Issues Involved in the Development of Internet-Based GIS Applications

Adam Forbes

A dissertation submitted for the degree of Bachelor of Applied Science at the University of Otago, Dunedin, New Zealand

Date: October 16, 2006
Abstract

Geographical Information Systems (GIS) are computer-based systems that use geographical data in conjunction with analysis and management tools to improve the decision-making abilities of organisations (Heywood et al 2006). The recent rapid development and increased accessibility of the Internet has led to the emergence of a new brand of GIS systems; Internet based GIS. Internet based GIS combine the decision-making abilities of GIS systems with the customisation, accessibility, and interactive power of the Internet.

This paper investigates a range of issues involved in the development of real-world Internet based GIS applications. These issues are evaluated from three distinct perspectives that impact on the development of GIS applications. These are the technical, commercial and social perspectives. The primary objective of this paper is to explicitly discover and explain the links between the issues from these different perspectives.

In order to discover these issues, a case study was conducted that involved the development of a web-based GIS application for an Auckland IT company, Coeus Ltd. This application utilises an online GIS Application Programming Interface to provide GIS functionality that has been customised to meet Coeus’ requirements. To supplement the issues identified from this case, an extensive literature review is also incorporated into this research.

Following the identification and explanation of the issues, links between each of the perspectives are explained. These links show that issues from one perspective have an impact on the success of a GIS from the other two perspectives. This highlights the importance of considering a range of issues from the different perspectives when developing a web based GIS application.
# Table of Contents

Abstract ................................................................................................................................. 2  
Table of Contents .................................................................................................................. 3  
Table of Figures ................................................................................................................... 4  

1. Introduction ....................................................................................................................... 5  
   1.1 - Defining GIS ........................................................................................................... 5  
   1.2 - Web-based GIS ..................................................................................................... 5  
   1.3 - Web-based APIs .................................................................................................... 6  
   1.4 - The Research ...................................................................................................... 7  
   1.5 - Research Relevance ............................................................................................ 7  

2. Case Study ......................................................................................................................... 8  
   2.1 - Background of Coeus Limited ........................................................................... 8  
   2.2 - The Addition of a GIS Services ....................................................................... 10  
   2.3 - Background of Metro Water ............................................................................ 10  
   2.4 - System Requirements ....................................................................................... 11  
   2.5 - A Comparison of Web-Based APIs .................................................................. 12  
   2.6 - The Completed Application ............................................................................. 14  
   2.6 - Client Feedback ................................................................................................ 19  

3. Technical Issues ............................................................................................................... 20  
   3.1 - Components of a Web-based GIS .................................................................... 20  
   3.2 - System Architecture ........................................................................................... 21  
   3.3 - Implementation Software .................................................................................... 24  
   3.4 - Navigation and User-Interface Design ............................................................. 26  
   3.5 - Quality of Service ............................................................................................... 28  

4. Commercial Issues ......................................................................................................... 30  
   4.1 - Investing in GIS .................................................................................................. 30  
   4.2 - Organisational Changes .................................................................................... 32  

5. Social Issues ...................................................................................................................... 33  
   5.1 - Public Participation in Geographic Information Systems .................................. 33  
   5.2 - Developing PPGIS Applications ..................................................................... 34  
   5.3 - Security and Data Privacy Issues ...................................................................... 35  

6. Findings and Conclusion .................................................................................................. 37  
   6.1 - Technical & Commercial Linkages .................................................................... 37  
   6.2 - Social & Technical Linkages ............................................................................ 38  
   6.3 - Commercial & Social Linkages ........................................................................ 39  
   6.4 Overall Linkages .................................................................................................... 40  
   6.4 Conclusions ........................................................................................................... 40  

7. References .......................................................................................................................... 41
### Table of Figures

FIGURE 1. The Outpost Data Logging System ................................................................. 9
FIGURE 2. A Dynamically Generated Graph of Data ...................................................... 9
FIGURE 3. User Login .................................................................................................. 14
FIGURE 4. Outpost Overview Screen ......................................................................... 15
FIGURE 5. The Integrated GIS Control Map ................................................................. 16
FIGURE 6. Live Outpost Data .................................................................................... 17
FIGURE 7. A History of Recorded Data ..................................................................... 18
FIGURE 8. The Basic GIS System Architecture ............................................................ 28
FIGURE 9. Coeus Web-based GIS Architecture ............................................................ 28
FIGURE 10. Costs-benefit Graph ................................................................................. 31
1. Introduction

1.1 Defining GIS

Many differing definitions exist to describe the complex field of Geographical Information Systems (GIS). GIS is an inter-disciplinary field that involves information science, geography, cartography and urban planning (Adam and Gangopadhyay 1997). Because of this, any attempt to define GIS varies depending upon the discipline that is describing it (Heywood et al 2006). Cho (1998) provides a list of basic definitions to describe what GIS systems are including “computer-based systems that are used to store and manipulate geographic information” and “an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data”.

Heywood et al (2006) states that in general, definitions of GIS cover the three major aspects that GIS are composed of: These are computer systems, geographical data and management and analysis capabilities. With these components a GIS provides the ability to access, manipulate and output geographical data. The main purpose of which is the addition of value to spatial data. This added value facilitates better decision-making within organisations.

1.2 Web-based GIS

GIS have been continually evolving since their first conception in the 1960’s. The growth of the Internet throughout the 1990’s has lead to the emergence of a new brand of GIS, Internet-based or online GIS. Peng and Tsou 2003 state that Internet based GIS add to the traditional GIS system by making them “more mobile, powerful, flexible and better able to share and communicate geographic knowledge”. This development as stated by Colas et al (2002) has made it a very exciting time in the history of geographic information systems.

An online GIS can be described as a service that uses the Internet to distribute interactive maps and other spatial data derived from a GIS (Colas et al 2002). This involves the distribution of data amongst different computers in different locations that
communicate through the Internet. Internet GIS allows for “universal accessibility to remotely distributed data and analysis functions” (Peng et al 2003). This means that users can use the Internet to access GIS services without having to have a complex GIS system installed on their own computer. Infrequent users are able to easily find out useful geographical information such as the location of the nearest retail outlets to them.

This increased accessibility encourages an important shift in the way GIS are developed. The once large-scale one-size fits all applications can be made into smaller, more specialised services.

1.3 Web Based APIs

Application Programming Interfaces (APIs) are software with a clearly defined set of functions that expose the functionality of an underlying system so that external developers can make use of that software’s functionality. In the context of web-based GIS these API can be seen as web-services that specialise in GIS functionality and allow developers to “plug-in” to them and use their specialised mapping features. These web-based API’s provide basic GIS functionality including mapping and querying tools. More complex features are now beginning to emerge in these systems.

Web based API have further extended the accessibility of GIS services. Internet-GIS systems can now be created without developers having to have an extensive knowledge of how to construct GIS maps. Instead the developer can focus on the customisation of the application. There are a wide variety of commercial web-based API’s that provide features including map creation, editing, display, spatial analysis, and web site design tools useful in developing and implementing an online GIS (Colas et al 2002).
1.4 The Research

This research investigates the issues involved in the development of Internet based GIS applications. The issues for developing web-based GIS applications can be viewed from three distinct perspectives that impact on the development of GIS applications. These are the technical, commercial and social perspectives. The importance of these different perspectives is evidenced by Heywood et al 2006 stating that “the successful application of GIS projects depends not only on the technical aspects, but also on the human and organisational factors relating to the implementation of systems”. Technical issues refer specifically to the technical development aspects of an application. The introduction of a GIS system into an organisation also depends on the commercial viability of that system. Social issues have an impact on the environment that a GIS operates within. A more detailed explanation of their perspectives is detailed in their corresponding sections.

In order to discover these issues, a case study was conducted that involves the development of a web-based GIS application for an Auckland IT company, Coeus Ltd. This application utilises an online GIS Application Programming Interface to provide GIS functionality that has been customised to meet Coeus’ requirements. To supplement the issues identified from this case, an extensive literature review is also incorporated into this research. The lessons learned from developing a real world application for Coeus in conjunction with this literature review provide an in-depth analysis of the issues involved. Unfortunately, due to time constraints and the complicated nature of GIS, only a few of the most pertinent issues from each of these perspectives are evaluated in this paper.

1.5 - Purpose of Research

The purpose of this research is to prove that links exist between the different perspectives that GIS can be viewed from. Proving these linkages will help to promote the idea that a range of different issues should be considered when embarking on a GIS project.
2. Case Study

This paper is based around a case study that involves the development of a web-based GIS for a New Zealand IT company; Coeus Ltd. Coeus required a specialised GIS application to extend the capabilities of their existing services to meet the needs of one of their major clients, Metro Water. Background information about Coeus and their major client Metro-water are described in this section, followed by the requirements of the developed application, and then finally results of the developed application.

2.1 Background of Coeus Limited

Gaining background knowledge of Coeus services was an important part of the requirements gathering process, so that requirements of the proposed system could be gauged as accurately as possible.

Coeus Limited is an innovative New Zealand IT company that was formed in 2002 as a partnership between four IT professionals. Since completing the development of their core service, the outpost data logging system, they have attracted business from clients including Auckland’s Metro Water, Vector Limited and the University of Auckland.

Coeus specialises in wireless online monitoring and control services. This is achieved through their custom built monitoring devices; the primary model of which is called the Outpost. The Outpost is a wireless stand-alone unit that can be powered either by an attached battery or if site conditions allow, by solar power. Outposts can record varying types of data depending on the types of sensor that are attached to their ports. This data is then sent using GPRS (General Packet Radio Service) to the Coeus server in Auckland. Clients can log on to the Coeus website from anywhere in the world at any time, via the Internet, and view the live data that their outposts are monitoring. This is illustrated in figure 1 where an Outpost has a pump attached to it that is recording data that is sent via GPRS to the Coeus server where it can be viewed and controlled through a web-browser or WAP.
In addition to this service, Coeus also offers a range of data customisation services. These services provide flexibility in the applications that their system can be applied to. Clients can display data in many different formats through dynamically generated charts and graphs as displayed in figure 2 below. Automatic alarms can also be easily created and set to be triggered when set events occur e.g. if an Outpost was monitoring the water levels of a water reservoir a trigger could be set up to monitor if the water level of the reservoir went below a certain level. If this occurred an automatic SMS text message could be sent to a specified cell phone number.

FIGURE 1. The Outpost Data Logging System

FIGURE 2. A Dynamically Generated Graph of Data
2.2 The Addition of a GIS Services

One of the main focuses of Coeus’ business strategy is that they will continually develop and improve upon the functionality of their services. This is to ensure that they remain competitive and are seen as the market leaders in their field. Because of this, it was a logical next step for Coeus to incorporate GIS into their service. The development of this extension was accelerating when one of their existing clients, Metro-water requested the addition of GIS Services with the promise of purchasing additional Outpost units.

2.3 Background of Metro Water

Metro Water is one of Coeus’ major clients with over sixty outposts distributed around the Auckland region. Metro Water is a water and wastewater utility company that is owned by the Auckland City council. They buy and deliver fresh water and collect and transport wastewater for the entire Auckland region.

Metro Water has been using Coeus services for over a year now primarily as an early warning system. Outposts have been fitted at dry weather wastewater overflow hotspots around the city in order to help reduce the amount of wastewater spilled into streams and harbours. When a pipe breaks or is blocked the spill must be contained quickly otherwise an overflow into the environment will occur. The Coeus service has helped them to monitor and prevent potentially damaging wastewater overflows.

Following the “improvement in the speed and efficiency of our reaction to network problems and resulting sewage overflows” (Metro Water, 2006), as a result of the implementation of Coeus services, Metro Water decided that the addition of GIS functionality to the system would further improve their performance. After consulting with Coeus it was agreed that this functionality would be added to their service.
2.4 System Requirements

The following section outlines the requirements for the integration of GIS services to meet the needs of Coeus and their client Metro Water. These are the original system requirements that were accepted by Coeus in order to proceed with the development of the GIS application.

The main aim of the project is the integration of an Internet based GIS capabilities into Metro Water’s existing wastewater monitoring system. This will allow users to visualise data collected by outposts in a geographical context, improving upon the data analysis, management and response times of the existing system. This will involve the production of a central control map that will display the location, status and data of Outposts.

Specific System Features

- A mapping control centre will be created and integrated into Coeus’ existing data monitoring web service. It will be accessible as an additional tab on Metro Waters overall control view of existing outposts.

- The creation of a control map that will initially display the default location that will be adjustable by Coeus through the editing of code. The map will enable navigation and zooming in and out using the functionality provided by the mapping API tool.

- Outposts will be represented as nodes on the control map. Functionality will be provided to enable users to add, delete and edit the locations of currently owned Outposts on the map.

- The ability to “zoom-in” to an outpost node on the control map to view the live data that it is monitoring. This will be presented using additional non-spatial data functionality provided by the mapping API tool.

- The ability to convey the status of an Outpost quickly by using different node representations.
• The ability to configure descriptive information about outpost nodes including names and descriptive text.

2.5 A Comparison of Web-based GIS APIs

Web based GIS application programming interfaces allow developers to utilise the power of displaying geographical information without having to create complex mapping software themselves. Developers can use these web services to specify how they want maps to be displayed. All of the specialist knowledge of having to draw the maps is handled completely by the web service.

There are a vast number of GIS API tools available for use on the Internet. Each of these tools differs in the functionality, costs and other features offered. Because of this it is essential that the selection of an API that best fitted with Coeus requirements was selected. Three APIs were selected to be analysed in more detail in order to determine their suitability. APIs tools were assessed using a set of developed criteria. These criteria formed the basis for the selection with Coeus’ approval. The Criteria were:

**Price** - This is the cost of developing with an API and the periodic charges for the use of the software.

**Customisation** - This is the degree that the appearance and functionality of the Internet GIS can be modified to meet differing requirements.

**Usability** - How easily users are able to perform intended functions on the map.

**Developer Usability** - The degree of with which developers can use this API to make Internet based software.

**Supported Browsers** - The Browsers that correctly display the API features.

**Data Visualisation** - The API’s ability to visually display data.

**Non-spatial data** - How the API displays additional non-spatial data.

**Spatial analysis facilities** – The APIs support for features such as zooming, centring, address-matching, full coordinate system and projection support.
The Mapping API Tools


Google maps have become the most widely used mapping API in the world. Google offers a good set of functionality in a medium price range. The interface provided is highly customisable and has an acceptable level of usability for developers. Detailed developers forums are available to find out how to use the complex features of the API. It supports spatial data well as allowing the addition of non-spatial data. Google maps are supported by all major types of browsers.

Zoom-In Maps - [http://developer.zoomin.co.nz/](http://developer.zoomin.co.nz/)

Zoom-in maps are a newly developed New Zealand based mapping API tool. They offer a relatively small amount of functionality compared to the other API. This functionality is however well supported by documentation and examples that implement it. The system has very low costs and offers free service if a certain number of “map loads” are used per month. It supports spatial and non-spatial data, however it has been designed primarily for use in the Internet Explorer browser only.


Via Virtual Earth is a newly developed mapping service produced by Microsoft. It offers extensive functionality but at a relatively high cost. It offers limited support to developers of applications. It supports spatial and non-spatial data and operates on all web browsers.

The Decision

It was decided that functionality of Zoom-in mapping services best met the requirements of Coeus. The additional functionality offered by other API’s was not necessary for this application. The low usage prices and the fact that Zoom-in is a NZ based company were also advantages. The restricted use of the API within only IE browser was not an issue due to the fact that all Coeus’ current services are designed to function with only in IE.
2.6 The Completed Application

This section showcases and describes the features of the completed web-based GIS system. The system fulfils the majority of the original requirements that were set out in requirements section. It has also had the approval of both Coeus and Metro Water. More information about the client feedback can be found following this section.

Unfortunately, the actual application login details cannot be disclosed due to data security issues. Screen shots have been taken instead to show the functionality of the system as it is seen through Microsoft IE browser.

Screen One

This screen allows system users to login into the Coeus monitoring and control system by using a password supplied to them. This page is accessible from Coeus central website portal located at [www.outpostcentral.com](http://www.outpostcentral.com).

![FIGURE 3. User Login](image-url)
Screen Two

After users have completed login authentication to the system they are directed to an overview of the Outpost units they are currently monitoring. A limited set of data is detailed about each Outpost including information about it’s model type, signal strength and battery life. Users have the option of logging onto an individual outposts to view specific data that the outposts are monitoring including a detailed graphical analysis. The functionality available on this screen was already part of the existing system that Metro Water was using before the addition of GIS services.

FIGURE 4. Outpost Overview Screen
Screen Three

This screen displays the integrated GIS functionality of the system. It allows users to view the outpost data that was displayed in figure 4 in a geographical context. Two significant data layers are used, the first being a map of the Auckland area, and the second being Outpost nodes storing information about the data they are monitoring. A control panel on the right allows users to perform various functions on the GIS. Options include the ability to navigate to a location by using a place name, go directly to an outpost and add/remove an owned outpost location on the map.

![The Integrated GIS Control Map](image)

FIGURE 5. The Integrated GIS Control Map
Screen Four

Figure six below illustrates how Outpost nodes can be selected to view the live data that they are monitoring. When a marker is selected, monitoring data is extracted from Coeus live database and displayed directly into the information box as shown.

FIGURE 6. Live Outpost Data
Screen Five

In addition to displaying an Outposts current data reading, a history of recorded data is also accessible. This information is displayed through a graph that is generated when an individual data measurement is selected. This additional data layer adds a temporal aspect to the GIS that allows data to be viewed over time, adding to the decision-making capabilities of the system.

FIGURE 7. A History of Recorded Data
2.6 Client Feedback

Coeus are pleased with the final system and have since made the service available to Metro Water. The completed application was put display at the New Zealand Waste Water Association Conference where it received interest from a number of different organisations. Metro Water’s management team have also expressed their approval of the GIS system. As a result of this they have agreed to purchase additional Outpost units to extend their monitoring capabilities in the future.
3. Technical Issues

This section focuses on the technical and software engineering issues involved in the development of Internet based GIS applications. The design and implementation of a web-based GIS is a complicated process that involves many issues that vary in their complication depending on the scale of the proposed system. The issues covered in this section include system architecture design, navigation and user-interface design and implementation software.

“Creating an Online GIS involves categorizing content, preparing data, designing the web site navigation structure, designing the interface, installing software, configuring the server(s), and testing using potential users. Periodic improvement of the service in response to user feedback is also essential to maintaining a successful Online GIS.”

Colas et al 2002

3.1 Components of a Web-based GIS

The following section describes some of the major components that make up a Web-based GIS System in order to gain an understanding of how Web-Based GIS operate.

Client/Server Architecture

The Internet uses a client server approach for distributing information. Information is stored and processed on servers and then sent to a client when it is requested. This process is usually carried out without the user having any knowledge of it (Peng and Tsou 2003). “In a client/server computing model, the element that makes a request is called a client, and the element that fulfils the request is called a server.” (Peng and Tsou 2003). This approach means that the client that displays information is separated from the site of the data processing. This can cause problems for operations that rely on processing speed (Green and Bossomaier 2002).
Hypertext Mark-up language (HTML)

HTML is the language that is used to display web pages content on a client’s computer. HTML code is sent between the client and server using the Hypertext Transfer Protocol (HTTP). A browser then renders the received HTML code in a user’s browser.

Web-based APIs

As described previously, web-based APIs provide access to GIS functionality that has been developed by external organisations. When a client sends a request to an API, the server passes this request to the program for processing. When the program responds, HTML-formatted results are sent back to the server, and subsequently to the client's browser (Colas et al 2000).

3.2 System Architecture

After the requirements of a system have been decided upon, the most important technical factor to be determined is the architecture of system. System architecture describes how the major components of a system are organised and interact with each other. This will allow for “developers to begin visualizing” (Colas et al 2000) what the proposed system will be like. A well thought out system architecture will ensure that the correct components are selected that will enable them to interact with each other properly. Without a well thought out architecture unforeseen problems might be encountered down the road that will seriously affect the success of a project.

Figure 8 below displays the typical basic overview architecture adopted by most GIS applications (Peng and Tsou 2003). In order to develop and display the full architecture of a system each of these components should be described in more detail including the software packages and languages used to implement them. In the case of the Coeus case study, the proposed system was integrated into a pre-existing system. Details of this integration should be described in the architecture of the system.
The architecture of the system developed for Coeus was made up of four major components and follows architecture similar to other web-based system such as that described by Bapna and Gangopadhyay (2005). An overview of the architecture can be seen in figure 9 below, and is also described in more detail following the diagram. The architecture consists of four tiers; a presentation layer, an application layer, a data layer and a map-generation layer.

FIGURE 9. Coeus Web-based GIS Architecture
The application layer forms the centre of the architecture and oversees the relationship between other components in the system, as well as determining how the system functions. It extracts the data requested by a client from the data layer and then processes it. This is then passed to the presentation layer to display to the client. The application layer is also responsible for performing modifications to the database layer that are requested by the client.

The presentation layer displays the combined output of the application layer and the map generation layer to the client. The Internet and HTML are used to transport this information and allow the communication between these components. In addition to the display of information, change requests are also posted to the application layer through the presentation layer. Essential system operations such as the setting of marker positions are handled through this mechanism.

The data layer is responsible for the storage and provision of data to the application layer. Databases employ Database Management Software (DBMS) that handle a number of issues including concurrent user access, and the efficient storage of data (Adam and Gangopadhyay 1997). It was necessary to create a distinctly separate database to store GIS specific information due to the distributed nature of development of this project. It was not possible to gain direct access to Coeus central database due to security concerns. The existing database already provided most of the data necessary for the GIS, including a temporal database that recorded a history of data readings.

The main function of the web service-mapping layer is the generation of the visual map layer according to the variables passed to it. Initially, the geographic co-ordinates that are passed to it determine the map that is generated. The web service also provides additional features such as the processing of standard text based addresses in geographic co-ordinates e.g. the find a location feature illustrated in figure 5 previously.

Mapping services are implemented using a combination of different languages and technologies and allow the generation and display of maps. Currently, two varieties of raster image formats are supported for display on the Internet. These are CompuServe's Graphic Interchange Format (GIF) and the Joint Photographic Experts Group (JPEG) based format. Technologies that mapping services implement include Web servers, GIS rendering and Geo coding databases. Typically these services are accessed through the
API using client-side languages that allow processing to occur on the user’s machine. Languages include JavaScript, CSS and DHTML.

The system architecture for the Coeus system was determined by the existing system that it was to be integrated with. Language selection and data-base selection also had to be compatible with what was currently being used by Coeus’ other services.

### 3.3 Implementation Software

There is wide diversity in the range of software technologies available to implement web-based GIS. The choice of the technology implemented depends on many different factors including the nature of the project itself, any existing software it must be integrated with and the environment it is to operate within.

“Companies choose a specific web application solution based on a variety of reasons, including installation requirements, language architecture, development environment, performance, and online support.” (Peng and Tsou 2003)

Web based GIS consists of four main types of different technologies as described by (Peng and Tsou 2003):

**Middleware Technology**

In order to link the client and the server together a middleware layer is necessary. Middleware processes and delivers client requests and communicates with the server. There are a number of different middleware technologies that are briefly described below from (Peng and Tsou 2003)

Remote Procedure Call (RPC) involves a client machine calling a function directly on a server and then waiting for a response to be sent back. The server then calls the requested function and sends the results to the client.

Message-Oriented Middleware (MOM) allows server requests to be queued meaning that the both the client and server do not need to be active at the same time. This is ideal for mobile GIS systems although it may cause delays in response times.
The Publish and Subscribe (PUSH) method involves a client subscribing to a server. When a server produces an event, the client is informed of this. This is important in GIS when a map has been updated and the client needs to refresh a map to reflect these changes.

**Server Side Languages**

Server-side scripting languages enable the creation of dynamic web pages. Examples of languages include:

- **Active Server Pages (ASP)** – developed by Microsoft this language is well supported by web hosting, books and online tutorials.

- **PHP** - PHP is open source, runs on Unix and Windows servers. It has a more powerful overall performance and is more flexible with cross-platform support than ASP. It is not, however, as widely supported by services such as ASP.net (Touesnard 2001).

**Integrated Development Environment (IDE)**

IDEs are software designed to assist in the development of software. They help with the design and debugging of software. Examples of IDEs include Visual Studio.NET, Eclipse and Zend IDE. Most IDE are designed to be developed with a particular language so the selection of an IDO and language impact on each other.

**Database Management Systems (DBMS)**

DBMS are described by Dale and MCLaughlin (1988) as “A computer program to control the storage, retrieval and modification of data” A DBMS allows data to be defined, provides security and provides an interface between the end-users the application and the actual data (Heywood et al 2006). SQL is the standard language to allow communication with the database from outside applications. Examples of DBMS include:

- **SQL Server** – Expensive, robust, extensive features.
- **MS Access** – Easy to develop with, limited features, low-cost.
3.4 - Navigation and user-interface design

Increased accessibility is one of the key advantages of web based GIS over stand alone GIS. In order for this accessibility to be utilized, web-based user-interfaces must be designed so that they are highly useable for the intended audience.

It is critically important to identify what the function of a system is by understanding the needs of those that will be using the system that is being developed. This is because like any system, online GIS is a form of communication, and requires that developers know their audience. This can be achieved by involving users throughout the system development lifecycle.

Extensive investigation is usually not required to identify the types and groups of a system's potential users. Most online GIS development projects begin after the potential benefits of providing particular groups with Online GIS services have become obvious (Colas 2000). The requirements of users are, however, hard to identify and require the use of requirements analysis techniques.

Guidelines for Identifying System Functionality as described by Regenbrecht 2006 include:

- Ascertain the user’s needs and then determine what tasks and subtasks they carry out.
- Include tasks that are only performed occasionally. Common tasks are easy to identify.
- Functionality must match need or else users will reject or under utilize the product.

When the requirements of the users have been discovered, alternative interface designs can be evaluated by designers through the use of mock-ups or high-fidelity prototypes (Regenbrecht 2006). The trade-off for early prototype design is getting feedback early and less expensively in the development process versus having a more real interface evaluated later in the development process (Regenbrecht 2006).
Universal Usability

The concept of universal usability refers to a system being usable by the majority of the population.

“Universal usability can be defined as having more than 90% of all households as successful users of information and communications services at least once a week”

(Shneiderman 2000)

Achieving this kind of usability is not easy and involves the consideration of many different kinds of user. When designing a system for universal usability there is no “average user”. Compromises need to be made or multiple versions of a system must be created in order to cater for as wide an audience as possible.

Universal systems need to account these difference in users as described by (Regenbrecht 2006)

- Physical abilities e.g. Vision: depth, contrast & colour blindness. Hearing abilities.
- Cognitive and perceptual abilities e.g. Problem solving and reasoning and decision making and risk assessment abilities.
- Personality differences – Different people have different responses to various stimuli
- Cultural and international diversity e.g. date and time formats, etiquette, tone and formality.
3.5 - Quality of Service

The quality of performance of a GIS system is an important issue for Internet based systems. If users are left waiting for long periods i.e. for more than 10 seconds their attention will be lost and they may become frustrated with the system. (Nielsen 1994).

When producing map images large amounts of vector and raster data must be processed and then sent to clients through a network. This means that delays need to be minimised when transmitting data and possessing requests by the server. There are two standard methods to measure the performance of a system as described by Peng and Tsou (2003):

Throughput - The amount of work processed by a server in a given amount of time.
Response Time - The amount of user perceived time between sending a request and receiving a response.

Two categories of clients exist, thin and thick clients. Thin clients have limited processing load placed on them, such as server side Web-GIS systems. Thick clients have heavy processing loads and implement plug-ins and java applets. If the response time is considered too slow for the intended operation, options for improving it can be pursued from both the client and server sides (Peng and Tsou 2003).

Client side performance depends on two major factors, the size of the workload and the speed of the client’s computer. Performance can be improved by using concurrency design. This involves sending out multiple requests at the same time instead of in a sequence. This optimises the client computer’s CPU and allows it allocate tasks more efficiently (Peng and Tsou 2003).

Servers are similarly affected by the size of workload and speed of server to process it. A properly configured server that implements multi-threading allows for the processing of multiple client requests simultaneously and leads to improved performance (Peng and Tsou 2003).
Network performance is also an important factor in overall system performance. It can be measured using throughput (bits per unit of time) and latency (user-perceived delay). In order to improve network performance the number and size of network transmissions needs to be minimised. This can be achieved with such technologies as AJAX. Asynchronous JavaScript and XML (AJAX) allows a small amounts of data to be sent from a server to a client instead of having to refresh the content of the entire page.

The GIS system developed for Coeus maximised performance by utilising thin clients and optimised server processing. In addition to this AJAX technology is used where appropriate e.g. when an outpost marker is selected and the data it is recording is displayed the information box as shown in figure 6 previously.
4. Commercial Issues

This section investigates some of the commercial issues related to the development of web-based GIS systems. The development of GIS systems originates from a consumer demand for better systems that enable them to make faster and more informed decisions. In order to be successful the GIS must meet commercial goals and integrate with existing processes within a business.

“GIS should fit seamlessly and effectively into the information technology strategy of an organisation.” (Heywood et al 2006)

4.1 - Investing in GIS

Before a decision is made to proceed with a GIS project the objectives of the proposed system need to be set out, and advantages of introducing the system need to be evaluated. Stakeholders of the business need to be persuaded that the implementation of a GIS is worthwhile.

Factors to be evaluated are described by Heywood et al (2006):

- How the proposed system fits with the overall strategy of the company. The introduction of a GIS may fit well with the strategy of a company in the case of Coeus, or else adjustments to the strategy of a company may need to be made.

- The costs and benefit of the proposed system. Developing software has been described by Sullivan et al (2001) as “investing valuable resources under uncertainty with the overall goal of maximizing value added”. The costs of these invested resources need to be evaluated against the amount of value added to an organization.
Some typical benefits of using internet based GIS as opposed to other GIS services as described by Green and Bossomaier (2002) include:

- World-wide access to information.
- Standard interfaces through the use of web-browsers.
- Faster and more cost effective maintenance as information can be modified at one central server.

A commonly used business method to determine whether or not a project is worthwhile is the cost-benefit analysis method. In this method, all of the costs and benefits of the project are identified. The monetary value of each cost and benefit is then approximated. These costs and benefits are then drawn on a graph to show the effect of these benefits and costs over time. In GIS projects there is however a degree of difficulty in identifying and quantifying these proposed costs and benefits.

![Cost-benefit Graph (Heywood et al 2006)](image)

For smaller GIS applications it has been suggested by Mounsey (1995) that the cost benefit analysis may not be worthwhile, where there is only limited development time and resources involved in the project. This can be seen in the Coeus case study where benefits were obvious in their case with their strategy of investing in technology to remain competitive.
Mounsey (1995) details a short cut method for evaluating GIS projects:

- The determination of the business drivers for GIS.
- The identification of the range of applications that the GIS will fulfil.
- The Identification of the technological framework that the GIS will operate within.
- The Development of an implementation plan.

4.2 Organisational Changes

The introduction of a new GIS often involves changes within an organisation. These changes can impact on the organisation itself and its relationship with external companies and individuals. This is evidenced by Somers et al 2001 in stating “the impact of GIS on work processes and business operations can be profound”. Depending on the scale of the introduced GIS system it may require an organisation to undergo extensive internal restructuring e.g. may require the addition of a new business analysis department (Heywood et al 2006). The amount of restructuring required will vary depending on the function of the company that is implementing the GIS.

In order to quantify the impact of organizational changes of the proposed system the role of the proposed system within an organization needs to fully understood (Somers et al 2001). This involves understanding the business environment and how the proposed application will be used.

Additional factors that should be considered as identified by Sommers et al (2001) include:

- The scope and extent of the GIS operation, including the number of users and applications.
- GIS databases and their distribution throughout the organization.
- The degree to which GIS is integrated into existing applications.
- The frequency with which the GIS will be used.
- The complexity of proposed application.
- The operational structure of the organization.
Considerations of these factors will allow for changes in an organisation to be planned for. Some of the potential issues that should be considered for when adopting a GIS system include:

- The redeployment or retraining of staff, users may need to be trained in how to operate the GIS, and understand its purpose.
- The introduction of new or modified polices regarding data security
- The involvement of users in system planning. This may take away time from their other responsibilities.
- Changes in the way employers relate to customer, competitors and employers.
5. Social Issues

This section discusses the social considerations that arise when developing GIS systems. Specifically this chapter will focus on the social issues that are brought about through the use of web based GIS systems. Accordingly, issues related to public participation GIS systems are the major focus of this section.

5.1 Public Participation in Geographic Information Systems

Public Participation in GIS (PPGIS) involves the use of GIS systems to broaden public involvement in policymaking and to promote the goals of commercial and community-based organizations (Weiner et al 2002). This is achieved through the use of GIS as a tool for communication between interest groups like planners, decision makers and the public (Banger 2006). The Internet allows the collaborative use and input of data into a GIS system.

“In a fair society, all individuals would have equal opportunity to participate in, or benefit from, the use of computer resources regardless of race, sex, religion, age, disability, national origin or other such similar factors.”

(ACM Code of Ethics)

PPGIS are used for economic development, environmental dispute resolution, participatory planning, and other activities that involve public collaboration. The increased usage of the Internet and the development of web-based GIS have made public participation GIS systems much easier to implement and much more prevalent. PPGIS should be capable of managing and integrating all data components from different participant contributions. This requires an accessible medium. “The Internet and Web-based GIS is an effective medium for PPGIS” (Banger 2006).

Traditional methods of public participation in GIS as identified by (Kingston et al 2000) involve the public members being invited to organized planning meetings. This kind of public participation has disadvantages including a possible atmosphere of confrontation leading to only certain views being expressed. Limited accessibility to these meetings also leads to certain views being disproportionately expressed by those who are in attendance.
As it stands Coeus GIS system is currently private. Coeus has however envisioned the addition of a PPGIS to help to market their services. The system would allow individuals and businesses to sample the kind of services that Coeus can perform. It would involve the setting up of several Outposts around Auckland to record data of interest e.g. weather conditions. This would then be made available on a public website. There are however potential issues involved in this that are discussed in the following section.

5.2 Developing PPGIS Applications

A PPGIS approach to the development of applications involves designing an application that is capable of representing the diverse views of different participants. This application should be built using existing GIS tools and methodologies that have been described previously.

“A public participation approach would situate GIS analytical tools within an expanded framework of communication and discourse, opening opportunities for public participation across the processes of problem definition and problem resolution” (The National Center for Geographic Information and Analysis, 1996).

Particular aspects that need to be considered when developed PPGIS system as described by Kingston et al 2000 are that:

- A PPGIS should provide equal access to data and information to all participants of a community.
- A PPGIS should have the ability to provide the necessary data and information to meet the needs of the community who are participating in it.
- Trust and transparency needs to be established and maintained to give a PPGIS legitimacy and accountability.
4.3 Security and Data Privacy Issues

Data security and privacy considerations can pose a number of potential problems for GIS thus it is crucial that they are evaluated early in the design process.

“In providing instant access to vast amounts of data, GIS also provide the opportunity to abuse, to misinform and to invade the privacy of individuals on a greater scale than ever before.” (Cho 1998)

PPGIS involves different groups pooling their data and having trust in each other that the data will not be misused e.g. the disclosure of the location of a person or items requires trust in the people who have access to that data. The disclosure of exact locations can be a problem e.g. if Coeus set up a PPGIS with exact locations of Outposts devices it would be possible that people could steal them. A possible solution to this could be adding a range of uncertainty of plus or minus 500 meters to the location of the outposts. This could however have an impact on the quality of the system if decisions are being made based on the accuracy of the location of the outpost devices.

Data can also take on different meanings depending on the person who is viewing it. Epstein (2000) states that the law needs to keep up with this complexity to ensure data is not being used inappropriately.

Care also needs to be taken when selecting system architecture and the security of data it will provide, along with how that system is maintained. This is evidenced in Epstein (2000) stating, “An appropriate level of care must be used in the selection and maintenance of the system”. It is very difficult to have a system without any data errors. The tasks that a system will perform should be considered along with the issues that could arise from having inaccurate data. The likelihood and impact of these events occurring should then be evaluated to give an idea of chances of potential problems occurring.

The accuracy of system data should also be considered, as incorrect data can result in devastating consequences depending on the application of the system. There may also be grounds for legal actions depending if proper care is taken with regard to data accuracy. Organisation policies should be developed to address the issue of data privacy.
6. Findings and Conclusion

This section discusses and explicitly links the technical, commercial and social issues that have been discovered and detailed in the previous sections. Linkages between couples of perspectives are discussed first, with analysis from both sides. This is followed by a review of the linkages between all the three perspectives. Conclusions are then drawn about the ramifications of these linkages.

6.1 Technical & Commercial Linkages

The commercial viability of a system is the driving force behind whether or not the technical development of a system will proceed. Methods such as cost benefit analysis help to determine whether the benefits of a proposed system will outweigh its costs. However, in order for this analysis to be carried out properly there needs to be a detailed understanding of the technical issues involved in the system development. Such technical issues include the system architecture and implementation technologies that the application will use. This requires the presentation of technical issues to managers and business decision makers so that they can factor in these issues when deciding whether or not a GIS project should be undertaken.

This approach demands that detailed requirements of the proposed system are gathered in advance of project acceptance, in order to gauge what the technical issues are likely to be. This is supported by Sommers et al (1998) in stating that “Analysis and planning are critical activities that must be carefully completed before beginning GIS implementation.” This causes a conflict, as creating detailed requirements and committing to the design of a system in a certain way, will mean that it is inflexible to the changing requirements of users. Both the technical and commercial perspectives point to the importance of a user-centric development approach. The main feature of this approach is that user input is taken into account throughout the development process of the system. This can lead to a very different system from what was originally envisioned.
There is also currently a lack of cohesion between the technical and commercial development of systems. This is evidenced by Sullivan et al (2001) by stating that “Our critique of current software design thinking is that no strong links are made from the use of technical design concepts to the goal of economic value added”.

My findings suggest that people working within the commercial and technical perspectives need to maintain close links with each other for the development of GIS systems. Using this relationship they will be able to facilitate a semi-structured design process that allows for the planning that the commercial perspective requires, whilst still leaving room for changes in a user-centred design approach. This will be achieved through communicating and understanding their different view points.

This reinforced by Sommers (1998) stating that “While the technical tasks involved in system design and implementation are occurring, the organizational issues that facilitate the design and affect the implementation and adoption of the GIS must also be addressed. The key to success is coordinating all of the goals, activities, and impacts.”

Facilitating this approach should stem from the management of an organization and can be evidenced by the (Louisiana GIS Council) in stating “An important role for any manager is to build a bridge between policy makers, their goals, and the technical staff.”

Commercial and technical issues can also be viewed from the opposing viewpoint. This is that the technical design of a system effects how well it meets the requirements of users and thus how much of a commercial success it is. This is evidenced by Sullivan et al (2001) in stating that “the structure of a software product, process or project influences its economic value in critical and often decisive ways.”
6.2 Social & Technical Linkages

Social issues have a considerable impact on the technical decisions made in the implementation of a GIS project. There is however a lack of literature that compares technical and social linkages to discuss this relationship. Clear examples of how social issues impact on the technical aspects of how a system is implemented can however be identified. PPGIS systems require a universal usability approach to the design of the user interface. In order to facilitate this approach, technical issues that need to be considered include the architecture of a system and the language that it implements. Quality of service issues also need to be considered when using PPGIS.

A user-centric approach to the design of a system is particularly important when developing PPGIS. PPGIS systems require that user interfaces facilitate universal accessibility. This kind of accessibility can only be achieved through knowing the potential users of a system and developing the technical requirements of the system to cater to the needs of these users.

Inversely, the technical attributes of a system impact on whether or not social issues arise. The development of well thought out systems can mean that social issues such as data security and data reliability are not issues for the users of a system.

6.3 Commercial & Social Linkages

Social Issues have a direct impact on commercial aspects of an application. When social issues are pertinent to a large base of the users, these concerns will be pushed through to the commercial perspective. The commercial perspective will then seek to solve these issues in order to fulfil user requirements. This can be evidenced in such areas of concern as data security. Social concern for this issue has caused a shift in the way GIS are developed and guidelines have been designed to address this social issue.

In addition to this, social issues for PPGIS systems also introduce new problems that have an impact on the commercial viability of a system, and the way that people use a system.
6.4 Overall Linkages

It is clear that additional linkages exist between all of the different perspectives and knock-on effect occurs. This can be seen by the fact that a change in one perspective can cause a change in another perspective; this change can then go on to effect the other remaining perspective. This can be evidenced by the social issue of data reliability also becoming a commercial issue in order to satisfy the requirements of the system users. This issue is then in turn passed on to the technical perspective where the data reliability functionality is implemented within the system.

A user-centric design methodology is a concept that appears across multiple literature sources in each of the different perspectives. This reinforces the fact that the system users are of the utmost of importance when developing GIS systems.

“Making computer-based products (and services) more usable is smart business. Usability increases customer satisfaction and productivity, leads to customer trust and loyalty, and inevitably results in tangible cost savings and profitability.” Marcus (2002)

6.5 Conclusion

The Technical, Commercial and Social perspectives all play an important role in development of successful web-based GIS systems. Issues from one perspective impact on issues in another perspective, so it is critical that when a web-based GIS is designed, issues from all perspectives are considered.

The issues involved from each of these perspectives needs to be evaluated and planned for before a GIS project is embarked upon. A compromise must however be met because if a system is too rigid in its requirements, it may end up not being able to adapt to the changing requirements of system users. The solution is the strong communication and sharing of ideas from people involved in all of the described perspectives of internet based GIS.
7. References


Mounsey, H 1995 ‘GIS: Justification in the face of Organizational change’ GeoInformation International, Banbury, UK, pp. 25-8


Peng, Z, Tsou, M 2003 ‘Internet GIS. Distributed geographic information services for the Internet and wireless networks’ John Wiley & Sons, New Jersey, United States of America.
Regenbrecht, H 2006 ‘Usability of Interactive Systems’
http://www.hci.otago.ac.nz/info340/Lecture2_Usability/INFO340_lecture02_Usability.pdf


Sullivan, K, Chalasani, P, Jha, S & Sazawal, V 2001 ‘Software Design as an Investment Activity: A Real Options Perspective’, National Science Foundation

Touesnard, B 2001 ‘Active Server Pages 3.0 Versus Hypertext Preprocessor 4.0’ The University of New Brunswick. Faculty of computer science.


http://books.google.com/books?id=x4e2IVV0u9gC&pg=PA3&lpg=PP19&dq=GIS+definition&sig=us5Af5BvSegvqYfZxwBVYXCBXKA