A PROTOTYPE OF WEB-BASED PPGIS FOR MUNICIAL PLANNING USING OPEN SOURCE SOFTWARE

by

Xiaohong (Serena) Ma

Bachelor of Applied Science

in the Program of

Computer Application

XIDIAN University

Shanxi, China

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Xiaohong (Serena) Ma

Department of Civil Engineering

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A Prototype of Web-based PPGIS for Municipal Planning Using Open Source Software

Xiaohong (Serena) Ma
Master of Applied Science, 2006
Department of Civil Engineering
Ryerson University

Abstract

Web-based Public Participation Geographic Information System (WebPPGIS) is inherently about empowering GIS and Web technology and enabling the public users to use the technology to capture their local knowledge and immerse them into the spatial decision making process. However, there have some common barriers to WebPPGIS implementation such as lack of communication mechanism for the public; lack of friendly use interface for the non-expert public users; and the cost of the GIS software packages etc.

This thesis presents the results of a research project, aiming at overcoming the above barriers and implementing a practical WebPPGIS. General requirements of WebPPGIS are summarized based on the analysis of current researches and a prototype is implemented to demonstrate the feasibility of the approach. Also this thesis illustrates that Open Source Software (OSS) is a competitive solution for developing cost-effective WebPPGIS. Further, the evaluation of the prototype has been performed against the requirements.

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List of Abbreviations and Acronyms

CIAC	Citizen Involvement Advisory Committee
CSDM	Computer-Supported Decision Making
DBMS	Database Management System
FAQ	Frequent Asked Questions
GIS	Geographic Information System
GML	Geographic Make-up Language
GUI	Graphic User Interface
ICT	Information Communication Technology
MBMS	Model Base Management System
MBR	Minimum Bounding Rectangle
NCGIA	National Center for Geographic Information and Analysis
OGC	Open Geospatial Consortium
OS	Open Specification
OSS	Open Source Software
SDBMS	Spatial Database Management System
SDSS	Spatial Decision Support System
SFSSQL	Simple Features Specification for SQL
SVG	Scalable Vector Graphics
UML	Unified Modeling Language
VDME	Virtual Decision Making Environment
VEDIS	Vallejo Economic Development Information System
WebCGM	Web Computer Graphics Metafile

WebPPGIS	Web-based Public Participation GIS
WFS	Web Feature Service
WKB	Well Known Binary
WKT	Well Known Text
WMS	Web Map Server
WWW	World Wide Web

CHAPTER 1 INTRODUCTION

1.1 Background

Local government has the responsibility to inform the public a variety of issues of their concerns and get them involved into the planning process. Planning process is an important and complex decision making process. According to Huxhold [1991], an urban planning professor and author, "good decisions require good information". The fast growth of Web technology has increased the amount of information available and the speed at which it is transmitted. Also a GIS (Geographic Information System) can be extraordinarily useful in helping the public understand all the spatially-related information of planning issues and providing information throughout the process [Fleming, 2006]. The integration of GIS and Web technology has been recognized of providing more possibilities to engage the public into the planning process.

WebPPGIS (Web-based Public Participation GIS) is inherently about enhancing GIS and Web technology and empowering the public users in using the technology to capture their local knowledge and immersing them into the spatial decision making process. The design and implementation of WebPPGIS should take the public into the core consideration. A successful WebPPGIS should be able to meet both the requirement of planning process and the need of the public.

Although the technology has provided possibilities to implement the WebPPGIS, there still have several problems during the implementation.

1.2 Problems

First, recent WebPPGIS research mainly focuses on how to make the information more accessible. However, only providing the access to information is not enough for the public to get involved into the complete planning process. Since the planning issues are more often considered as ill-defined issues, it is important to provide a mechanism through which the public can input their comments to the planning issues and exchange their ideas transparently.

Second, WebPPGIS is too costly for the local governments especially for small cities and non-profit organizations. The tight budget becomes one of the major barriers to WebPPGIS implementation. Bringing the GIS tools on the Web and sharing the GIS data through the well-designed central database are two solutions. Open Source Software (OSS) is another effective solution adopted in this thesis.

Last but not least existing WebPPGIS does not have a user-friendly interface for the public. WebPPGIS is a user-oriented GIS application which has wider user involvement comparing to the traditional GIS applications. Most of the public does not have sufficient technical background to understand the complex GIS concepts, such as buffer etc. A user-friendly and accessible interface is necessary for a successful WebPPGIS, through which the public use queries to find out the answer they need but without any idea they are accessing a GIS and databases working behind.

1.3 Research Objectives

This thesis research aims at using user-centered methodology to design and develop a prototype of WebPPGIS to fulfill the requirements of the public participation in the planning process. The research will try to achieve the following objectives:

- Summarize the general requirements of the WebPPGIS based on the analysis of the municipal planning process and the evaluations of the existing applications
- Design and develop a prototype of WebPPGIS by integrating the Web-based GIS with online discussion forum to provide a platform for the participants to exchange ideas on planning-related issues
- Use OSS to develop the prototype system to make the system cost-effective
- Design and implement a user-friendly interface for the public to use the GIS tools and process GIS queries

1.4 Thesis Organization

The thesis consists of five chapters organized as follows:

Chapter 1 introduces the context of the thesis research including the background and problems. The objectives of this research and the thesis organization are given in this section as well.

Chapter 2 reviews relevant literature for this research on WebPPGIS in the planning process. The importance and the necessity of the public participation in planning process are

introduced. Then how GIS has facilitated the public participation is discussed. In the second section, the components and technical aspects of Spatial Decision Support System (SDSS) are discussed.

In chapter 3, the evaluation of some selected existing WebPPGIS systems is introduced first and the methodology is discussed as well.

In chapter 4, requirements of a WebPPGIS are summarized based on the current research at first. Then the software components and the framework are demonstrated in detail, followed by an introduction of the prototype deployment. At last, the evaluation is discussed.

Chapter 5 summarizes and concludes the research. The achievements and limitations of the research are discussed first. Then the recommendations are given for the future WebPPGIS system design.

CHAPTER 2 REVIEW OF RELEVANT LITERATURE

This chapter reviews relevant literature for this research on WebPPGIS in the municipal planning process. The first section begins with the necessity of the public participation in planning process followed by a discussion in both depth and width aspect of the public participation. The possibilities that GIS has provided for increasing the public participation are then discussed. In the second and third section, the components and technical aspects of a SDSS and the OSS are reviewed and discussed.

2.1 Public Participation in E-government

2.1.1 Public Participatory Planning Process

Planning process in the municipal governments is a complex decision-making system which requires effective cooperation between planners, decision-makers and citizens. Public participation is a process to allow those affected by a decision to have an input into that system [Tang, 2005]. Public participation has increasingly become a way to get the public involved into the planning process owing to a convergence of new legislative requirements, growth of citizen activism, and change of the professional values [Peng, 2001].

Various public participation methods in the traditional planning process ranged from neighbor notification, exhibitions, public meeting, public enquires through telephone, letters, email, fax or public hearing [Kingston, 2002; Li et al., 2004]. The proposed planning alternatives are presented to the public and discussed by the public, at the same time public opinions are collected by the government to be used in the decision-making or planning process

[Li et al., 2004]. Traditional planning process has been criticized for being unable to effectively deal with stakeholder demands [Dragicevic, 2004]. The disadvantage of the traditional planning process is listed below:

- They are held at fixed places and most often at the fixed time. Due to the limitation of time and location, the public is hard to arrange to physically attend the event, especially young, senior and disable people.

- They are often confrontational, which can be dominated by minority vocal groups. Research shows people who have very strong opposition against the plan show more enthusiasm.

- The public has difficult to understand the complex planning process and planning regulations.

- The public have less opportunity to exchange information between each other.

- The public has been poorly informed throughout the whole planning process.

Recently, more governments are going online and using the Internet to provide public services to its citizens. E-government is a concept which refers to governments' use of technology, particularly Web-based applications to enhance the access to and delivery of government information and service to citizens, business partners, employees, other agencies, and government entities [McClure, 2000]. E-government is about transforming government to be more citizen-centered [Pacific, 2002], which means e-government will interact with the citizen (also referred as 'the public') smoother, easier, and more efficient. E-government will

provide a framework to encourage and increase the public participation into the planning or decision making process.

The greater degree of public participation will lead to a greater number of alternative scenarios which in turn will result in a better plan. Moreover, the complexity of the planning process makes it impossible to make effective plan without the public involvement. Five reasons why the public should have the opportunity to participate in the planning has been stated by the Oregon State Citizen Involvement Advisory Committee (CIAC) [Sadagopan, 2000]:

- **Planning for effective citizen involvement:** A strong planning for citizen involvement is the best way to have strong citizen involvement in planning.

- **Getting information to the public**: The public has the right to know the relevant planning information.

- **Getting information from the public:** The public often knows their community better than anyone else. Incorporation of local knowledge into planning process will help the government make better decision.

- **Exchanging ideas and information with the public**: Effective communication involves more than just sending or receiving message. It involves an exchange of ideas and information between the decision maker and the public or among the public.

- **Working with media:** The planning program can be issued through the media, such as the radio, the TV or the Internet, e.g., websites.

2.1.2 Two Dimensions of Public Participation

In an ideal scenario, the public would fully participate in and control the whole planning process from the earliest possible stage to the final decision-making and evaluation procedure. Due to the social and technological factors in the reality, the ideal goal is difficult to implement. However, recent research efforts have focused on different aspects to approach it. The framework of public participation actually includes two dimensions:

- Different levels of public participation, and
- Different phrases or stages of public participation.

The public participation ladder has been widely used to represent the levels of public participation. The base of the ladder represents zero opportunity to participate, while the top of the ladder represents full public control and responsibility for final decision [Carver, 2002]. [Arnstein, 1969] claims that citizen involvement in planning represents a redistribution of power from managers to the public. She developed the typology of citizen participation ladder to describe the eight steps of involvement and power sharing typically found in planning process (Figure 2-1). She also divides the eight levels into three classifications: from totally non-participation, through various degrees of tokenism, on to the highest level of involvement that would result in citizen control the planning process.

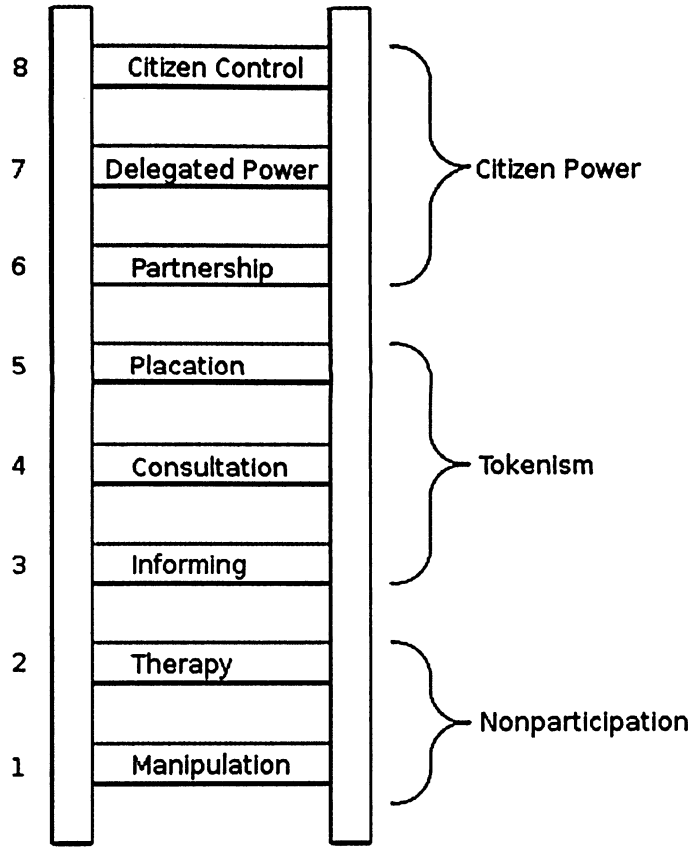


Figure 2-1 Ladder of Citizen Participation (Arnstein, 1969)

Weidemann and Fermers [1993] further developed the revised ladder of public participation based on the rights authorities provided to the citizens. According to their description, public participation increases with the level of access to information as well as the right the citizens have in the decision making process. Different levels of public participation are illustrated in Figure 2-2.

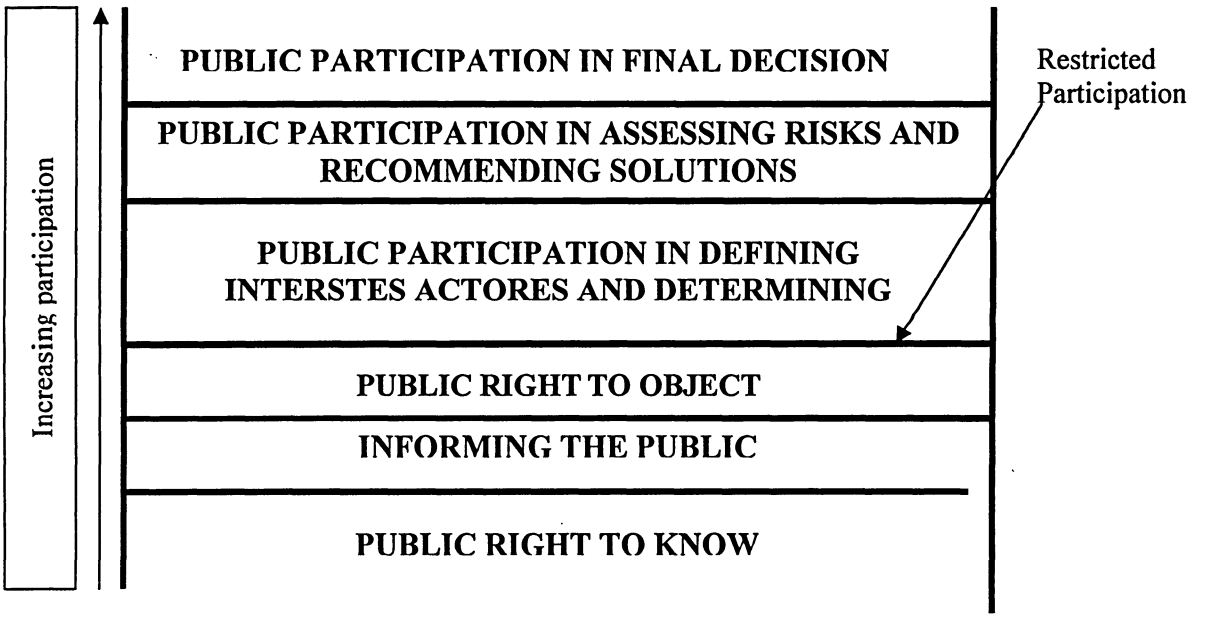


Figure 2-2 Public Participation Ladder (Weideman and Fermers, 1993)

Three levels of participation in policy making has been suggested by Macintosh: information (unidirectional information flows), consultation (citizens provide feedback) and participation (citizens define the process and content of policy making) [Komito, 2005].

The planning process is different according to the problem scenario. However, it always involves objectives definition and description, options identification and evaluation, optimum solution selection, plan implementation and outcomes evaluation. The general planning process can be described in following eight steps (http://halifax.ca/regionalplanning) which listed in Figure 2-3. The output of one step is the input of the next step.

- **Step 1 - Public awareness campaign.** The problems are presented and the existing conditions or status are considered. The output of this step will provoke the public awareness.

- **Step 2 - Develop goals, objectives and opportunities.** The public consults on the issues, goals, objectives and opportunities and their inputs are presented to the decision-maker.

- **Step 3 - Develop alternative plans.** The planners will synthesize opportunities and constraints to several alternatives.

- **Step 4 - Public consultation on the alternative.** The public discusses alternatives and also develops the evaluation method to evaluate alternatives and presents to the planner.

- **Step 5 - Evaluation of alternative plans.** The planner committee evaluates the alternatives based on the evaluation method and develops the implementation strategy for the recommended one.

- **Step 6 - Recommend alternative to council.** All alternatives are presented to the council and one alternative with the implementation strategy is recommended to council.

- **Step 7 - Develop a plan.** Implementation plans are developed and polices in preparation for legislation process are finalized.

- **Step 8 - Adoption of the plan.** The final plan is presented to council and the public for approval.

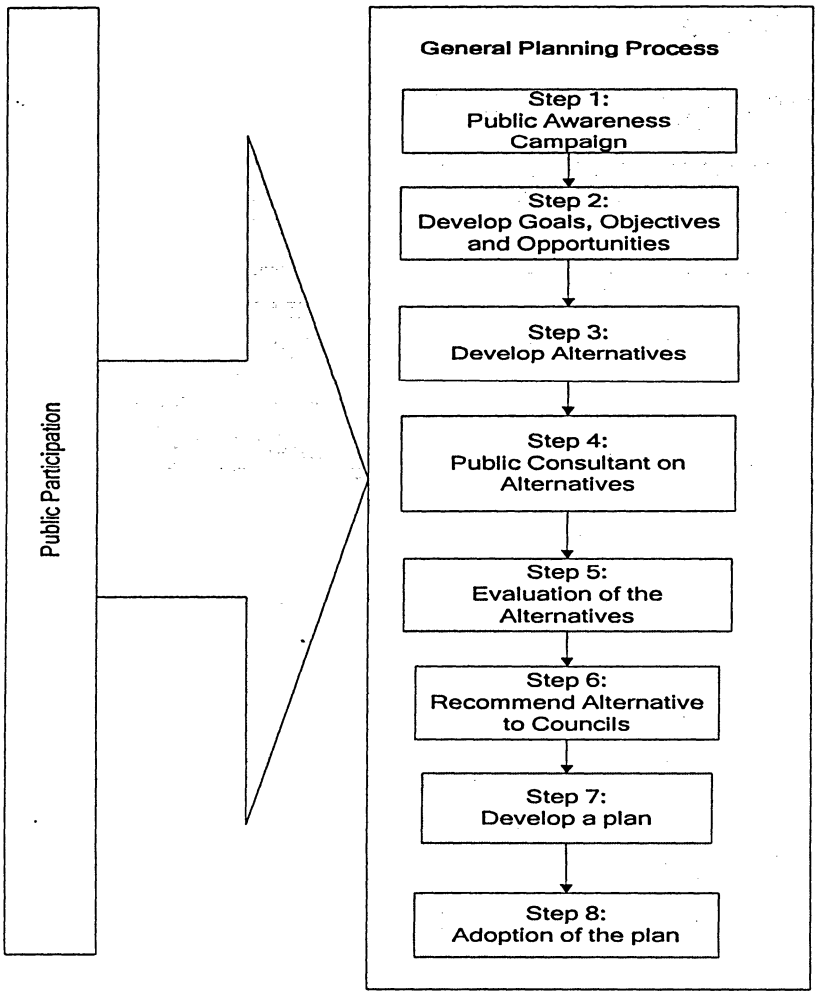


Figure 2-3 General Planning Process (after http://halifax.ca/regionalplanning/)

The public is encouraged to participate in every stage to improve the adaptability of the planning system. The public is encouraged to participate from the earliest possible stage in order to reduce the volume of objections at later stages. Meanwhile the public is encouraged to participate throughout the complete process in order to achieve the desired goals and objectives.

2.1.3 Web-based GIS for Public Participation

To ensure meaningful participation of the public in the planning and decision-making process, communication channels and tools should be provided [Peng, 2001]. The integration

of the World Wide Web (WWW, referred to as the Web) and GIS has provided huge potential for the success of public participation.

The popularity of the Web technology has changed the way of information dissemination, communication, and transaction. The public can access the information anywhere at any time without the time and space limitation. Also the Web is an interactive way by which the public can communicate with each other in more comfortable way and the public can express their opinion freely without the commonly-occurred confrontation during the public meeting.

GIS has been recognized as an important tool to facilitate public participation in the planning process since most planning information has spatial features. The level of the accessibility and understandability of the spatial information is crucial to the success of the public participation in the planning process. GIS is such a system which has provided the functionality to deal with geospatial data, such as capturing, storing, querying, analyzing, and displaying geospatial data. GIS has been widely utilized to help with perception and understanding of spatially-distributed phenomena. However, in many years, the lack of access to GIS data, software, and hardware by the public makes it difficult for the public and community groups to use GIS in participating in planning process [Peng, 2001]. GIS was mostly only used by the specialists in commercial organizations, universities, and governments. Over the last decade, the increasing adoption of information technologies, the affordable computer hardware and software have made GIS more accessible for the public to geo-referenced statistical information.

The idea of Public Participation GIS (PPGIS) has been brought out by NCGIA [1996]. PPGIS is aimed to make GIS tools and information easily to access, understand, and use by the public. Considering the advantage of the Web, spatially-related information should be visualized and distributed through the Web, which is Web-based PPGIS. Web-based PPGIS plays an important role in the planning process by providing the public more opportunities in the public debate than the traditional way of planning.

Different Web-based PPGIS have provided different levels of public participation possibility. Peng [2001] provides a framework of a Web-based PPGIS system that provides the levels of services based on the information content and interactivity (see Figure 2-4). The level of services in a PPGIS ranges from the lowest level at the lower-left corner to the highest level at the higher-right corner. The lower level of service only deals with information distribution; whereas the highest level of service offers the public a much more active role in building scenarios and suggesting alternatives.

The details of different levels of services are discussed below:

- **Web browser:** The spatial information is only provided in textual format.
- **Static maps:** Spatial information is processed on the desktop GIS software and is stored as static image files on the server. Static maps were adopted in the early years and are still used by many websites.
- **Discussion forums:** The discussion forums provide the interactive communication.

- **Interactive maps:** Interactive maps provide the access to the spatial information stored in the database on the server which allows users to perform interactive GIS functionalities

- **Building scenarios**: This is the highest level of Web-based PPGIS which simulates the real planning scenarios. The public can access both the spatial data and non-spatial data. Also, the public can mark up a discussion thread on the map, and share the opinions with each other in order to build up a consensus on an interested planning problem.

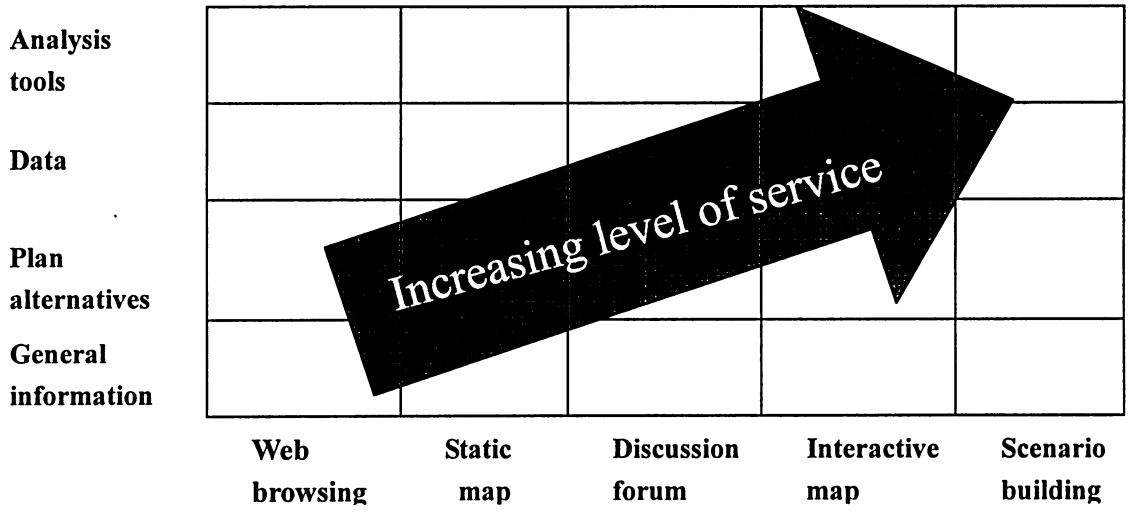


Figure 2-4 Framework for Web-based PPGIS (after Peng, 2001)

Web-based PPGIS breaks down geo-processing into server-side and client-side tasks. Two strategies sometimes are combined into a hybrid strategy, which are commonly used to design the Web-based GIS [Miller, 2004].

- **Server-side (also called thin client) strategy:** This strategy expects that everything is done on server side. The server does the selection, the rendering and the display

element generation and sends rendered maps to the client. In this model the client is typically a standard browser.

- **Client-side (also called thick client) strategy:** This strategy expects that everything is done on client side. This requires the client to provide more or less GIS functionality. And it gives the user full access to the original data.

- **Hybrid (also called balanced client) strategy:** In this strategy, model selection and display element generation are done on server side while rendering and display are done on client side. This allows the client side to perform some data manipulation and analysis locally on their own machines. Either a browser plug-in or an applet needs to be installed on the client side.

2.2 Web-based SDSS

2.2.1 Framework of Web-based SDSS

The planning process is a decision-making process. Since more than 80% of planning information are geographically based, the planning process mostly is considered as a spatial decision making process. One way to integrate all the actors, such as the public, the decision-maker and the planner into the planning process is the use of SDSS. SDSS is an interactive, computer-based system designed to support a user or a group of users in achieving a higher-level effectiveness of decision making while solving a semi-structured or ill-structured spatial decision problem [keenan, 2003].

Decision making process can be structured into three major phases [Simon, 1960]. GIS provides an important source of tools and techniques in all three phases to make use of spatial data.

- **Intelligence:** This phase involves searching or scanning the environment for conditions calling for decisions.

- **Design:** This phase involves inventing, developing and analyzing a set of possible decision alternatives for the problem identified in the intelligence phase.

- **Choice:** This involves selecting a particular decision alternative from those available.

Armstrong and Densham [1990] suggest that a SDSS needs to provide a framework for module integration of Database Management System (DBMS), ModelBase Management System (MBMS), display and report generator and possibly intelligent user interface. The architecture of a SDSS is shown in Figure 2-5.

- **DBMS:** DBMS of a SDSS must be able to store and manipulate locational, topographical and thematic data types to support cartographic displays, spatial queries and analytical models. Spatial data identify the coordinates at locations, topological data represent geographic objects, and thematic data provide the attributes of topographical objects. Also DBMS of a SDSS must permits the user to construct and exploit complex spatial relations between all three types of data at a variety of scales, degrees of resolution and levels of aggregation.

- **MBMS:** MBMS is another core component that transforms data from DBMS into useful information, sends the results to the display for the user to view or map, and

reports for tabular output. MBMS stores elements of models that solve a step in an algorithm. MBMS can facilitate the modification of existing elements and implementations of new algorithms.

- **Display and report generators:** Display and report generators provide capabilities to better depict the results derived from models in SDSS.

- **User interface:** The user interface is the environment in which decision makers interact with the SDSS. For the most non-expert people, the interface is mostly the whole SDSS system. The interface needs to provide two spaces: objective space and map space. Objective space depicts parameters and solutions of an analytical model, while map space represents the study area and output of the model. These two spaces are linked internally. A change in one space will be reflected in the other space.

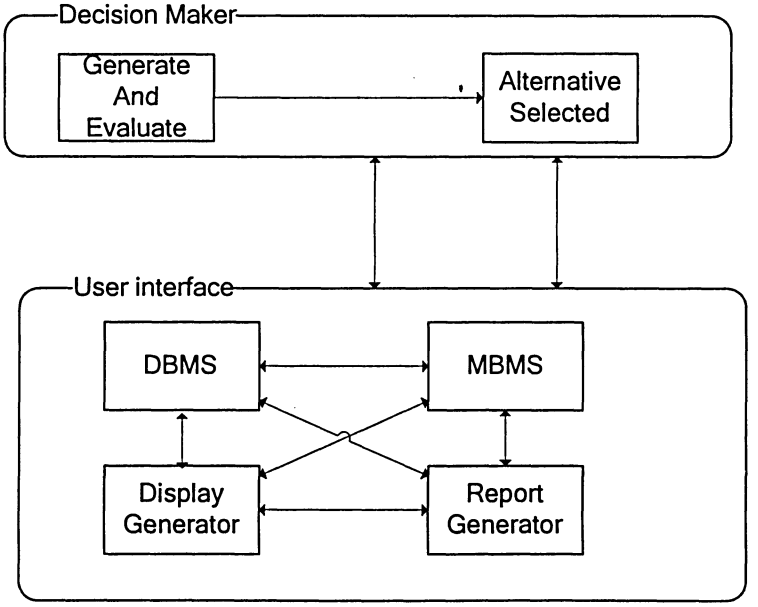


Figure 2-5 SDSS Architecture (Source: Rinner 2003)

Six characters are making SDSS different from other software system [Geol, 1999]:

- It is designed to solve semi-structured or ill-structured problems.
- It provides an interface, which is powerful and easy to use.
- It enables the users to combine models and data in a flexible manner.
- It helps the users to explore the solution space and generate a series of feasible alternatives.
- It supports a variety of decision-making styles.
- It provides an interactive and recursive problem solving environment.

Web-based SDSS extends traditional SDSS characteristics and distributes the information, the feasible solutions and the final decision through the Internet. Web-based GIS is a core component of Web-based SDSS using a geographic data query, display and analysis process. Based on the three strategies of Web-based GIS, Web-based SDSS falls into a continuous scale with regards to the program logic [Rinner, 2003]:

- Server-side Web-based SDSS
- Hybrid Web-based SDSS (mixed client- side and server-side)
- Client-side Web-based SDSS

The common motivation and aim of Web-based SDSS is to support group decision making. Web-based SDSS makes wider public access to data and tools for spatial planning and decision-making, which moves the public involvement in decision making further up the public

participation ladder as described in Figure 2-2. Due to the lack of GIS knowledge and potential limited performance of the client computer, the Web-based SDSS for the public participation mostly designed as a hybrid Web-based SDSS which moves more workload to the server side. This "heavy" server, "light" client Web-based SDSS framework fully utilizes the high-performance server platform and at the same time provides the client more interactive functions. The typical components of a hybrid Web-based SDSS are shown in Figure 2-6.

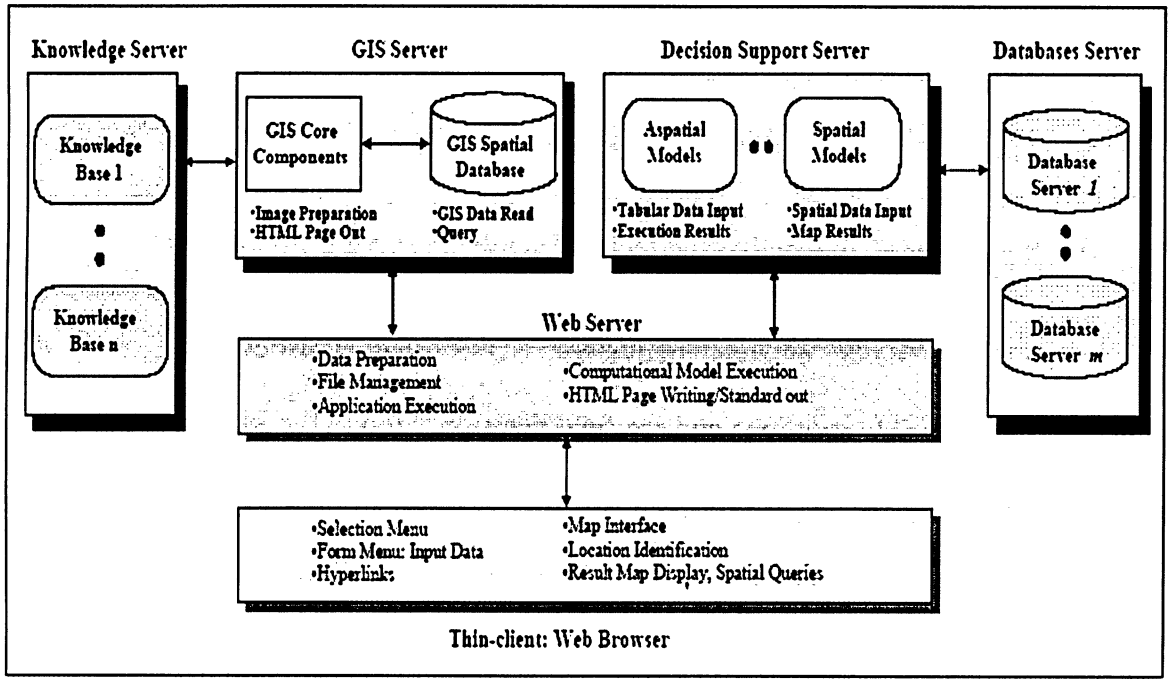


Figure 2-6 Components of Hybrid Web-based SDSS (Source: Sugumaran, 2005)

Web-based SDSS has the potential to increase the use and accessibility of spatial data, as well as the accuracy and efficiency of decision-making, thereby improving the effectiveness of planning process.

2.2.2 Integrated Technologies in Web-based SDSS

Planning and decision-making process relies on effective usage of the both spatial and non-spatial information. The public needs an effective strategy to allow them access to and share of the information related to the planning scenario. Also the public needs an effective tool to help them better understand the complex planning process and the specialized knowledge which is hard for them. In order to bring more potential public to participate in planning process, a Web-based SDSS system should integrate GIS and multimedia interactivity with the Internet.

2.2.3 Spatial Database Management Systems (SDBMS)

GIS plays an important role to help minimize conflicts and arrive at a decision that is acceptable to the majority of stakeholders through consensus-building approaches based on awareness of the spatial implications of a decision problem [Roeder, 2002]. GIS provides a convenient mechanism for the analysis and visualization of spatial data. The demand of sharing large amount of spatial data over the Web motivates the development of SDBMS. A SDBMS is a software module that can work with an underlying DBMS, supports spatial data models, spatial data types and query languages, supports spatial indexing, efficient algorithms for processing spatial operations, and domain specific rules for query optimization. The SDBMS focuses on more efficient storage, retrieval, and analysis of spatial data. SDBMS works with a spatial application at the front end and a DBMS at the back end. Three layers of the SDBMS are shown in Figure 2-7.

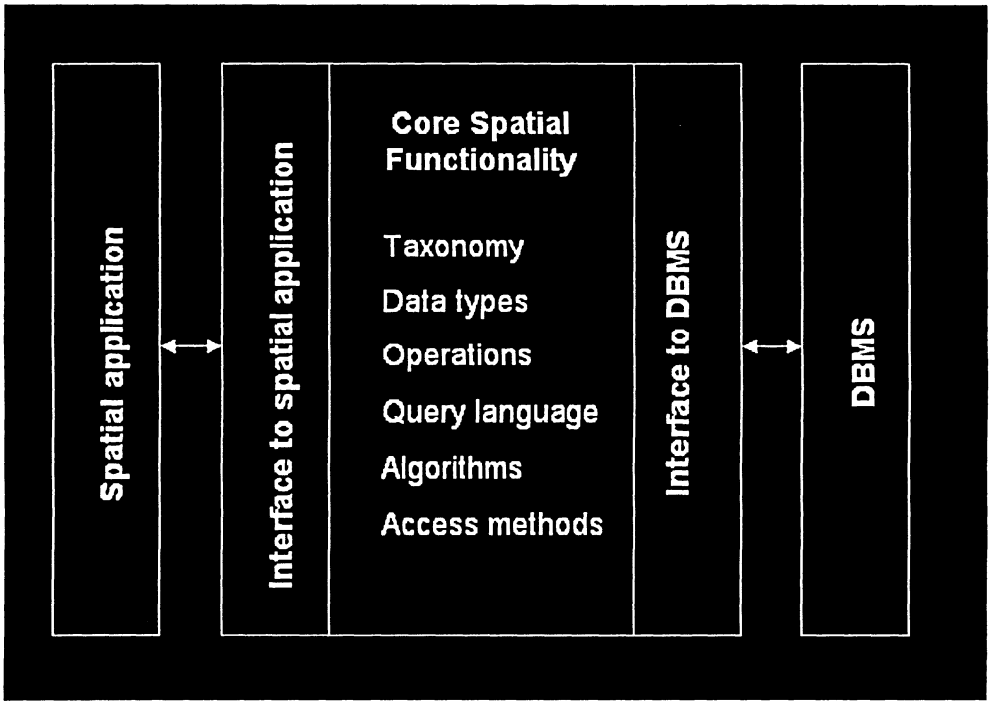


Figure 2-7 Three Layers of SDBMS (Source: Shekhar, 2003)

2.3 Open Source GIS

GIS are moving from isolated, standalone, monolithic, proprietary systems working in client-server architecture to smaller Web-based applications and components offering specific geo-processing functionality and transparently exchanging data among them [Anderson, 2003]. The Internet creates the perfect setting for the distribution of spatial data and services in terms of the network and platform independence. However, interoperability, which is the capability of autonomous systems to exchange data and to handle processing requests by means of a common understanding of data and request [Shaig, 2001], becomes a main barrier. Compliance with Open Specifications (OS) will enable the interoperability. The high costs, complexity and special requirements of the Web-based SDSS prevent many organizations from deploying their data and geo-processing capabilities over the Web. The alternative solution is using OSS.

Combined OS and OSS will make the Web-based SDSS solutions low-cost, simple and flexible to implement, and also have the potential of interoperating with other systems and applications.

2.3.1 OpenGIS Specification

Web-based SDSS often needs the users' request information from multiple Web servers and use them to perform spatial operations. Open Geospatial Consortium, Inc. (OGC) is an international consortium of companies, government agencies and universities working together to develop publicly available interface and encoding specifications that enable interoperability among and between diverse geospatial data stores, services and applications. OGC facilitates their reaching agreements on OpenGIS Specifications for interfaces, schemas and architectures. Systems implementing OpenGIS standards can interoperate with each other, which provides essential infrastructure for thoroughly integrating geospatial resources over the Web. Simple Features Specifications for SQL (SFSSQL), Web Map Server (WMS) and Web Feature Service (WFS) are three important specifications.

2.3.1.1 Simple Feature Specifications for SQL

The SFSSQL defines extensions to a SQL-based relational database to allow for GIS objects and operations. Four important areas have been defined in this specification in order to allow the interoperability [Karlsson, 2004]. Those four areas are data types, operations, the ability to input and output data, and spatial indexes.

- **Data types**: There needs to be data types to store the GIS information. SQL has been extended with a set of Geometry Types. Geometry is the root type and has subtypes for Point, Curve, Surface and GeometryCollection (Figure 2-8). Also in

order to model Spatial Reference System information, each geometric object in the SQL with Geometry Types implementation is associated with a Spatial Reference System.

- **Operations**: There must be additional operators to support the management of spatial objects. Some operations deal with the spatial relationships among spatial objects, such as proximity, adjacency and containment. Some operations deal with spatial operations such as area, length, intersection, union and buffering. Some operations perform conversion to and from text and binary formats.

- **The ability to input and output GIS data:** To make systems interoperable, OGC has specified two formats for external representation of spatial data, WKB (Well Known Binary) and WKT (Well Known Text). This allows data to be exported and imported in binary and text formats. Functions that convert between WKB and WKT formats and all the spatial data types are also provided.

- **Indexing of spatial data:** To use the different operators, spatial data may be indexed just like other data in SQL in order to speed up the query. R-tree index is the mostly used spatial indexing method which organizes the Minimum Bounding Rectangle (MBR) of spatial objects in a tree structure which is then used by the different spatial functions.

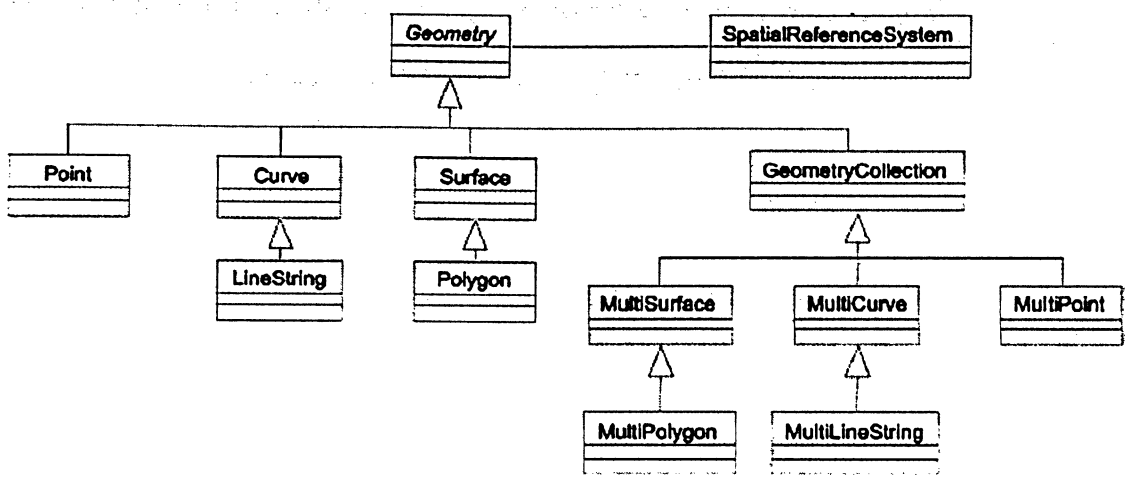


Figure 2-8 SQL Geometry Type hierarchy [OGC, 2005]

Almost all SQL databases now have the spatial extension which follows the SFSSQL, such as Oracle Spatial, IBM DB2 Spatial Extender, Informix Spatial DataBlade, MS SQL Server (with ESRI SDE), PostGIS for PostgreSQL and MySQL Spatial Extension.

2.3.1.2 Web Map Server

The WMS specification specifies "the behavior of a service that produces geo-referenced maps. This standard specifies operations to retrieve a description of the maps offered by a service instance, to retrieve a map, and query a server about features displayed on a map [OGC, 2005]. The specification defines a map to be a portrayal of geographic information as a digital image file suitable for displaying on a computer screen. The WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF, JPEG, vector-based graphical elements in Scalable Vector Graphics (SVG), or Web Computer Graphics Metafile (WebCGM) format. Three operations have been defined in WMS specification: one returns service-level metadata (GetCapabilities); another return a map whose geographic and dimensional parameters are well defined (GetMap); and an optional third operations returns

information about particular features shown on a map (GetFeatureInfo). The implementation of WMS on the Internet can use both the GET method and POST method.

2.3.1.3 Web Feature Service

The WFS specification defines interfaces for describing data manipulation operations of geographic features. Data manipulation operations include the ability to create, delete, update a feature instance and get or query features based on spatial and non-spatial constraints. WFS interface allows requests for geographical features across the Web being more interoperable. It uses the XML-based GML (Geographic Make-up Language) for data exchange.

The WFS provides great transparency and openness in mapping applications. Instead of merely being able to look at a picture of the map, the user can determine how to visualize the raw geographic and associated data.

2.3.2 Open Source Software in GIS

OSS is freely available and the source code is with less or no licensing restrictions on distribution. The development of OSS has received a substantial attention recently and its use has becoming increasingly prevalent in many areas of information technology. The successful examples are for instances the operating system Linux, the Web server software Apache, Web browser Firefox, and database management MySQL. Comparing with the commercial software (often referred to as close source software), the OSS has the following benefits:

- **Cost-effectiveness:** With the confliction of the increasing budget deficits and increasing demand for public services, the OSS is often regarded as a low budget

solution for the challenges in the reform of the local government administrations, especially in the developing countries and non-profit organizations.

- **End-user driven development priority:** The entire community of OSS consists of various types of end users who know exactly what they need. Furthermore, since the resources are available for everyone, the users can use those resources to customize the applications based on their specific requirements.

- **Interoperability by adopting of open specifications:** OSS community has provided many tools enabling the setup of multi-component solutions following open standards. Also, a relatively large group of software developers can build in the newest standards and insights in the software.

- **Active users' community:** An engaged community of OSS users can provide superior feedback, documentation and testing within the community. Also the community can quickly discover, isolate and fix the problem and distribute the solution free.

- **Availability of more OSS tools**: The OSS users have tools available not only from the software developers, but also from the whole OSS community.

- **More security:** With the large number of users examining code and the rapid distribution of the patches, the OSS is proven to be more secure than other commercial software.

OSS also has some drawbacks. Since all the OSS components are developed by different groups, the version confliction could be a big issue. When new version of one

software product is introduced, some other software products may not support the new functionalities of the new version, which may results in reinstalling all other software in order to make the whole system working smoothly.

Although OSS has drawbacks, its advantages make it popularly used. OSS is not a new topic. However it has received more attention recently since the growing number of interesting possibilities in the field of GIS. The technical GIS community adopted open source technology relatively early, and now mainstream GIS and broader IT industries have come on board as open source products have matured. Organizations are increasingly realizing the value of incorporating open source software as a core part of their business [MapServer, 2004].

2.3.3 Two Tribes of Open Software GIS

The Open Software GIS (OS GIS) spaces include products that fill every level of the OpenGIS spatial data infrastructure stack. OS GIS software can be categorized into two largely independent development tribes, the 'C' tribe and the 'Java' tribe.

- **The 'C' Tribe** (Figure 2-9): The core of the 'C' projects are the shared libraries which are reused across the application space and form the base infrastructure for common capabilities, such as format support (OGR/GDAL,OSSIM, TrraLib), coordination re-projection (Proj4), and the Open GIS Simple Feature for SQL (PostGIS). The applications fall into two categories: server application (MapServer) and client application (OpenEV), Internet map server (MapServer) and GIS viewer (OpenEV, QGIS, Thuban).

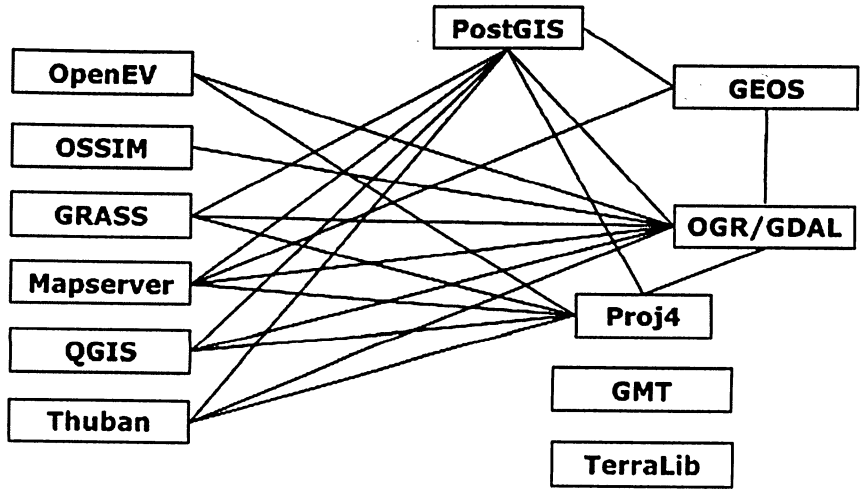


Figure 2-9 'C' Tribes of OSGIS Software [Ramsey, 2005]

- **The 'Java' Tribe** (Figure 2-10)**:** This tribe is not as mature as the 'C' tribe which has long history. GeoAPI, WKB4J, JTS Topology Suites and GeoTools are shared libraries. OpenMap, GeoServer, JUMP, gvSIG, uDig and DeGree are applications or projects which are developed based on the shared libraries in this tribe.

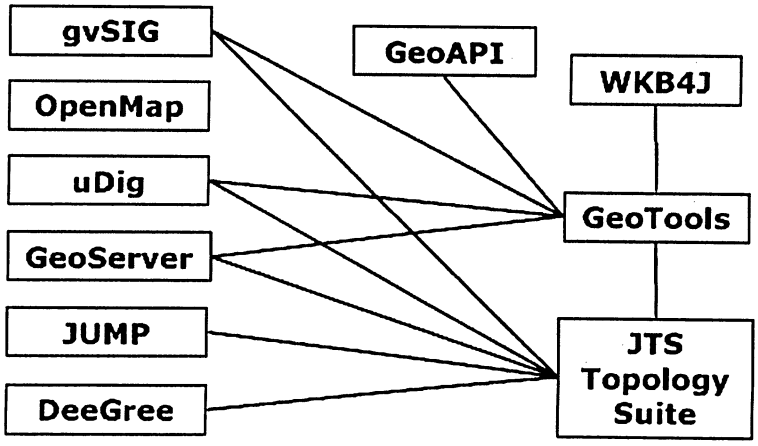


Figure 2-10 'Java' Tribe of OSGIS Software [Ramsey, 2005]

2.4 Summary

This chapter has contributed in reviewing the relevant technologies to design and develop a WebPPGIS. WebPPGIS is considered as a complicated Web-based SDSS which aims to encourage the public participation and guide the public through the planning process.

In this chapter, public-participated planning process is reviewed, including the disadvantage of the traditional planning process, the importance and necessaries of public participation in planning process, and the two dimensions of public participation which means different levels and different stages of public participation.

Then the framework and integrated technologies of Web-based SDSS is reviewed. The discussion includes the different levels of services in the framework for Web-based PPGIS and the components in the framework of Web-based SDSS.

Finally, this chapter reviews the OS GIS technologies and emphasizes the advantage of OS GIS. The review focuses on the OpenGIS specification and OSS in GIS.

WebPPGIS aims to fulfill the requirement of the planning process and overcome the disadvantages of the traditional way of public participation. In the following chapters, a WebPPGIS prototype is designed and developed by inte grating Web, GIS and other ICT technologies in order to provide a more flexible way to facilitate public participation and to improve the quality of decision making. The WebPPGIS prototype is developed using OSS and OS in order to make the system low-cost, simple and flexible. Also, the WebPPGIS prototype focuses on building a channel for the public to communicate with each other in order to simulate the real planning scenarios.

CHAPTER 3 METHODOLOGY AND DESIGN CONSIDERATION

In this chapter, some existing WebPPGIS systems are evaluated first. Then the methodology and design consideration of the WebPPGIS prototype are discussed. The requirements of the WebPPGIS system are summarized at last.

3.1 Evaluation of Existing WebPPGIS Systems

In order to better summarize the requirements of the WebPPGIS, several available WebPPGIS applications and prototypes are ev aluated. The evaluation focuses on the GIS functionality, the communication efficiency, and the friendliness of their interfaces.

3.1.1 Virtual Slaithwaite

Virtual Slaithwaite (Figure 3-1) is developed by Leeds University's School of Geography as map-based planning support in order to identify areas for the new developments. Users can view the map, perform zoom and pan operations for navigation, perform spatial queries and pick up a location on the map and make comments on that location. The comments are presented as dots on the map which the users need to click on the individual dot to view the text comment.

As a part of Virtual Decision Making Environment (VDME), this prototype of Virtual Slaithwaite, considered as a map-based annotation system, has partially fulfilled the project goal. Two drawbacks are more obvious. First, the comments are not tightly linked the spatial context which makes the display not explicitly. Second, the comments are not well organized to

simulate the real public meeting scenarios, rendering a "one-way" communication. In the real public meeting, discussions are held under a hierarchical structure, some people may bring a new topic and other people may discuss under the existing topics.

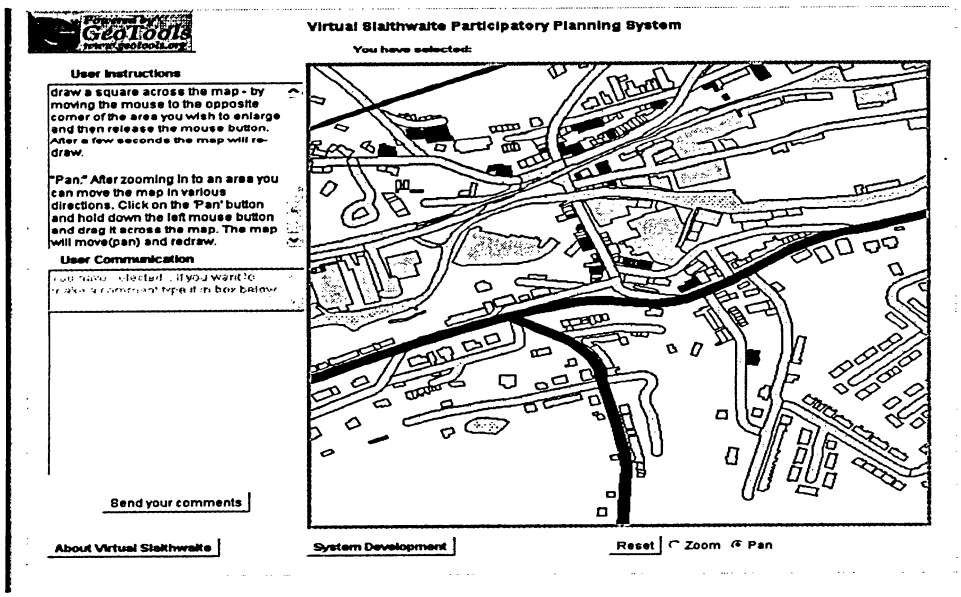


Figure 3-1 Virtual Slaithwaite (http://www.ccg.leeds.ac.uk/slaitwaite/)

3.1.2 Vallejo Economic Development Information System (VEDIS)

The Vallejo Economic Development Information System (VEDIS) (Figure 3-2) used in Vallejo and Mare Island provides a government-business interactive model. Prospective businesses visiting the site can search the City's database to locate available commercial sites; access business listing information; analyze demographic, economic, and traffic count data for the surrounding areas; and generate custom reports. Authorized persons in the real estate agencies working with the City have the ability to add new property to the database.

The planning portal is introduced by the UK Government. The key idea is to provide the access to all planning application forms, development plans and a facility to track the planning applications and appeals among many services.

VEDIS has provided an example of how to provide the information along with the spatial context. The drawback of VEDIS is that the system does not provide enough tools to let the public make a comment and communicate with each other.

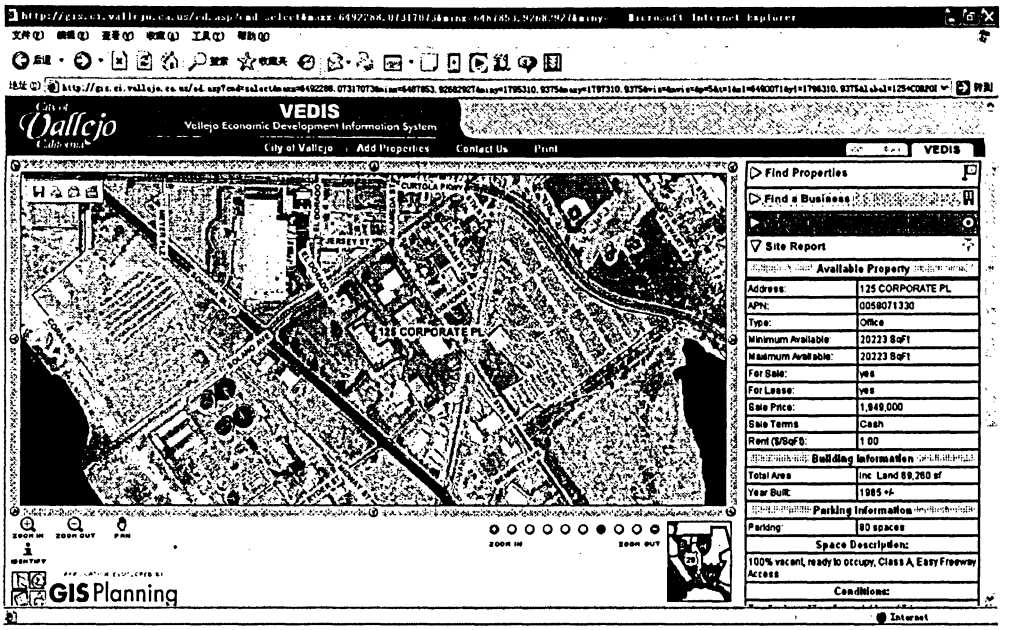


Figure 3-2 Vallejo Economic Development Information System (VEDIS)

(http://gis.ci.vallejo.ca.us/ed/asp)

3.1.3 Argumentation Map

The argumentation map (Figure 3-3) is a model which connects the plan elements with typed discussion contributions [Rinner, 2003]. Integrated the discussion forum with the GIS component, this model effectively provides mechanisms not only by showing the contents and attributes of discussion contributions, but also by showing the distribution of discussion contributions on the map. The system focuses on facilitating the planning process by using Computer-Supported Decision Making (CSDM). This prototype system supports access to map locations to which arguments refer, attachment of a geographical reference to each new argument, access to discussion messages through map symbols that signify geographical

objects, and insertion of a new message for a map object or region. This system is good in documenting and displaying the evolution of issues. However, its map component cannot communicate the spatial context effectively [Tang, 2005]. Also, too many browser windows need to be open in order to view one comment; therefore the interface would be hard for the public to handle.

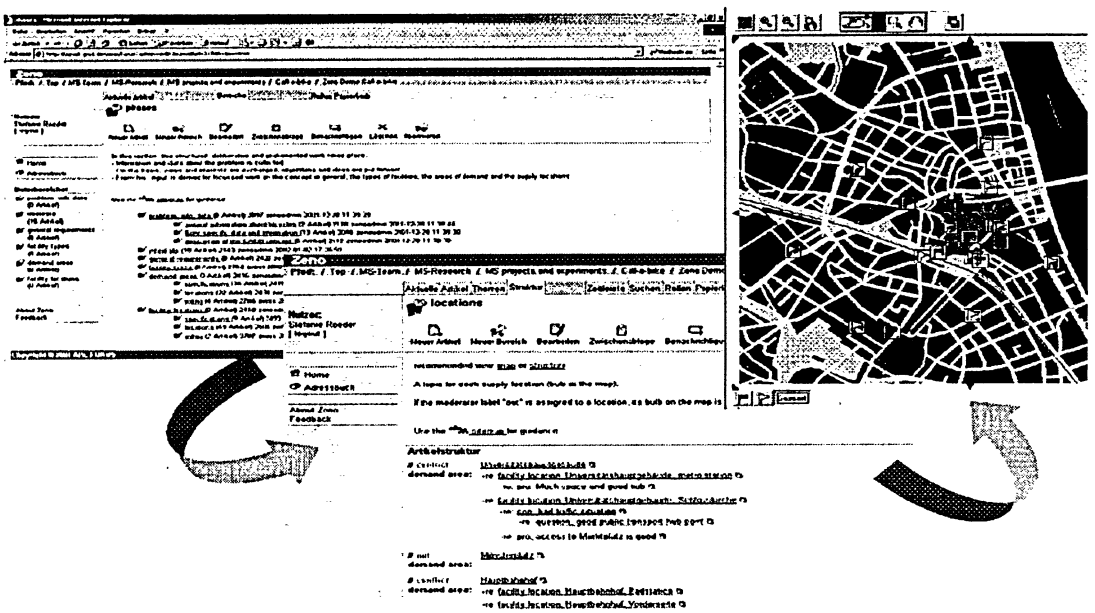


Figure 3-3 Argument Map

(http://zeno8.gmd.de/zeno/forum?action=editJournal&id=2066&view=front)

3.2 Methodology

The design and development of the WebPPGIS is based on the user-centered design methodology (Figure 3-4), which splits the overall process into four parts: requirements analysis, data preparation, prototyping design, and evaluation. In the future, after the evaluation and modification, a real practical system can be implemented and deployed.

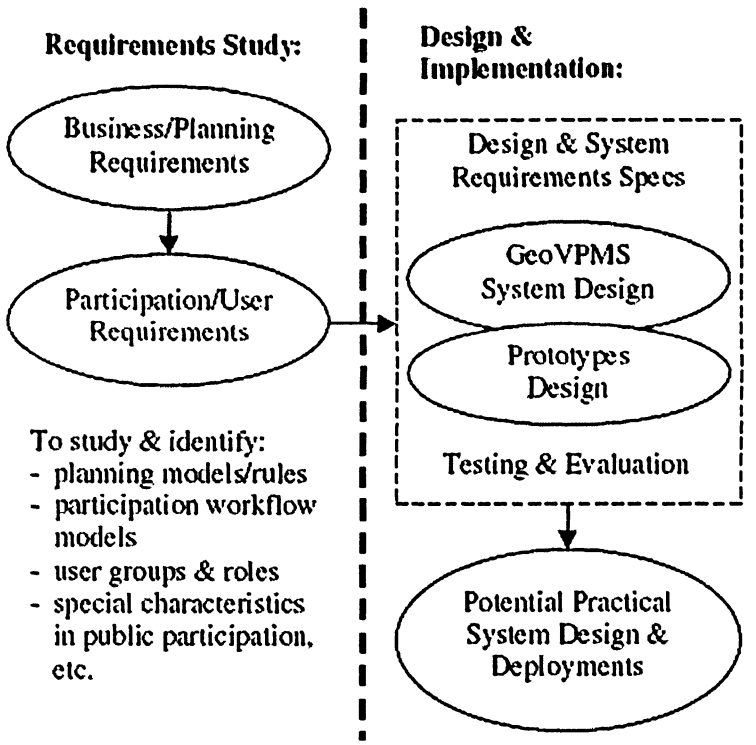


Figure 3-4 User-centered System Design Methodology [Li and Ma, 2006]

The first step is requirements analysis. The requirements are summarized by evaluating the existing WebPPGIS systems and the requirement of planning process. In this step, the actors of the system and their roles are defined. Based on the roles of different actors, the basic functions are defined. After the requirements of the system have been defined, evaluation criteria need to be established for the later evaluation.

The next part of the design focuses on data preparation. In the real planning scenarios, data always comes from different resources and different formats. This stage involves checking out the availability of required data and converting them to the format which the system can recognize, if necessary. Then the data need to be organized in order to outline how the data will be displayed in the future system. The organization includes the order of the layers, the geo-

reference system used, and the symbol and font used. The database design is implemented in this stage too.

Once data preparation is done, the next stage is the system prototyping. This stage begins with building the architecture of the prototype. The architecture building includes choosing the software components, Web pages organization, and database deployment. Web server, Map server, database and the programming platform are chosen and installed in this stage. Then layouts of different pages are determined, which includes the welcome pages, the page which integrated the interactive map with discussion forum. Also the help page need to be constructed too. The design of this stage focuses on the friendly HCI (Human Computer Interface) and makes the operation easily to follow. At last, based on the database schema design, database needs to be deployed.

The last stage in this WebPPGIS Prototype is to test if the system meets the evaluation criteria. Before turning the prototype into a practical system, the evaluation needs to be done. Ideally, the evaluation will involve different actors from different levels and get the feedback. But in our prototype, the evaluation has only been done among a small group to test against the evaluation criteria.

3.3 Use Case Diagrams

3.3.1 Unified Modeling Language

The Unified Modeling Language (UML) is a standard language for specifying, visualizing, constructing, and documenting the artifacts of software system, as well as for business modeling and other non-software systems. The UML represents a collection of best

engineering practices that have proven successful in the modeling of large and complex systems. The municipal planning process is an extremely complex decision-making process affected by a number of distinct factors. The UML is an effective technique to manage the complexity of systems.

Use case modeling is a usage of UML. The use case modeling is a view of system that emphasizes the behavior as it appears to outside users. In many design process, the use case diagram is the first step to specify the functional requirements of systems. A use case diagram includes core elements (actor, use case, system boundary) (Table 3-1) and the relationship (association, generalization, include, extend) (Table 3-2).

Table 3-1 Core Elements of Use Case Modeling

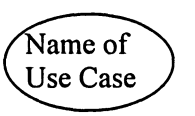
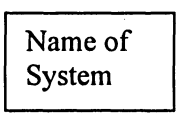
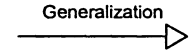
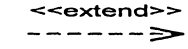
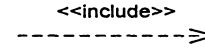
Construct	Description	Syntax
Use case	A sequence of actions, including variants that a system (or other entity) can perform to accomplish a specific goal with interacting with actors of the system.	
Actor	A coherent set of roles that users of use cases can play when interacting with these use cases.	 Name of actor
System boundary	Represents the boundary between the physical system and the actors who interact with the physical system.	

Table 3-2 Core Relationships of Use Case Modeling

Construct	Description	Syntax
Association	Associations are draw between actors and use cases to show that an actor carries out a use case.	
Generalization	A taxonomic relationship between a more general use case and a more specific use case.	
Extend	A relationship from an *extension* use case to a *base* use case, specifying how the behavior for the extension use case can be inserted into the behavior defined for the base use case.	
Include	A relationship from a *base* use case to an *inclusion* use case, specifying how the behavior for the inclusion use case is inserted into the behavior defined for the base use case.	

3.3.2 Use Case Design

There have many different groups of actors involved in the complex municipal planning process and they play different roles in the decision making process. The actors are categorized into three groups: public participants, experts/consultants and mediators. The public participants are the major user of the WebPPGIS. The experts/consultants act as guides in the system to provide assistance when needed. Mediators are special authorized group which can

access and analyze the original information and modify the system. The design of the WebPPGIS prototype focuses more on meeting the requirements of the public participants. Figure 3-5 is a use case diagram which summarizes the different actors and different roles they play in the municipal planning process.

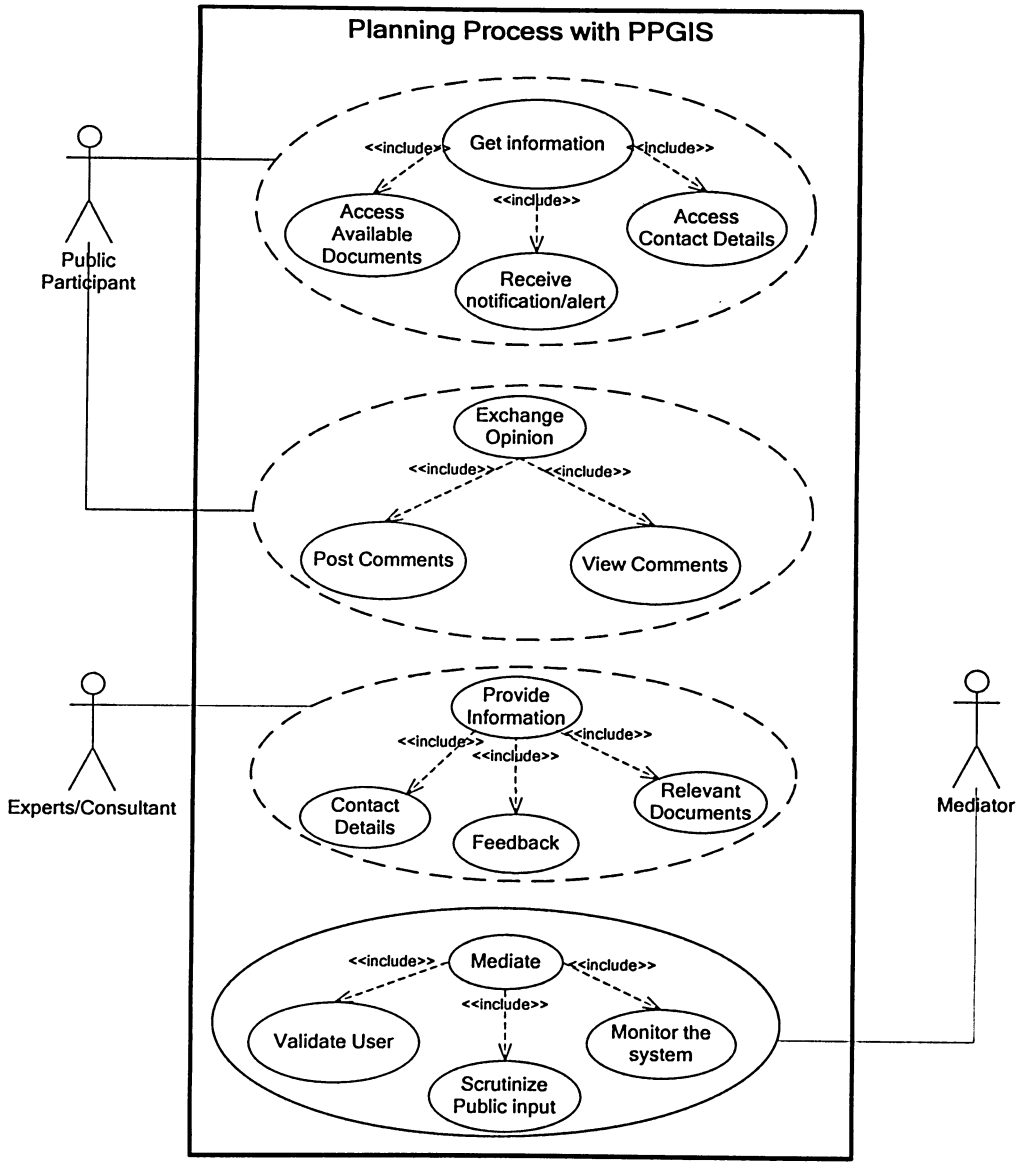


Figure 3-5 A Use Case Model for Planning Process with PPGIS

- **Getting information:** The information is the core component in any planning processing system. It is essentially important for the public participation. The information is coming from all aspects of the planning processing procedure. Accessing the contact detail means the public have the way to know the contact information of the local authorities who are in charge of the plan. The contact information includes name, phone number, email address or other available way that the public can get in touch with. The contact information can make the public trust the government more. The available documents will help the public understand the scenario of the plan, such as why the plan is necessary, what is going to affect if the plan is implemented, or how to get involved. Also the tutorial materials are the instruction to help the public understand the complex planning regulations and obtain the relevant knowledge. The integration of multimedia, text and GIS technologies provide the clearer explanation. The public also should get the notification or alert before the planning process start and during the planning process, since the public can participate only when they know what is happening. When the public are getting sufficient information, knowledge and having more confidence, they are available to participate into the planning process.

- **Exchanging opinions:** Exchanging opinions includes giving comments and viewing comments. The planning processing needs the collaboration of the public and all other actors. An effective platform on which the public can exchange their opinions is very important. In order to make the spatial information more comprehensive to the non-professional public, the effective platform should facilitate with visualization and simulation functions. In order to encourage a wider variety of

people get involved, the effective platform should provide both one-to-many and one-to-one communication [Chen, 2006]. For example, an online discussion forum is a one-to-many communication way mostly used. Through the online discussion forum, the public can access the system to make their comments, view other's comments and reply to their interested comments at any time. The whole process is more transparent and more open which makes the public more comfortable to share their opinions. Sometimes the public feel comfortable to leave the comments only to local authorities instead of posting the comments in an open forum, and then the one-to-one communication way is also important for public participation. The common way for one-to-one communication could be emails between the public and the local authorities, the "Frequent Asked Questions (FAQ)" function, and so on. In both of the above strategies, the GIS always play a facilitating role.

- **Providing information:** In order to let the public participate in the planning process more efficiently, the relevant information must be provided by the planner and the local authorities clearly and efficiently. The relevant documents are the materials to explain the problems, demonstrate the alternatives, provide the tutorials, and show the bylaws. Both spatial and non-spatial information should be presented clearly for the public to understand. The complex procedure of the planning process should be demonstrated clearly for the public to follow. The authorities also should provide the detailed contact information. At the beginning of the planning process, someone or some agencies need to be assigned to be in charge of the whole process. The detail of contact information of them should be easily accessed by the public. The feedback is the most important information for the public participation. The local

authorities should deal with the comments the public provided and ensure the feedback is sent. Without the effective feedback, the public may lose their interest in participation because they may feel that their comments are not respected. The public will therefore hesitate to take more action if they feel they have little influence.

- **Mediating.** Mediation is also very important factor in the planning process to make sure everything is on the right track. The mediators are often the representatives from all actors groups of the planning process. They are a special authorized group which can access and analyze the original information and modify the system. They should be neutral and professional which means they do not represent any special group, and they should have broad knowledge of all aspects of the planning process procedure. The functions they provide include validate the users, scrutinize the public input, and monitor the system.

CHAPTER 4 WEBPPGIS PROTOTYPE DESIGN AND DEVELOPMENT

A WebPPGIS prototype is designed and implemented following the methodology discussed in Chapter 3. In this chapter, firstly the requirements of WebPPGIS are summarized based on the previous discussion. Secondly the data and database design are presented. Then the software components and the framework design are demonstrated in detail. Detail in prototype implementation is discussed also. At last, the evaluation is discussed.

4.1 WebPPGIS Requirements Summary

The role of WebPPGIS is more and more important in planning process. However, the nature of WebPPGIS makes it a complex system containing multidisciplinary knowledge such as psychology, organizational science, sociology, political science, etc. Even through the Internet, GIS and the geodatabase provide the possibility for the WebPPGIS, there still has no such a system that can fully support the spatial decision making system in the planning process. A successful WebPPGIS system should provide information, tools and channels to encourage the public participation. Peng [2001] indicates a WebPPGIS should provide the following four functions: exploration, evaluation, scenario building, and forum. Weiner [2003] indicates WebPPGIS should not only confront GIS and society concerns, but also design and adapt geographic information systems that specially address the need of participant communities.

A successful WebPPGIS should be "public centered" and "issue driven" [Peng, 2001], which implies two aspects. One is that WebPPGIS needs to focus on the public from the early

stage of the planning process; the other is that WebPPGIS needs to focus on some specific issues instead of providing a heal-all solution. Since the public most likely have limited knowledge on GIS, Internet and Planning Process, some issues are important for an successful WebPPGIS system, such as how to make the complicated WebPPGIS and planning process easy to understand, how to bring the public's awareness, and how to facilitate the different opinions. Meanwhile, a WebPPGIS system need to be designed and developed to solve one specific issue which will make the system more flexible and easily to understand.

Based on the research on the current WebPPGIS systems, the following considerations should be taken into account when designing and developing our WebPPGIS system :

- **HCI:** The complexity of traditional GIS products requires users to have or acquire considerable technical knowledge to operate them. This presents major obstacles before the non-expert users. In this situation, HCI aims to increase the usability and effectiveness of the interaction between humans and computer systems, is vital to the success of WebPPGIS [Haklay, 2003]. The successful systems should be developed such that the setup can be done based on different levels of skills depending on the user's knowledge [Kingston, 2000]. The successful WebPPGIS system is designed to make user carry out their tasks safely, effectively and enjoyably.

- **Understandable information:** The WebPPGIS should clearly present the spatially-related planning information. Firstly, the certain type of map may be difficult for lay person to understand, such as Watershed. Lack of clear explanation may handicap the public participation. Secondly, the different alternatives and their consequences

should be clearly presented so that the public can access and make decision. The last but not the least, the complexity of the analysis tools would hinder the public to using WebPPGIS. Simplified tools, standardized HCI and user-friendly output should be helpful for the public to understand GIS principles.

- **Communication mechanism:** During the planning process, the communication is important either between the planner and the public or among the public. The system should provide an effective communication mechanism for the public to facilitate the information exchange. The public can express their preferences, view others' opinions and vote for the preferred alternative through e-mails, online forum, online chatting room, etc.

- **The awareness:** In order to encourage more public participation into planning process, WebPPGIS should raise the public awareness. To raise the public awareness, WebPPGIS should provide appropriate channels through which messages (problem, comments, alternative, feedback, etc.) can be delivered during the whole planning process procedure. There are three ways of raising public awareness: interpersonal, group-based and mass media. The first approach provides a one-to-one communication channel. For example, the feedback to the comments and answers to the public questions can be sent through email directly to the individuals. Using group-based approach, the messages are delivered to a specified group or an interested group. For example, the interested public people can add their email address into mailing list, and the message can be sent through the mailing list when they are available. Mass media is a way to bring the public's awareness. Newspapers, Web notice aboard, the TV are all good mass media. The more

awareness the WebPPGIS system has brought to the public, the more opportunities the public can get to know the planning activities around their community and the more opportunity the public can choose to get involve into the planning process.

- **Mediation:** The complexity of WebPPGIS requires mediators to take the responsibility to facilitate and maintain the process. The spatial planning process is often complex and requires the cooperation of experts from different fields, stakeholders with diverging interests, and a large number of public people. The mediator can ensure the process is not corrupted by hidden agendas or results biased toward the desires of a small group of influential participants. He or she can also immediately react to any disturbances, try to clarify misunderstandings or to adapt the procedure in consensus.

- **Low cost:** WebPPGIS requires low cost system. The development of WebPPGIS is expensive compared with more traditional approaches to public consultation based on meeting and surveys. Tight budget often slows the local government and non-profit organization to widely use the WebPPGIS. The ideal WebPPGIS should be a low cost system.

- **Integration of GIS and other ICT** (Information Communication Technology)**:** Although GIS is a useful tool to visualize and analyze the spatial data; GIS alone can not solve all the problems in a planning process. The other ICT tools such as video, audio, flash, and PowerPoint are also needed in WebPPGIS for supporting decision making process. Such as the video of the local public meeting may make the public easily understand the planning scenario.

Considering the requirements of the Web-based PPGIS, this prototype should have the following functionalities:

- Basic GIS functions:
  - ✓ Zoom in and out, zoom to selected extends
  - ✓ Pan by clicking into the image
  - ✓ Query information by clicking on an objects in the map
  - ✓ Changeable map size
  - ✓ Switching on and off of the thematic layers
- Public Participation Tools
  - ✓ Providing documents in multimedia
  - ✓ Providing training material in multimedia
  - ✓ Providing the contact detail of the group in charge
  - ✓ Providing the online survey
  - ✓ Providing the online forum
  - ✓ Making text comments and viewing others comments
  - ✓ Making annotations on the map related to the comments

4.2 Software Components of the WebPPGIS Prototype

The software components presented in this section form a multi-components prototype (Figure 4-1). All the software components in use are Open Source Software. They are discussed in the following subsections.

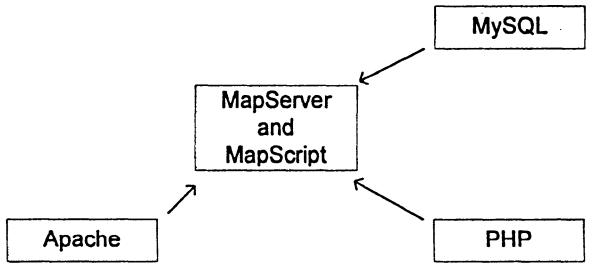


Figure 4-1 Software Component of the Prototype

4.2.1 Apache Web Server

The Apache Web Server is a well known Web Server that is maintained as an Open Source project by the Apache Software Foundation. It has been the most popular Web server on the Internet since 1996 and runs on both UNIX/LINUX and Windows operating systems (http://httpd.apabhe.org).

4.2.2 PHP

PHP (acronym derived from its origin as Personal Home Page tools) is an OSS, server-side, cross-platform, HTML-embedded scripting language (http://www.php.net). PHP structured code can be embedded inside HTML tags. PHP is used on server side to process control and generate the Web pages based on client's requests. PHP is able to connect to several RDBMS such as MySQL which is used in this prototype. PHP has becomes very popular for its dynamic Web development.

4.2.3 MySQL and Spatial Extension

The MySQL database has become a popular open source database because of its consistent fast performance, high reliability and ease of use (http://www.mysql.com). Also PHP and MySQL has become a good combination for creating data-driven sites.

MySQL has had a spatial extension since Version 5.0, which allows the generation, storage, and analysis of geographic features by following the OpenGIS Simple Features Specifications for SQL. MySQL implements a subset of the SQL with Geometry Types environment proposed by OGC. A geometry-valued SQL column is implemented as a column that has a geometry type. The specifications describe a set of SQL geometry types, as well as functions on those types to create and analyze geometry values.

MySQL has data types that correspond to OpenGIS classes discussed in Chapter 2. Table 4-1 lists the geometric types implemented by MySQL.

Table 4-1 Geometric Types Implemented by MySQL

Geometry Type	Representation
POINT	Point (x, y)
LINESTRING	LineString (pt1, pt2...)
POLYGON	Polygon (ls1, ls2)
MULTIPOINT	MultiPoint (pt1, pt2...)
MULTILINESTRING	MultiLineString (ls1, ls2...)
GEOMETRYCOLLECTION	GeometryCollection (g1, g2...)

MySQL provides a set of functions to perform various operations on spatial data. These functions can be grouped into for major categories according to the type of operation they perform:

- **Geometry format conversion functions:** These functions convert geometry value between internal format and either WKT or WKB format.

- **Geometry functions:** Those functions take a geometry value as its argument and return some qualitative or quantitative properties of the geometry.

- **Functions that describe relations between two geometries:** These functions take two geometries entities as input parameters and return a qualitative or quantitative relation between them.

- **Functions that create new geometries from existing ones:** These functions are designed to implement spatial operators such buffer, intersection, union etc. They are not implemented in MySQL in the current version.

4.2.4 UMN MapServer

UMN MapServer (http://mapserver.gis.umn.edu), commonly called just "MapServer", has been designed and developed by the University of Minnesota in cooperation with NASA. MapServer is an Internet map server, a server-side piece of software which renders GIS data sources into cartographic map products on-the-fly. MapServer is a very successful Open Source GIS product which supports more input data sources than most proprietary products, has higher performance, and is simper to install and set up. It is not a fully-featured GIS system, but provides core functionality to support a variety of Web mapping applications. Its most important features include:

- Vector formats supported: ESRI shapefiles, simple embedded features, and ESRI ArcSDE

- Raster formats supported (8-bits only): TIFF/GeoTIFF, GIF, PNG, ERDAS, JPEG and EPPL7
- Quadtree spatial indexing for shapfiles
- Fully customizable, template driven output
- Feature selection by item/value, point, area or other feature
- True Type font support
- Support for tiled raster and vector data (display only)
- Automatic legend and scale bar building
- Scale dependent feature drawing and application execution
- Thematic map building using logical or regular expression based class
- Feature labeling including label collision mediation
- On-the-fly configuration via URLs
- On-the-fly projection

On-the-fly projection is supported through PROJ4, a USGS (United States Geological Survey) cartographic projection library (http://www.remotesensing.org/proj/). Additional vector input is supported through OGR (Optimal Golomb Rulers), a simple features library for the display of various vector data formats (http://gdal.velocet.ca/projects/opengis/) .

MapServer is compliant with OGC's WMS. It can be used not only as a WMS client in order to include map layers from remote WMS servers into MapServer applications, but can also work as a WMS compliant server, from which clients can build customized maps.

MapServer system supports MapScript which allows popular scripting languages such as PHP, Perl, Python and Java to access the MapServer C API. MapScript provides a rich environment for developing applications that integrate disparate data. PHP/MapScript module is used in developing the prototype. PHP/MapScript module has become an integral part of the MapServer distribution that makes MapServer's functions and classes available in a PHP environment. The functional flow of MapServer can be shown in the following diagram (Figure 4-2).

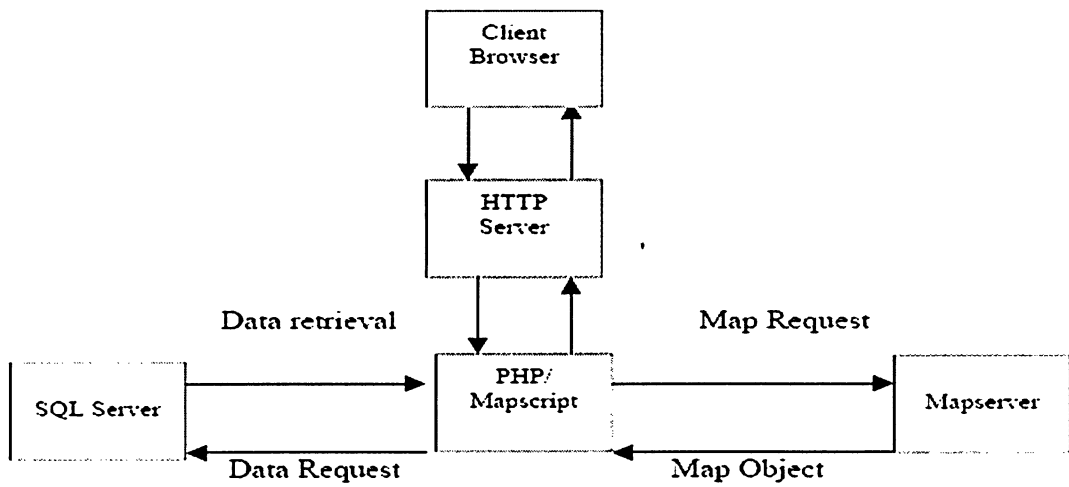


Figure 4-2 Functional Flow (Map India, 2005)

4.3 Conceptual Design

The design of WebPPGIS prototype utilizes a hybrid Web-based SDSS strategy to provide a platform through which the public can interactively communicate with system and

the other users. Planning scenarios are visualized on an interactive map and the information can be queried with the spatial context. Meanwhile, an open forum is provided for the public to express their opinions related to the planning problem freely and exchange their ideas between each others effectively. The public also can make an annotation on the map, either feature-linked or random annotation. Those annotations are stored with the comments together and can be retrieved when other people review the comments.

Figure 4-3 illustrates the system architecture of the prototype. The client browser is the user interface for the public. The public send the request through HTTP protocol to the Apache Web Server. The application server is a program run on the server side to process the client request and customize the client output. This module is programmed using PHP and MapScript. The parameters from the client side are passed to the application server. The application server in turn communicates with the map server and Database. The application server sends the SQL query to the Database. If the client requests the map information, the request is first sent to the MapServer through the PHP/MapScript Module. The PHP/MapScript Module can either process spatial data from a file or from the MySQL with spatial extension. The attribute data from the RDBMS or the image file rendered by MapServer is embedded into the HTML code by the Apache Web server and is finally sent back to the client browser to show to the public.

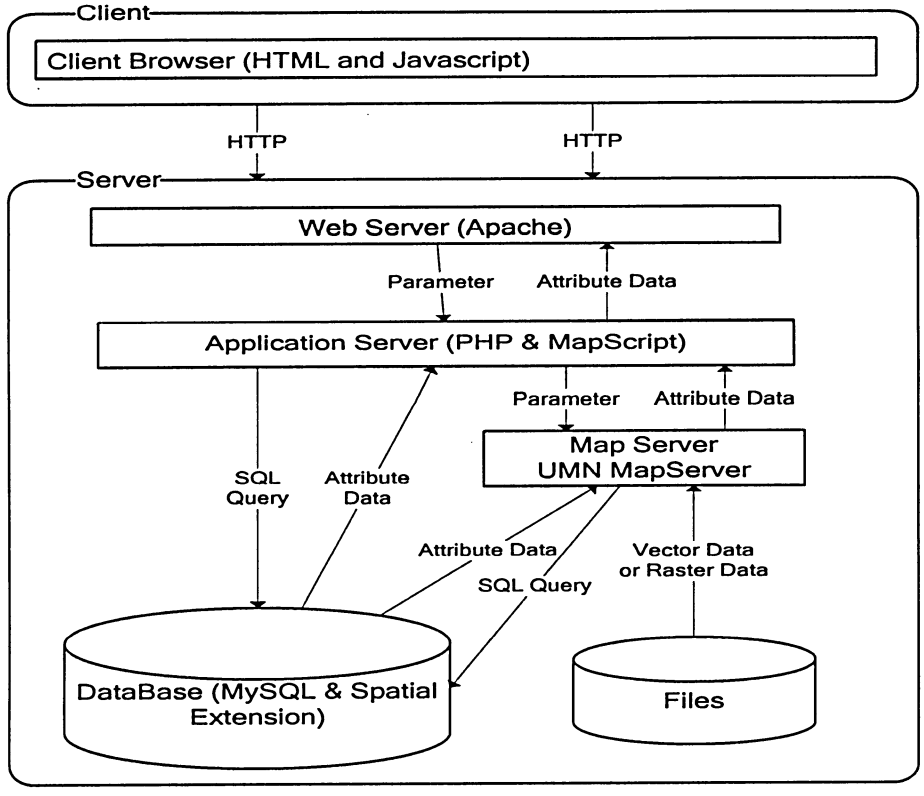


Figure 4-3 System Architecture of Prototype

4.3.1 System Components and Application Logic

Figure 4-4 demonstrates the application logic of this WebPPGIS prototype. Five main components are constructed to implement the requirements of the WebPPGIS framework: user management component, document component, communication component, spatial component, and database component.

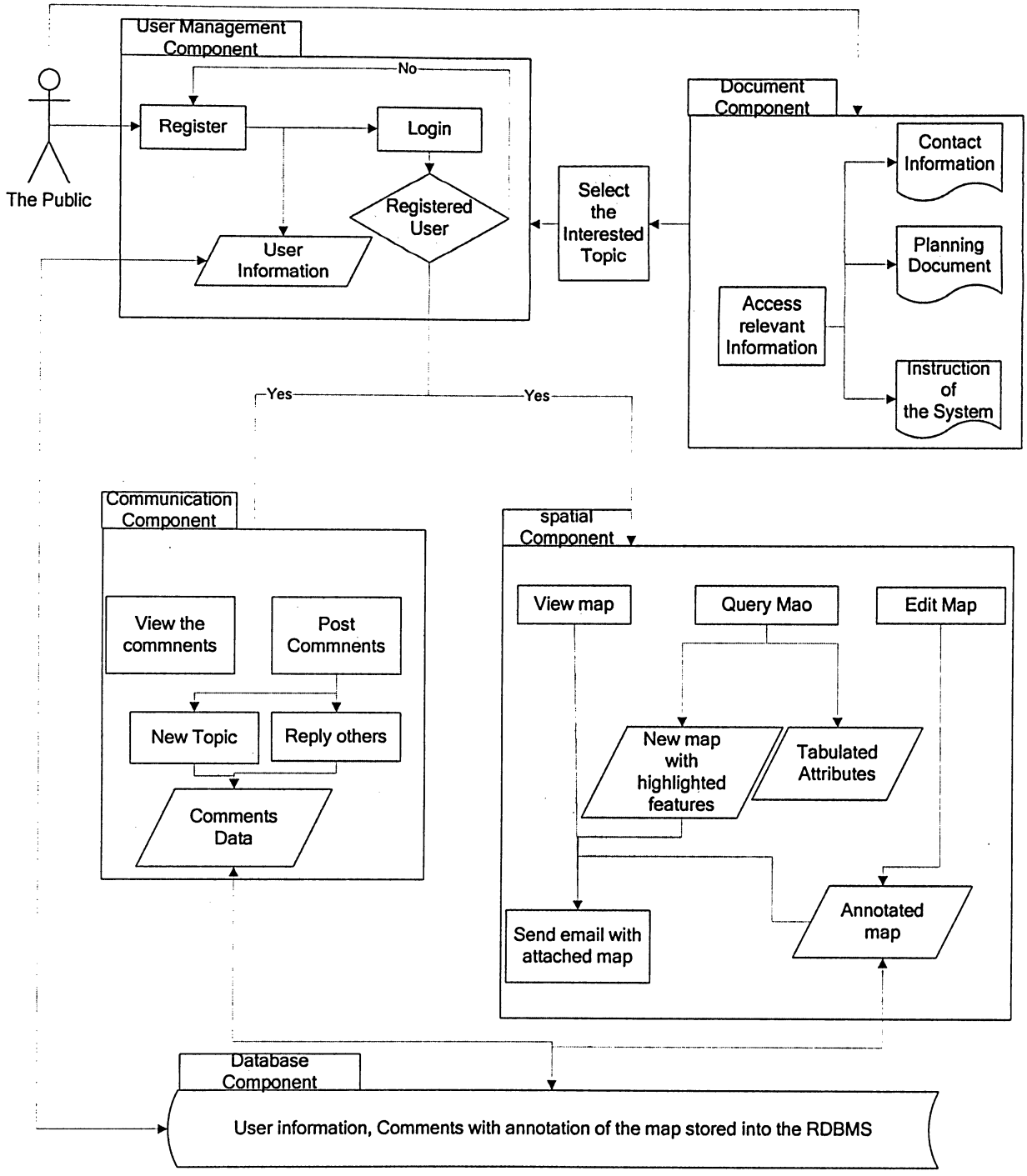


Figure 4-4 Application Logic of WebPPGIS Prototype

- **User management component:** This component allows the public to register, login and logout the system. During the registration, the public input their basic information, such as the name, phone number, email, address, gender, occupation, age range, etc. The information depends on the system requirements. Some information are mandatory, some may be optional. Meanwhile, a username and a password are unique for each person. The public can use their username and password later to login the system. The user information is stored into the database. The information will help validate responses and analyze the type of people who were using the system. In some planning process procedure, user information needs to be securitized to be legal. Such as the selection of the casino site, the user must be over 18 years old. Even though some researcher criticizes that the user registration will stop some people using the system, the benefit of registration is obvious, such as for statistic use, abandon illegal users, etc. Since this is a prototype, only username, password and email address are required.

- **Document component:** In this component, the public can get pre-prepared information related to the planning problem. This component could be a separated web page with all the relevant links or could be embedded into a frame of the forum interface which makes it easy to see. The documents include the planning information, the contact information and the instruction of the system. The planning information includes planning regulations, the current planning procedure, description of alternatives and consequences. The contact information includes the name of the people or authorities who are in charge, their email, phone numbers and responsibilities. The instruction of the system is also important for the no-expert

public. The instruction includes the description of the system, the functions and the tools, how to operate the system and what kind of output the system will create.

- **Communication component:** In this component, the public can post their own comments or view comments made by other people. It creates a virtual community in which the public can exchange ideas and communicate with each other. Since the map file is not always available to the public to access or is hard for the public to publish on the Web, the problems are always brought by the planners by creating a discussion topic attached with a relevant map. The public will make the discussion under the topic by making a comment or reply other people's comment. Meanwhile, the public is able to make an annotation on the map and save the change with the comments to the RDBMS. When other people view the comment, the map with the annotation will be presented at the same time. This helps the public to understand the other people's idea more clearly.

- **Spatial model:** This model is the spatial information processing center. The public can view, edit and analyze the maps related to the planning problem. Basic GIS functions and some advanced analysis functions are provided. The public can zoom and pan the map to view the certain interested areas. The public also can identify the features on the map to see the related attributes. The attributes are displayed in a tabulated format. The public are also allowed to make some annotations on the map. The annotation could be text, points, lines or even polygons. When the public finish their comments and annotations, the results are stored in the database and will be retrieved later. Also the map can be stored as map images (GIF, or JPEG, or PDF)

and can be sent as an attachment of email to other users, the planners and the authorities.

- **Information component:** This component is the heart of the whole system. This module is a relational database with an open-architecture design to ensure interoperability between different components of the system. The user information, comments data, the parameters of the map such as the extension, the projection, and the annotation of the map are all stored in the database. The public can access and search the database from the client side interface through the SQL commands embedded in the server side script. The RDBMS with spatial extension allows the pubic to conduct complex spatial and no-spatial querying, searching and reporting.

4.4 Implementation

This section will discuss in detail how each part of prototype has been implemented by demonstrating how the data are handled through different components in WebPPGIS prototype.

4.4.1 Data Preparation

Mapfile is used to lay out the configuration of a MapServer application [MapServer, 2004]. Mapfile defines the relationship between objects, points to the location of the data and how things are to be drawn. Mapfile holds the information and status of the map in a pseudo object-oriented way. Sample Mapfile can be found on Appendix A

Mapfile is a standard ACSII text file and can be edited either by general text editor or Web tools Maplab. MapLab allow users to create, edit and manage MapServer Web mapping applications and map files. It consists of three components: MapEdit, MapBrowser and

GMapFactory. MapEdit is a visual administration tools for the editing and management of Mapfile. It features a form-based interface for modifying Mapfile symbol, color, font, and file selector dialogs. MapBrowser is tool to visualize the selection of spatial data from local and WMS sources. The GMapFactory is an intuitive tool for the rapid creation and deployment of mapping applications. The Figure 4-5 is the screenshot of the Maplab.

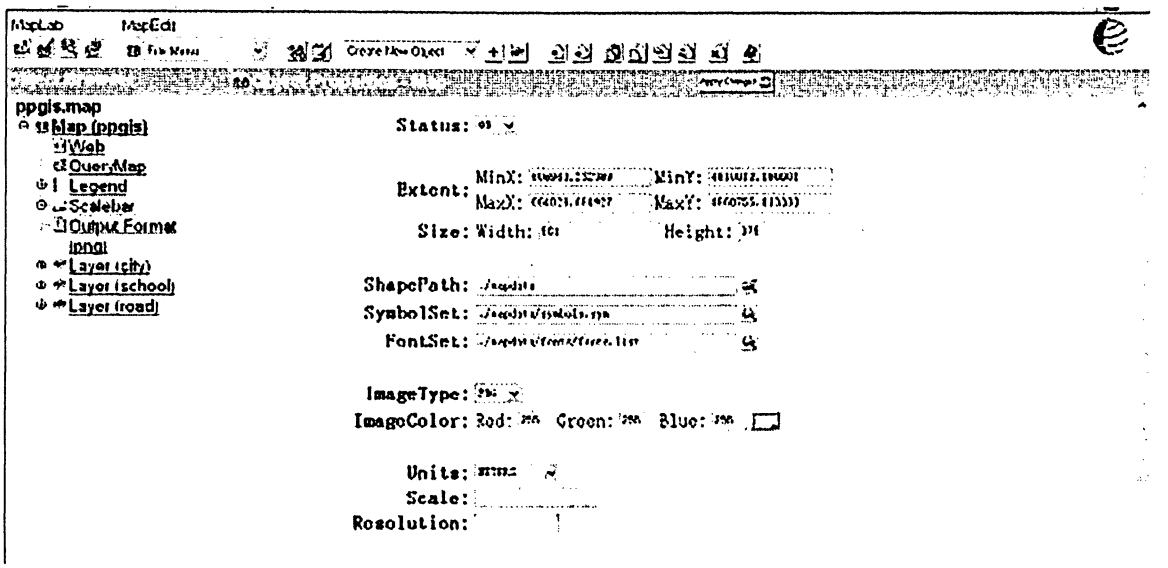


Figure 4-5 Screenshot of MapLab

4.4.2 Database Deployment

MySQL and spatial extension are used to implement database component. Four tables are created to manage the user information, the posted messages, and the annotation on the map. Figure 4-6 shows the schema design of the table and the detail of each table is discussed below.

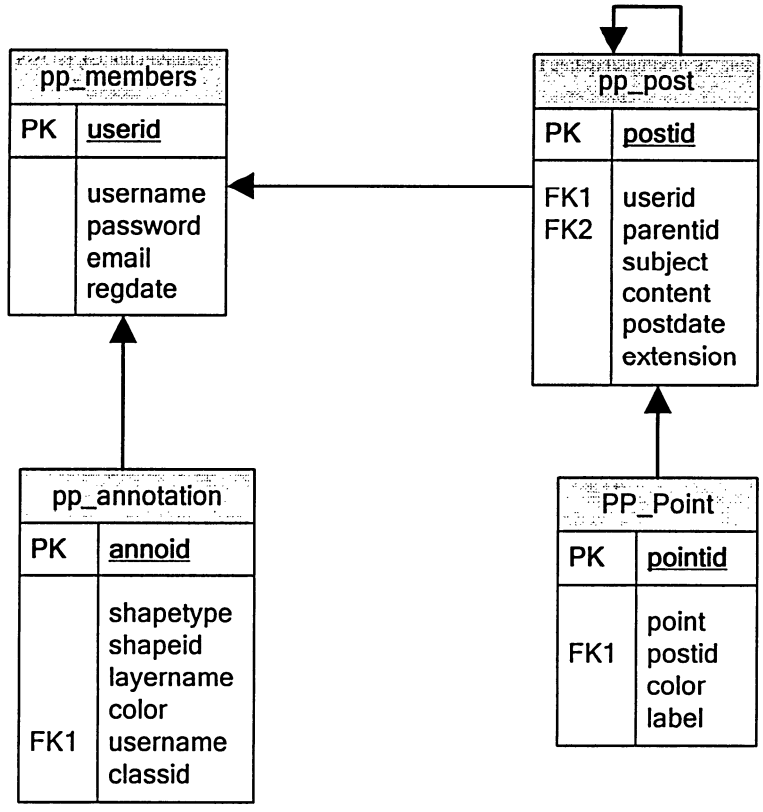


Figure 4-6 ER Model of Database Design

pp_member: This table stores the users' information. The username and password are used to identify the unique user. The email address will be validated and be used by the email alert component to notice the public the topic they are interested in.

pp_post: This table stores the comments the public post through the Website. When the comments are posted, the subject and the content are stored. 'parentid' field shows if the comment is a new topic or a reply of other topic. If it is a new topic, the 'parentid' field is set up to '0', otherwise the 'parentid' field equals to the 'postid' field of the comment which it replies to. 'Extension' field stores the extension of the relevant map when the comment is posted. This will be retrieved when the comments are reviewed and be applied to the map to rebuild the scenario.

pp_point: This table stores the information of the manual marks. The users can mark a point, write the description and choose the color of the label. The marks are saved at same time when the users saved their comments. When the comments are retrieved, the marks they made are shown on the map.

pp_annotation: This table stores the information of the feature-related annotations of the map. The users can annotate the selected feature and saved the related information into database. The annotations are related with the certain user. The user can get their preferred features whenever they log in the system. This function will help the user focus on the certain features their comments talk about.

4.4.3 User Management Component

User management components include login component and register component. The public need to register with username, password, and email address to the system in order to use the prototype. The returning users only have to input the username and password to get into the system. After the correct user information is input, the public is able to select the interested topic and enter the communication center. Figure 4-7 shows the interface to login in and registered.

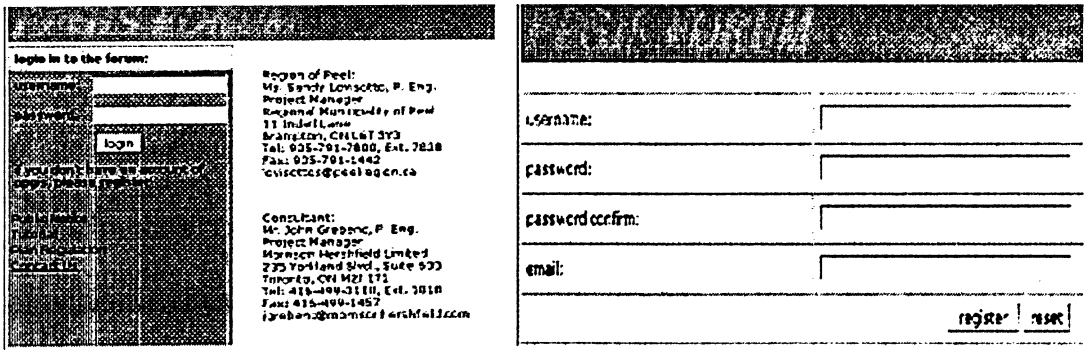
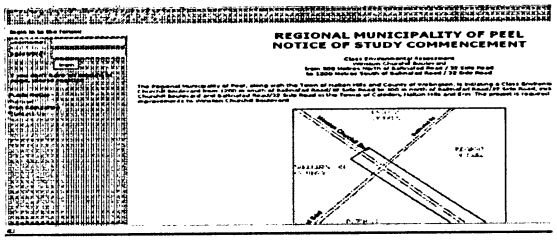


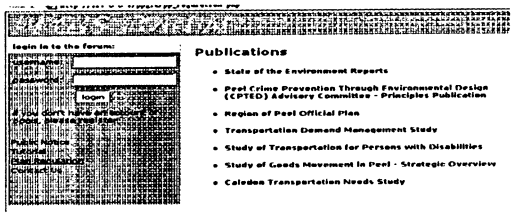
Figure 4-7 Interface of Register and Login in of WEBPPGIS Prototype

4.4.4 Document Component

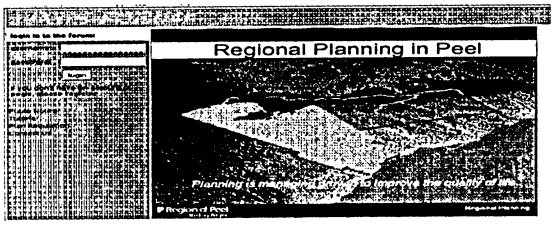
Before the public can express their opinions on the planning problem, it is important for them to understand the planning problem and how to use the system to participate into the planning process. Document center provides relevant information, including public notice, tutorial, planning regulations and contact information. Figure 4-8 shows the implementation of those components.



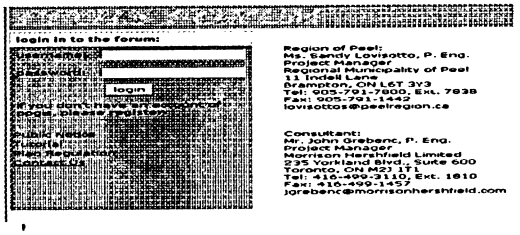
Public notice



Planning regulations



Tutorial



Contact Information

Figure 4-8 Implementation of Document Center

4.4.5 Communication Component

Public participation requires the public to exchange their view transparently on the certain topic, and the experts facilitate the whole discussion. Communication center is such a platform where the public can post their comments. There have two ways the public can post their comments (Figure 4-9), first by starting a new topic and second by replying other people's opinions. When the comments are posted, the related spatial objects, spatial extension and annotation (collectively called spatial context) are stored at the same time. When other users

view the comment, the spatial context is restored in order to provide a mutual understanding between the two public users.

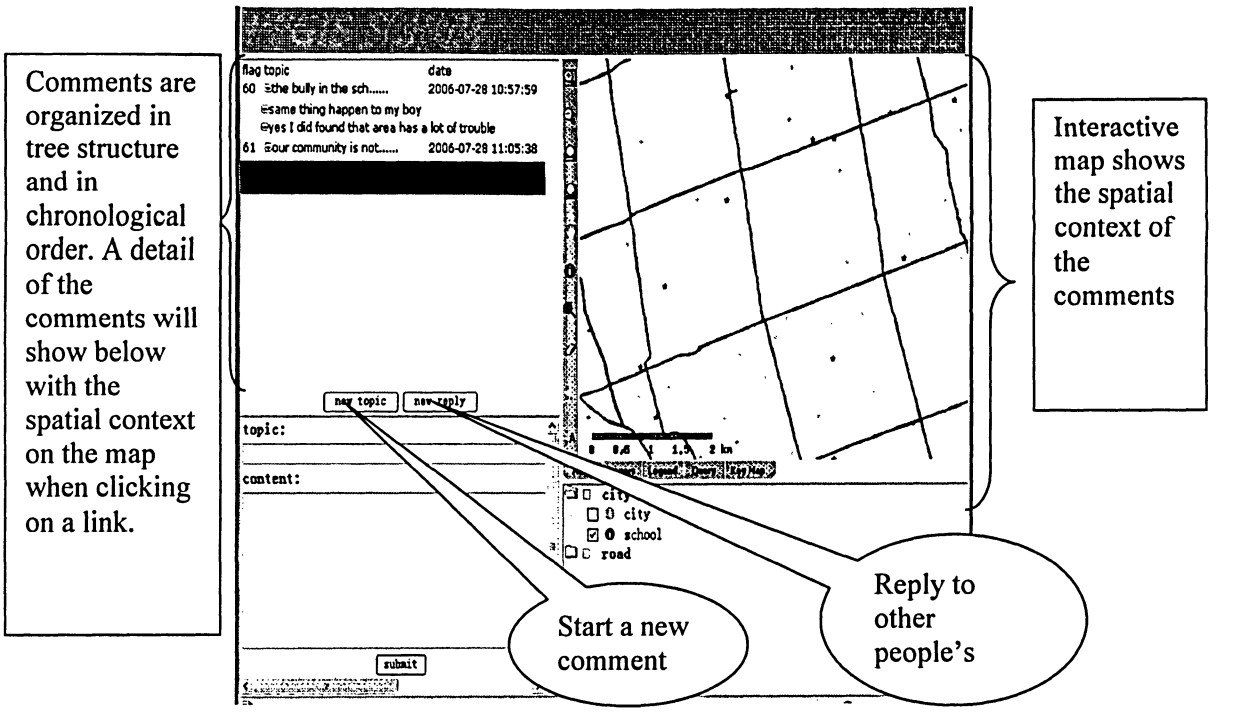


Figure 4-9 Communication Center of WebPPGIS Prototype

4.4.6 Spatial Component

Spatial components provide the core GIS functions which act as the spatial context in the communication center. Since the major user of the WebPPGIS system is the public who has limited knowledge of GIS, only the basic functions of GIS are provided in the prototype (see Figure 4-10).

- **Zoom and Pan:** The prototype provides the basic operation on the map, which allows the public to focus on the certain interested area or overlook the whole region. The basic function includes the zoom in, zoom out, zoom to full extension, and pan.

- **Identify:** The prototype also provides the tool to identify the feature by click on it. The attributes of the identified feature are tabulated below the map which makes it easier to access:

- **Feature-linked annotation**: The prototype provides the tool for selecting the feature, and making the annotation on the selected feature using the predefined field in the attribute table. Also a tool is provided to erase the selected and annotated features. The annotated features will be stored in the database. When the user login the system, all annotated features resume in the way they log out last time.

- **Reference map:** The reference map is the overall version of the main map and marks the current extent using the red rectangle. This makes the user easily identify where the current view locates on the overall map.

- **Scale bar:** The scale bar is located under the main map. It is rendered at together with the main map.

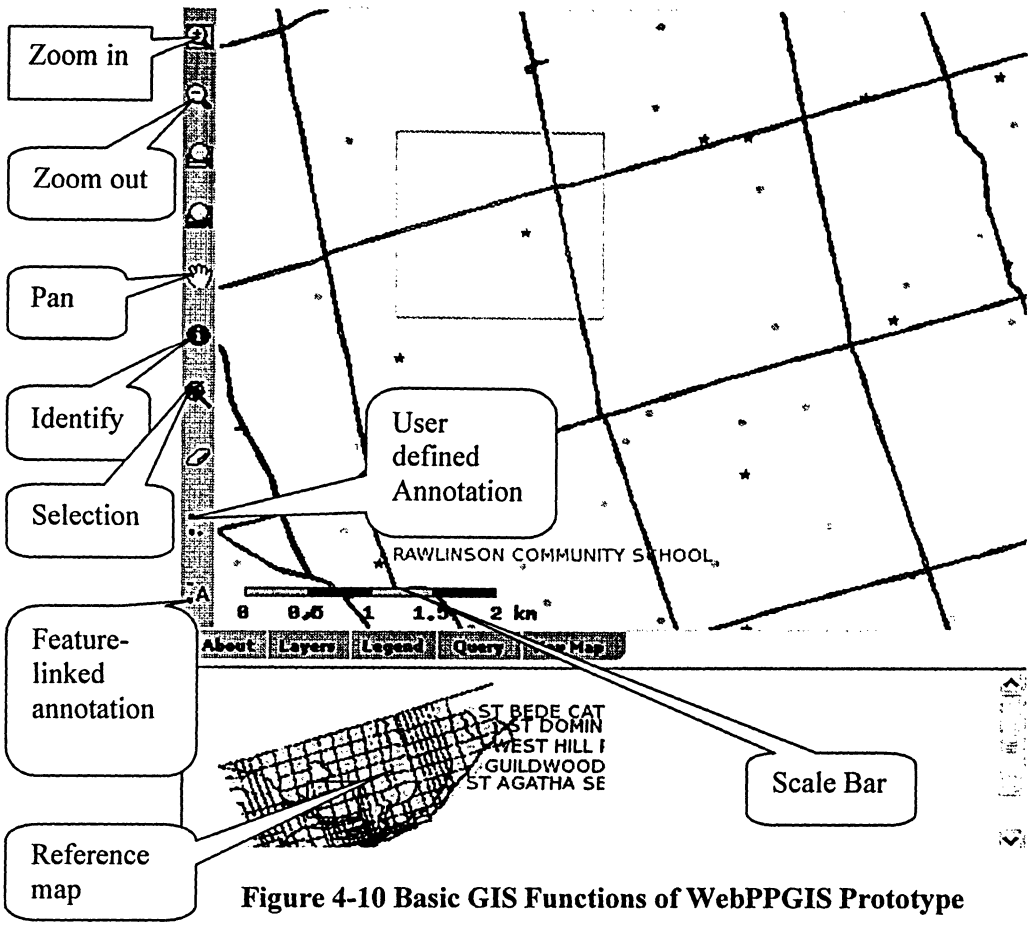


Figure 4-10 Basic GIS Functions of WebPPGIS Prototype

- **Layers and Legend:** The prototype provides the tool to show the legend of the main map and the status of each layer. The layers are catalogued as active layers ❶ and inactive layers, visible layers and invisible layers which marked by the hood of the checkbox. These makes the public knows the meaning of the map more clearly (Figure 4-11).

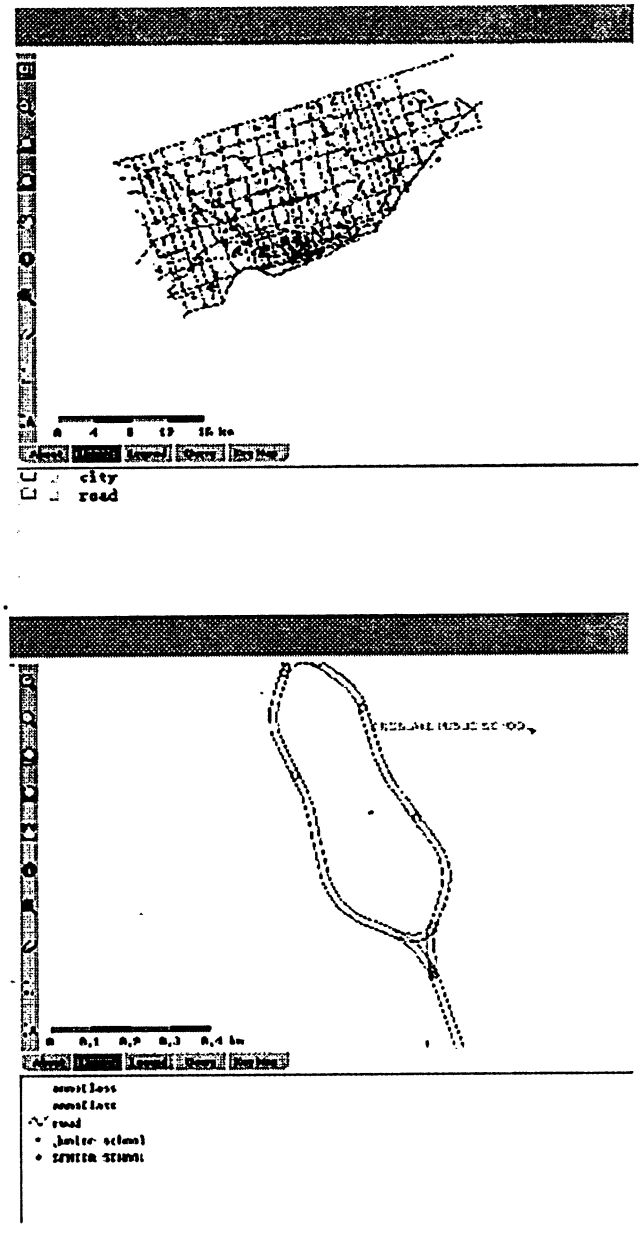


Figure 4-11 Dynamic Layers and Legend of WebPPGIS Prototype

- **Query by attribute:** The prototype provides the tool to query the features by attribute. The selected features are then showed on the map and the attributes of the features are listed on the window below the main map (Figure 4-12).

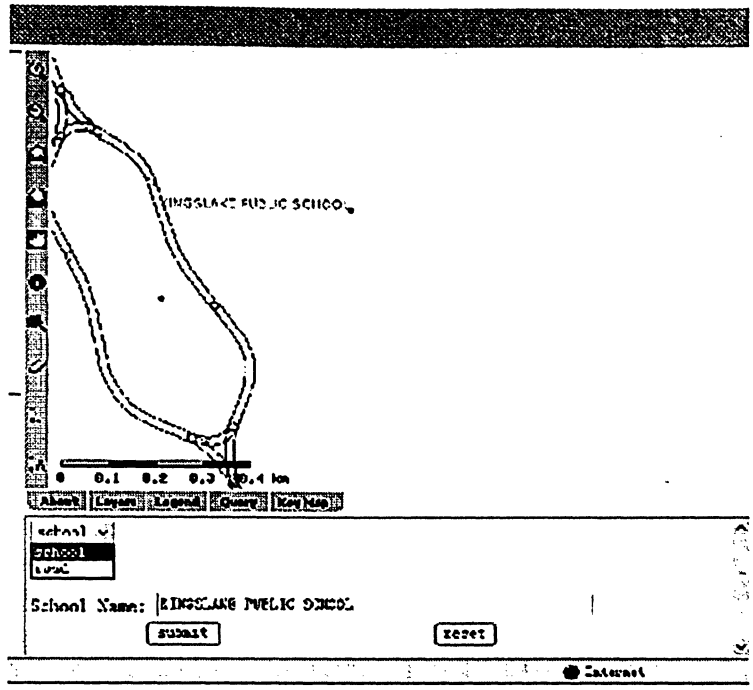


Figure 4-12 Query Function in WebPPGIS Prototype

- **User defined annotation:** The prototype also provides the public a unique tool to make a user defined annotation. Figure 4-13 illustrates the interface of this tool. The user can pick up the spot on map and write an annotation. When the users submit the comment, the annotations they made on the map are also stored in the database. When other people review the comments, the annotation will be retrieved and marked on the original spot. This function allows the public the flexibility of making the comments and more efficient sharing their opinions.

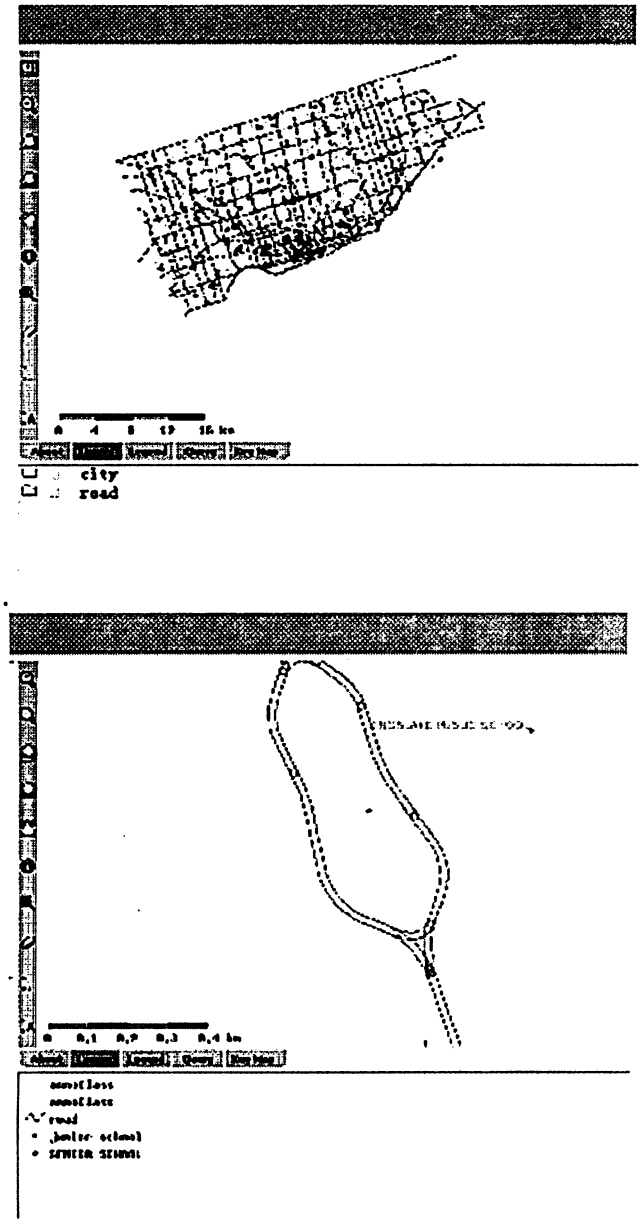


Figure 4-13 User-defined Annotation in WEBPPGIS Prototype

4.5 Discussion and Evaluation

The requirements specified for this WebPPGIS prototype has been fulfilled. The GIS functionalities and communication functionalities have been implemented. Since the prototype design is user centered, the evaluation will consider how the system facilitates the public users into the decision-making system. The evaluation was performed in the following five aspects:

- **Communication:** In this prototype, the public users can communicate with each others through a well-designed forum. Since an interactive map has been embedded into the system, the communication content has spatial context associated with traditional text content.

- **Educational:** The welcome page provides an introduction of the problems that need to be solved, the regulations of the planning process, and the tutorial of the system. All of those materials are easily accessed and easily understood.

- **Visualization:** In this prototype, the interface is designed friendly to the public users. The main interface of the WebPPGIS prototype is based on the frames. All the functions of the prototype are organized in single interface, which different frame has different function. The functionalities are categories into different menu items. When a certain menu item is picked up, the related information or related tools will be displayed on the certain frame. The benefit of this design is that the public users do not need to switch from different interfaces.

- **Awareness:** In this prototype, the awareness was fulfilled by the email alert. The email alert has two parts, one is the linkage of the WebPPGIS prototype was sent to the registered users, the other is certain comments with the attached map can be sent to the selected person.

- **Mediation:** The mediation is a way to make the system run smoothly. In this prototype, the public can send email to the consultants. The most frequently asked questions will be posted on the website for reference. The consultants also can join

the discussion forum to lead a topic or answer questions. A consultant will be displayed on the screen in a special icon which obviously shows the special status.

CHAPTER 5 CONCLUSIONS AND OUTLOOKS

5.1 Achievements

The main goal of this thesis was to summarize general requirements of a WebPPGIS in planning process and to implement a prototype that meets those requirements. Based on the analysis of the current research efforts, this thesis discussed the general requirements in detail. Also, a prototype has been designed, developed, tested and deployed using OSS technologies. The outputs of this research contribute to the overall development of WebPPGIS from a different angle – the use of OSS. The following highlights are major work done so far:

- **Application of the user-centered design, development and deployment approach.** In this research, I took into account the public users' needs from several aspects. First, the development of the discussion forum with spatial context gave the public users more power to express their opinions. Second, the usage of user friendly HCI eased the public users from the complex concept of GIS and planning process. Integrating all the main functions into one web page avoided the confusion from wandering among different web pages. Third, the educational materials and tutorials in the welcome page provided better understanding of the specific knowledge about the underlying municipal development. Finally, the email alert mechanism provided the public users notification of certain issues. Bringing more public users' attention to the issues makes the final decision represent more public users' right.

- **Adoption of OSS technology in the prototype development.** Although OSS has some drawbacks comparing with the commercial software, the advantages of OSS was demonstrated in the research. First, the usage of OSS meets the low cost requirement of WebPPGIS. No license fee for the whole developing suite, such as MySQL, PHP, MapServer, MapScript and Apache. Second, the usage of OSS makes developing job easy. OSS has a strong developer network throughout the Web, such as an open forum for discussing relevant problems. Some projects provide source codes free for reuse, which shortens the development time. Third, the usage of OSS provides more security. Less bugs experienced during the prototype development.

- **Integration of a RDBMS with spatial extension.** MySQL with spatial extension is used to store both spatial and non-spatial information in the prototype. The information related to the forum is stored in the MySQL database, such as the query results, the extensions of the map, and the users' comments. The spatial extension stores the spatial objects, such as the user-defined point into the database and provides spatial indexes and functions for basic analysis. Spatial extensibility of traditional database makes it possible to integrate the spatial context into the discussion forum.

5.2 Conclusions

WebPPGIS has been demonstrated as a commonplace mechanism for the exploration, experimentation, and formulation of decision alternatives by the public and thus have the potential to involve the public more closely in the planning process. WebPPGIS has some common characteristics as discussed before. First, WebPPGIS should hide the complexity of

GIS behind friendly, easy-to-use GUI (Graphic User Interface) while building up the specific planning scenarios. Second, WebPPGIS should make the spatial problems easily to understand, such as using visualization tools and multimedia. Third, WebPPGIS should provide the channels through which the public can express their opinions and communicate with each others. Fourth, WebPPGIS should be cost-effectively which even small communities can afford to use it.

In developing the WebPPGIS prototype system, the use of OS and OSS has been proved to be an effective way to implement WebPPGIS especially for organizations with scarce resources. MapServer, PHP and MySQL are working effectively to offer considerable geo-processing functions and communication functions.

This research focused more on the technical requirements of WebPPGIS and how to provide an effective platform for the public to participate into the planning process. Further improvements of the prototype should consider other aspects, which are discussed below. First, the traditional public participation methods are not simply abandoned, but modified and integrated with the new WebPPGIS. Second, the WebPPGIS should be combined with other more ICT technologies within a general virtual public meeting system framework to further facilitate the understanding of problems and information as well as the exchange of ideas. As such, the GIS tools should be integrated with not only groupware such as online discussion forum but also other components such as those supporting more pro-active notification and awareness. Third, an important issue identified through the research relates to the evaluation of the system, which is proved difficult to be performed in the lab environment. The effective evaluation of WebPPGIS needs to be set up in the real scenario which involves the public from diversity background and has different level of knowledge, and skills.

5.3 Limitations of the Research

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

- The requirement summary of WebPPGIS in this thesis is based on selected cases and has its limitations. The system that does not meet the general requirements may easily fail to succeed, however only meet those general requirements may not guarantee the success.

- The WebPPGIS prototype is not a fully-functional system. First, GIS functions are limited. Some GIS functions such as address searching, dynamic map size changing are not provided in this prototype even though they are important for real world cases. Second, the communication functions are limited. The public may need more channels to exchange their opinions such as chat room, newsletters etc. In this thesis, the prototype only shows the possibilities of the integration of ICT and GIS and its implementation.

- The WebPPGIS prototype needs more changes on the interface which make the public more comfortable in using the WebPPGIS as a media to participate in the real decision making process. The interface should allow the public operate the system smoothly without paying attention which one is GIS-related information. For instance, query wizard will lead the public through the spatial database query procedure, without touching the specific GIS items.

- The prototype of WebPPGIS is only intended for demonstration and proof of concept. Therefore, it only uses simple data that is not specific to any actual problem and does not deal with complex real world issues.

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APPENDIX: Sample Mapfile

```
MAP
 NAME "ppgis"
 STATUS ON
 EXTENT 601550.610263 4810012.0809 669441.307053 4860755.41333
 SIZE 500 400
 SHAPEPATH "./mapdata"
 SYMBOLSET "./mapdata/symbols.sym"
 FONTSET "./mapdata/fonts.txt"
 IMAGETYPE png
 IMAGECOLOR 255 255 255
 UNITS METERS
 WEB
  IMAGEPATH "d:/webroot/temp/"
  IMAGEURL "/temp/"
 END
 SCALEBAR
  STATUS ON
  COLOR 208 195 0
  ......
  LABEL
   TYPE BITMAP
   SIZE MEDIUM
        ......
 END
 END
```

```
 OUTPUTFORMAT
  NAME "png"
  MIMETYPE "image/png"
  DRIVER "GD/PNG"
  ......
 END
 LAYER
  NAME "city"
  GROUP "city"
  STATUS OFF
  DATA "./toronto"
  TYPE POLYGON
  UNITS METERS
  ......
  CLASS
   NAME "city"
   TEMPLATE "void"
   STYLE
    SYMBOL 2
    COLOR 224 255 255
   ......
   END
  END
 END
.....
END
```