UNIVERSITY OF NAIROBI

IMPLEMENTATION OF SERVER GIS: CASE STUDY OF ESRI EASTERN AFRICA AND OAKAR SERVICES

PROJECT REPORT

BY

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F56/P/7767/06

A project submitted to the Department of Geospatial and Space Technology in partial fulfillment of the requirements for the award of the degree of:

Master of Science in Geographic Information Systems

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DECLARATION

This project is my original work and has not been presented for a degree in any other university to the best of my knowledge. No part of this work should be produced without the prior permission of the author and/or University of Nairobi.

Signed: ____________________ Date: ____________________

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I confirm that the candidate under my supervision carried out the work reported in this project.

Signed: ____________________ Date: ____________________

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DEDICATION

This work is dedicated to my family. Thank you for your unwavering support through the years. You are my inspiration.

ACKNOWLEDGEMENT

My sincere thanks go to my supervisor, Dr. –Ing J.B.K. Kiema and the University of Nairobi's Department of Geospatial and Space Technology staff members who guided me throughout my studies and in accomplishing this project.

Thanks to my classmates, workmates and friends who always helped whenever necessary.

God bless you all abundantly.

ABSTRACT

Most geo-referenced (spatial) data related to ESRI Eastern Africa and Oakar Services Limited is held in desktop GIS systems. Server GIS is experiencing tremendous growth and gaining popularity in terms of use, especially as a platform to enable sharing of GIS data and information.

The purpose of this project was to explore various server GIS options available, identify the most suitable one, implement a prototype of it, recommend it and schedule for its full scale implementation. The project case study was ESRI Eastern Africa and Oakar Services Limited. Selected existing data was imported to be used in the prototype server GIS.

The server GIS will enable performance of all the tasks of the current desktop GIS systems and in addition, provide functionality to aid in the efficient management of the GIS data. The server GIS shall enable more efficient sharing of data, information and GIS products amongst users. It shall also provide necessary and accurate information, including maps, as and when needed by the end user quickly and efficiently thus enabling timely and sound management.

Keywords: GIS, server GIS, desktop GIS, spatial data, maps

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LIST OF ABBREVIATIONS

CPU	Central Processing Unit
DBMS	Database Management System
ESRI	Environmental Systems Research Institute
ESRI EA	ESRI Eastern Africa
GIS	Geographic Information System
GUI	Graphical User Interface
ISO	International Organization for Standardization
LAN	Local Area Network
OGC	Open Geospatial Consortium
ORDBMS	Object-Relational Database Management System
OSL	Oakar Services Limited
P2P	Peer-to-Peer
PC	Personal Computer
RAM	Random Access Memory
RDBMS	Relational Database Management System
RS	Remote Sensing
SQL	Structured Query Language
URL	Uniform Resource Locator
WAN	Wide Area Network

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

There has been a phenomenal growth in the use of Geographic Information Systems (GIS) in recent years. This can be attributed to numerous factors some of which include: advances in capability and increased availability of GIS software, increased availability of spatial data and its vendors, increased number of users of GIS due to increased awareness via seminars, training sessions, websites and academic programs, reduction in the cost and increased availability of computer hardware, growth of the internet and man's continual drive towards achievement of a "global village".

GIS developed in several different parallel channels that were centered on institutions and vendors. These various channels can be summarized into major events that shaped the development of GIS as follows:

The first known automated mapping was produced in 1957 by Swedish meteorologists and British biologists. The next was the development of Canada Geographic Information System in 1963, introducing the term GIS. Harvard Laboratory for Computer Graphics and Spatial Analysis was formed in 1964 and led to the creation of SYMAP the first raster GIS in 1966. The first GIS books such as "Design With Nature" by Ian McHarg were published in 1969. The first digitizing production line was set up by the ordnance survey of Britain in 1973. 1976 saw GIMMS (a vector-based mapping and analysis system) used in 300 sites worldwide. In 1981, the first major commercial GIS software, ArcInfo was launched. It was based on vector and relational database data model and set a new standard for the industry. First accessible source of information about GIS was a collection of papers published in book form in 1984. In 1986 MapInfo software develops into first major desktop GIS product. GIS World the first worldwide magazine devoted to GIS published in 1988. Digital Chart of the world, the first integrated 1:1 million scale database offering global coverage launched in 1992. The OpenGIS Consortium of GIS vendors, government agencies and users is formed to improve interoperability was formed in 1994. 1995 saw the first complete national mapping coverage by the British Ordnance Survey. 1996 was the year that saw the introduction of internet GIS products by Autodesk, ESRI, Intergraph and MapInfo. MapQuest internet mapping service was also launched the same year. In 1999, the first GIS Day was held. The core users of GIS hit the 1 million mark in the year 2000 with casual users at 5 million. Online National Atlas of the United States launched in 2002 while online national statistics for the UK launched 2003. 2003 also saw the launch of Geospatial One-Stop, a US Federal E-government initiative providing access to geospatial data and information **(Longley et al, 2005).**

The whole of GIS now centers on enterprise architecture. It is also believed that the value is in the quality of data, viz accuracy, completeness, consistency and up-to-dateness as we move forward. Enterprises face a greater need to understand location. GIS is therefore no longer a complex technology of domain specialists. GIS is now demonstrating its value across the enterprise **(Reddy, 2007)**.

An enterprise GIS is a geographic information system that is integrated through an entire organization so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualization, analysis, and dissemination **(Wikipedia, 2008).**

In the last few years a new method of software interaction has evolved that allows software systems to communicate over the web using a web services paradigm. A web service is an application that exposes its functions via a well-defined published interface that can be accessed over the web from another program or service. This new software interaction paradigm will allow geographically distributed GIS functions to be linked together to create complete GIS applications **(Longley et al, 2005).**

With the growth of GIS more and more people are holding vital data and information within their GIS systems, majority of these GIS systems are at the desktop level. The desire to share this data and information held in these GIS systems with others (both within and outside their organizations) leads to a new need. How can GIS data and information be effectively and efficiently shared?

Majority of computer's are connected to a network (local area network and/or the internet), the solution lies in having the ability to share GIS data and information through these existing networks. It is this thinking that has led to the emergence and growth of server GIS.

This growth of server GIS is two-pronged: Use of thin client-server GIS setups where GIS capability and functionality primarily lies on the server and thick client-server setups where GIS capability and functionality primarily lies on the client while the server is used for data storage, publishing and serving of final products.

ESRI Eastern Africa (ESRI EA) is the authorized distributor of Environmental Systems Research Institute (ESRI) products and a Trimble Business Partner for Mapping & GIS serving Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania and Uganda **(ESRI EA, 2008)**. ESRI EA began trading in the year 2007. Before its formation, its sister company, Oakar Services Limited (OSL) was the authorized distributor.

Oakar Services Limited (OSL) is Eastern Africa's leading GIS and Remote Sensing (RS) consulting firm helping to deliver solutions that enable our clients to become high-performance businesses. OSL has been providing GIS solutions to hundreds of clients in Eastern Africa since the late nineties **(OSL, 2008)**.

1.2 PROBLEM STATEMENT

ESRI EA and OSL have a lot of data and information that is held in numerous desktop computers within the desktop GIS environment. There has been a growing need for the sharing of this GIS data. This has led to duplication of data and also non-uniformity of data held by different people in their GISs (some having more up-to-date data than others). There is therefore a need to implement server GIS so as to leverage the benefits of shared resources such as data, processing capabilities and user interfaces.

Server GIS is an increasingly popular trend in the world today. It seeks to harness the advantages of client-server architecture which have been established over time within the Information Technology industry and integrate them into GIS. Organizations continually strive to have all persons within it having access to the same up-to-date information.

This project sought to consider server GIS solutions and implement a prototype of the most suitable solution for ESRI EA and OSL so as to derive maximum benefits from a synergized desktop and server GIS combined environment.

1.3 OBJECTIVES

The main objective of the research project was to identify and implement server GIS for ESRI EA and OSL.

1.3.1 SPECIFIC OBJECTIVES

1) To identify various server GIS options available.
2) To recommend the best option and implement it.
3) To import/transfer data.
4) To produce and consume resources from workstations using server GIS.

1.4 JUSTIFICATION AND LIMITATIONS

The implementation of server GIS will greatly improve data sharing and especially so between persons working on the same project. It will also ensure all persons within the organizations have the same holistic view of the latest up-to-date data.

This research project was limited to the two organizations, ESRI EA and OSL and the data already held by them and did not involve data collection or data acquisition. It also focused on sharing of data within the two organizations and not with the outside world.

CHAPTER 2: LITERATURE REVIEW

2.1 GIS DEFINED

Many definitions of GIS have been suggested over the years, and none of them is entirely satisfactory, though many suggest it is more than a technology. Two well expressed definitions of GIS are:

A Geographic Information System is the organized activity by which people: measure aspects of geographic phenomena and processes, represent these measurements, usually in the form of a computer database, to emphasize spatial themes, entitles, and relationships; operate upon these representations to produce more measurements and to discover new relationships by integrating disparate sources, and transform these relationships to conform to other frameworks of entities and relationships. These activities reflect the larger context (institutions and cultures) in which these people carry out their work. In turn, the GIS may influence these structures **(Chrisman, 2003).**

A Geographic Information System is a computer system for capturing, storing, querying, analyzing and displaying geospatial data. Geospatial data, also called geographically referenced data, are data that describe both the locations and characteristics of spatial features such as roads, land parcels and vegetation stands on the earth's surface **(Chang, 2008).**

Administrative and regulatory responsibilities have placed tremendous pressure on existing information delivery systems. The traditional methods of acquiring, storing and analyzing spatially referenced data are proving to be too costly and inflexible. Organizations must quickly respond to the complicated problems associated with geographically referenced data sets. Some of the more common problems include **(Aronoff, 1993)**:

1) Spatial information is poorly maintained or is out of date. This may take the form of outdated maps, long delays in processing map revisions or inaccurate

data records and summaries. User mistrust of the quality of the information may lead to the use of the alternative data sources.

2) Spatial data is not recorded or stored in a standardized way. The geographic coordinate systems may differ and map scales may vary, making it difficult to use multiple data sets together.

3) The spatial data may not be defined in a consistent manner. In some cases, different departments may require that similar data be organized using different classification systems.

4) Data are not shared. This may result from fear of misuse or because potential users would not know of the existence or whereabouts of the data. As a result users may keep their own copy of the original data leading to duplication of data, resulting in the existence of different versions which will not be updated at the same time.

5) Data retrieval and manipulation capabilities are inadequate. The retrieval of information such as routine reports may be too slow and the ability to perform complex or special purpose analyses of spatial information may be limited or non-existent.

6) New demands are made of the organization that cannot be met using the current information system. The organization’s mandate may be changed or a new legal requirement may take effect that cannot be satisfied without the capabilities of server GIS. To be prepared for the unexpected, unlimited expansion of the data base is often made a system requirement.

GIS differ from other information systems in that the data contained in them can, as a special characteristic, refer to objects or phenomena with a specific location in space and therefore have a spatial address. In addition they have the capability to store attribute data related to the objects or phenomena. It is the spatial analysis capabilities of the computer-based GIS that distinguish it from related graphics-oriented systems like computer-aided design and drafting.

The analysis of complex, multiple spatial and non-spatial data sets in an integrated manner forms the major part of a GIS's capabilities. It is a function that cannot be done effectively with manual methods or with computer-aided design and drafting systems. These spatial analysis capabilities of a GIS together enable geo-referenced information to be created and used in a completely different context than before **(American Society for Photogrammetry and Remote Sensing, 1997)**.

Hence, a GIS would integrate the spatial and non-spatial aspects of objects or phenomena of interest. Not only can diverse data sets be integrated, diverse procedures can also be integrated.

Further, maps are no longer the final products they used to be. The paper map functioned and functions as a medium of storage and presentation of geospatial data. The introduction of GIS and indeed on-screen maps and their corresponding databases resulted in a split between these functions **(Menno-Jan and Ferjan, 2003)**.

GIS has provided an exciting potential for geographic information to be used more systematically and by a greater diversity of disciplines than ever before. For example GIS based Land Information Systems are used for various tasks including: land registration, conveyance, taxation and valuation, utility management, planning and mapping.

2.2 GIS IMPLEMENTATION

GIS is implemented at several levels **(Longley et al, 2005)** identify four levels, namely: Project, Workgroup, Enterprise and Societal.

Usually GIS is first introduced into organizations in the context of a single, fixed-term project. An operational GIS is assembled for the duration of the project. The 'one-off' nature of projects, coupled with an absence of organizational vision often leads to duplication as each project develops different hardware, software, data, people and procedures. Sharing data and experience is usually a low priority.

As interest in GIS grows, to save money and encourage sharing and resource reuse, several projects are amalgamated. This often leads to creation of common standards, development of a focused GIS team and procurement of new GIS capabilities. Yet it is quite common for different departments to have different GIS software and data standards.

As GIS becomes more pervasive, organizations learn more about it and begin to depend on it. This leads to the realization that GIS is a useful way to structure many of the organization's assets, processes and workflows. Through the process of natural growth and possibly further major procurement, GIS gradually becomes accepted as an important enterprise-wide information system. At this point GIS standards are accepted across multiple departments and resources to support and manage the GIS are often centrally-funded and managed.

A fourth type of societal implementation has additionally been identified in which hundreds or thousands of users become engaged in GIS and connected by a network. Today there are few examples of societal implementations with perhaps the best being the State of Qatar in the Middle East where more than 16 government departments have joined together to create a comprehensive nationwide GIS with thousands of users.

Diagrammatically, these can be shown as in Figure 1 **(Kiema J.B.K., 2007/2008)**:

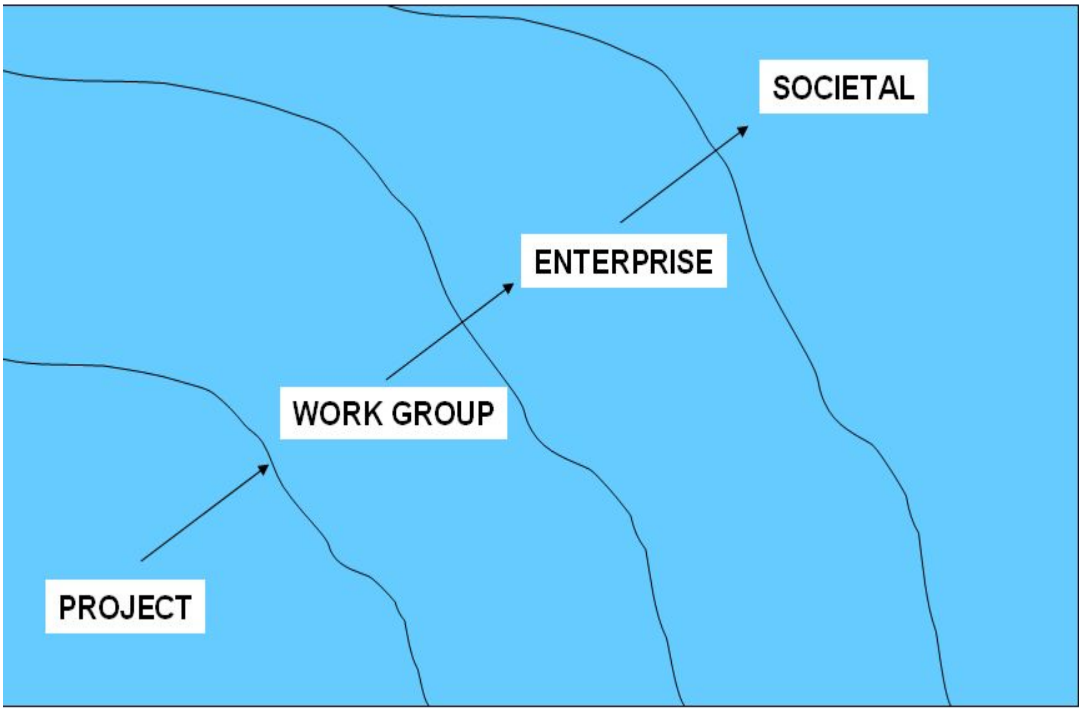


Figure 1: GIS Implementation Levels

2.3 KEY GIS PARTS

From an information systems perspective there are three key parts to a GIS: the user interface, the tools and the data management system. In standard information system terminology this is a three tier architecture with the three tiers being called: presentation, business logic and data server.

The user's interaction with the system is via a graphical user interface (GUI), an integrated collection of menus, tool bars and other controls. The GUI provides access to the GIS tools.

The toolset defines the capabilities or functions that the GIS software has available for processing spatial data.

The data is stored in files or databases organized by data management software.

Diagrammatically they are represented as shown in figure 2 **(Kiema J.B.K., 2007/2008)**:

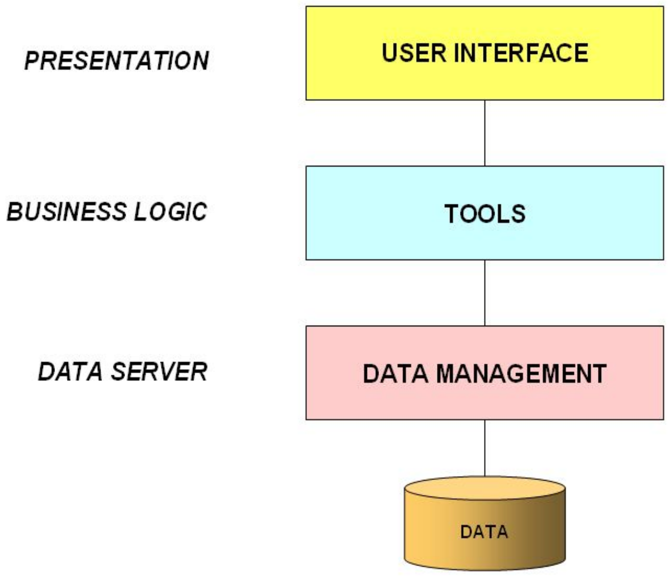


Figure 2: Key GIS Parts

Based on the above schema in figure 2, we may represent the GIS implementations diagrammatically as illustrated in figures 3 and 4:

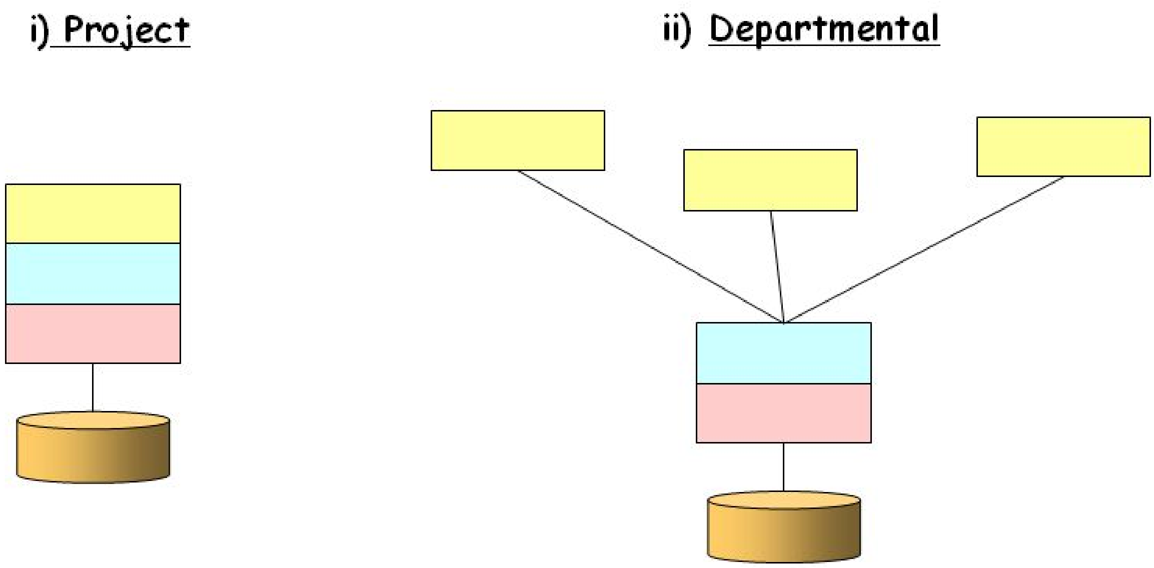


Figure 3: Project and Departmental GIS Implementation Representations

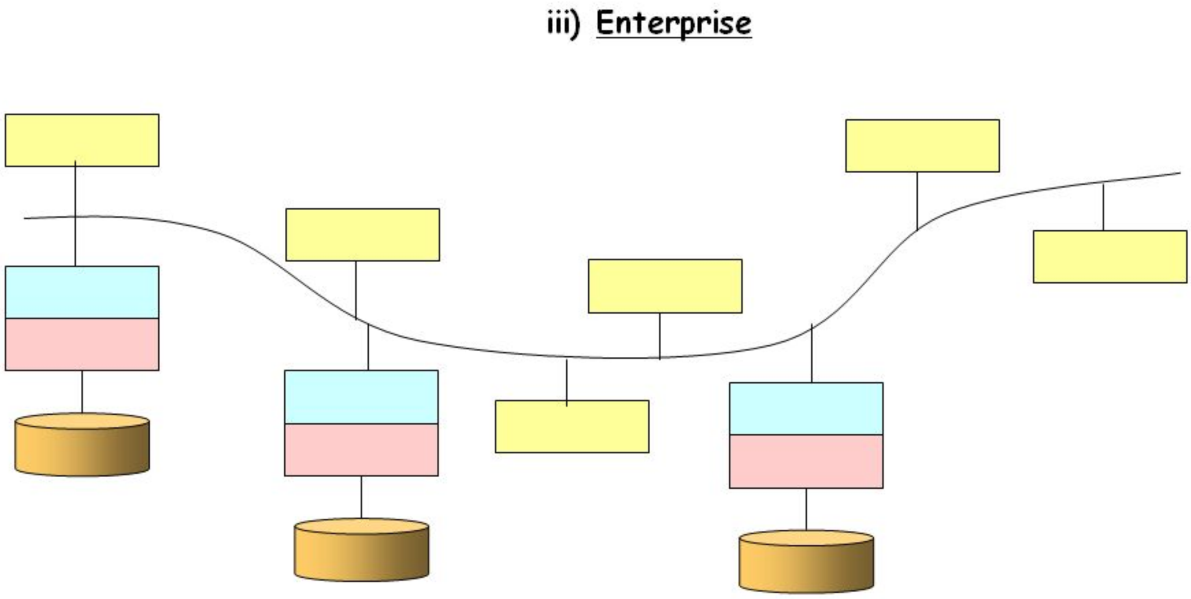


Figure 4: Enterprise GIS Implementation Representations

Four types of computer system architecture configurations are used to build operational GIS implementations: desktop, client-server, centralized desktop and centralized server.

In the simplest desktop configuration, as used in single-user project GIS, the three software tiers are all installed on a single desktop personal computer (PC).

In a variation of this theme, data files are handled on a centralized server, but the data server functionality is still part of the desktop GIS. This means that the entire contents of any accessed file must be pulled across the network even if only a small amount of it is required.

In larger and more advanced multi-user workgroup or departmental GIS, the three tiers can be installed on multiple machines to improve flexibility and performance. In this type of configuration, the users in a single department still interact with a desktop GIS GUI on their desktop computer which also contains all the business logic but the database management and data may be located on another computer connected over the network. This is client-server architecture.

Both the desktop and client-server architecture configurations discussed above have significant amounts of functionality on the desktop and are said to be thick clients. In contrast, in the centralized desktop architecture configuration all the GUI and business logic is hosted on a centralized server called an application (or middle tier) server. An additional piece of software is installed on the application server allowing users on remote machines full access to the software over a local area network (LAN) or wide area network (WAN). Here the desktop PCs are said to be thin clients.

In a more common variation of the centralized desktop implementation, the business logic is implemented as a true server system and runs on a middle tier server machine. In this configuration a range of thick and thin clients running on desktop PCs, web browsers and specialist devices communicate with the middle tier server over a network connection. The server machines may be connected over a LAN but increasingly the internet is used to connect widely distributed servers. This implementation is common in enterprise GIS.

Although organizations often standardize on either project, departmental or enterprise system, it is common for large organizations to have all operating in parallel or as subparts of a full-scale system.

Diagrammatically, these architecture configurations can be represented as shown in figures 5 to 8 **(Kiema J.B.K., 2007/2008)**:

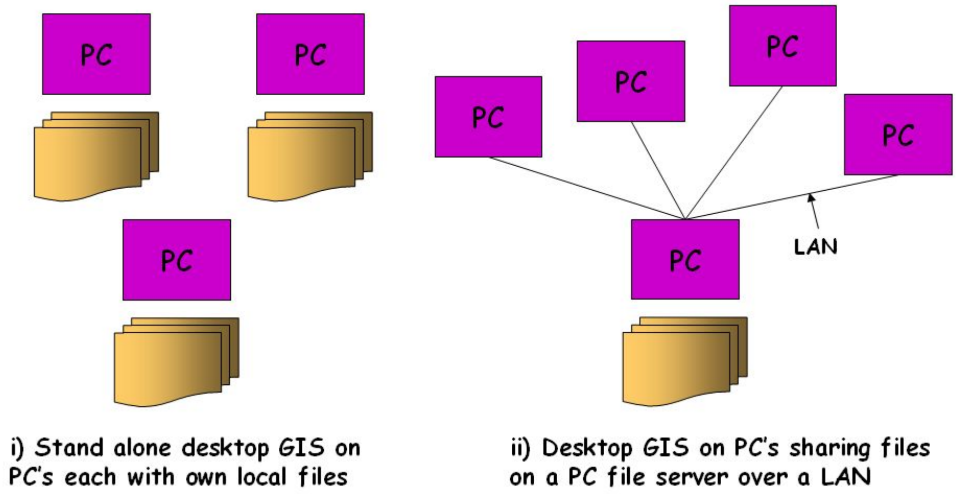


Figure 5: Architecture Configurations-Desktop

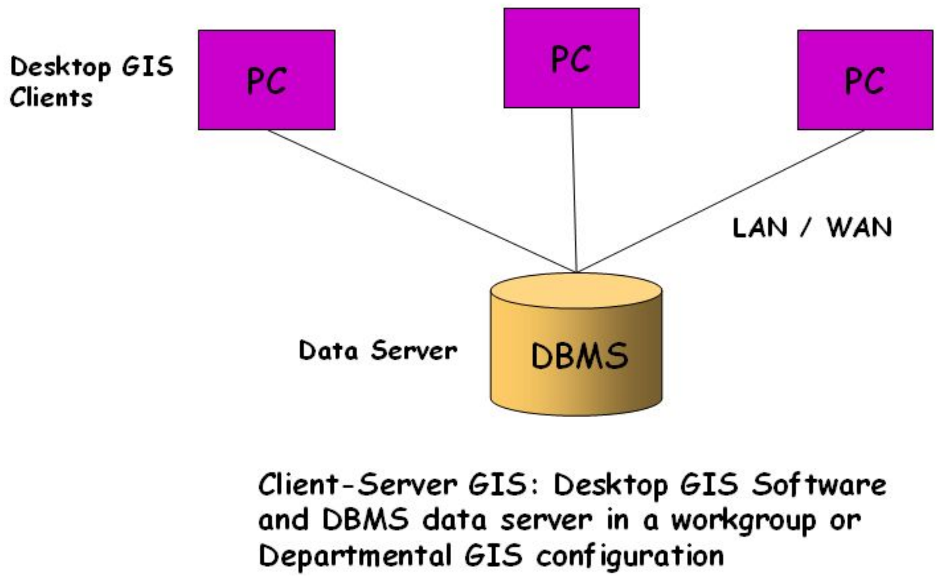


Figure 6: Architecture Configurations-Client-Server

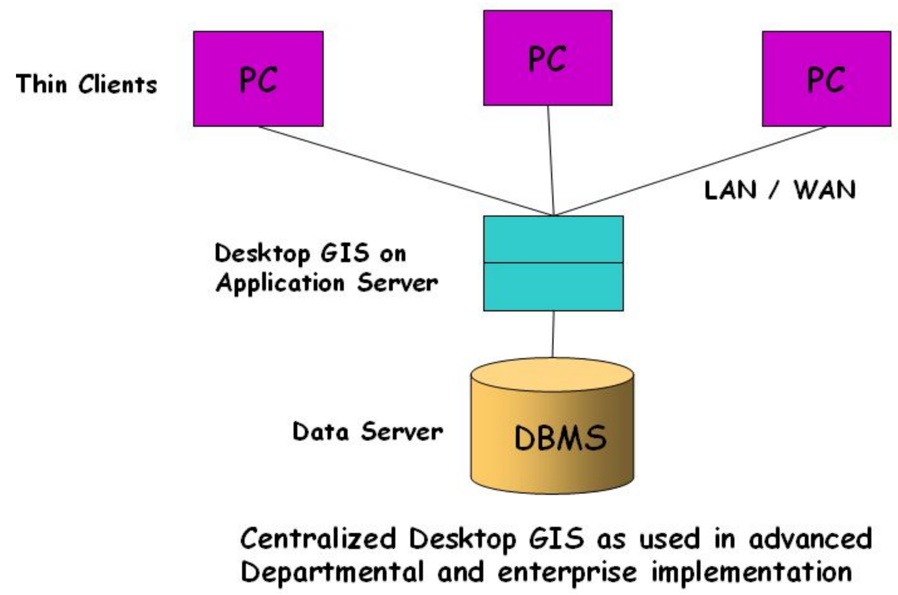


Figure 7: Architecture Configurations-Centralized Desktop

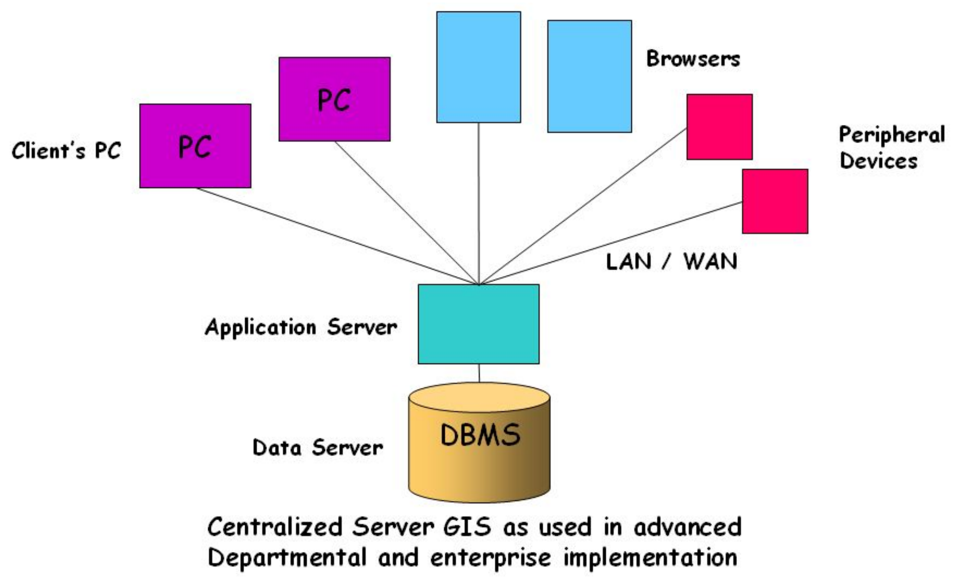


Figure 8: Architecture Configurations-Centralized Server

2.4 DATABASE MANAGEMENT SYSTEM

A key component of server GIS is the database management system (DBMS). A DBMS is defined as "a software system that enables users to define, create and maintain the database and provides controlled access to this database" **(Connolly and Begg, 1998).** A database is defined as "a shared collection of logically related data (a description of this data), designed to meet the information needs of an organization" **(Connolly and Begg, 1998).**

A relational DBMS (RDBMS) is a DBMS that is based on the relational model as introduced by E. F. Codd. Most popular commercial and open source databases currently in use are based on the relational model **(Wikipedia, 2008).** The relational model is based on the mathematical concept of a relation, which is physically represented as a table with rows and columns. An attribute is a named column of a relation while a tuple is a row in a relation **(Connolly and Begg, 1998).**

Spatial data differs quite significantly from other data in terms of form and structure. Typically what makes a database spatial is the connection of the data to a geographically referenced co-ordinate system. Storage of spatial data within a DBMS requires careful consideration as it is not inherently possible in traditional DBMSs. Most available RDBMSs have directly or through extensions implemented support for these spatial data in particular and objects in general **(Pick, 2004).**

An object-relational database management system (ORDBMS) is a database management system (DBMS) similar to a relational database, but with an object-oriented database model: objects, classes and inheritance are directly supported in database schemas and in the query language. In addition, it supports extension of the data model with custom data-types and methods **(Wikipedia, 2008).**

ORDBMS are systems that “attempt to extend relational database systems with the functionality necessary to support a broader class of applications and, in many ways, provide a bridge between the relational and object−oriented paradigms.” Whereas traditional RDBMS or SQL-DBMS products focused on the efficient management of data drawn from a limited set of data-types (defined by the relevant language standards), an object-relational DBMS allows software-developers to integrate their own types and the methods that apply to them into the DBMS.

ORDBMS was created to handle new types of data such as audio, video, and image files that relational databases were not equipped to handle. In addition, its development was the result of increased usage of object−oriented programming languages, and a large mismatch between these and the DBMS software.

One advantage of ORDBMS is that it allows organizations to continue using their existing systems, without having to make major changes.
A second advantage is that it allows users and programmers to start using object−oriented systems in parallel.

Since the development of RDBMS and ORDBMS, many vendors have extended their systems with the ability to store new data types such as images and texts, and with the ability to ask more complex queries **(Chaterjee J., 2008).**

2.5 SERVER GIS

Server GIS systems have emerged as the spatial data handling tools of choice for solving complex geographical problems, the advent of computer technology having stimulated the development of GIS. Various advantages and disadvantages of sever GIS have been cited: **(Wikipedia, 2008 and Sadoski D., 2008).**

Advantages include:

1) In most cases, client-server architecture enables the roles and responsibilities of a computing system to be distributed among several independent computers that are known to each other only through a network. This creates an additional advantage to this architecture: greater ease of maintenance. For example, it is possible to replace, repair, upgrade, or even relocate a server while its clients remain both unaware and unaffected by that change. This independence from change is also referred to as encapsulation.

2) All the data is stored on the servers, which generally have far greater security controls than most clients. Servers can better control access and resources, to guarantee that only those clients with the appropriate permissions may access and change data.

3) Since data storage is centralized, updates to those data are far easier to administer than would be possible under a peer-to-peer (P2P) paradigm. Under P2P architecture, data updates may need to be distributed and applied to each "peer" in the network, which is both time-consuming and error-prone, as there can be thousands or even millions of peers.

4) Many mature client-server technologies are already available which were designed to ensure security, 'friendliness' of the user interface, and ease of use.

5) It functions with multiple different clients of different capabilities. This improves performance on the client computers.

Disadvantages include

1) Traffic congestion on the network has been an issue since the inception of the client-server paradigm. As the number of simultaneous client requests to a given server increases, the server can become severely overloaded. Contrast that to a P2P network, where its bandwidth actually increases as more nodes are added, since the P2P network's overall bandwidth can be roughly computed as the sum of the bandwidths of every node in that network.

2) The client-server paradigm lacks the robustness of a good P2P network. Under client-server, should a critical server fail, clients' requests cannot be fulfilled. In P2P networks, resources are usually distributed among many nodes. Even if one or more nodes depart and abandon a downloading file, for example, the remaining nodes should still have the data needed to complete the download.

2.6 STANDARDS

Standards are very important in today's world and especially so in the technological fields. There are several organizations that are involved in the development and publishing of standards. The International Organization for Standardization (ISO) is the best known such organization. ISO is the world's largest developer and publisher of International Standards. ISO is a network of the national standards institutes of 157 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. The ISO Technical Committee 211 (ISO/TC 211) is charged with the development of geographic information standards.

However in the GIS industry, the Open Geospatial Consortium, Inc. (OGC) is the most notable and authoritative standards body. This is because OGC has by far more GIS-related standards due to its concentration on the GIS standards industry.

OGC is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services **(OGC, 2008).**

The Open Geospatial Consortium, Inc (OGC) is an international industry consortium of 369 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications **(OGC, 2008).**

For this project, OGC standards shall be used as the basis for the evaluation of server GIS software and their functionalities or capabilities.

CHAPTER 3: METHODOLOGY

The project was divided into several parts as follows: Product/Solution scoping, implementation, data importation/transfer, integration.

3.1 PRODUCT/SOLUTION SCOPING

This stage involved finding out the various sever GIS products/ solutions are available, analyzing them and recommending the best product/solution.

The following generic method was used as a guide **(Longley et al, 2005 and Kiema J.B.K., 2007/2008)**:

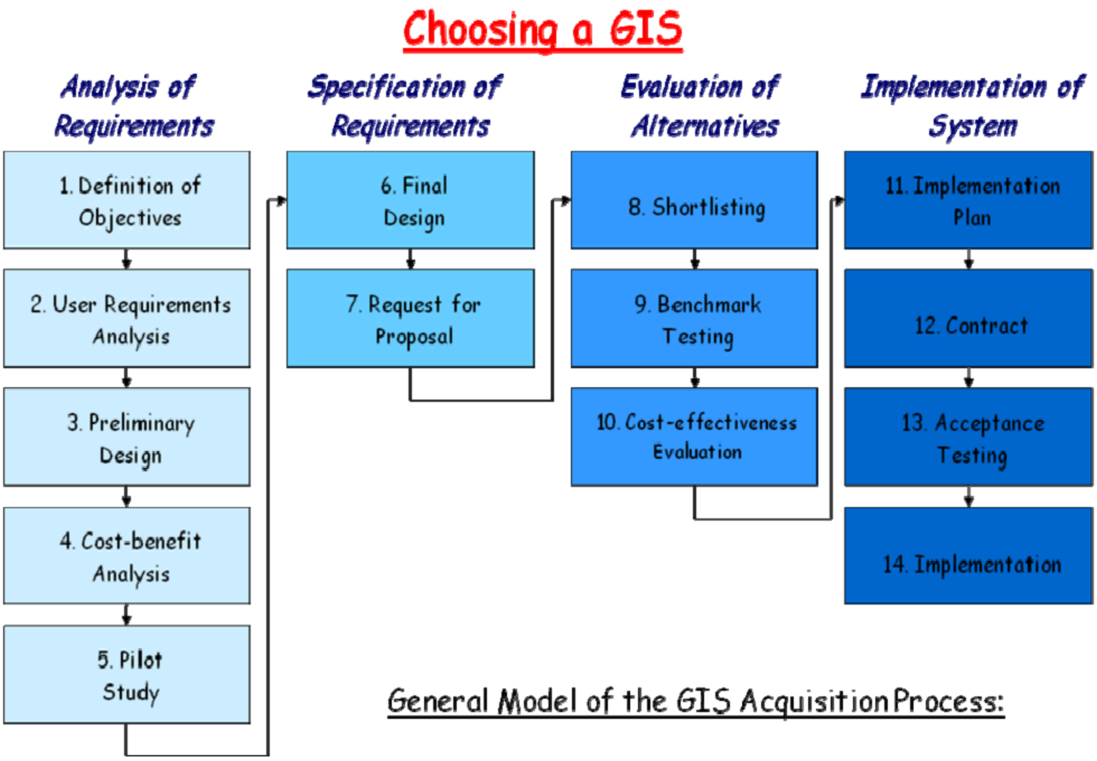


Figure 9: Choosing a GIS

Since this project was concerned with the selection and development of a prototype, only the first five steps within the section on "analysis of requirements" from figure 9 were used. However for purposes of full-scale implementation the rest of the model will be utilized.

3.1.1 Definition of Objectives

The objective was to identify a server GIS solution and implement a prototype of it.

3.1.2 User Requirements Analysis

The user requirements were captured by using a questionnaire. (See questionnaire in the appendix). 15 members of staff drawn from all departments (Administration, Training and Professional Services and Sales and Marketing) were the respondents of the questionnaire. A summary of the findings of the user requirements conducted using the questionnaire is as shown in the Table 1and Table 2:

Table 1: Questionnaire Response – Software Proficiency and Current Use

		PROFICIENCY					CURRENT USE				
SOFTWARE	**PRODUCT NAME AND VERSION**	**None**	**Little**	**Average**	**Good**	**Expert**	**None**	**Rarely**	**Average**	**Often**	**Very**
ArcGIS Desktop	ArcGIS ArcInfo 9.2	3	1	1	9	1	3	2	2	2	6
ArcGIS Server	ArcGIS Server 9.2	9	2	2	2		9	3	1		2
Erdas/Leica Desktop	LPS	7	4	3	1		9	4	2		
Erdas/Leica Server		15					15				
Autodesk Desktop	AutoCAD	13	2				15				
Autodesk Server		15					15				
Microstation Desktop		12	2	1			14	1			
Microstation Server		15					15				
Geonetwork Desktop		13	2				13	2			
Geonetwork Server		15					15				
Geomedia Desktop		15					15				
Geomedia Server		15					15				
MapInfo Desktop	MapInfo Professional	14	1				14	1			
MapInfo Server		15					15				
Manifold Desktop		15					15				
Manifold Server		15					15				
Geomatica Desktop		14	1				14		1		
Geomatica Server		15					15				
TerraVision Desktop		15					15				
TerraVision Server		15					15				
Idrisi Desktop	Idrisi Kilimanjaro	11	1	2		1	13	2			
Ilwis Desktop		13	1	1			14	1			
Other	Instant Atlas	14	1				14			1	

From table 1, the following can be deduced concerning the users and their requirements:

The most commonly used desktop product is ArcGIS Desktop with average or higher proficiency standing at 80%. The only server product for which users have an experience in using is ArcGIS Server with 40% of users having little or greater proficiency.

Table 2: Questionnaire Response - Server GIS Features

SERVER GIS FEATURE	LEVEL OF INTEREST None	Low	Moderate	High
Data Management (Store geospatial data in an RDBMS, such as IBM DB2/Informix, Oracle, Microsoft Access/SQL Server, and PostgreSQL)	3	1	3	8
GIS Web Services (Map, Globe, Image, WMS, WFS-T, WCS, KML, locator, and geoprocessing services)	4	1	3	7
Mapping (Tools for creating rich browser-based Web mapping applications)	3	1	1	10
Spatial Analysis (server-based analysis and geoprocessing, including vector, raster, 3D, network analytics, as well as models, scripts, suitability analysis, cut-fill, line-of-sight and terrain modeling)	3	3	3	6
Publishing (Support a broad range of thick and thin clients including browser-based applications)	4	1	4	6
Image Management (Support a complete image management system for delivering large quantities of imagery that can be consumed in desktop, mobile, web and imagery clients.)	4	2	4	5
Web Application (Support tools and tasks, including pan, zoom, identify features, measure distances, find addresses, query and search attributes)	3	2	3	7
Application Developer Tools (Support .NET and Java ADF components and open APIs for REST, JavaScript and Flex)	7		3	5
Other Distributed Database Management (extraction & replication services)	14			1

From Table 2, the following can be deduced concerning the users and their requirements:

The features of server GIS which many users have a high level of interest are mapping, data management, web applications and GIS web services. The feature of server GIS which users have the least interest is application developer tools.

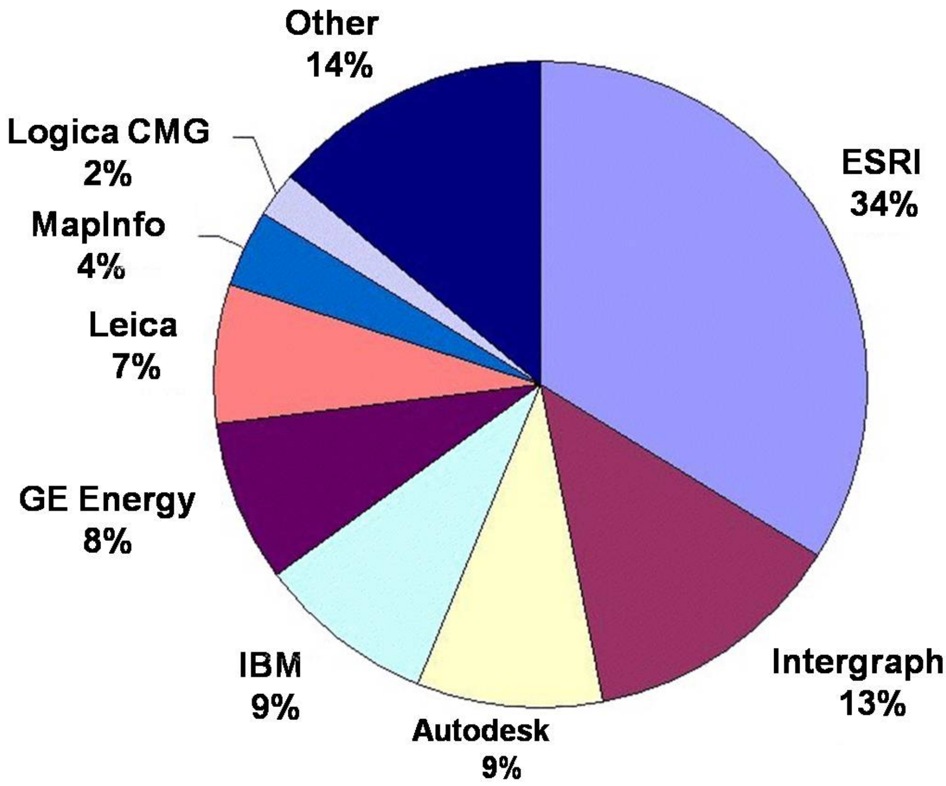


Figure 10: Software Vendors Market Share (Daratech, 2004)

Figure 10 **(Daratech, 2004)** shows GIS software vendors and their market share. The data is for the year 2004 and shows ESRI and Intergraph as the market leaders with 34% and 13% market share respectively.

3.1.3 Preliminary Design

The desired design of the server GIS was a three tier system having the clients, the server and the DBMS. This design was most preferred for its high integration, robustness and scalability ensuring easy expansion future.

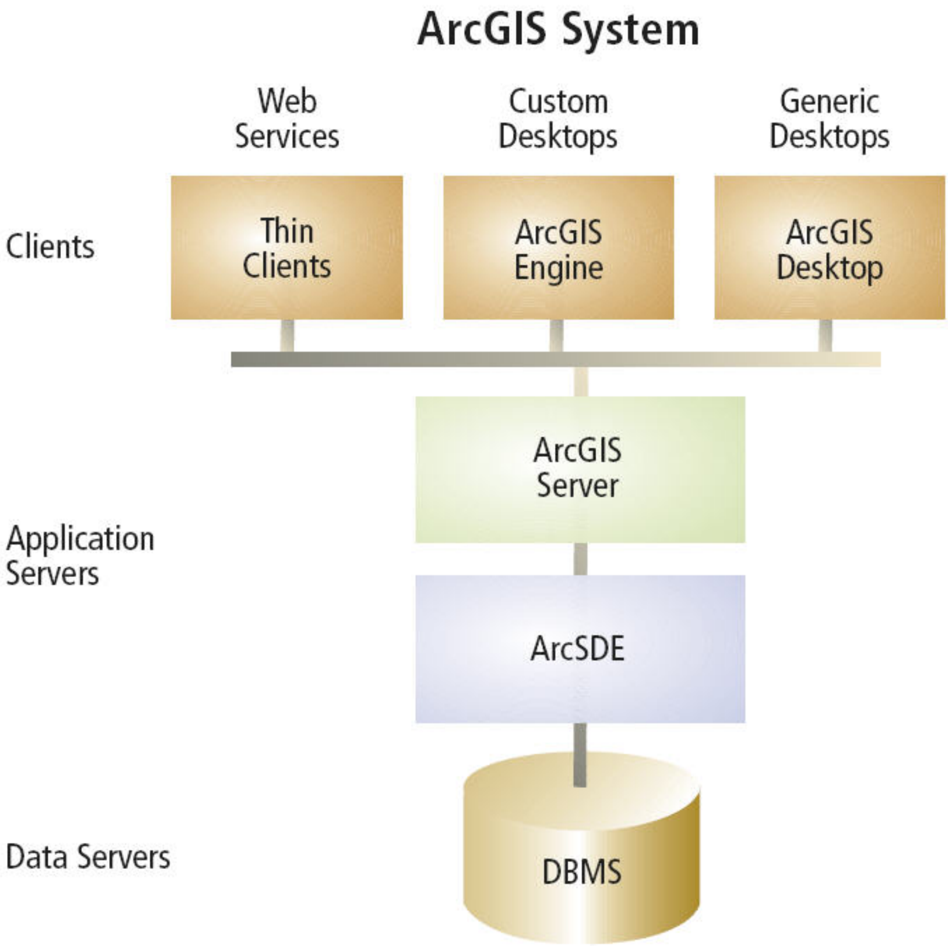


Figure 11: Server GIS design

Figure 11 **(ESRI, 2008)** shows the desired implementation design, clearly demarcating the various levels and how they interlink. The clients tier consists of the platform through which users consume/use the various GIS services. The server tier consists of the platform used to serve GIS services. The DBMS tier consists of the platform that hosts data used in creating the GIS services.

3.1.4 Cost Benefit Analysis

The benefits to be derived from a server GIS solution are dependent on the functionalities it can achieve and hence the standards set for these functionalities provide a good benchmark.

Information on various server GIS products available was sourced. The OGC standards that the software products meet were compiled into a product comparison matrix as seen in the table 3:

Table 3: Server GIS Comparison Matrix

SOFTWARE	OGC STANDARDS AND VERSION MET
ESRI: ArcGIS Server	WFS 1.1, WCS 1.1.1 c1, WCS 1.1.0, WCS 1.0.0, WCS 1.0, SLD 1.0, SFS(TF) 1.1, SFS(NG) 1.1, SFS(BG) 1.1, SFS 1.1.0, SFS 1.1, SFO 1.1, KML 2.2, KML 2.1.0, GMLsf 1.0.0, GML 3.2.1, GML 3.1.1, Filter 1.1, Filter 1.0, Common 1.1.0, Common 1.0, WMS 1.0, WMS 1.1, WMS 1.1.1, WMS 1.3.0
Erdas: Red Spider	CAT 2.0.2, CAT2 AP ebRIM 1.0.0, Common 1.0, Filter 1.0, Filter 1.1, GML 2.1.2, GML 3.1.1, WFS 1.0, WFS 1.1, WFS(T) 1.0, WMC 0.1.7, WMC 1.0, WMC 1.1, WMS 1.0, WMS 1.1, WMS 1.1.1, WMS POST 0.0.3, WSDL/SOAP/UDDI 1.0
Autodesk: Autodesk	WMS 1.1.1, WFS 1.0
Bentley Systems: Microstation	WMS 1.1.1
FAO-UN: Geonetwork	CAT 1.1.1, CAT CS/W 2.0.1, CAT2 AP 19115/19119 0.9.3, GeoRSS 1.0.0, SOAP 0.8, WMC 1.1, WMS 1.0, WMS 1.1.1
Integraph: Geomedia	GML 2.1.1, WMS 1.0, WMS 1.1, WMS 1.1.1, GML 2.0, WFS 1.0
Manifold: Manifold	WMS 1.0, WMS 1.1, WMS 1.1.1, WMS 1.3.0, WMS 1.3.0
MapInfo: MapInfo	WMS 1.1.1 (compliant), GML 2.1.1, GML 3.0, WFS 1.0, WMS 1.0, WMS 1.1
PCI Geomatics: Geomatica	WMS 1.1.1, WFS 1.0, WCS 1.0 (compliant)
SRI International: TerraVision	WMS 1.1

Abbreviated OGC standards

CAT: Catalogue Service

Common: Web Service Common Implementation Specification

CT: Coordinate Transformation

Filter: Filter Encoding

GO: Geographic Objects

GML: Geography Markup Language

GeoXACML: Geospatial eXtensible Access Control Markup Language (GeoXACML)

KML: formerly Keyhole Markup Language

OpenLS: Location Services

O & M: Observations and Measurements

SensorML: Sensor Model Language

SPS: Sensor Planning Service

SFS: Simple Features

SFO: Simple Features OLE/COM

SLD: Styled Layer Descriptor

Symbol: Symbology Encoding

TML: Transducer Markup Language

WCS: Web Coverage Service

WFS: Web Feature Service

WMC: Web Map Context

WMS: Web Map Service

WPS: Web Processing Service

WSC: Web Service Common

3.1.5 Pilot Study

This involved the implementation of server GIS as a prototype. The prototype would be a scaled-down implementation of the enterprise server GIS.

3.2 IMPLEMENTATION

This involved the actual implementation of the product/solution. It was agreed that a prototype be developed first before full scale implementation.

The product selected for implementation was ArcGIS server for the following reasons:

1. It was the most familiar to the users based on the information compiled from the questionnaires.
2. It has the most functionality and meets the most OGC standards of all the server GIS products.
3. It allows for seamless integration with existing desktop GIS applications.
4. It was provided at no cost by ESRI.
5. Free support both local and international is readily available.
6. ESRI's domination in the GIS software market.

The server platform used in implementing ArcGIS Server was as follows:

- Intel Xeon CPU 2.33 GHz
- 2 GB RAM
- 204 GB Hard disk drive
- DVD-RW
- Windows 2003 SP2 (32-bit) Server Standard
- Internet Explorer 6
- Internet Information Services (IIS) 6
- Microsoft .NET 2.0
- Microsoft SQL Server 2005 SP2 (32-bit)

Security levels were then implemented. Here each staff member's domain account was placed in either the "GIS administrators group" and/or "GIS users group", the former being for those users who create and serve GIS data and information, while the latter was reserved for those users who use or consume GIS services.

All procedures and data were integrated into one functional whole. The server GIS was then be checked and analyzed to ascertain functionality and compatibility with the desktop GIS systems.

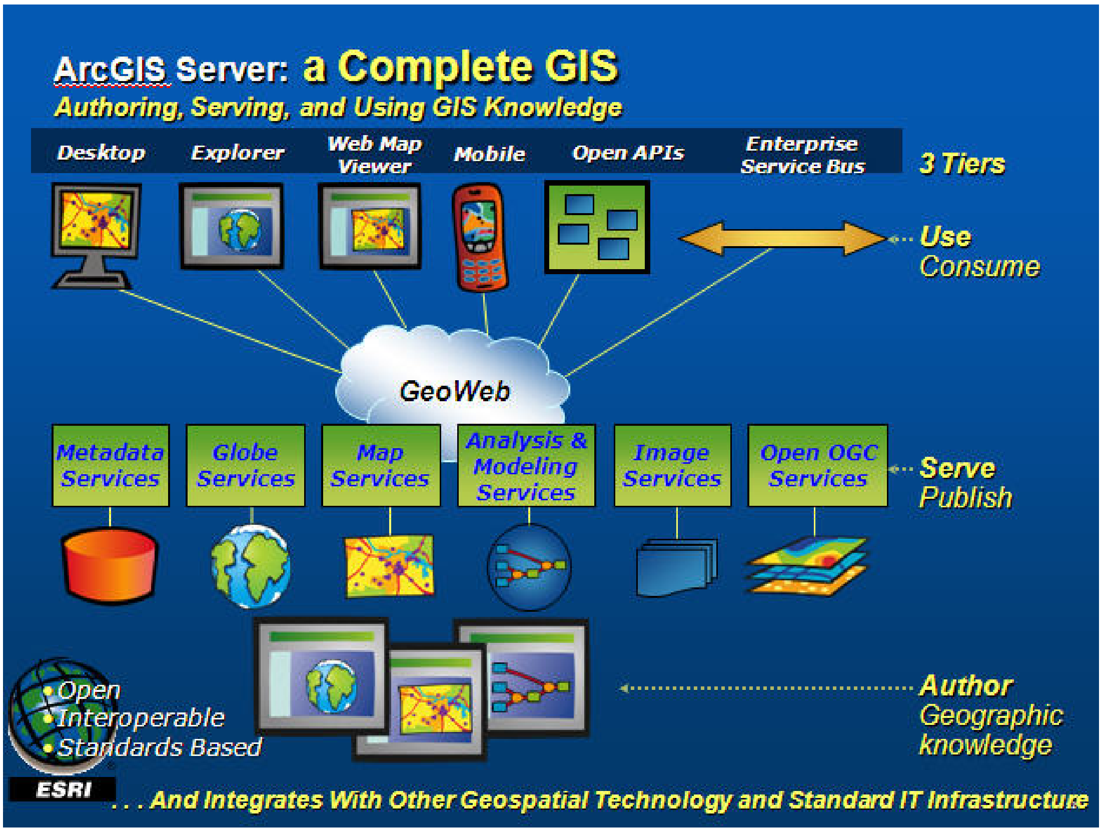


Figure 12: ArcGIS Server Integration

Figure 12 **(ESRI, 2008)** shows a summary of the ArcGIS system and its completeness in terms of authoring GIS knowledge, Serving or publishing it and using or consuming this knowledge. This seamless link between server and desktop systems is critical to a smooth flowing workflow and eases the process of adaptation and acceptance amongst users.

3.3 DATA IMPORTATION

ESRI EA and OSL have a lot of data stored within various different distinct desktop GIS systems. For the purposes of implementation of a prototype, some existing data was selected then be transferred to the server GIS from the desktop GIS systems.

The data was selected such that various types of datasets were represented. These types include: satellite imagery, scanned topomaps, shapefiles, triangular irregular networks (TIN), coverages, tabular data (spreadsheets) and geodatabases. All transferred data is contained in a centralized spatial database. Appended to the spatial data, within the database, is attribute data related to the spatial data.

CHAPTER 4: RESULTS AND ANALYSIS

The results of this study are output as follows:

4.1 ACCESS

GIS administrators have access to the server GIS services using:

- a thin client such as a web browser or
- a thick client such as ArcCatalog.

For browser based access, this was done by navigating to a dedicated server GIS URL.

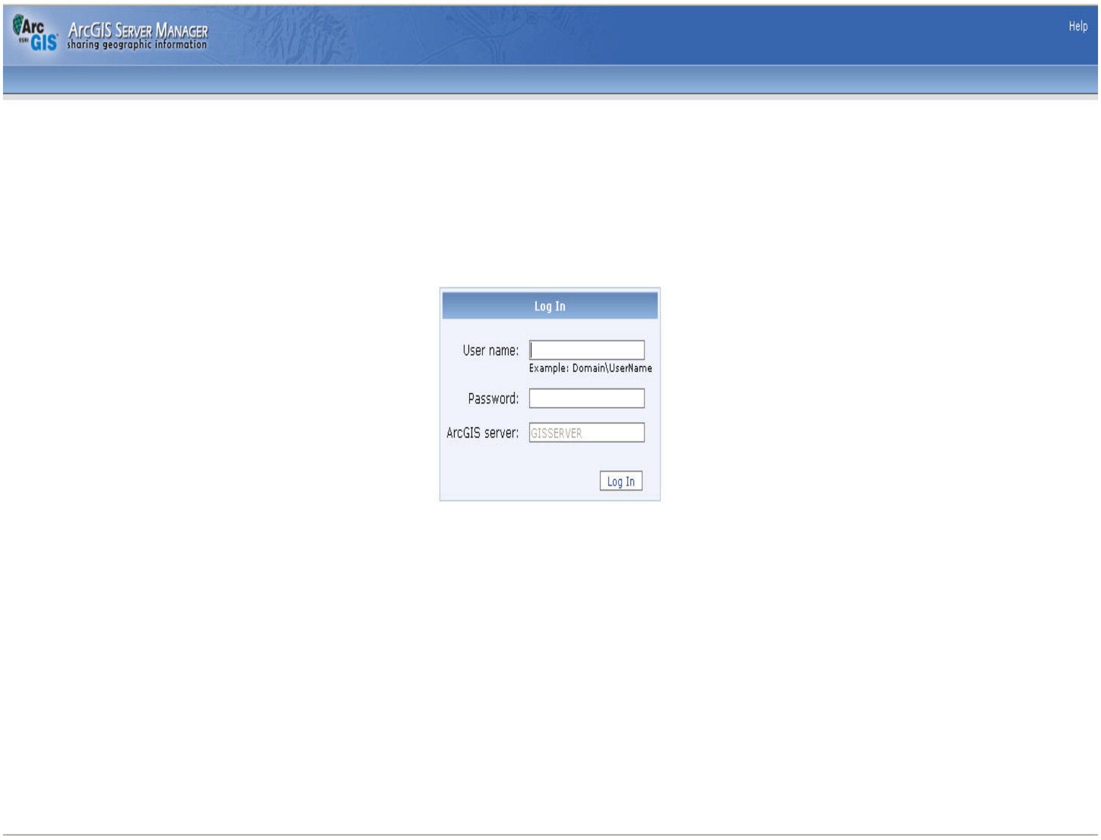


Figure 13: ArcGIS Login Screen

Figure 13 shows that the user is prompted to enter their login credentials. Only GIS administrators can log into the server GIS manager.

For thick client access, this was done using ArcCatalog. This was done by adding the GIS server and selecting to manage services as in figure 14 and entering the server URL as in figure 15.

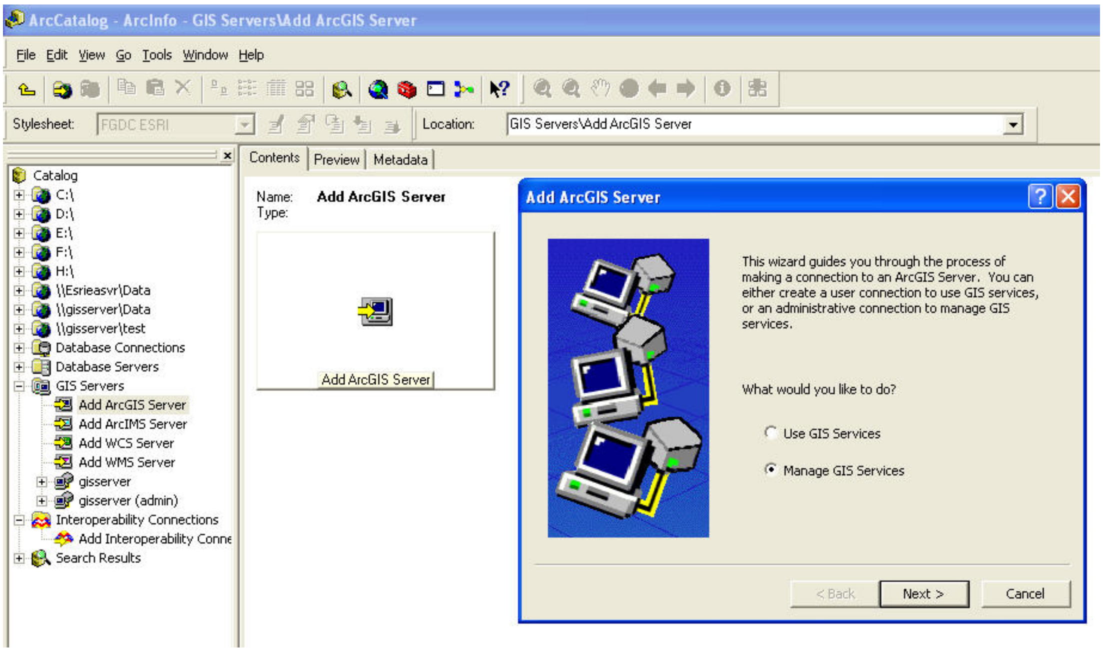


Figure 14: ArcCatalog adding Server

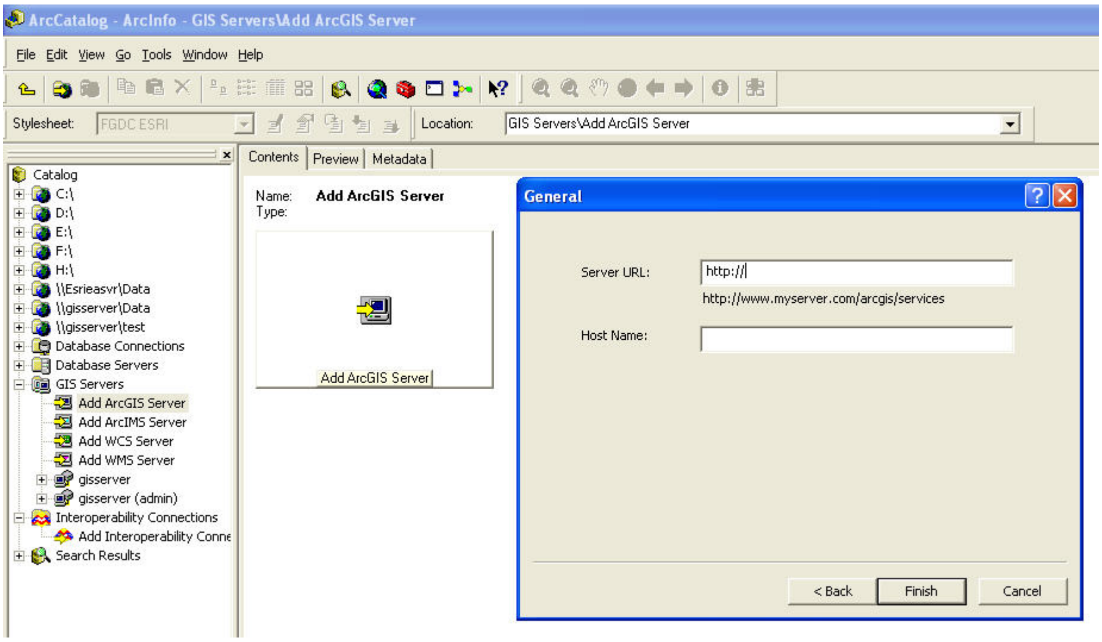


Figure 15: ArcCatalog URL

Once these steps were done an administrative connection from ArcCatalog was established for use from where server administration could be done.

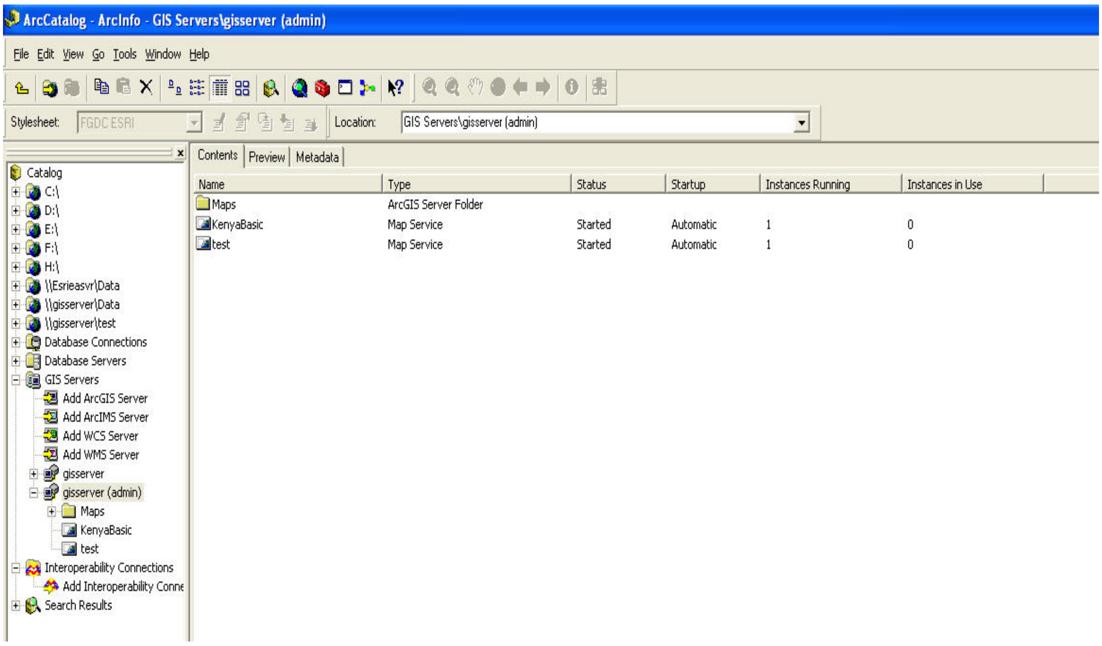


Figure 16: ArcCatalog Administrative Connection

Figure 16 shows the administrative connection and the services that have been created and whether they are running or not.

GIS users access is covered in the section 4.3 which covers consuming content.

4.2 CREATING CONTENT

Creation of content on the server GIS is the domain of the GIS administrators. These tasks can be accomplished both via thin and thick clients. For the thin clients, a web browser was used while for the thick clients, ArcCatalog was used.

For the web browser, the GIS administrator logs in and the page from which various tasks can be accomplished is revealed:

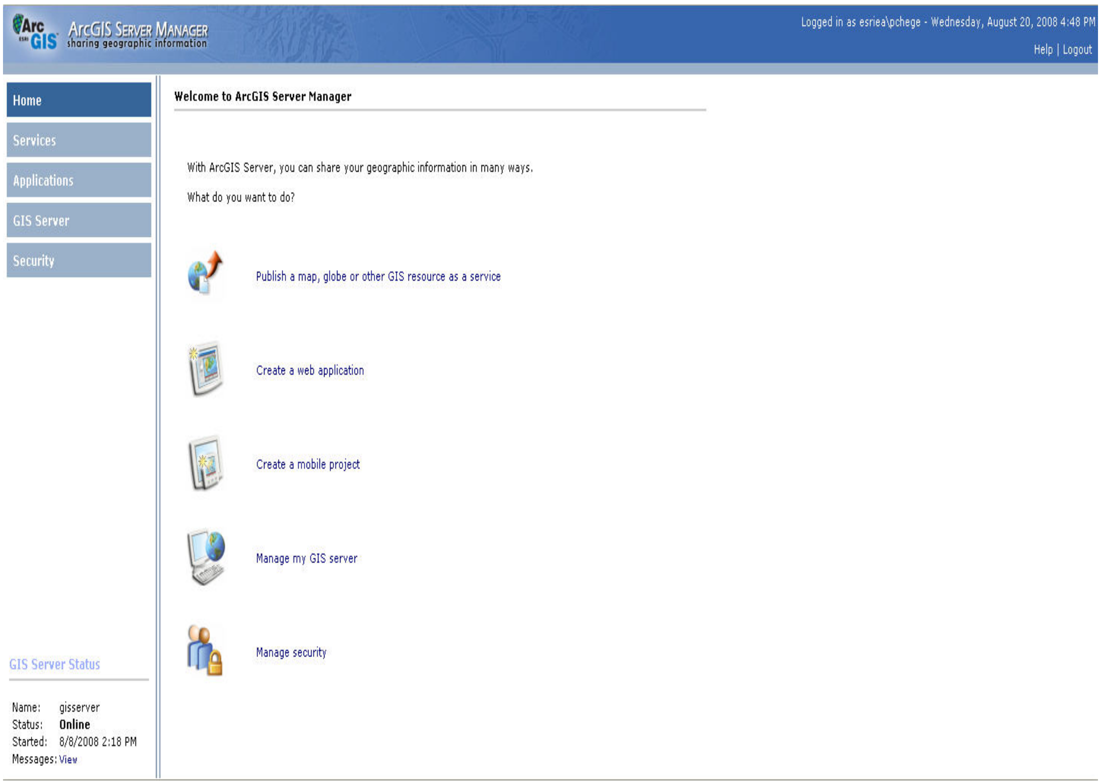


Figure 17: ArcGIS Server Main Menu

Figure 17 shows the home page of the server manager. From this page some of the tasks that can be undertaken by an administrator include:

- Publishing a map, globe or GIS resource
- Create a web application
- Create a mobile project
- Manage the GIS server
- Manage security

From ArcCatalog, the administrator navigates to the resource that they want to publish and does so by right-clicking on it.

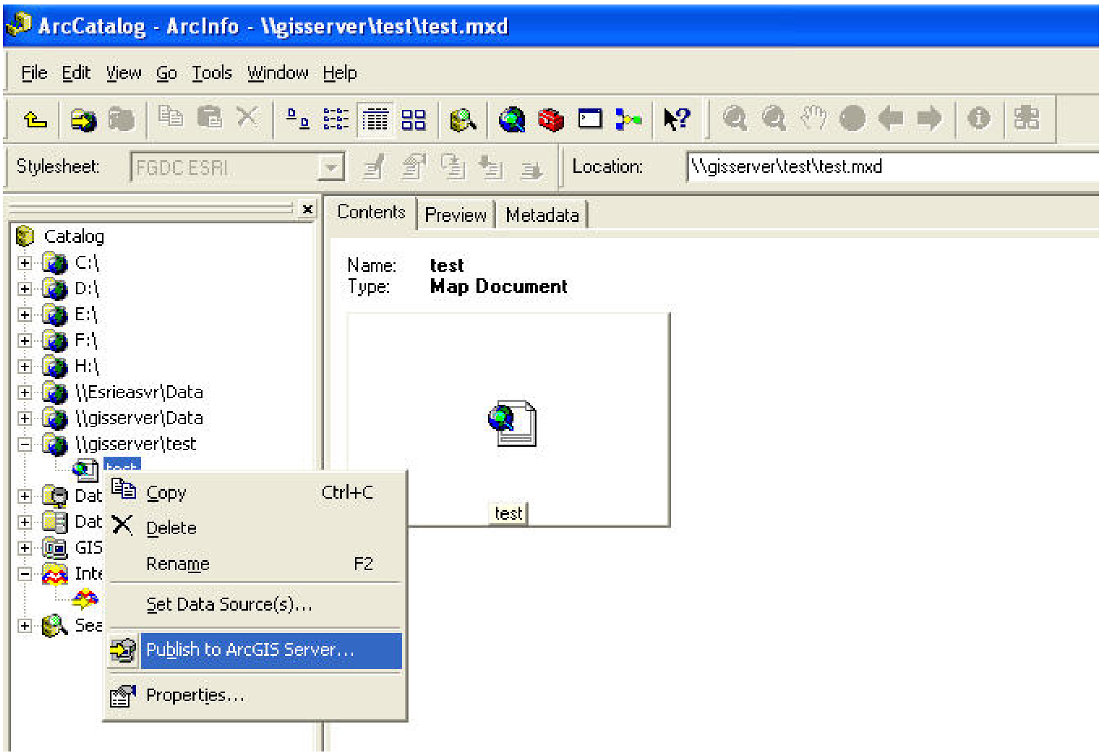


Figure 18: ArcCatalog Publishing Resource

Figure 18 shows a map document being published as a map service using ArcCatalog.

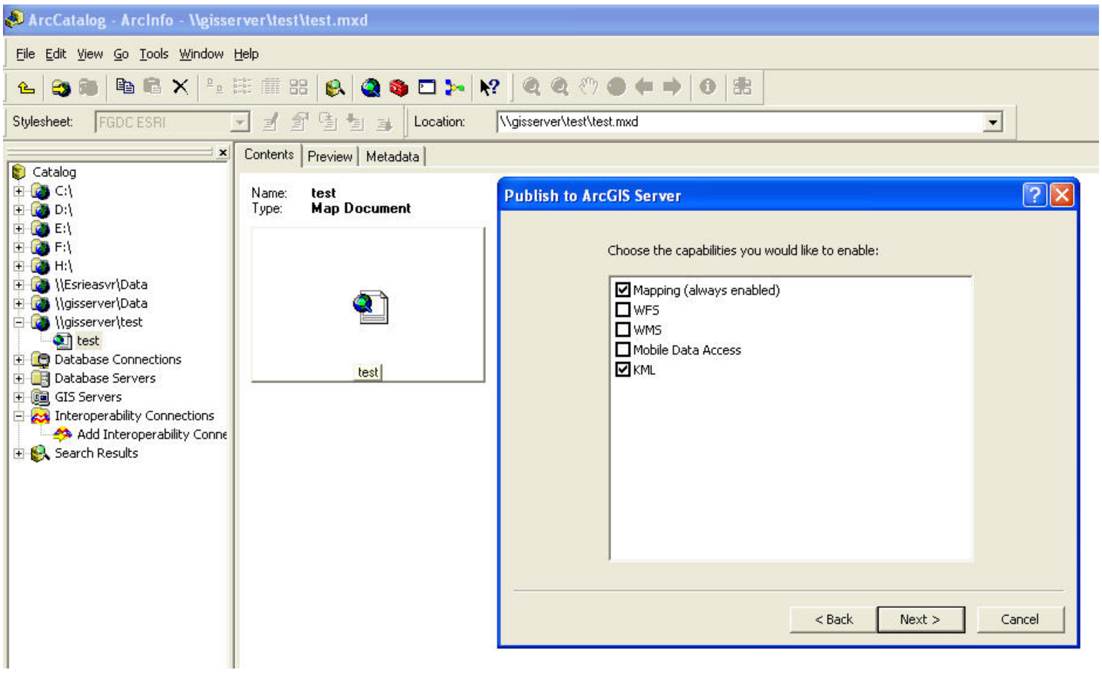


Figure 19: ArcCatalog Service Options

Figure 19 shows the various capabilities that the map document can have when running as a service.

4.3 CONSUMING CONTENT

There are numerous ways of consuming services. They can be broadly classified as either by using a thin client or by using a thick client.

For the thick client, ArcMap was used.

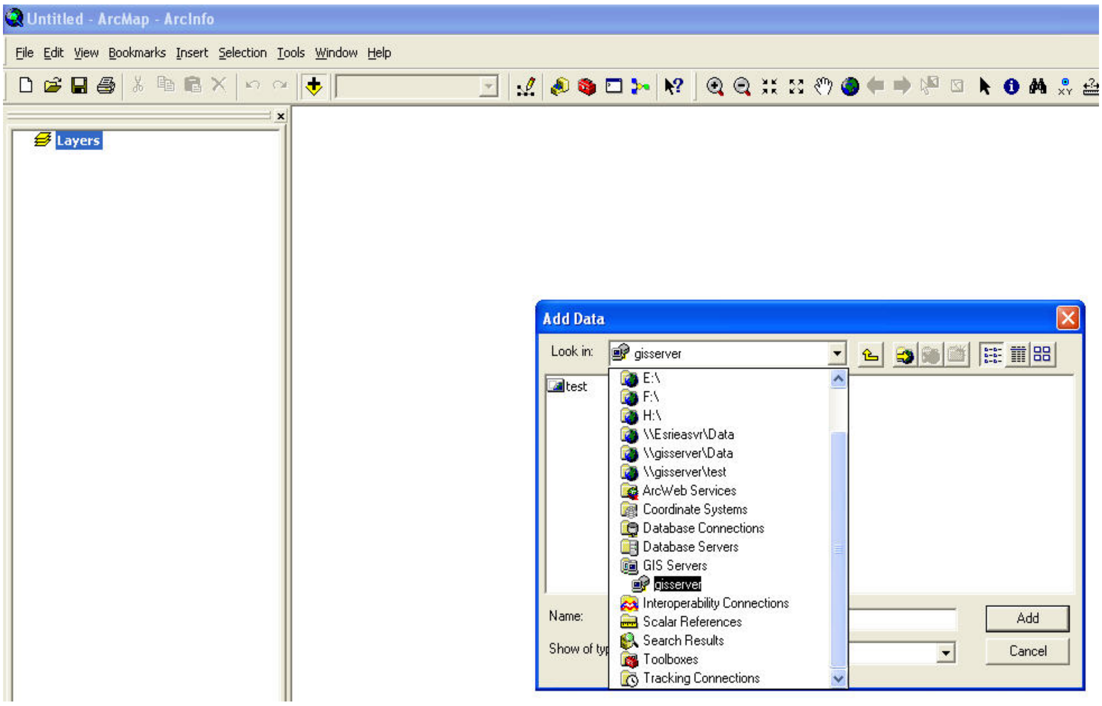


Figure 20: Using ArcMap

From ArcMap a service can be added as in figure 20. The service is being added to ArcMap for consumption.

For the thin client, ArcGIS explorer was used.

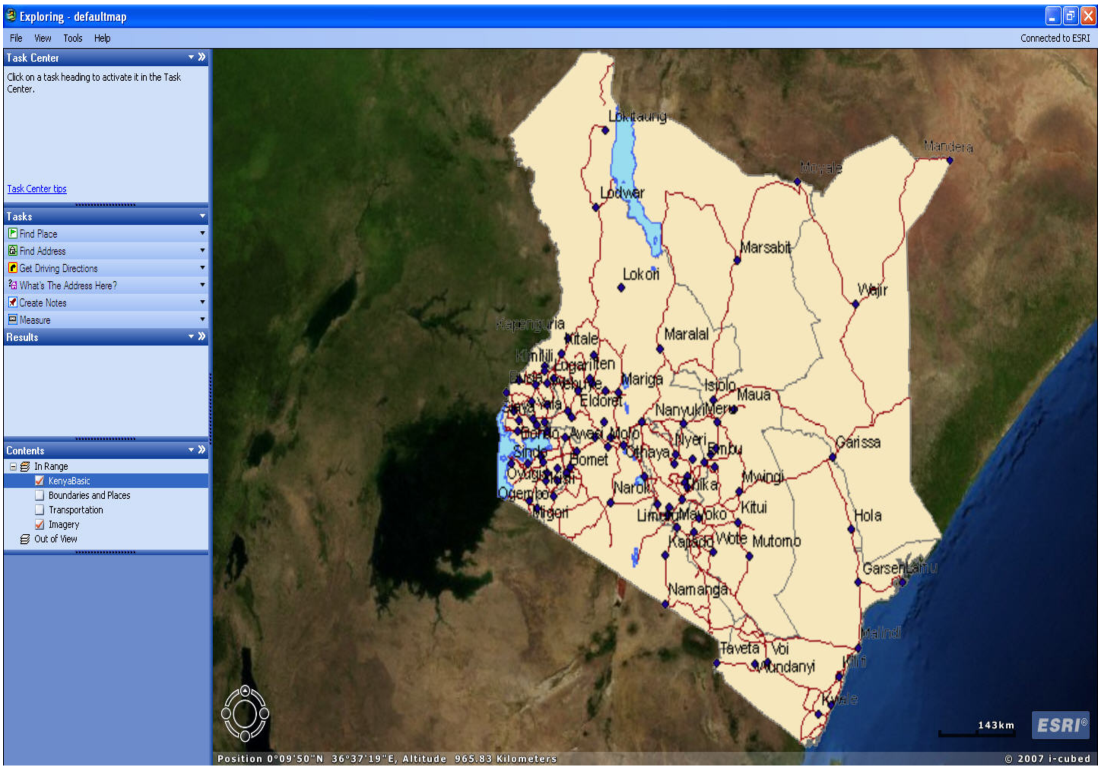


Figure 21: ArcGIS Explorer

Figure 21 shows ArcGIS Explorer being used to consume a service. The user can use the service and combine/overlay with other services from other servers and/or data from their computers or network.

4.4 DISCUSSION OF RESULTS

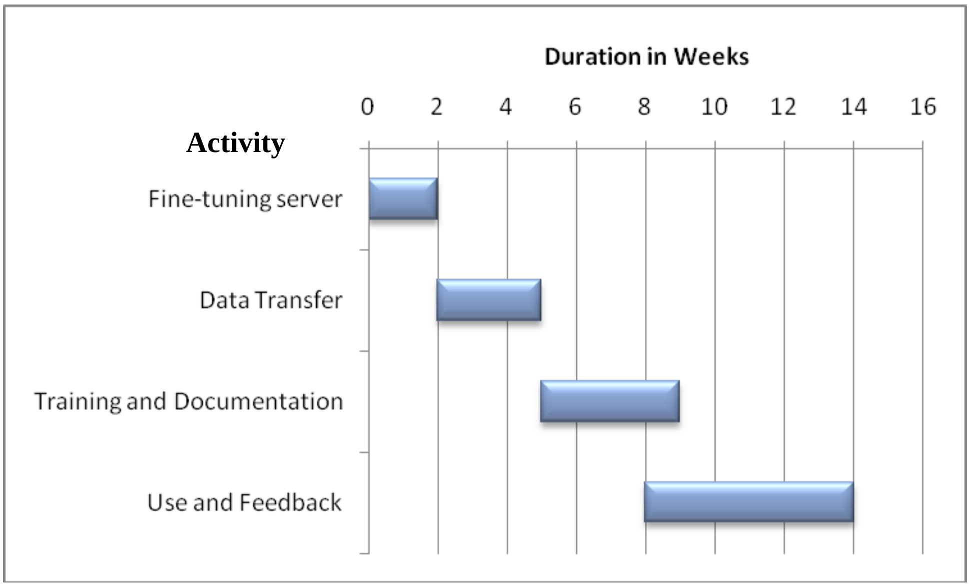
The results of the prototype implementation were very encouraging. The prototype server GIS was found to enable easy sharing of data and resources between users. It also enabled better management of data and resources by centralization.

The server GIS is thus proposed for full-scale implementation so as allow the organizations to fully benefit from it. The tiered architecture of authoring-serving-consuming would be maintained. This would ensure that the benefits of the server GIS are experienced by all users.

IMPLEMENTATION SCHEDULE

The recommended schedule for the full-scale implementation, data transfer and training is as below:

Table 4: Implementation Schedule



As per table 4, the order of events in the schedule should be as indicated. Fine-tuning of the server involves working on the ArcSDE Schema and also installation of the geoportal toolkit. The geoportal toolkit will ensure that the server GIS is ready for access from the internet.

The data transfer involves transferring data from existing desktop systems to the ArcSDE database. This should be done meticulously to ensure that no duplication of data and no omission of data occur.

The training involves a series of classes be conducted and a user manual be provided for the users to learn the features available for their use in the new server GIS. It should also highlight the integration capabilities of the server GIS with existing desktop systems.

Thereafter users should continue to actively use the new server GIS system. Feedback should be provided constantly to ensure that the system meets and exceeds the needs of the organization in general and the users in particular.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

Users were able to use map services, web applications and GIS web services using their web browsers and desktop GIS applications as well as perform multiuser editing. Thus the capabilities of server GIS are very powerful allowing for the efficient and effective management and dissemination of data and information.

Server GIS is recommended as a viable GIS implementation for organizations that are GIS-centric or those that have a medium to large GIS department. Server GIS would enable such organizations achieve better data management and easier data and information sharing. Server GIS is also recommended in the implementation of Spatial Data Infrastructure (SDI) for example Kenya National Spatial Data Infrastructure (KNSDI).

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APPENDIX

QUESTIONNAIRE

USER INFORMATION TO AID IN IMPLEMENTING PROTOTYPE SERVER GIS

Names:	
Email address:	
Job Title:	

What is your proficiency in the use of GIS Software products and how often do you use these products?

SOFTWARE	PROFICIENCY	CURRENT USE	PRODUCT NAME AND VERSION
ArcGIS Desktop			
ArcGIS Server			
Erdas/Leica Desktop			
Erdas/Leica Server			
Autodesk Desktop			
Autodesk Server			
Microstation Desktop			
Microstation Server			
Geonetwork Desktop			
Geonetwork Server			
Geomedia Desktop			
Geomedia Server			
MapInfo Desktop			
MapInfo Server			
Manifold Desktop			
Manifold Server			
Geomatica Desktop			
Geomatica Server			
TerraVision Desktop			
TerraVision Server			
Idrisi Desktop			
Ilwis Desktop			
Other (Specify)			

Which Server GIS features are of greatest interest to you?

SERVER GIS FEATURE	LEVEL OF INTEREST
Data Management (Store geospatial data in an RDBMS, such as IBM DB2/Informix, Oracle, Microsoft Access/SQL Server, and PostgreSQL)	
GIS Web Services (Map, Globe, Image, WMS, WFS-T, WCS, KML, locator, and geoprocessing services)	
Mapping (Tools for creating rich browser-based Web mapping applications)	
Spatial Analysis (server-based analysis and geoprocessing, including vector, raster, 3D, network analytics, as well as models, scripts, suitability analysis, cut-fill, line-of-sight and terrain modeling)	
Publishing (Support a broad range of thick and thin clients including browser-based applications)	
Image Management (Support a complete image management system for delivering large quantities of imagery that can be consumed in desktop, mobile, web and imagery clients.)	
Web Application (Support tools and tasks, including pan, zoom, identify features, measure distances, find addresses, query and search attributes)	
Application Developer Tools (Support .NET and Java ADF components and open APIs for REST, JavaScript and Flex)	
Other (Specify)	
Other (Specify)	
Other (Specify)	

Other Comments:

Each of the options available on the questionnaire was as captured in the figures 22 to 24:

SOFTWARE	PROFICIENCY	CURRENT USE	PRODUCT NAME AND VERSION
ArcGIS Desktop	None	None	
ArcGIS Server		None	
Erdas/Leica Desktop		None	
Erdas/Leica Server		None	
Autodesk Desktop	None	None	

Proficiency:
- None
- Little
- Average
- Good
- Expert

Figure 22: Questionnaire Proficiency Options

SOFTWARE	PROFICIENCY	CURRENT USE	PRODUCT NAME AND VERSION
ArcGIS Desktop	None	None	
ArcGIS Server	None		
Erdas/Leica Desktop	None		
Erdas/Leica Server	None		
Autodesk Desktop	None	None	

Use:
- None
- Rarely (Once a month)
- Average (Fortnightly)
- Often (Weekly)
- Very Often (Every 2 days)

Figure 23: Questionnaire Current Use Options

SERVER GIS FEATURE	LEVEL OF INTEREST
Data Management (Store geospatial data in an RDBMS, such as IBM DB2/Informix, Oracle, Microsoft Access/SQL Server, and PostgreSQL)	None
GIS Web Services (Map, Globe, Image, WMS, WFS-T, WCS, KML, locator, and geoprocessing services)	
Mapping (Tools for creating rich browser-based Web mapping applications)	None

Interest:
- None
- Low
- Moderate
- High

Figure 24: Questionnaire Level of Interest Options