF EVENTS

Actor Action	**System Response**
The use case begins when the actor attempts to login	
	System prompts the actor to identify himself by displaying a dialog box. Dialog box contains two text fields for Id and password plus a combo box with types of users for instance general user etc.
Actor enters his id and password	System verifies the actor's id and password with his user profile.

	If id and password matches system will allocate user his access token (set of security identifiers (SIDs) for user and user's session. On the other hand system gives an error and again prompts the user to identify him.
If actor's various attempts to login fail that means he has no rights on that system. He needs to contacts the administrator for enabling his/her login.	

Table IV: Detailed level use case (login)

USE CASE: LOGOUT	
Primary actors	Registered general, corporate and managerial users
External actors	Notification, Participation and Feedback
Purpose	The main purpose of this use case is to log out the Actor from the system.
Overview (flow of events)	Use case begins when the Actor wants to close his session. He will just press the Logout button. After the logout, a message will confirm that he has logout from the system.
Alternative flow of events	None
Starting point	The use case begins when the actor attempts to logout.
Ending point	The use case ends when the actor's attempts to logout succeeded.
Measurable result	The actor is logged out.

Type	Primary and essential.
Cross References	Functions: F13
TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
The use case begins when the actor attempts to logout	
	System checks the current state of the user's session. If system find any application window open it closes it
	Logs the information and save it.
	Logout the actor.
Actor is logged out	

Table V: Detailed level use case (logout)

USE CASE: CREATE PROJECTS LISTING	
Primary actors	Project Manager/Project Proponent/Mediators
External actors	Database Administrator
Purpose	The main purpose of this use case is to create a projects availability list.
Overview (flow of events)	In this list, the actor maintains the projects listing with its state so that general user and other actors can view the recent and future project work within the specific municipality or city.
Alternative flow of events	The actor might unintentionally entered the wrong marking or unmarking of project with reference to its host corporation so he can eliminate the error by comparing it with the information list provided by corporation.
Starting point	The use case begins when the actor starts making the

	projects listing.
Ending point	The use case ends when the actor safely enters the information of projects.
Measurable result	System has the information about projects launching by different corporations as well as its current state.
Type	Primary and essential.
Cross References	Functions: F5, F6, F7, F13

TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
This use case begins when the actor receives orders to create and maintain the projects availability list.	
Actor records the number of project in the list and their current state. (working or future concerns)	System accepts the values according to the fields and persist the information.
Actor sends the Acknowledgment to specific corporate user.	

Table VI: Detailed level use case (create projects listing)

USE CASE: CREATE PROJECT DETAIL LIST	
Primary actors	Project Manager/Mediators
External actors	Spatial DBA, Corporate User.
Purpose	The main purpose of this use case is to create a project detail list.
Overview (flow of events)	The use case begins at the start of the process. A detail of a specific project provided by any cooperate user entered into a system by the project manager. Spatial database

	administrator will also update his/her system if the information has any interaction with the database. This list contains all the necessary information about a new project (i.e. background, future concerns, public notification/remarks, project related conferences and papers etc).
Alternative flow of events	If the actor unintentionally enters wrong information about the project into the system database then it will alarm him and restrict the actor to proceed further until he/she corrects that information.
Starting point	The use case begins at the start of the process and actor decides to view the specific project details.
Ending point	The use case ends when the actor browsing other information not relevant to any project.
Measurable result	System has full information about all the projects in details.
Type	Primary and essential
Cross References	Functions: F6, F7, F14

TYPICAL COURSE OF EVENTS

Actor Action	**System Response**
This use case begins when the actor receives orders to create and maintain the project details (specification).	
Actor gets the project specification manually from the hotel corporation and enters in the system.	System accepts the values according to the fields and persist the information.
Actor sends the ACK to corporation	

Table VII: Detailed level use case (project detail list)

USE CASE: MODIFY PROJECTS LISTING AND DETAIL LISTING	
Primary actors	Project Manager/Mediators
External actors	Spatial DBA
Purpose	The main purpose of this use case is to modify projects list.
Overview (flow of events)	The use case begins when the actor wants to modify project availability list. If any corporation wants to change the project name in the listing, actor will perform this task. Another use case "project detail listing" also starts if corporation change any details of the project. Other information related to system database is also updated.
Alternative flow of events	If the actor enters wrong updating information the system prompts the actor to correct that information.
Starting point	The use case begins when the actor wants to modify project availability list.
Ending point	The use case ends when the actor enters the updated information safely.
Measurable result	The system has the current and solid information about projects.
Type	Primary and essential
Cross References	Functions: F6, F7, F14

TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
This use case begins when the actor receives some change order from the corporations in the project list.	
Actor gets the old information which	System determines and displays the

end users want to update.	available project listing.
Actor modifies values of list according to the change ordered.	System updates and saves the information.
Actor sends ACK to the corporation	

Table VIII: Detailed level use case (project list & project detail list)

USE CASE: DISABLE A USER	
Primary actors	Project manager, Database Administrator, Mediators
External actors	
Purpose	The main purpose of this use case is to disable a user.
Overview (flow of events)	The use case begins when the actor wants to delete, disable or ban an existing user record, system will present the selected customer information. System prompt when an actor revokes user's rights If the actor accepts the operation, the user is disabled from the system and user list database is updated. This use case is applicable for all user i.e. corporate, mobile etc.
Alternative flow of events	
Starting point	The use case begins when the actor wants to disable an existing user record.
Ending point	The use case ends when the actor disables the user record.
Measurable result	System has updated it's user record information.
Type	Primary and essential
Cross References	Functions: F6, F7, F9, F13, F14

TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
This use case begins when the actor attempts to disable a customer record	
Actor gets the customer information list and revoke particular user rights	System prompts the actor an alert dialog box asking for surety of his decision.
If the actor press yes button the system proceeds.	System updates the record in user listing table.
Actor receives completion notification from the system.	

Table IX: Detailed level use case (disable a user)

USE CASE: CREATE HOSTING CORPORATION LIST	
Primary actors	Project Manager/Mediators
External actors	Database Administrator
Purpose	The main purpose of this use case is to create a list of hosting corporations.
Overview (flow of events)	This use case begins when a corporation wants to register with the system (GeoVPMS). The management verifies its presence and after that makes a contract with them in which they decide that they will issue a bill for their expenditures on monthly basis and some other procedures internal to both parties. Both parties sign the contract. They get and save their contract's copies individually. The contract can be lifetime or based on some duration specified and agreed by both the parties. Another option is that they both made a contract and when one of the party

	wants to leave, it will inform the other party.
Alternative flow of events	The corporation and GeoVPMS management might not get agree on the agreement policy and both deny developing a contract.
Starting point	This use case begins when a corporation wants to register with the system.
Ending point	When the GeoVPMS management and the hosting corporation get copies of their contracts (final form).
Measurable result	Corporation registered
Type	Primary and essential
Cross References	Functions: F6, F7, F13

TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
This use case begins when the actor receives the creation order of hosting corporation list	
Actor gets the manual list of hosting corporations and enters into the system	System saves the information
Actor sends the ACK to corporation	

Table X: Detailed level use case (hosting corporation list)

USE CASE: MODIFY HOSTING CORPORATION LIST	
Primary actors	Project Manager/
External actors	DBA
Purpose	The main purpose of this use case is to modify a list of hosting corporations.

Overview (flow of events)	This use case begins when the actor wants to change the information regarding the particular hosting corporation information on its request. For example, the corporation has changed its place or developed a new office and wants to add that information.
Alternative flow of events	If the actor enters wrong updating information the system prompts the actor to correct that information.
Starting point	The use case begins when the actor receives the order to modify information.
Ending point	Actor modifies the information.
Measurable result	System has the updated information.
Type	Primary and essential
Cross References	Functions: F6, F7

TYPICAL COURSE OF EVENTS	
Actor Action	**System Response**
This use case begins when the actor receives change order from corporation.	
Actor gets the hosting corporation list	System determines and displays the hosting corporation's list.
Actor modifies the list according to the change	System updates and save the information.
Actor sends ACK to corporation	

Table XI: Detailed level use case (modify hosting corporation list)

USE CASE: DELETE HOSTING CORPORATION LIST	
Primary actors	Project Manager/Proponent
External actors	DBA

Purpose	The main purpose of this use case is to delete any entry in the list of hosting corporations.
Overview (flow of events)	The use case begins when the actor wants to delete the information regarding the particular hosting corporation information on its request. For example, the corporation wants to get unregistered and wants to leave.
Alternative flow of events	If the actor enters the wrong information system prompts the actor to correct that information and not allow him to proceed further until he corrects the information.
Starting point	This use case begins when the actor receives the order to perform deletion on some record.
Ending point	The actor do the deletion as ordered.
Measurable result	System has updated information now.
Type	Primary and essential
Cross References	Functions: F6, F7, F9

TYPICAL COURSE OF EVENTS

Actor Action	**System Response**
This use case begins when the actor receives delete order from agency management.	
Actor gets the hosting corporation list	System determines and displays the hosting corporation's list.
Actor deletes the record according to the delete request	System updates and save the information.
Actor sends ACK to hotel management.	

Table XII: Detailed level use case (delete hosting corporation list)

APPENDIX II ANALYSIS AND DESIGN DOCUMENTATION OF GEOVPMS USING UML DIAGRAMS

II.I Use Case Diagrams (Level 1)

i. General User Use Case Diagram

As previously discussed a general user is a composition of different users such as public participant/ citizens or municipality staff/local bodies. Figure II.I illustrates the relationship of an actor general user with its use cases.

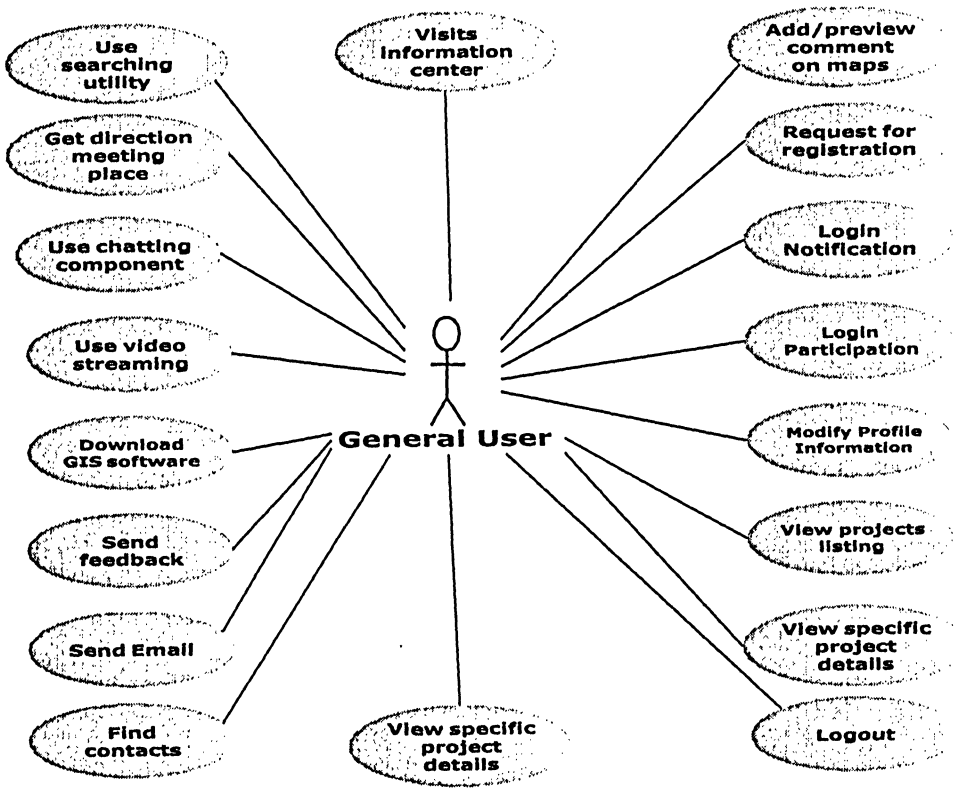

Figure II.I: Use case diagram of general user

ii. Corporate User Use Case Diagram

Corporate users are described either as agency public participant or consultants included domain experts. Figure II.II portrays the corporate actor (expert user) relationship with its use cases.

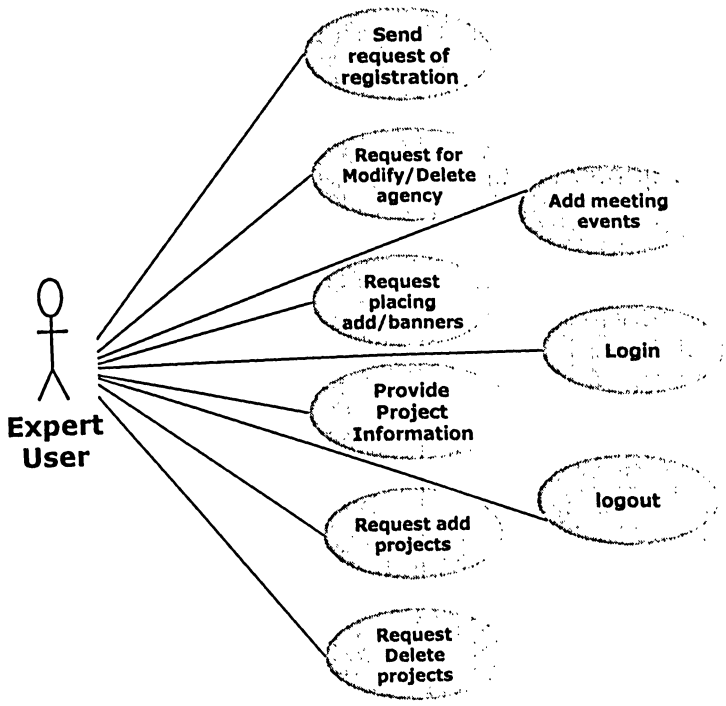

Figure II.II: Use case diagram of expert user

iii. Managerial User Use Case Diagram

Managerial user is the one, who perform the system maintaining tasks e.g., mediators and project manager. These users have the most administrative rights. Figure II.III depicts managerial user use case diagram with relation to its use cases.

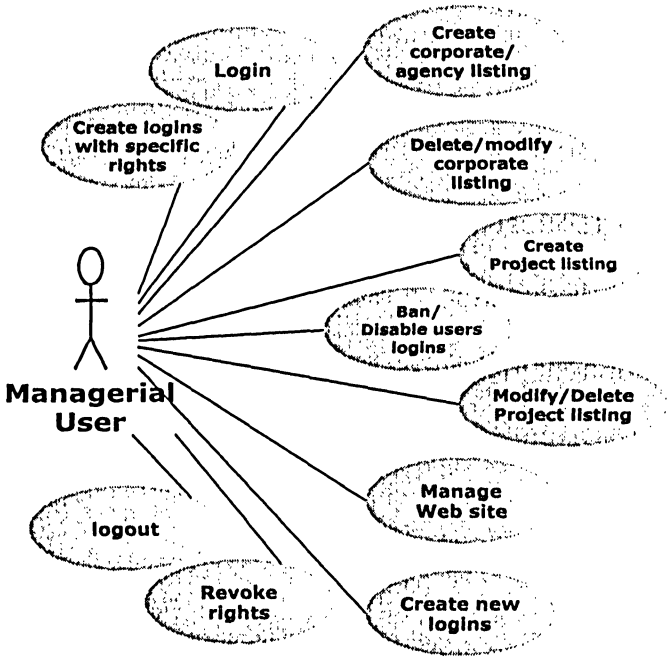

Figure II.III: Use case diagram of managerial user

II.II Sequence Diagrams

UML sequence diagrams model the flow of logic within the system in a visual manner. These are commonly used for both analysis and design purposes. Furthermore, a sequence diagram displays object interactions arranged in a time sequence or in other words, it shows the objects and messages involved in an interaction.

Figure II.IV shows the sequence of messages generated internally when an actor (public participant) put a request to search any particular notice related to municipal project on April 12, 2007. It describes how a browser (user-interface object) interacts with the notification component in the n-tier system architecture.

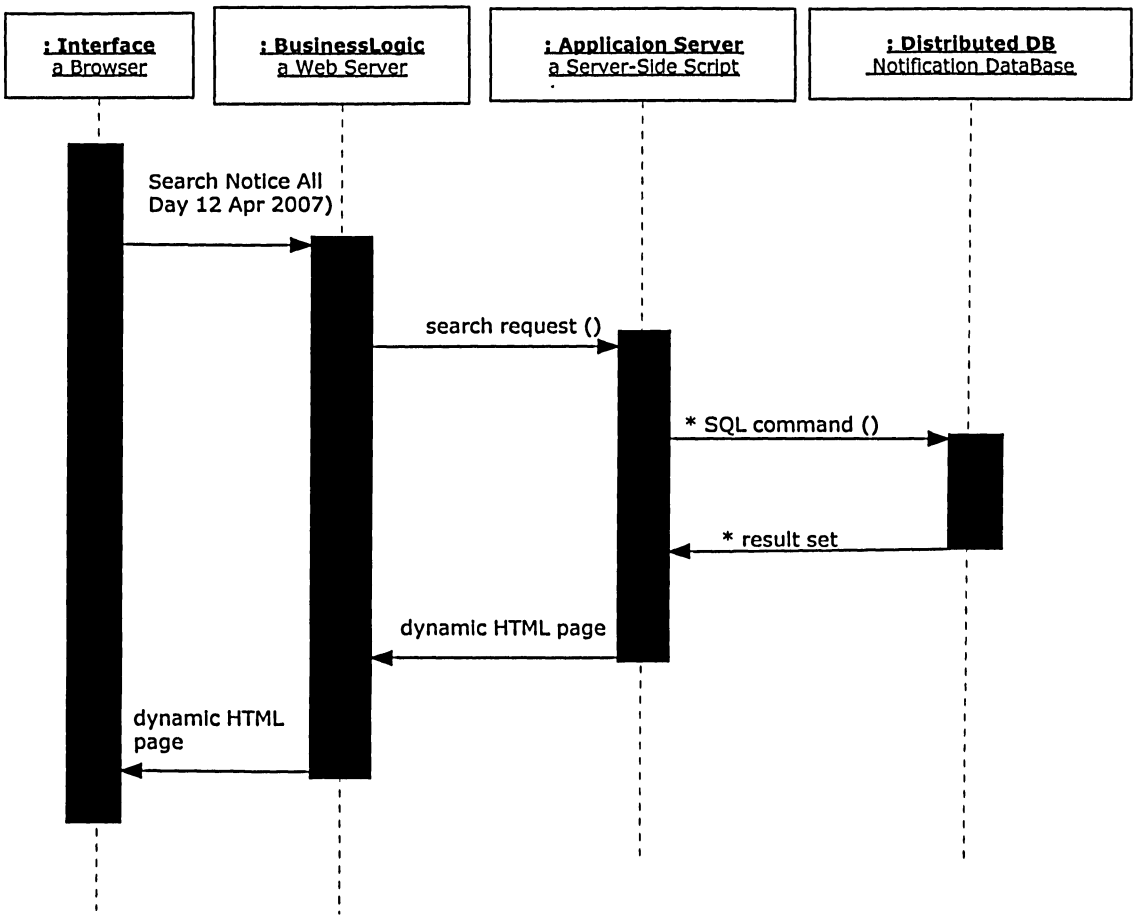

Figure II.IV: Sequence diagram for searching specific all day notices

In short, sequence diagram describes some aspects (i.e. how information flows between objects) that are helpful in designing the system architecture.

Sequence diagrams are the most popular UML artifact for dynamic modeling, which focuses on identifying the behavior within the system. Figure II.V shows how general

user (public/citizen) gets register with GeoVPMS by making interaction with different objects in a certain time frame.

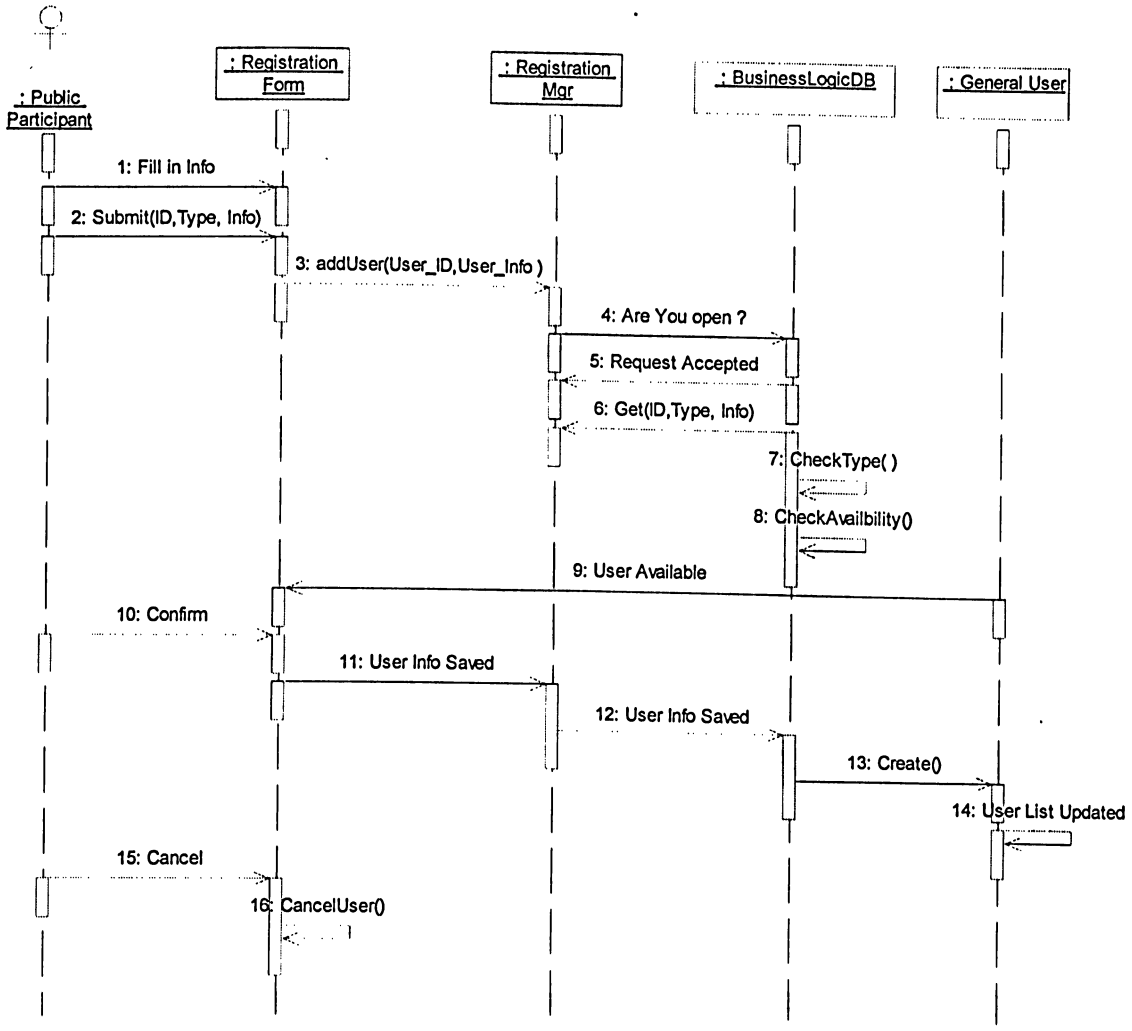

Figure II.V: Sequence diagram for registration of public participant

Figure II.VI depicts how one of the managerial user get the permission for sign in with the system component "BusinessLogicDB", who's objective is to access the systems general database later.

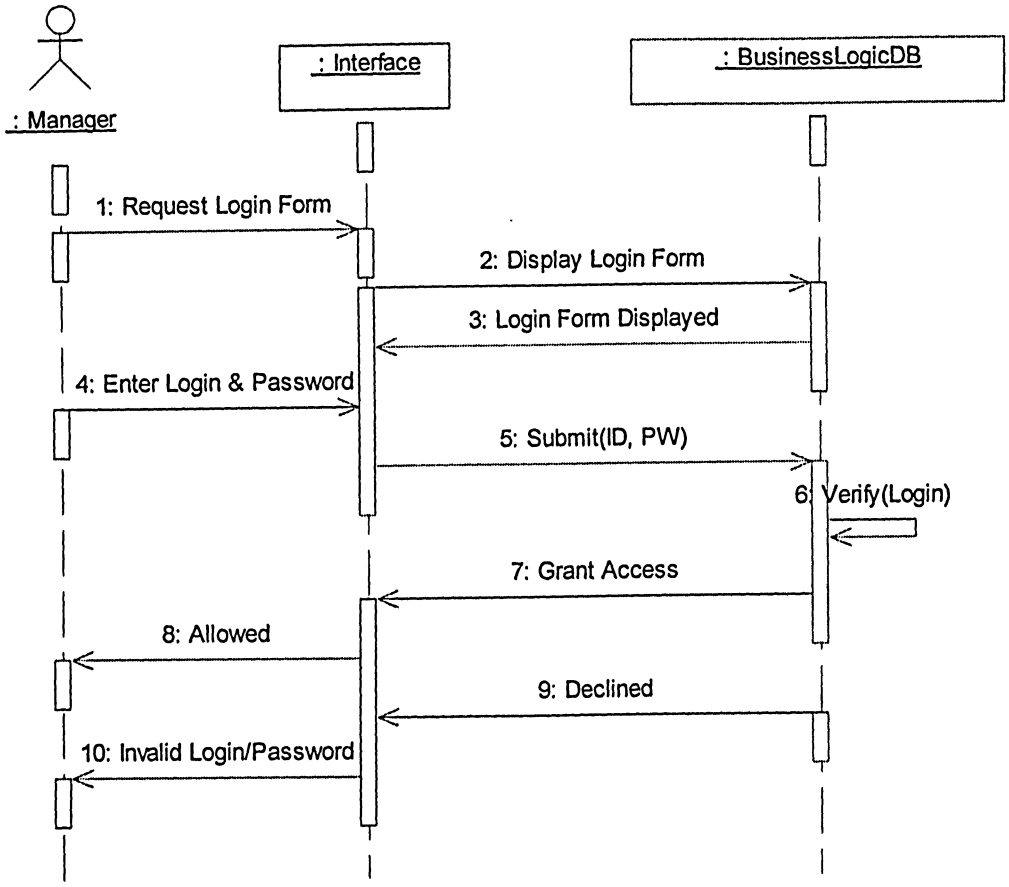

Figure II.VI: Sequence diagram for sign in

Figure II.VII illustrates flow of logout sequence from the system's component "Business LogicDB". Furthermore, it shows how the front interface class interact in the series of steps with business logic component which would be placed in the middle tier of the enterprise/distributed system (GeoVPMS).

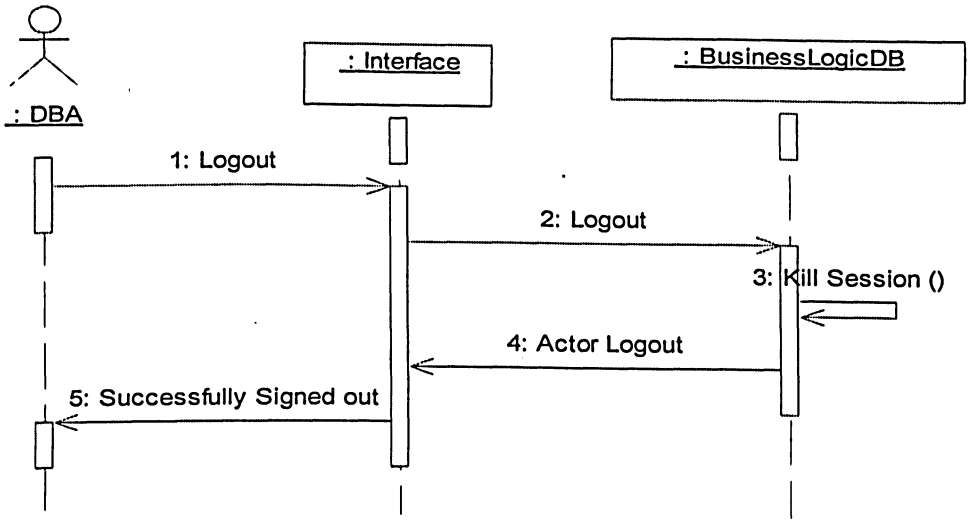

Figure II.VII: Sequence diagram for sign out

Figure II.VIII shows, how user EA researcher interacts with different objects of a system during his/her request for viewing projects.

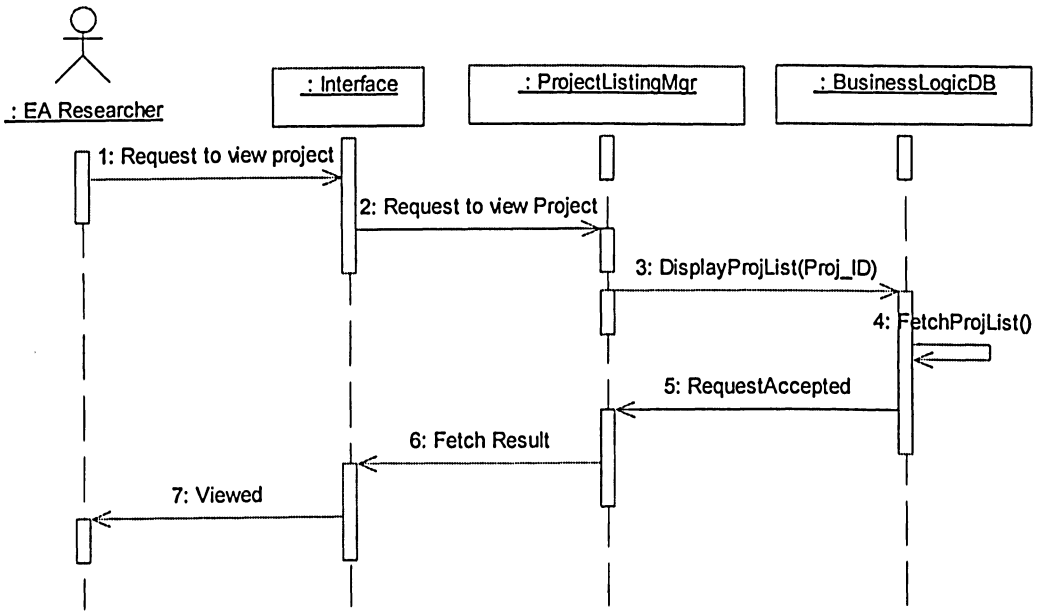

Figure II.VIII: Sequence diagram for viewing project listing

Figure II.IX is an example of series of steps which every managerial user/project proponent has to go through while updating project listing database. This request of modification is usually based on our corporate users as well as, in some cases, our general users.

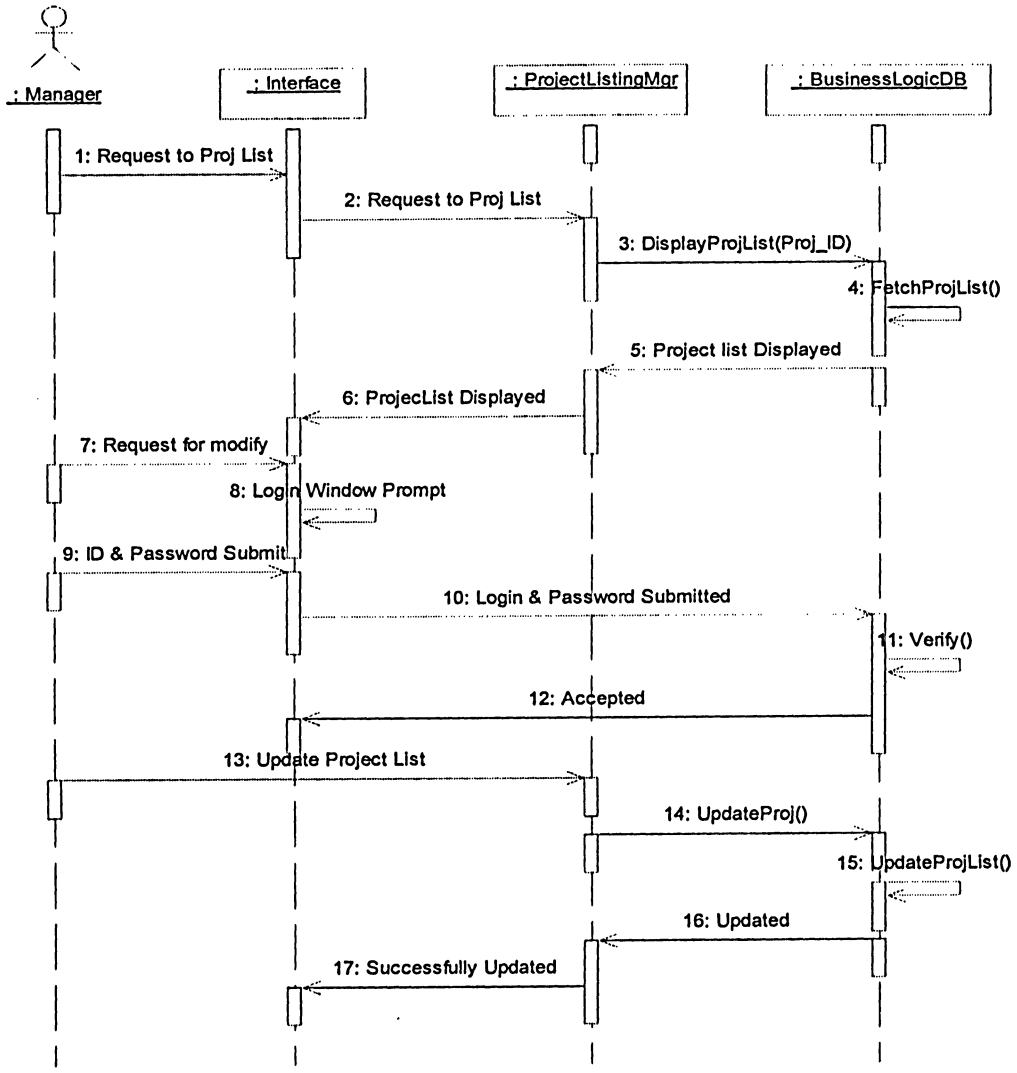

Figure II.IX: Sequence diagram for updating project listing database

II.III Collaboration Diagrams

A collaboration diagram displays object interactions organized around objects and their links to one another. Moreover, it shows. more focus on the objects and their relationships involved in an interaction and the sequence of messages exchanged among the objects during the interaction.

Figure II.X illustrates the collaboration diagram of a general user (public participant) showing the registration process with the system (GeoVPMS).

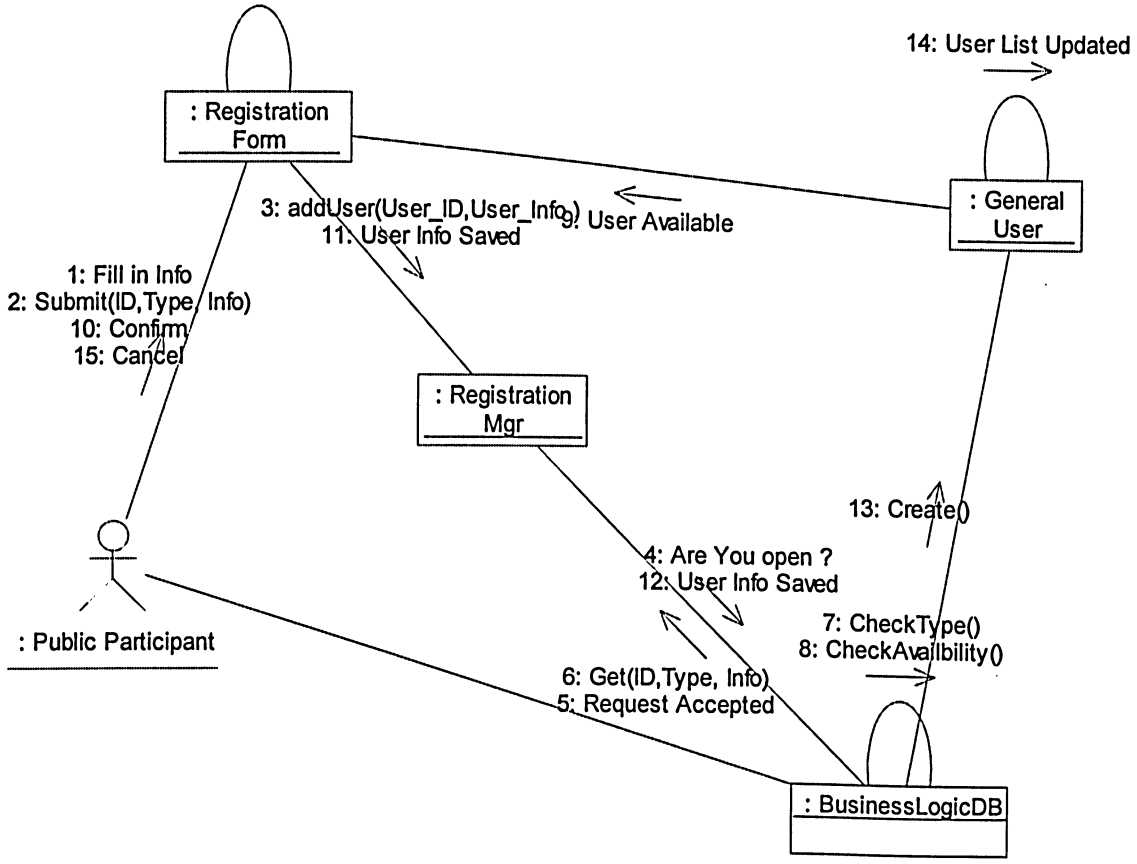

Figure II.X: Collaboration diagram of public participant

Following Figure II.XI is an example of collaboration diagram which represent the sign in process with the system.

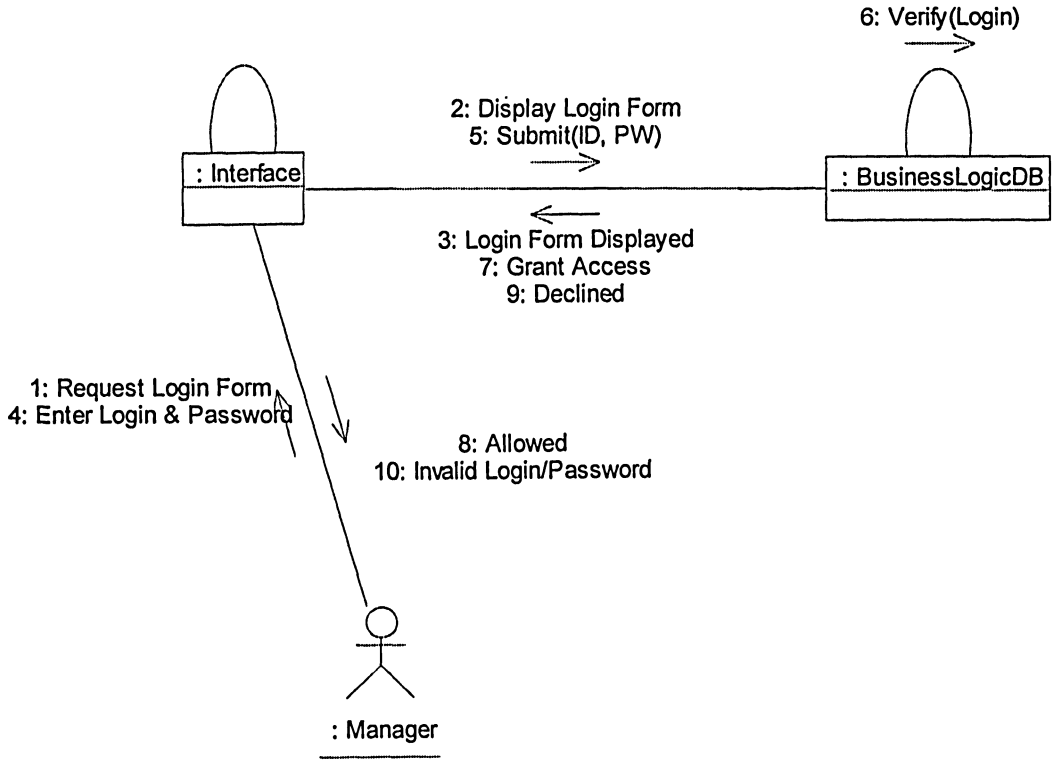

Figure II.XI: Collaboration diagram of sign in with system

II.IV UML 2 Communication Diagrams

A fundamental concept of the Unified Modeling Language (UML) is that you use different diagrams for different purposes. Sequence diagrams as we discussed earlier are used to model sequential logic. But what happens when you need to show the behavior of several objects collaborating together to fulfill a common purpose? This is what UML 2 communication diagrams, formerly known as collaboration diagrams in

UML 1.x, can be used for because they provide a birds-eye view of a collection of collaborating objects.

UML 2 communication diagrams show the message flow between objects in an object-oriented application and also imply the basic associations (relationships) between classes. Figure II.XII presents a simplified collaboration diagram for displaying a login scenario details screen or page. The rectangles represent the various objects involved that make up the application. The lines between the classes represent the relationships (associations, composition, dependencies, or inheritance) between them. The same notation for classes and objects used on UML sequence diagrams are used on UML communication diagrams, another example of the consistency of the UML. The details of associations, such as their multiplicities, are not modeled because this information is contained on your UML class diagrams. Each UML diagram has its own specific purpose and no single diagram is sufficient on its own. Messages are depicted as a labelled arrow that indicates the direction of the message, using a notation similar to that used on sequence diagrams.

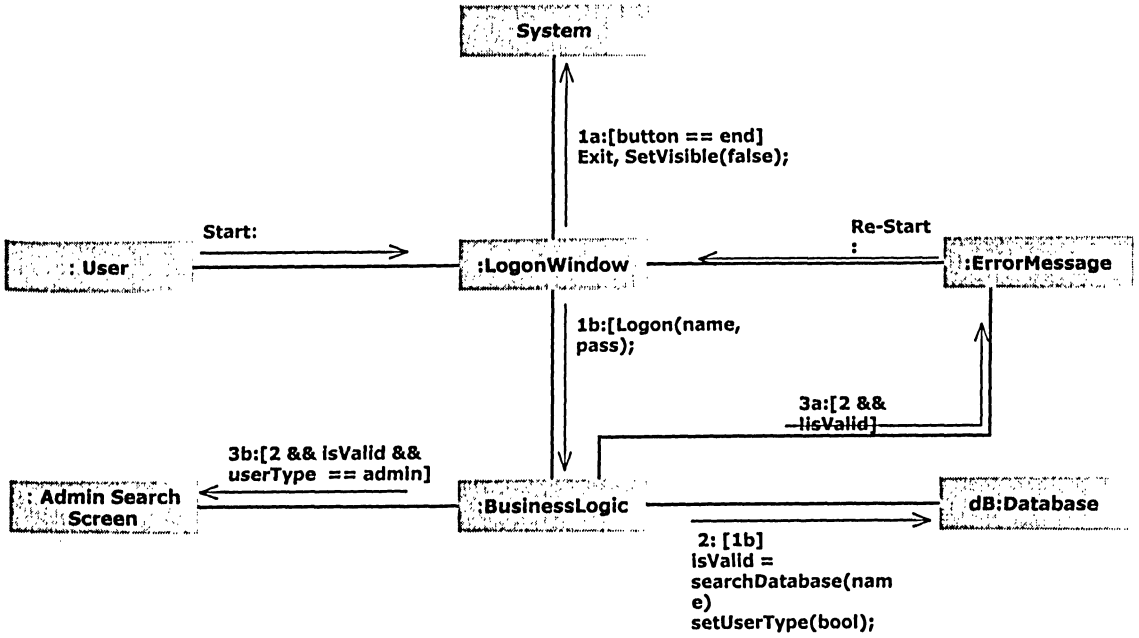

Figure II.XII: Communication diagram for login scenario

II.V GoeVPMS Class Diagrams Realization

In unified modeling language class diagrams show the static structure of the object, their internal structure, and their relationships. A class diagram shows the existence of classes and their relationships in the logical view of a system. UML class diagrams show the classes of the system, their interrelationships (including inheritance, aggregation, and association), and the operations and attributes of the classes. Most important element of the class diagram is to draw a conceptual class diagram that usually, based on preliminary classes and depict a start of a simple UML class diagram. In addition, classes are depicted as boxes with three sections, the top one indicates the name of the class, the middle one lists the attributes of the class, and the

third one lists the methods. By including both an attribute and a method box in the class it's arguably making design decisions in the model.

i. Preliminary Classes

Moreover, classes should be named using the vocabulary of the domain such as naming standards should be created for example all classes are singular nouns starting with a capital letter. This section of analysis model identifies all possible preliminary classes which are used in designing detailed class diagrams in the design model section.

After successful completion of requirement and analysis model phases of a system design, usually preliminary classes are identified that are shown in Figure II.XIII as follow:

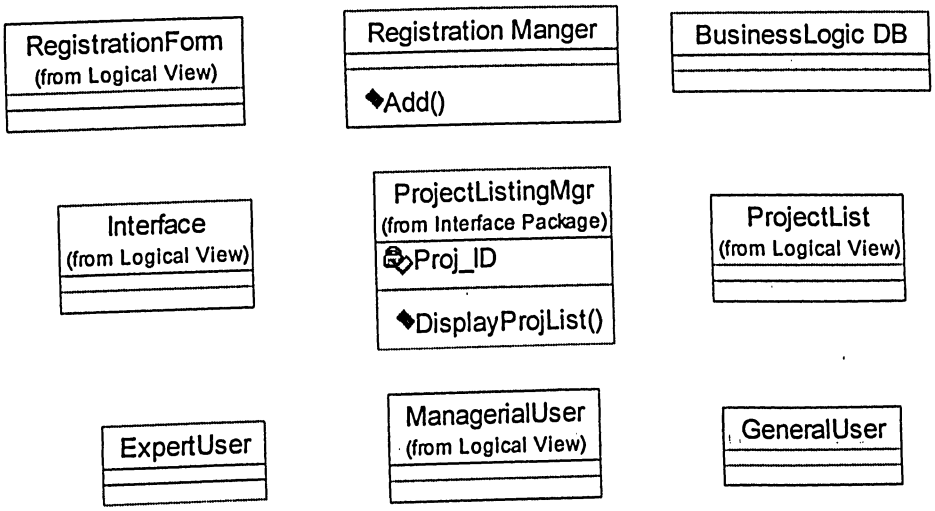

Figure II.XIII: Preliminary identifiable classes

ii. Steps of Class Diagram Realization

First step in class diagram realization is to identify the operation/method of all the classes. Operations may be found by examining interaction diagrams. Figure II.XIV helps to understand the concept of finding the operation from the sequence diagram

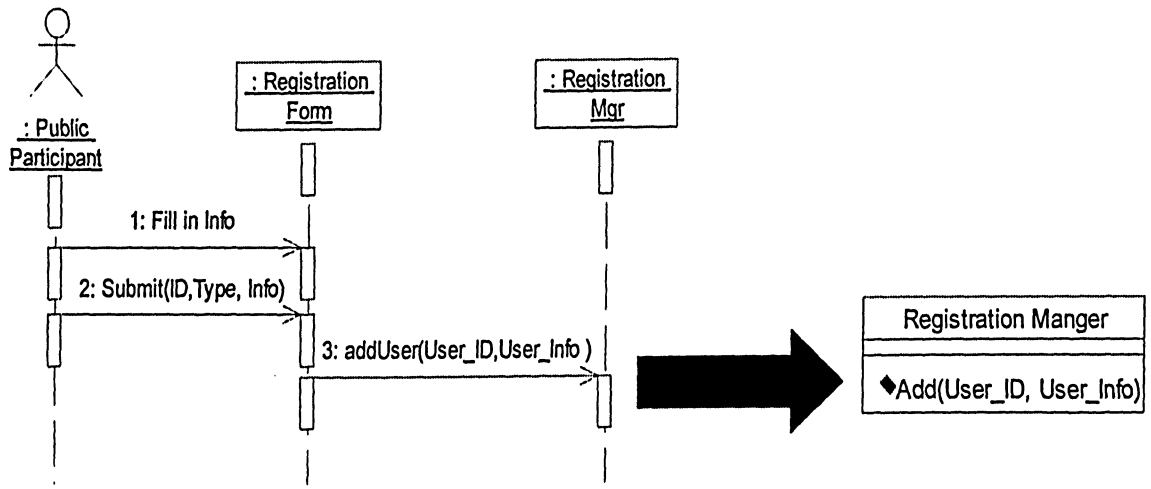

Figure II.XIV: Finding operations from sequence diagram

Second step is to identify the structure of the class which is represented by its attributes. Attributes may be found by examining class definitions, the problem requirements, and by applying domain knowledge.

Figure below shows procedure of identifying the structure of the class forest-stand.

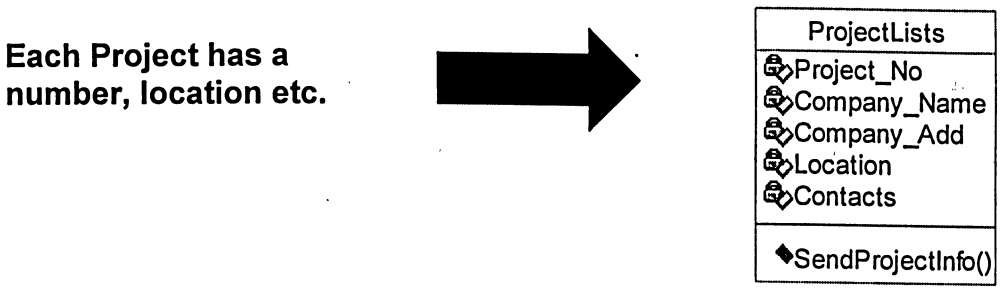

Figure II.XV: Finding attributes

Third step is to identify the relationship among these classes. Moreover, Relationships provide a pathway for communication between objects. Sequence and/or collaboration diagrams are examined to determine what links between objects need to exist to accomplish the behaviour - if two objects need to "talk" there must be a link between them. Relationship can be discovered by examining interaction diagrams as shown in following figure.

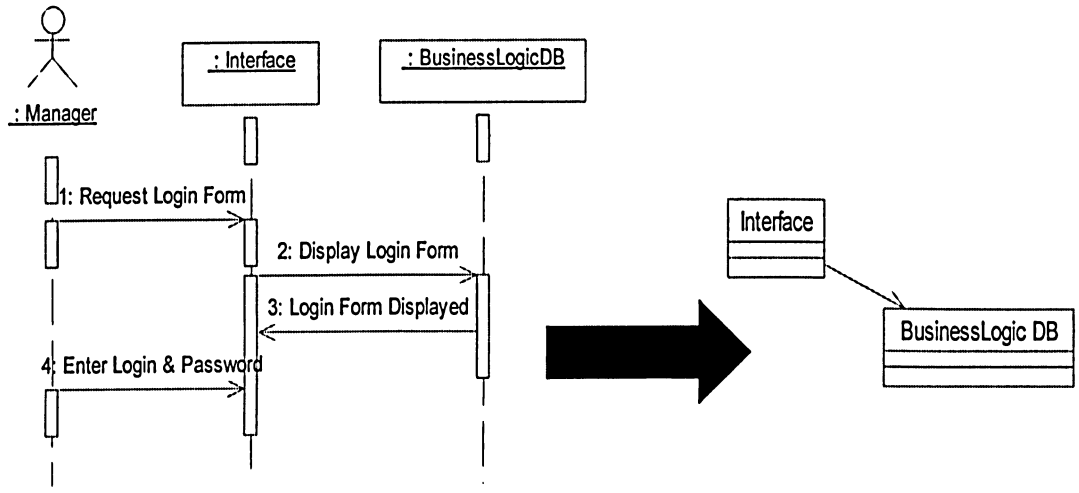

Figure II.XVI: Finding relations among objects from sequence diagram

Moreover, three types of relationships that I have already discussed in above section of this paper (association, aggregation and dependency). Another step is to find the class hierarchy. Inheritance is a relationship between a super-class and its sub-classes. Generalization and specialization are another name for inheritance which can be determined by finding "is a" relationship among objects. It refers to a relationship between two classes where one class is a specialized version of another. That is generalization of entity types into a single super-class.

For example, registered user is a super class of three sub classes named general user, corporate user and managerial user. In other words the registered user class would have a generalization relationship with the other above mentioned user's subclasses. Furthermore, general, expert and managerial user classes are specialized (public participant), (domain expert/municipality staff), (project proponent/manager, DBA) classes respectively. Figure II.XVII is an example of class diagram which shows inheritance (generalization) relationship between registered user and other objects such as general, managerial and expert users.

Final step is to find cardinality among classes objects. Multiplicity defines how many objects participate in relationships. It is the number of instances of one class related to one instance of the other class. Although associations and aggregations are bi-directional by default, it is often desirable to restrict navigation to one direction. If navigation is restricted, an arrowhead is added to indicate the direction of the navigation.

Figure II.XVII also shows the multiplicity and navigation among classes' objects of GeoVPMS.

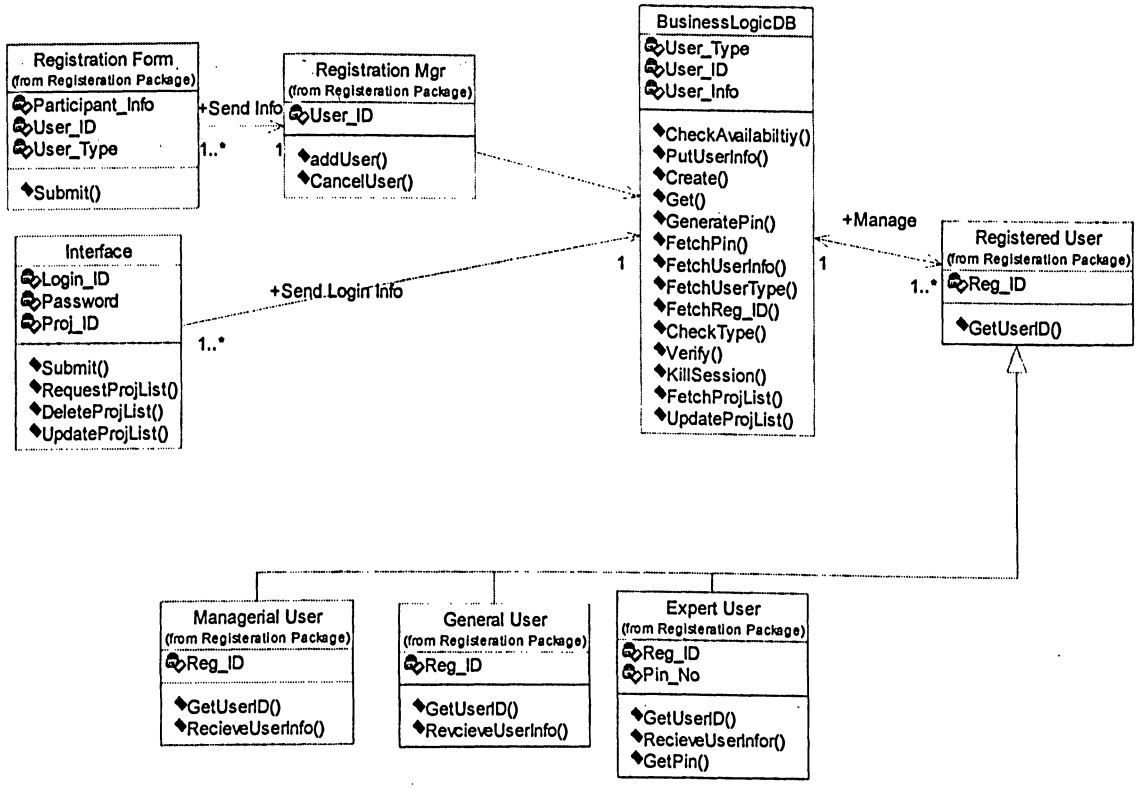

Figure II.XVII: Class diagram with inheritance relationship and cardinality

Class diagrams are used for a wide variety of purposes, including both conceptual and detailed design modeling. Figure II.XVIII depicts the class diagram for the proposed prototype.

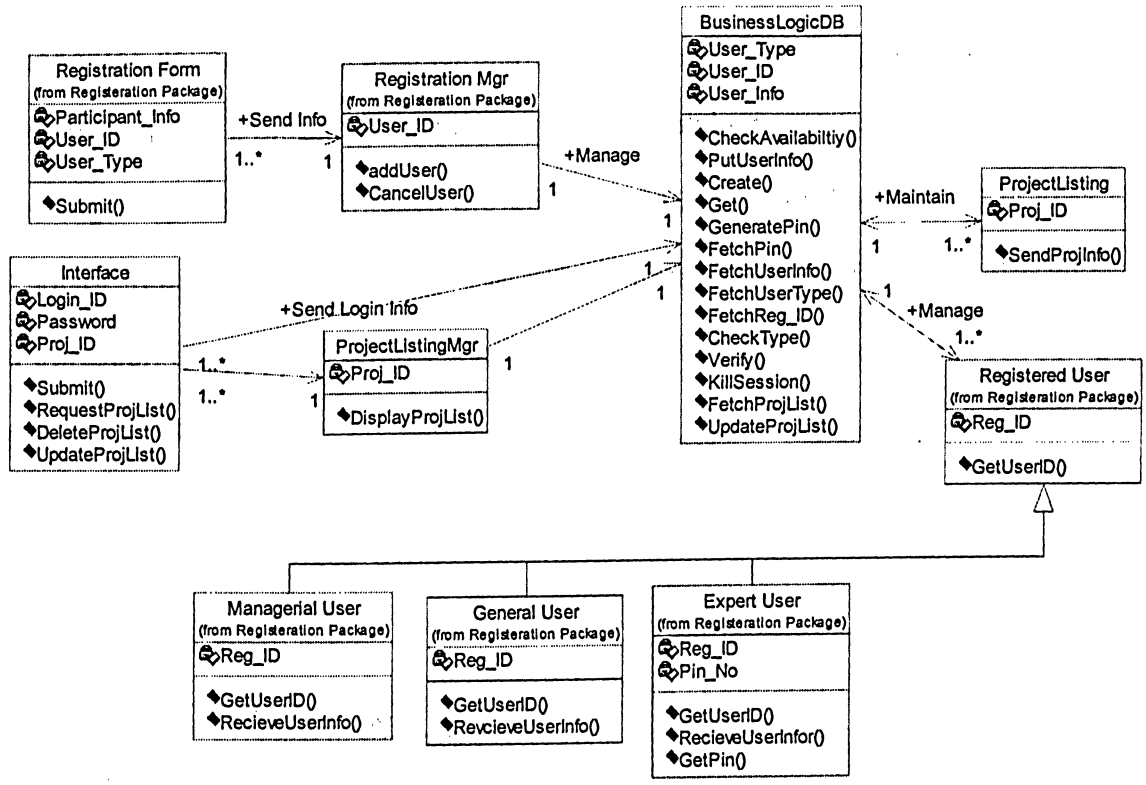

Figure II.XVIII: Final class diagram of prototype

The UML class diagram provides the logical or structural view of the system. The relational database structure for the proposed prototype is identified effectively by understanding the navigation and multiplicity among different objects of classes. For instance, Figure II.XVIII depicts the logical reasoning of methods and datasets that are required to find out or view the particular municipality project information.

II.VI GeoVPMS UML Packages

As unified modeling language supports or based on pure object-oriented language software engineering techniques therefore, it supports packaging or component based

designing too. In addition, in designing phase of the system author decide to make some packages such as Interface, registration, business logic, spatial database etc. These packages provide encapsulation i.e. to hide application data and information from the user interface layer of the system and make the system more secure. Figure II.XIX shows different packages used in designing phase of the system.

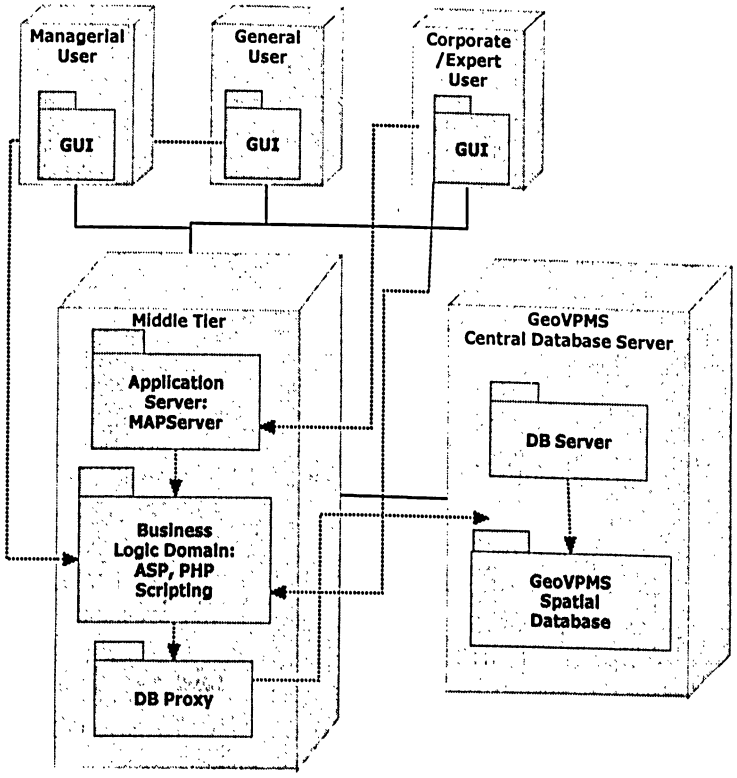

Figure II.XIX: Package diagram of GeoVPMS

II.VII State Transition Diagram

State machine/transition diagrams are used to model the behavior of complex classes. State transition diagrams are created for objects with significant dynamic

behavior. State transition diagrams describe all of the states that an object can have, the events under which an object changes state (transitions), the conditions that must be fulfilled before the transition will occur (guards), and the activities undertaken during the life of an object (actions). State transition diagrams are very useful for describing the behavior of individual objects over the full set of use cases that affect those objects. State transition diagrams are not useful for describing the collaboration between objects that cause the transitions.

Figure II.XX shows the dynamic behavior of a registered applicant/general user with the system to view particular project list information by interacting project list manager (server-side stored procedure). Dynamic state also depicts by changing the user state from idle to active after validation of password that is allotted to a registered user at the time of registration with the system.

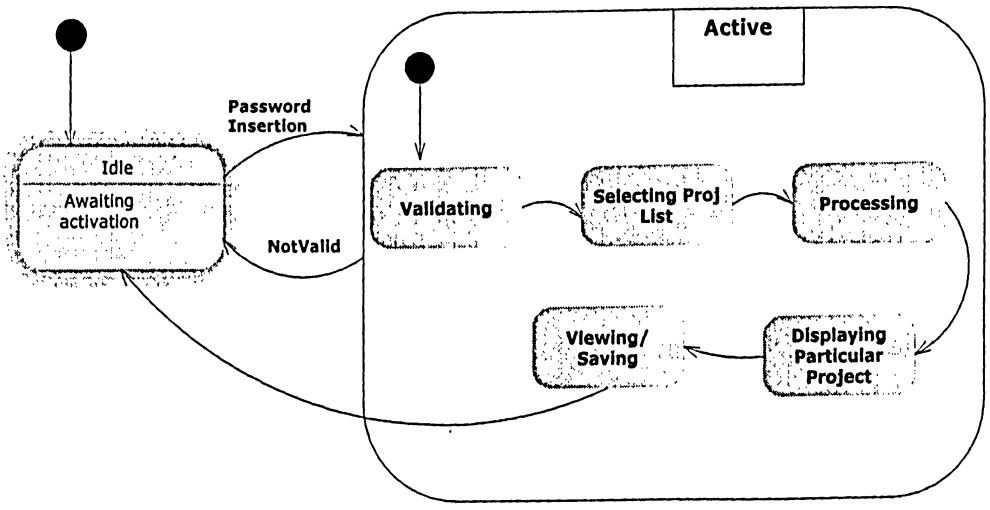

Figure II.XX: State transition diagram to explore a particular project-info as a registered user

The UML state-transition diagrams in Figure II.XXI shows the dynamic behaviour of the user sign in process to the system. In this scenario, user restrict for ten numbers of tries for sign in, after ten unsuccessful tries system automatically disable the user and send him/her a notification.

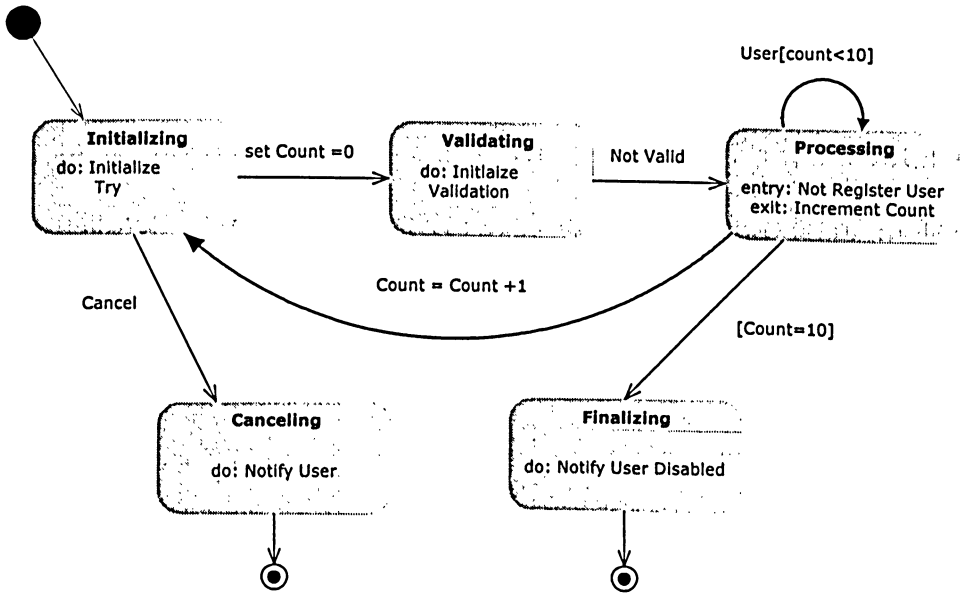

Figure II.XXI: State transition diagram to restrict user

II.VIII Implementation Model

In object-oriented software analysis and design, the implementation model comprises of component diagrams. The following section discusses about the actual design and implementation of the prototype system.

- **Component Diagram**

The component diagram's main purpose is to show the structural relationships among the components of a system. It illustrates the organizations and dependencies among software components while a component may be a source code component and a run-time components or an executable component. A component represented implementation items, such as files and executables. A component diagram describes the organization of the physical components in a system. It comprises with three elements such as component, interface and dependency.

- ***Component:*** A component is a physical building block of the system. It is represented as a rectangle with tabs.
- ***Interface:*** An interface describes a group of operations used or created by components.
- ***Dependencies:*** Draw dependencies among components using dashed arrows.

Figure II.XXII shows the all three element described above with reference of proposed system.

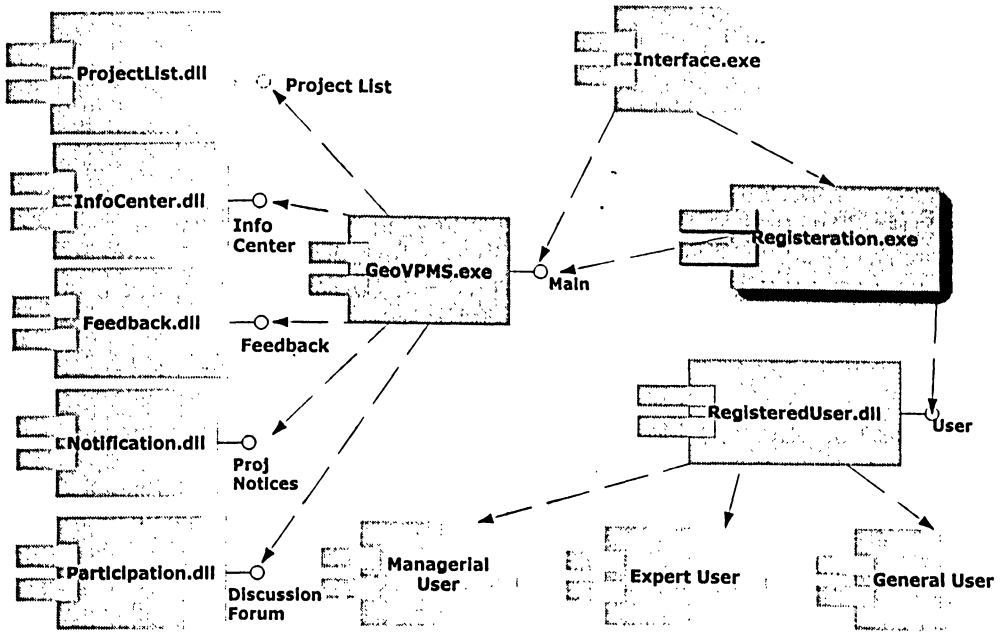

Figure II.XXII: Component diagram of a system

II.IX Deployment Model

In object-oriented system analysis and design, test/deployment model consists of deployment diagram. The following section discusses the implementation using UML for the proposed prototype.

- **Deployment Diagram**

Deployment diagram depicts a static view of the run-time configuration of processing nodes and the components that run on those nodes. In other words, deployment diagrams show the hardware for your system, the software that is installed on that hardware, and the middleware used to connect the disparate machines to one another.

It shows the configuration of run-time processing elements and the software processes living on them. Figure II.XXIII, the prototype's deployment diagram, visualizes the distribution of components across the enterprise.

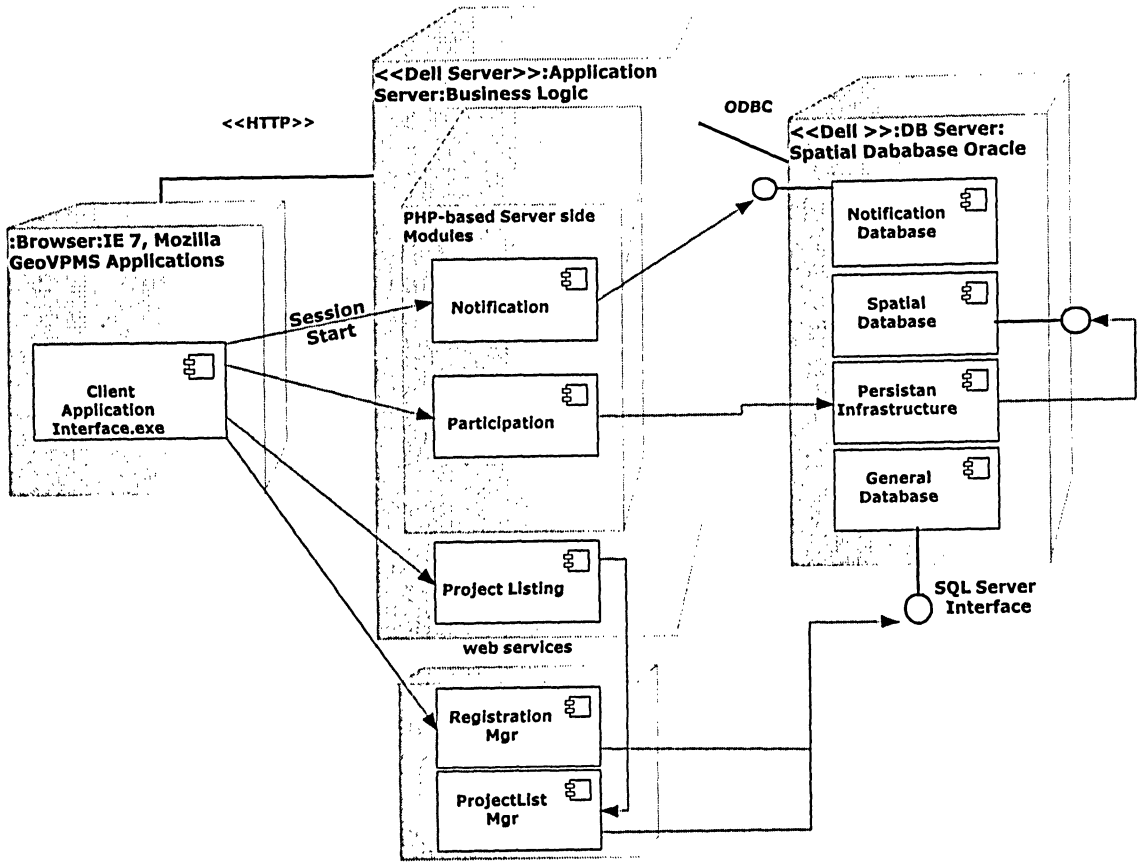

Figure II.XXIII: Deployment diagram of prototype