Thesis submitted to Addis Ababa university, Science Faculty, Earth Science Department in partial fulfillment of the requirements for the degree of Master of Science in Remote Sensing and GIS

DECLARATION

I here by declare that the dissertation entitled "**Implementation of GIS Link-to-Node Network for Base Transceiver Station Inventory Management System the Case of Addis Ababa**" has been carried out by me under the supervision of Dr. Lulseged Ayalew, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2005-2006 as a part of Master of Science program in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date:

(Kebede Tadesse)

CERTIFICATE

This is certified that the dissertation entitled "**Implementation of GIS Link-to-Node Network for Base Transceiver Station Inventory Management System the Case of Addis Ababa**" is a work carried out by Kebede Tadesse under my guidance and supervision. This is the actual work done by Kebede Tadesse for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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Acronym

3D	Three Dimensional
AMPS	Advanced Mobile Phone Service
AUC	Authentication Center
BSC	Base Transceiver Station
BSS	Business Support System
CRM	Customer relationship management
DBMS	Database Management Systems
EIR	Equipment Identity Register
ETC	Ethiopian Telecommunication Technology
GIS	Geographic Information System
GIWU	GSM Interworking Unit
GSM	Global System for Mobile communication
HSR	Home Location Register
ICT	Information Communication Technology
ITU	International Telegraph Union
LA	Location Area
MSC	Mobile service Switching Center
OLE DB	Object Linking and Embedded DataBase
OSS	Operations Support Systems
PLMN	Public Land Mobile Network
RDBMS	Relational Database Management Systems
SDE	Spatial Data Engine
SQL	Sequential Query Language
SS	Switching System
TMN	Telecommunications Management Network
VCR	Visitor Location Register

CHAPTER I
INTRODUCTION

1.1. Background

Ethiopian Telecommunication Corporation (ETC) is a state owned company. It is a sole service provider in the telecom technology. One of its services is providing with reliable mobile connection throughout the country. The provision of mobile service in Addis Ababa commenced in 1999 with a capacity to support 36,000 customers. Now, the number of subscribers excels 500,000. ETC has also a qualitative and quantitative plan to increase the service it provides in the city with a vision of connecting with the state-of-the art ICT, infrastructure that provides highly qualitative, reliable and secured communication services at affordable price.

With the increasing number of subscribers and advancement of telecom technology the implementation of ICT, which integrate geographic information system (GIS), is a useful solution to all location base services. So, information technology that integrates spatial data will enable ETC to go in line with its objective.

Many telecommunication providers are using GIS to establish and work on a competitive base. With GIS, providers can integrate their workflow based on the location of their assets, customers, sales territories, and coverage areas. As telecommunication networks grow more complex, complementing GIS applications to their system becomes very important.

For example, Qwest Communications International Inc. (United States) is a leader in reliable, scalable, and secure broadband data, voice, and image communications for businesses and consumers. The Qwest Macro CapacitySM Fiber Network, designed with the newest optical networking equipment for speed and efficiency, spans more than 190,000 miles globally. Qwest Wireless uses ArcGIS software to enhance its customer service and increase its market share (Golden L.: 2001).

Mobile communication is now viewed as a basic necessity and is one of the fastest growing and most needed technologies. Mobile systems have evolved over time and dominantly follows a general standard called Global System for Mobile communication (GSM). There are three important stations in operationalisation of Mobile Communications Viz. 1. Mobile Services Switching Center (MSC) 2. Base Station Controller (BSC) and 3. Base Transceiver Station (BTS). Both MSC and BSC are intelligent units and communicate each other through microwave frequency (NOKIA, 1999). These two stations can be stationed anywhere inside the rooms or buildings, whereas the BTS have to be kept in high elevated place like high rise building top or mountain top or tower of height over 40 meters.(usually termed Tower) The installation of BTS is a critical component in the operationalisation of Mobile communications.

The coverage directly depends on the height of the tower, antenna configuration, cell configuration, connection type and other inventory. The function of the BTS is to receive and transmit the signal from the Cell/Hand phone to BSC and MSC. These signals were processed by BSC and MSC and in turn identify the position of the caller/receiver. In case caller/receiver goes outside the limit of the one BTS, BSC/MSC would identify the nearby BTS and connects to the caller/receiver. The position of the BTS is kept in such a way that the strength of the signal is good at the caller/receiver end.

In the case of ETC, Nokia and Erickson are the two vendors, who have a contract with ETC to install the mobile system through out the country. Every BTS is installed with the inventory of these two companies. The connection depends on the inventory. Namely; antenna configuration, number of antenna installed, power, cell configuration, etc. Mapping BTS area coverage and automating the respective attribute information about these inventories is the focus of this project.

In addition, modeling customer versus BTS capacity is another task of the study. The results can be used as additional inputs for decision maker.

1.2. Overview

To be competitive, telecommunication service providers depend on a smoothly functioning workflow process that integrates information for marketing, demand forecasting, engineering, customer management, operations support, etc. Although telecommunications providers generally have the same needs for information, how the workflow is organized can vary significantly from company to company.

Historically telecommunications companies have used an assortment of information systems-some developed in-house, some purchased-that were never designed to work together. Today telecommunications companies operate networks that have equipment from multiple vendors and lease bandwidth and antenna sites from other companies. Mergers with, or acquisition of, other companies require the incorporation of, or at least interaction with, completely foreign networks.

The need for information sharing within companies and interoperability between systems has been recognized by the telecommunications industry for a long time. Originally founded in 1865 as International Telegraph Union, the International Telecommunications Union (ITU) promotes standards in equipment that guarantee generalized interconnection between communication systems. To improve interoperability, ITU has developed the Telecommunications Management Network (TMN), a method of standardizing business organization. This hierarchy of support systems specifies interoperability through the use of industry-standard protocols. Geospatial applications need to support this same level of interoperability if GIS is to work well within this TMN-structured environment. (ArcUser: 2001)

A GIS can be defined as a "...system that contains spatially referenced data that can be analyzed and converted to information for a specific set of purposes, or application ... The key feature of a GIS is the analysis of data to produce new information" (Parent, 1988).

Many current applications of GIS in the telecommunications industry began as departmental tools that worked within a well-defined scope. These GIS-based tools have helped automate business processes and increase the efficiency of operations. Designing and building a wireless network is a costly process that involves several iterations of planning and testing.

Performing sophisticated GIS analysis on optimized geographic data can reduce planning and design costs. In some cases, effective use of geographic resources has made the difference between success or failure for a telecommunications company (ESRI).

Preliminary analysis with GIS uses customer, terrain, and landownership information and provides planners with potential antenna sites. The initial network configuration is evaluated using wave propagation modeling that simulates the wireless coverage resulting from a configuration. Once an optimal model is devised, engineers test the configuration in the field. The process is repeated until the configuration provides optimal coverage for the area.

Wireless engineering applications illustrate that sharing information and geographic data between phases of the workflow can reduce data redundancy while. Using GIS to limit the number of design iterations and restrict costly field testing provides significant savings for telecommunications providers.

The second necessary component for a GIS is the data storage and retrieval subsystem. This subsystem organizes the data, both spatial and attribute, in a form which permits it to be quickly retrieved for updating, querying, and analysis. Most GIS software utilizes proprietary software for their spatial editing and retrieval system, and a database management system (DBMS) for their attribute storage. Typically, an internal data model is used to store primary attribute data associated with the topological definition of the spatial data. Most often these internal database tables contain primary columns such as area, perimeter, length, and internal feature id number. Often thematic attribute data is maintained in an external DBMS that is linked to the spatial data via the internal database table.

Telecom Service providers can view the information they have for display to verify that the location and attribute information is current and to see how they fit into the distribution patterns of regional services in their industry. Map Elements in a GIS application are not just colored lines and dots that represent features in the real world. Each map element does have some intelligence, in that it has information in the form of a database record attached to it. Each database field contains an attribute - a value about a certain aspect of that map element. At a minimum, each element will have a unique identifier attribute, as well as spatial coordinate attributes (latitude and longitude) so that the GIS system can locate it properly on the face of the earth.

It can be included many more descriptive attributes in the database that represent such information as what facility, the contact person's name, what services the facility supports, etc. In the mapping application, there is an identify function that will allow you to click on a map element in the active data layer and obtain a listing of all of its attributes.

1.3. problem Definition

Currently, the inventory database is in a flat file format and it is not integrated with the spatial information. When the need arises to make some adjustment on any of the BTS equipment like changing antenna height, antenna direction and cell configuration frequent field checking and consulting others is required. The existing flat file is not linked with map information, and it is not updated regularly. To know about the signal coverage area of each BTS, field checking and drive test is highly required.

Some of the questions that are frequently asked and possibly that may get effortless reply by this study are the following: What is the configuration of the antenna? What type of link exists? Which area is covered by which BTS? Which one is more congested? Which one requires system expansion?

The following key problems will be addressed by this research:

1. Unavailability of map for the area covered by each BTS.
2. Problems in managing; accessing, updating, inserting inventory of the BTS
3. Absence of automated information about the link to node of the BTS
4. Difficulty (continuous field checking or drive test) in identifying which area is congested and which is not

1.4. Scope of the research

Ethiopian Telecommunication Corporation is a sole service provider in Ethiopia. The coverage of the service and the type of service rendered are enormous. However, this research tries to give solution to very restricted area and service. In terms of area the research delimited only to Addis Ababa. And with regard to service the research focuses on the Base transceiver station node to link inventory database with respect to their spatial location.

To model the BTSs capacity with respective potential customer and number of customer supported, the research is bounded only on one sub city, Kirkos. In the analysis part the factors considered are limited. Only three factors are considered as potential customers of cellular phone in a given location. As factors employees of international organizations and public institutions, students of secondary schools and colleges/universities and residents in the sub city are taken.

1.4. Objectives of the research

General Objective

The objective of this thesis is to provide the timely and accurate information to the engineers (users) who are dedicated in working on the Mobile Division of ETC. The information enables them to perform their tasks with less time and efficiently. This information includes cellular, paging, microwave, asset management, and facility management, etc.

When conducting analyses, users find these details extremely helpful for examining current service deployment, need/feasibility determinations of new services, coalocation of antenna structures, inventorying of structures, and network planning. This combination of data and software allows users to view, query, and thematically create their own maps based on their own data sets and group object for technical equipment, link object, connection, trace, and link report.

Specific objectives

At the end of this thesis, a GIS platform with a combination of SQL and Visual Basic Programming, the study able to:

- Display the BTS location and their respective area coverage map.
- Make available automated information about the link to node of the BTS.
- Create inventory management, database system.
- Model the distribution of mobile station users on time base.

1.5. Methodology

This project utilizes basically ArcGIS 9, SQL, and Visual Basic softwares to accomplish the objectives stated. They are integrated and implemented in performing their own specific tasks.

Microsoft SQL Server is a client/server database management system. A client/ server database management system consists of two components: a front-end component (the client), which is used to present and manipulate data; and a backend component (the database server), which is used to store, retrieve, and protect the databases.

To utilize the functionality of SQL server, the researcher uses the software to construct the necessary database in the project. Microsoft SQL server is multiusers support, secured and relational database software. It is also in querying any information stored in the database.

One can use a custom application written in Visual Basic on a client workstation to access databases on a Microsoft SQL server. A client/server system can support many users with different authority to manipulate the data stored. Visual Basic can be used to create an interface to the data access on a client station that may restrict to access the entire database-the server station.

In the project, a friendly window interface is created using Visual Basic Programming language. It has a capability to create a link with the database created using SQL. The interface enables users to access, view, edit and add data to the database.

The majority of the data processing is done on the server instead of the clients. This means that a client/server system can reduce your network traffic (because only the results of queries must be sent to the clients).

ArcGIS has a high-level generic information model for representing geographic information, such as features, rasters, and other spatial data types. ArcGIS supports an implementation of the data model for both file systems and DBMSs. Both the file-based datasets and the DBMS-based datasets define a generic model for geographic information. This generic model can be used to define and work with a wide variety of GIS applications. (ESRI)

The researcher uses ArcGIS intensively. Data management and preparation performed in ArcCataloge and ArcMap; map visualization and presentation in ArcMap and the analysis is done using ArcToolbox.

Conversion of point feature in to TIN surface is done in 3D Analyst. The 3D Analyst also implemented in converting the TIN surface in to raster surface. It is prerequisite for Spatial Analysis. Spatial Analysis tool contains so many functionalities to make different analysis.

As it was stated in the objective, one of the output of this research is to make analysis with respect to the service rendered by ETC in mobile sector and potential customers in the sector. The output of the analysis will enable the decision makers of the business to assess the service rendered and the service required.

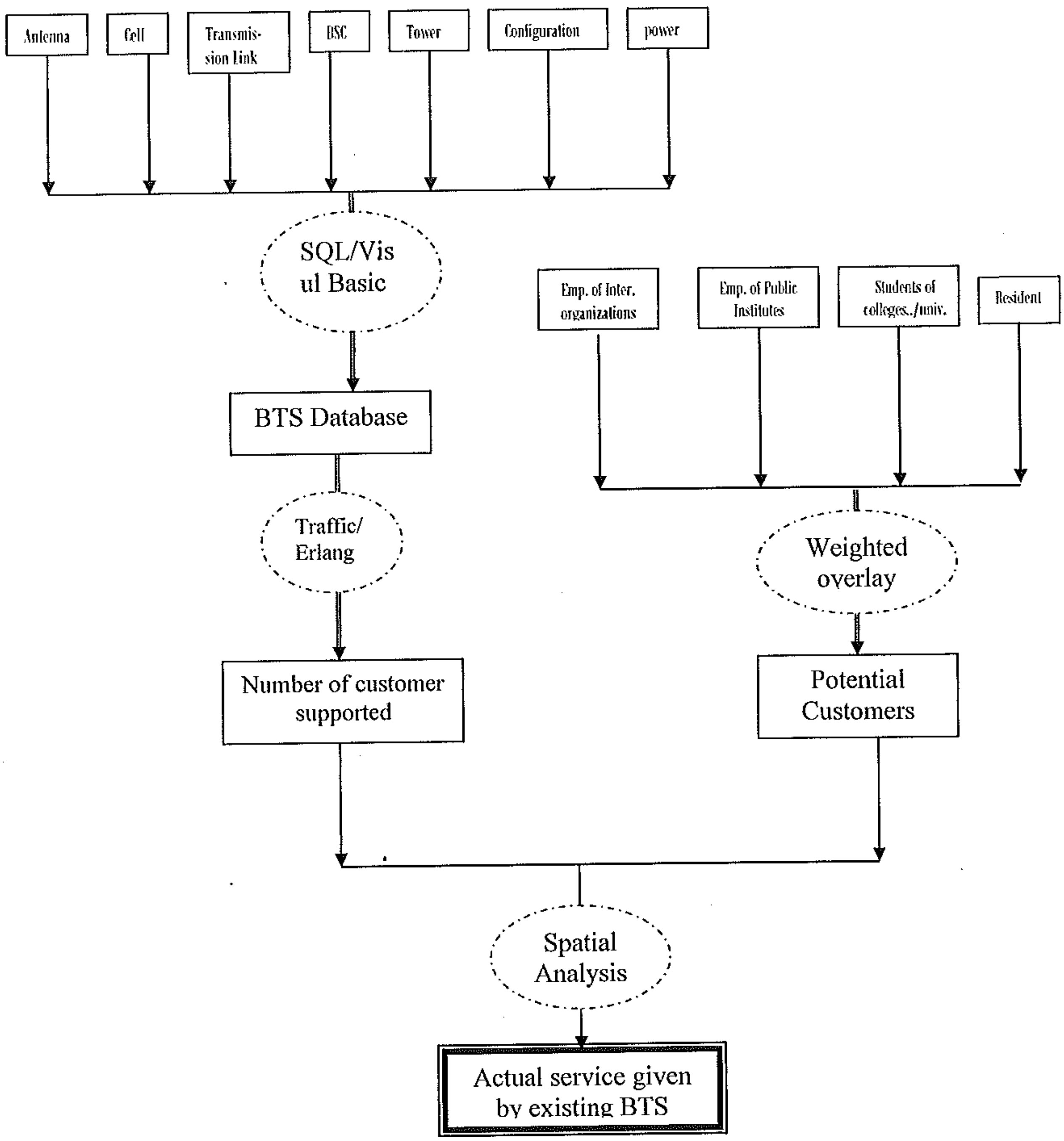


Figure1: Methodology

1.6. The Study Area

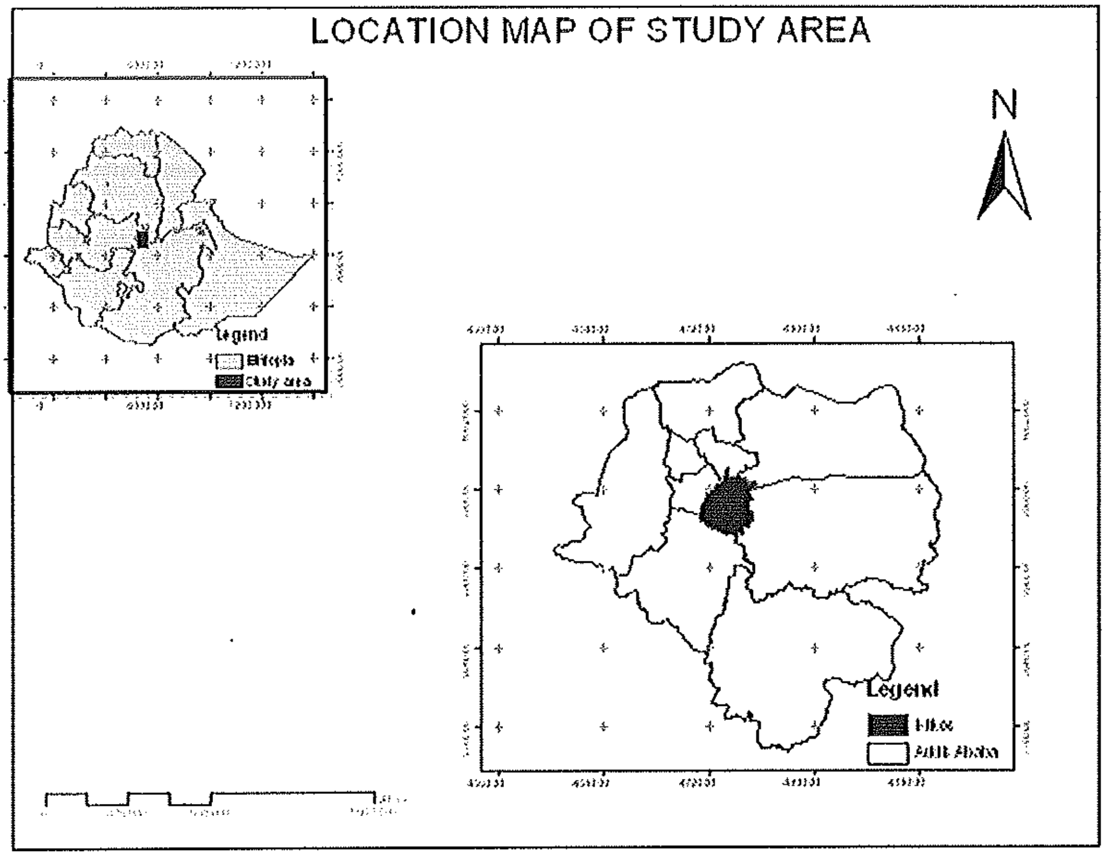
The study area for this thesis is Addis Ababa. Addis Ababa is the capital city of Ethiopia and also a capital for Africa, hence seat of the federal government and head office of African Union. The city is also a home to the African Union, Economic Commission for Africa and different local and international organizations.

Addis Ababa had a population of 65,000 in 1912, which grew to 100,000 in 1935. In a little over three years, it had increased to 143,000 (Techeste, 1987). According to Central Statistic Authority (CSA, 1999), the population of Addis Ababa has grown from 443,728 in 1961 to 683,530 in 1967, 1,167,315 in 1978, 1,423, 111 in 1984 and 2,112,737 in 1994. Its population currently is nearly four million.

Addis Ababa is found between $38\text{-}39^{0}$ longitude and 9^{0} latitude (between $38^{0}34''$E and $09^{0}03''$N).The average elevation of the city is around 2400m above sea level. Its area coverage is 520 km^2. The city is divided into 10 sub-cities, which are further divided into a total of 203 kebeles.

The description about the city emphasizes the importance of well-developed infra-structure and service utilities in the city. One of the services required in the city is a reliable and efficient telecom undertaking. The system implemented by ETC to render the service should in line with the increasing population and the advancement of technology and also the need of the international community.

Kirkos is one of the sub cities of the capital, Addis Ababa. Its population size is about 250,000. The parameters selected for discussion, public institutions, international organizations, secondary schools and colleges/universities and dwellers are available in the sub city. ETC also has full mobile service coverage in the area. So, selecting this sub city for analysis is justifiable.



Map1. Location map of the study area

CHAPTER II

APPLICATION OF GIS IN TELECOM ENVIRONMENT

2.1. GIS and Telecommunication

Geographic Information System

Geographic information systems (hereafter abbreviated to GIS) are computer –based systems that are used to store and manipulate geographic information. This technology has developed so rapidly over the past two decades that it is now accepted as an essential tool for the effective use of geographic information.

The recent and widespread introduction of the GIS has created a sudden need for users of geographic information to become knowledgeable about this technology. Managers within public and private organizations are being called upon to make decisions by the use of GIS technology and to establish policies. Practitioners are being asked to support expensive programs to convert mapped data into digital form suitable for use with a GIS. Students and educators who use geographic information are gaining access to GIS technology that can be used to increase the depth of their analysis. The technology has provided and exciting potential for geographic information to be used more systematically and by a greater diversity of disciplines than ever before.

A GIS is designed for the collection, storage and analysis of objects and phenomena Where geographic location is an important characteristic or critical to the analysis. For example the location of a tower or the locations where soil erosion is most severed are key considerations in using this information. In each case, what it is and where it is must be taken into account.

While handling and analyzing data that are referred to a geographic location are key capabilities of a GIS, the power of the system is most apparent when the quantity of data involved is too large to be handled manually. There may be hundreds or thousands of features to be considered, or there may be hundreds of factors associated with each feature or location. These data may exist as maps, tables of data or even as lists of names and addresses. Such large volumes of data are not efficiently handled using manual methods. However, when those data have been input to a GIS, they can be easily manipulated and analyzed in ways that would be too costly, too time-consuming or practically impossible to do using manual methods. (Stan Aronof)

As described by Aronof, the applications are diverse, for example.

- Managing municipal services, such as scheduling maintenance activities, notifying local residents of re-zoning application. Or assigning police patrol areas.
- Finding the coincidence of factors, such as the areas with a certain combination of soil type and vegetation or the areas in a city with a high crime rate and low-income level.
- Updating geographic information, such as forest cover maps to show recent logging or updating land use maps to show recent conversion of agricultural land to residential development

The number and type of applications and analyses that can be performed by a GIS are as large and diverse as the available geographic data sets.

Despite the analytical power of this technology, a GIS like any other system does not and cannot exist on its own: it must exit in a context. There must be an organization of people, facilities and equipment responsible for implementing and maintaining the GIS. Moreover, that organization like any organization must have a mandate –a reason to exit and the resource to satisfy that mandate. Without the organizational context it becomes unclear why the considerable expense of implementing a GIS has been made who should control the facility and how its success or failure should be judged.

The information in a GIS is presented in two basic forms: as maps and as tables. For example, a map can show where particular types of land use or activities occur. On the other hand information on how much of a resource exists can be given in tabular form. (Stan Aronof)

GIS Use in Telecommunications

To be competitive, telecommunications providers depend on a smoothly functioning work flow process that integrates information for marketing, demand forecasting, engineering, customer management, operations support, and fleet management. Although telecommunications providers generally have the same needs for information, how the work flow is organized can vary significantly from company to company. (ArcUser: 2001)

As it is described in the publication ArcUser, historically telecommunications companies have used an assortment of information systems-some developed in-house, some purchased-that were never designed to work together. When these systems were implemented, there was no perceived requirement for information sharing.

Today telecommunications companies operate networks that have equipment from multiple vendors and lease bandwidth and antenna sites from other companies. Like the case of ETC, Ericson and Nokia are the two vendors for the installation of mobile phone throughout the country. Mergers with or acquisition of other companies, require the incorporation of, or at least interaction with, completely foreign networks.

The need for information sharing within companies and interoperability between systems has been recognized by the telecommunications industry for a long time. Originally founded in 1865 as International Telegraph Union, the International Telecommunications Union (ITU) promotes standards in equipment that guarantee generalized interconnection between communication systems. To improve interoperability, ITU has developed the Telecommunications Management Network (TMN), a method of standardizing business organization. This hierarchy of support systems specifies interoperability through the use of industry-standard protocols. Geospatial applications need to support this same level of interoperability if GIS is to work well within this TMN-structured environment.

Before looking the application of GIS in telecom environment, it is useful to know the tasks and services performed in any telecommunication company. This enable to compare and contrast in which areas or services can GIS be implemented to support company's activity. Common services rendered by any telecom company can be stated as follows as it is summarized by Milind Deshpande and KM Jagadeesh (unpublished article)

- Placement of trenches, cables, structures and facilities in the OutSide Plant
- Plan, design and engineer network and expansion
- Facility layouts, equipment placement and end-to-link connectivity
- Inventory management including equipment assignment
- Repository of as-built and survey data
- Provide network data to OSS / BSS systems
- Answer service activation / provisioning queries
- Cable fault localization
- Marketing and service fulfillment related functions

Solving the many business problems of a telecommunications company requires a good understanding of where your customers and facilities exist today and where they will be tomorrow. In an industry that changes so rapidly, the capability to find, manage, and analyze data quickly and effectively makes a strategic difference.

Geographic information system (GIS) software enables telecommunication professionals to integrate maps with other information to make better decisions. From planning and maintaining network infrastructure to administering mobile telephone coverage, managing existing customers, and finding new ones, GIS users rely on location-based data to find the answers. GIS allows carriers to keep track of customer mobility and trends in the staggering bandwidth requirements driven by entertainment and Internet services. Viewing information on a map makes it quicker and more intuitive than relying on spreadsheets and other tabular data.

A well-designed and implemented telecom application based on GIS platform is a powerful tool available to the telecom enterprises. The application not only maintains inventory of ISP network elements and OSP objects geographically, but is also be used for vital activities like network planning and engineering. High value addition is observed by closely integrating the GIS / Telecom application with OSS and BSS making it a truly enterprise database application.

GIS has the potential to be the integrating technology for all aspects of the telecommunications industry. Today it is commonly used in typical automated mapping/ facilities management applications such as planning, fault tracing, and engineering design. However, there will soon be a greater use of GIS in applications such as demand forecasting, system design, and strategic marketing. GIS will help provide a much better comprehension of market segmentation and the recognition of population distribution patterns. This will allow the industry a greater understanding of their customer base and allow it to better provide optimal products and services.

As summarized by Milind Deshpande and KM Jagadeesh, the following can be considered as how and in which area of the telecom environment GIS is a specific solutions for the industry:

- ✓ Data modeling and database design
- ✓ Onsite Consultants for integration of Network Inventory Asset Management solution with other Network systems.
- ✓ Implementation of end to end GIS / Network Inventory Management system
- ✓ Development services (Onsite / offshore) for Network and Content applications/ location based applications
- ✓ Data management and maintenance services
- ✓ Web enabling of applications
- ✓ Mobile Mapping Solutions for field network operations

Many current applications of GIS in the telecommunications industry began as departmental tools that worked within a well-defined scope. These GIS-based tools have helped automate business processes and increase the efficiency of operations. As summarized by Lisa Godin in his book "GIS in Telecommunication" and other authors, telecommunications companies have integrated GIS into the overall work flow of the industry as described below.

Marketing/Market Segmentation

Telecommunications providers are tied to geography more closely than many other types of businesses. They operate within service areas and the infrastructure that delivers services is linked directly to the location of each customer. Telecommunication companies segment the characteristics for both consumer and business customers geographically using GIS. This not only lets them market more effectively but also helps them forecast the demand for services. Both targeting customers and predicting where and when growth will occur involves integrating corporate intelligence, demographic data, and information about the progress of building projects in the area with location data and applying various modeling techniques.

This paper also tries to show the power of GIS in providing information for decision in expanding service of mobile telephone. GIS enable us to model potential customers in different group (Market segmentation). The information obtained from the analysis drives network investment budgets and marketing campaigns (in competitive environment).

Operations Support Systems

Operations Support Systems (OSS) make sure that the network functions properly. OSS includes activities such as network monitoring, outage management, billing, and testing. With a shared GIS database, staff members have instant access to customer status and history, existing plant records, and signal quality information to support, updates, maintain and repair to the network.

Capacity and Capital Planning

Information generated by marketing and market segmentation activities that define current and future communication demands can be used to create a logical network of capacities and estimate the capital spending required to build this capacity. GIS is widely used in decision support for capital planning. Effective capacity planning uses current data describing the existing plant, the demand information from the marketing phase, and network performance information from OSS.

Wireline Engineering

Wireline engineering systems are GIS applications that work with the design and geographic layout of a company's outside plant infrastructure. Engineering applications allow for quick review and modeling of network routes, automation of the work order process, and high volume cartographic output to support technicians in the field.

Wireless Engineering

Nowhere is competition in the telecommunications industry more intense than in the wireless sector. While most second generation networks have rolled out, new wireless network technologies are forcing carriers to redesign all or parts of their networks. Designing and building a wireless network is a costly process that involves several iterations of planning and testing. Having paid handsomely for third generation licenses, many carriers are highly motivated to reduce the cost of building new networks.

Customer Relationship Management

In today's competitive telecommunications market, customer service is the number one differentiator for companies. Customer relationship management (CRM) applications improve the relationship between the company and its customers. Timely service provisioning, response to customer queries, and reporting on network performance are aspects of CRM. With GIS, call center operators can access all the information on a customer and the associated network based on location. Databases containing information on outside plant infrastructure, signal quality, and equipment can be integrated using GIS and made available using a corporate Intranet.

Fleet Management/Dispatch

Communications companies must manage and route service vehicles for outage response and service provisioning. An efficient dispatch process balances drive times, territories, and the skill sets of individual technicians. GIS routing applications can produce itineraries that take each of these factors into account. Optimizing the dispatch and routing of service vehicles results in significant cost and time savings.

Enterprise GIS: Putting It All Together

When GIS applications servicing various phases of the work flow are interoperable and a networked GIS distributes geographic data to desktops and mobile devices, the value of

GIS to the organization moves well beyond that of a departmental tool. For example, a sales representative can make a compelling business case for the sale of bandwidth to a corporate prospect by showing the prospect's location in relation to the telecommunications company's infrastructure. Network infrastructure provided by GIS is used for decision support in the provisioning process. Technicians in the field locate the correct manhole, pole, or access point by using the same data. Coverage maps and testing data for wireless networks can be instantly viewed by call center operators dealing with customer complaints. More complex applications include geospatial data in data warehousing systems and are used in conjunction with On Line Analytical Processing (OLAP) clients to add a "where" dimension to corporate business intelligence.

The investment telecommunications companies make in geospatial data and technology will yield benefits in business process automation, improved decision support, and value-added services for years to come.

2.2. Mobile Telephone system

Global System for Mobile Communication (GSM)

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. It is estimated that many countries outside of Europe will join the GSM partnership.

The Evolution of Mobile Telephone Systems

Cellular is one of the fastest growing and most demanding telecommunications applications. Today, it represents a continuously increasing percentage of all new telephone subscriptions around the world. Currently there are more than 45 million cellular subscribers worldwide, and nearly 50 percent of those subscribers are located in the United States. It is forecasted that cellular systems using a digital technology will become the universal method of telecommunications. By the year 2005, forecasters predict that there will be more than 100 million cellular subscribers worldwide. it has been estimated that some countries may have more mobile phones than fixed phones by the year 2000. (See Figure 1)

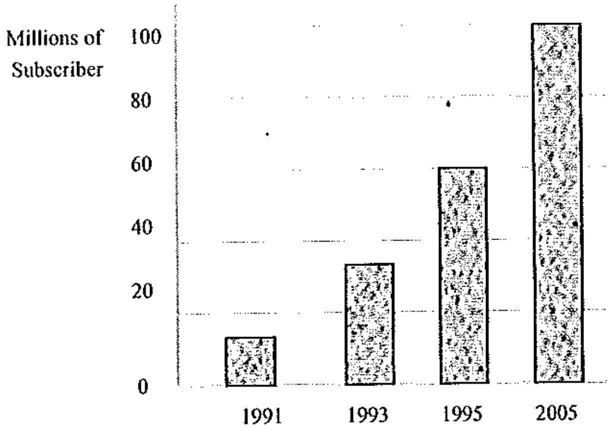


Figure2: Cellular Subscriber Growth Worldwide

The concept of cellular service is the use of low-power transmitters where frequencies can be reused within a geographic area. The idea of cell-based mobile radio service was formulated in the United States at Bell Labs in the early 1970s. however, the Nordic countries were the first to introduce cellular services for commercial use with the introduction of the Nordic Mobile Telephone (NMT) in 1981.

Cellular systems began in the United States with the release of the advanced mobile phone service (AMPS) system in 1983. The AMPS standard was adopted by Asia, Latin America, and Ocean countries, creating the largest potential market in the world for cellular.

In the early 1980s, most mobile telephone systems were analog rather than digital, like today's newer systems. One challenge facing analog systems was the inability to handle the growing capacity needs in a cost-efficient manner. As a result, digital technology was welcomed. The advantages of digital systems over analog systems include ease of signaling, and increased ability to meet capacity demands. Table 1 charts the worldwide development of mobile telephone systems.

Year	Mobile System
1981	Nordic Mobile Telephone (NMT) 450
1983	American Mobile Phone System (AMPS)
1985	Total Access Communication System (TACS)
1986	Nordic Mobile Telephony (NMT) 900
1991	American Digital Cellular (ADC)
1991	Global System for Mobile Communication (GSM)
1992	Digital Cellular System (DCS) 1800
1994	Personal Digital Cellular (PDC)
1995	PCS 1900-Canada
1996	PCS-United States

Table 1. The Development of Mobile Telephone Systems.

Throughout the evolution of cellular telecommunications, various systems have been developed without the benefit of standardized specification. This presented many problems directly related to compatibility, especially with the development of digital radio technology. The GSM standard is intended to address these problems. From 1982 to 1985 discussions were held to decide between building an analog or digital system. After multiple field tests, a digital system was adopted for GSM. The next task was to decide between a narrow or broadband solution. In May 1987, the narrowband time division multiple access (TDMA) solution was chosen. A summary of GSM milestones is given in

Year	Milestone
1982	GSM formed
1986	Field test
1987	TDMA chosen as access method
1988	Memorandum of understanding signed
1989	Validation of GSM system
1990	Pre operation system
1991	Commercial system start-up
1992	Coverage of larger cities/airports
1993	Coverage of main roads
1995	Coverage of rural areas

Table 2. GSM Milestones

The GSM Network

GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The reason for this is to limit the designers as little as possible but still to make it possible for the operators to buy equipment from different suppliers. The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS, and the operation and support system (OSS).

The Switching System

The switching system (SS) is respônsible for performing call processing and subscriber-related functions. The switching system includes the functional nits:

- **Home location register (HSR)**- the HLR is a database for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscription from one of the PCS operators, he or she is registered in the HLR of that operator.

- **Mobile services switching center (MSC)** the MSC performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.

- **Visitor location register (VLR)** –The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time.

- **Authentication center (AUC)** – a unit called the AUC provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects network operators from different types of fraud found in today's cellular world.

- **Equipment identity register (EIR)** –the EIR is a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations. The AUC and EIR are implemented as stand-alone nodes or as a combined AUR/EIR node.

The Base Station System (BSS)

All radio related functions are performed in the BSS, which consists of base station controllers (BSCs) and the base transceiver stations (BTSs).

Base Station Controller (BSC) – the BSC provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations. A number of BSCs are served by an MSC.

Base Transceiver Station (BTS) –The BTS handles the radio interface to the mobile station. The BTS is the radio equipment (transceivers and antennas) needed to service each cell in the network. A group of BTSs are controlled by a BSC. It is the radio transmission part of the base station system, controlled by BSC. It serves as cell radio transceiver equipment, handles conversion between BSC and radio channels and performs radio transmission between BTS and MS (mobile station) via air interfaces as well as related control functions.

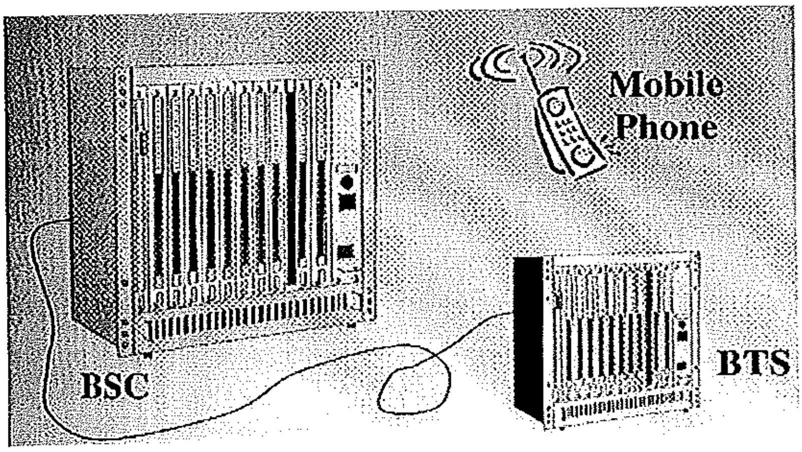


Figure3: a picture that shows BSC, BTS and Mobile phone

The operation and support system

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS). the OSS is the functional entity from which the network operator monitors and controls the system. The purpose of OSS is to offer the customer cost-effective support for centralized, regional, and local operational and maintenance activities that are required for a GSM network. And important function of OSS is to provide a network overview and support the maintenance activities of different operation and maintenance organizations.

Additional functional elements

Other functional elements shown in Figure 2 are as follows:

- **Message center (MXE)** The MXE is a node that provides integrated voice, fax, and data messaging. Specifically, the MXE handles short message service, cell broadcast, voice mail, and fax mail, e-mail, and notification.
- **Mobile service node (MSN)** –The MSN is the node that handles the mobile intelligent network (IN) services.
- **Gateway mobile services switching center (GMSC)** – A gateway is a node used to interconnect two networks. The gateway is often implemented in and MSC. The MSC is then referred to as the GMSC.
- **GSM interworking unit (GIWU)** – The GIWU consists of both hardware and software that provides and interface to various networks for data communications. Through the GIWU, users can alternate between speech and data during the same call. The GIWU hardware equipment is physically located at the MSC/VLR.

GSM network areas

The GSM network is made up of geographic areas. As shown in Figure 3 these areas include cells, location areas (LAs), MSC/VLR service areas, and public land mobile network (PLMN) areas.

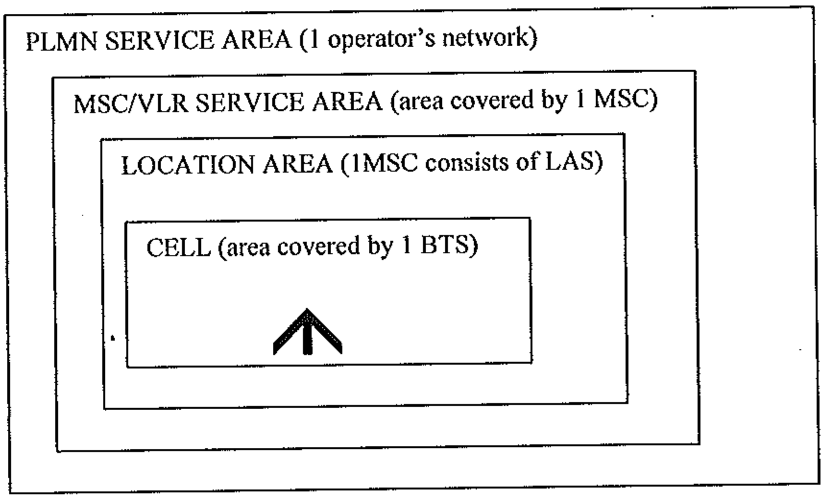


Figure4: Network Areas

The cell is the area given radio coverage by one base transceiver station. The GSM network identifies each cell via the cell global identity (CGI) number assigned to each cell. The location area is a group of cells. It is the area in which the subscriber is paged. Each LA is served by one or more base station controllers, yet only by a single MSC. Each LA is assigned a location area identity (LAI) number.

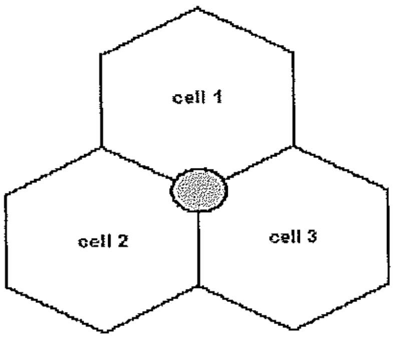


Figure5: cell coverage

GSM Subscriber Services

There are two basic types of services offered through GSM: telephony (also referred to as tele services) and data (also referred to as bearer services). Telephony services are mainly voice services that provide subscribers with the complete capability (including necessary terminal equipment) to communicate with other subscribers. Data services provide the capacity necessary to transmit appropriate data signals between two access points creating an interface to the network. In addition to normal telephony and emergency calling, the following subscriber services are supported by GSM:

- Dual –tone multi frequency (DTMF)-
- Facsimile group III
- Short message services-
- Cell broadcast
- Voice mail
- Fax mail

Supplementary Services

- Call forwarding
- Barring of outgoing calls
- Barring of incoming calls

- Advice of charge (AoC)
- Call hold
- Call waiting
- Multiparty service-.
- Calling line identification presentation/restriction-
- Closed user groups (CUGs)

Telephone in Ethiopia

Starting from Menilik'sII era the demand of telephone in Ethiopia has increased from time to time. The global agenda, New Millinium Development, can only be achieved through efficient infrastructure. One of these infrastructures is deployment of cellular phone throughout Ethiopia. Currently, ETC is working towards this agenda with motto of "connecting the future". Hence the demand is drastically changed from time to time but provision of service a little bit sluggish. Though slow, the delivery service of landline and mobile phones has shown a remarkable increase from year to year. For instance, the landline telephone, which was 49 per 1000 people in 1999, has reached 95 % per 1000 people in 2003 and mobile phone, which was 3 per 1000 people in 1999, has increased to 48 per 1000 people.

The Table in Appendix 2 shows the Information and Communication Sector Service trend of Addis Ababa % and their respective Estimates.

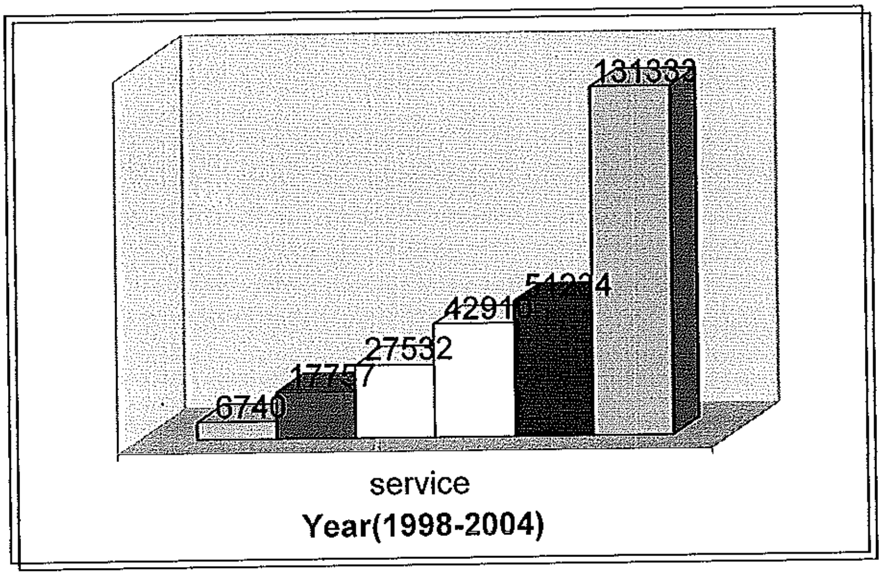


Figure6: Cellular Subscriber Growth in Ethiopia

2.3. GIS and Database management system

Why use a DBMS?

For years, file-based formats have been used to manage and share information using coverages, shapefiles, grids, TINs, computer–aided design (CAD) drawings, and many raster formats. There were some clear advantages to doing this. First, it was easy and inexpensive. Everyone could edit and manage file-based data. No DBMS investment was necessary. Plus, DBMSs lacked the ability to manage the larger, more complex data types and support for operations required by GIS. (ESRI)

In recent years, however, the use of DBMS in GIS has become more widespread. As DBMS capability has evolved into more powerful technology that could support complex data objects, larger queries, and stronger transactional support, the use of DBMS for geographic data management has become much more practical. Most multiuser GIS systems today manage their GIS data in a DBMS, and many smaller sites are beginning their migration to a DBMS. As with other information resources in an organization, GIS data can benefit from DBMS use. It makes good business sense to manage your GIS resources in a relational database.

Some of the reasons to use relational databases are as valid for GIS as they are for other information systems:

- A single data store for attribute and spatial data
- Base relational model (so GIS is compliant with other information technology system requirements)
- Concurrency management in a multiuser environment
- Standard data management practices, such as backup, recovery, and replication
- Performance for any number of users
- The need for managed and organized data
- Scalable data volumes with no size limitations
- Centralized systemwide or companywide access to the data

• Data maintenance over long time periods, spanning personnel changes and hardware and software upgrades
• System failure and recovery mechanisms
• Industry-standard client/server and Internet architectures (e.g., Web services)

DBMS in Telecom

Telecommunication and location service companies network deployments by combining market segmentation, network planning and engineering databases. The decision where to rollout networks first has an enormous impact on the organization. Geographic locations, as well as the package of services, are the two most crucial decision points in a telecommunication or location service business. The combination of the appropriate groups of business and consumers, existing infrastructure, and right-of-ways creates a location-based decision process, a process that GIS can enhance and simplify.
Telco application on GIS platform is the data master for all network inventory and network infrastructure data as well as network related reference data.

- Network inventory data includes equipment, cards and physical ports.
- Physical configuration data includes physical circuits and cross connections.
- Infrastructure includes facilities & other OSP data like trenches and cables.

The data volume of physical network inventory, connections and facilities runs in to a few million records for a large network. Single point data creation with automatic uploading in OSS ensuring synchronizing of the two databases saves several thousand man-hours.

What is the Geodatabase?

It is a comprehensive information model and a transaction model for GIS. It is the common application logic used in ArcGIS for accessing and working with all geographic data files and formats. It is a physical instance of a collection of datasets stored in a file system or DBMS.

Users usually think of geodatabases as physical instances of information collections—primarily using a DBMS. Geodatabases work across a range of DBMS architectures and file systems, come in many sizes, and have varying numbers of users. They can scale from small, single-user databases built on files up to larger work group, department, and enterprise databases accessed by many users.(ESRI)

Two types of geodatabase architectures are available: personal geodatabases and multiuser geodatabases. Personal geodatabases, which are freely available to all ArcGIS users, use the Microsoft Jet Engine database file structure to persist GIS data in smaller databases. Personal geodatabases are much like file-based folders and hold databases up to 2 GB in size. Microsoft Access is used to work with attribute tables in personal geodatabases. Personal geodatabases are ideal for working with smaller datasets for GIS projects and in small work groups. (ESRI)

As it is described by ESRI documentation, users will employ multiple personal geodatabases for their data collections and access these simultaneously for their GIS work. Personal geodatabases support singleuser editing. Multiuser geodatabases are primarily used in a wide range of work groups, departments, and enterprise settings. They take full advantage of their underlying DBMS architectures to support:

- Extremely large, continuous GIS databases
- Many simultaneous users
- Long transactions and versioned work flows

Multiuser geodatabases readily scale to extremely large sizes and numbers of users. Through many large geodatabase implementations, it has been found that DBMSs are efficient at moving the type of large binary objects required for GIS data in and out of tables. In addition, GIS database sizes and the number of supported users can be much larger than GIS file bases. (ESRI)

The geodatabase was designed as an open, simple geometry storage model. Open to many possible storage mechanisms, including DBMS files and XML implementations, the geodatabase is not tied to a single DBMS vendor.

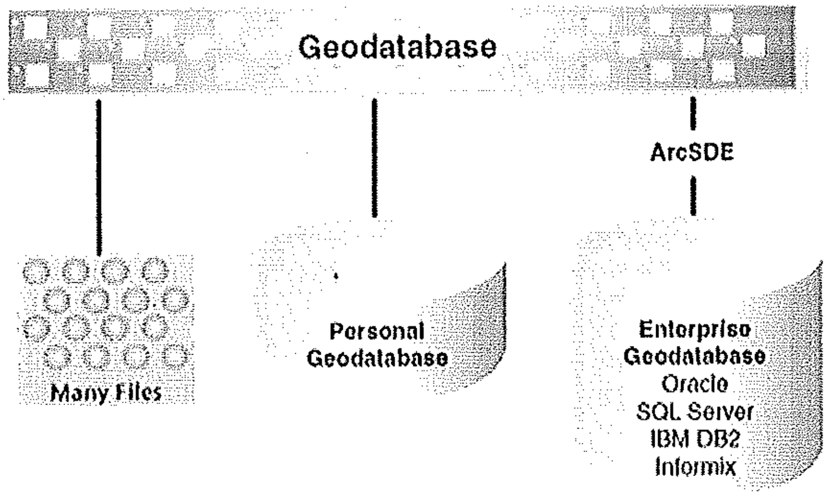


Figure: Geodatabase connection

GIS database requirements

- Scale to large sizes (multiple terabytes)
- Scale to large number of users (hundreds to thousands)
- Provide advanced GIS data models and behavior
- Maintain spatial data integrity
- Support multiple users
- Deliver fast data retrieval
- Use simple data structures such as ISO simple features
- Support long transactions and GIS work flows
- Support multiple uses and applications
- Proven to work through real case studies

The geodatabase provides a generic framework for geographic information. This framework can be used to define and work with a wide variety of different user- or application-specific models. How the data is stored in the database, the applications that access it, and the client and server hardware configurations are all key factors to a successful multiuser geographic information system (GIS). Successfully implementing a GIS with ArcInfo and ArcSDE starts with a good data model design. Designing a geodatabase is a critical process that requires planning and revision until you reach a design that meets your requirements and performs well. You can either start with an existing geodatabase design or design your own from scratch. Throughout this book, guidelines for good data modeling of each aspect of the geodatabase are discussed to help you implement a successful multiuser GIS system with ArcInfo, either with ArcSDE or with a *personal geodatabase*.

The geodatabase was designed as an open, simple geometry storage model. Open to many possible storage mechanisms, including DBMS files and XML implementations, the geodatabase is not tied to a single DBMS vendor.

2.4. Structured Query Language

If you're thinking about implementing a database on your network, you should understand the role that a database server such as Microsoft SQL Server plays. Microsoft SQL Server is a client/server database management system. A client/server database management system consists of two components: a front-end component (the client), which is used to present and manipulate data; and a backend component (the database server), which is used to store, retrieve, and protect the databases.

For example, you can use Microsoft Access or a custom application written in Visual Basic on a client workstation to access databases on a Microsoft SQL server. In a client/server system, the majority of the data processing is done on the server instead of the clients. This means that a client/server system can reduce your network traffic (because only the results of queries must be sent to the clients). In addition, client/server systems are easier to scale because you can upgrade their performance simply by upgrading the server's hardware. You can use SQL Server 2000 to support databases of almost any size. In fact, SQL Server easily supports terabyte-size databases.

You'll frequently hear Microsoft SQL Server 2000 referred to as a relational database management system (RDBMS). An RDBMS uses established relationships between the data in a database to ensure the integrity of the data. For example, if you're setting up an order-entry database system, you'll probably define a relationship between the customer and invoice tables so that a sales clerk can't enter a customer account number in the invoice table if that customer doesn't exist in the customer table. These relationships enable you to prevent users from entering incorrect data

SQL Server includes many features that make it a powerful database management system for enterprise networks and smaller networks. These features include everything from supporting a wide variety of operating systems to integration with Windows 2000 and the Microsoft Server applications.

Features of Sequential Query Language

Scalability

Microsoft SQL Server is scalable, which means your database management system can grow with your company. SQL Server is multi-threaded and can take advantage of Windows 2000's threading and scheduling services. Microsoft SQL Server also supports parallel database architecture. If your server has multiple processors, SQL Server will issue database commands to all processors simultaneously. Finally, the Standard edition of SQL Server 2000 can address up to 2 gigabytes (2 GB) of RAM and 32 terabytes (32 TB) of hard-disk space.

Replication

Depending on your network, you might find that you need more than one SQL server. For example, you'll typically need multiple SQL servers if your network consists of two or more sites connected by WAN links. You might also choose to configure more than one server for fault-tolerance. If you find that you need more, the maximum amount of RAM and disk space supported by SQL Server 2000 varies depending on the edition you're installing on SQL server for your network, you can configure SQL Server to automatically copy information from one SQL server to another. The process of copying data from one SQL server to another is called replication. Replication automates the process of copying data from one SQL server to another so that you don't have to manually copy data to your SQL servers.

Centralized Management

You can manage all of your SQL servers by using the Microsoft SQL Server Enterprise Manager utility. This utility provides you with a graphical interface for performing such management tasks as creating and maintaining databases and their objects, optimizing the server, and configuring replication.

Reliability

SQL Server includes reliability features such as transaction processing, online backups, and log shipping. Transaction processing enables SQL Server to detect and roll forward or back any incomplete transactions in a database. An incomplete transaction can occur if your server shuts down improperly (like when the power fails). SQL Server uses transaction processing to prevent databases from becoming corrupt. Online backups enable you to back up your server's databases without shutting down the server or disconnecting users. The log shipping feature makes it easy for you to set up mirrored SQL servers. Your primary server is called the production server, and the backup server is called the standby server. With log shipping, SQL Server automatically copies all changes to a database on the production server to your standby server.

Automating Tasks

One of the wonderful features of SQL Server is its ability to schedule jobs. You can use this feature to schedule jobs to run at a specific time or on a regular basis. For example, you can schedule jobs to import or export data, back up a database, or replicate information between servers. You can also configure SQL Server to notify you when a scheduled task is completed; SQL Server can send this notice via email, pager, or the net send command. SQL Server includes a sophisticated alerts management system that enables you to configure your server to automatically monitor for problems on the server, and even run jobs in the event a problem occurs.

CHAPTER III

DATABASE DEVELOPMENT

3.1. Microsoft SQL Server Application

The prior task in this project is constructing relational database using Microsoft SQL Server as tool. SQL server is preferred due to the functionalities that can be gained from this program that have been discussed above like security, multiuser support, access time, and ability to process huge data.

SQL server has two options in creating a database and its related objects, using Query Analyzer and Enterprise Manager. The researcher adopts to use in most cases the Query Analyzer option. This method is applicable through writing codes of instructions called Structured Query Language(SQL). Some of the codes used are shown below.

To create BTS_Inventory database the code is:

CREATE DATABASE BTS_Inventory

3.1.1. Creating Table

You should always plan the design of tables for a database before you actually create them. You can begin the design by examining the data you want to store in each table. Because SQL Server is a relational database, meaning you can link tables together using the constraint that will be created later in this paper. Normalizing the tables is also another task. When you normalize tables, you prevent duplications of data both within each table and across multiple tables.

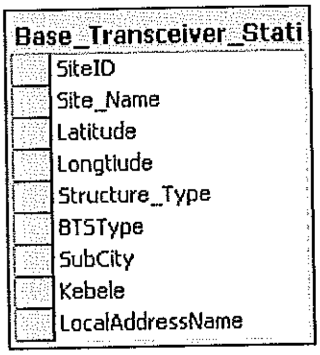
When you design normalized tables, you prevent the duplication of data across multiple tables. There are three normal forms, each one having a greater degree of normalization. In First Normal Form (1NF), you must configure the columns in a table so that each contains different information. In Second Normal Form (2NF), you can configure not to have a table where one of its columns is derived from another column. Finally, in Third Normal Form (3NF), you can't configure tables with any duplicate information.

One of the important table in the database is Base_Transceiver_Station, to create this you need to write the following code of statements:

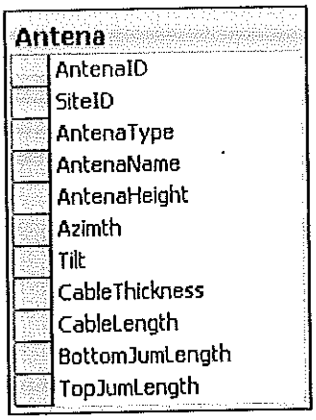
```
CREATE TABLE Base_Transceiver_Station
(
SiteID              varchar(15)     not null,
Site_Name           varchar(20),
Latitude            real            not null,
Longtiude           real            not null,
Structure_Type      varchar(15),
BTSType             varchar(20),
SubCity             varchar(20),
Kebele              varchar(2),
LocalAddressName    varchar(20)
)
```

The first column above lists available fields (field names) in Base_Transceiver_Station table. The second column displays the possible data types that will be populated as field value at the time of.data entery. The last column is about accepting or not accepting null value or not for the respective fields.

The possible tables that pass through normalization process and available in the BTS_Inventory database are created as shown below.

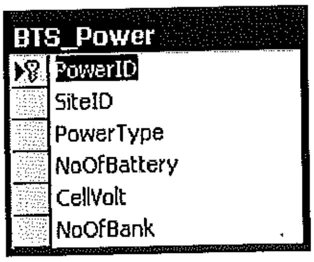


Base_Transceiver_Station table is a parent table for most tables in the database. Base Transceiver is one of the important equipment radio transmission part of the base station system. It is controlled by BSC and has a link with antenna and cell and has a power with its own configuration. The code is given above.



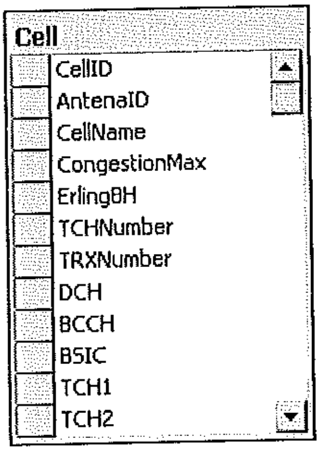
Antenna is another table used to describe the physical and logical part of the equipment. It has a link with a BTS using cable and other devices. The code used to create is:

```
Create table Antena
(
AntenaID      varchar(15)        not null,
SiteID        varchar(15)        not null,
AntenaType    varchar(20),
AntenaName    varchar(20),
AntenaHeight        real,
Azimth              real,
Tilt                real,
 CableThickness      real,
 CableLength         real,
 BottomJumLength     real,
 TopJumLength        real
 )
```



BTS_Power includes the type, and amount of power supplied for each BTS and the physical description of the power itself. It is created by the code:

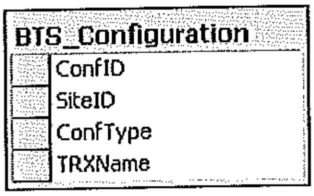
```
Create table BTS_Power
(
PowerID            varchar(15)          not null,
 SiteID            varchar(15),
 PowerType         varchar(15),
 )
```



A **cell** may be defined as an area of radio coverage from one BTS antenna system. It is the smallest building block in a mobile network and is the reason why mobile networks are often referred to as cellular networks. The code used to create the table is:

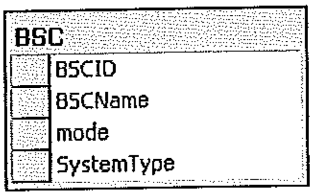
```
Create table Cell
(
CellID              varchar(15)          not null,
AntenaID            varchar(15),
CellName                 varchar,
CongestionMax            int,
ErlingBH                 varchar,
TCHNumber                int,
TRXNumber                int,
DCH                      varchar,
BCCH                     varchar,
BSIC                     varchar,
```

```
TCH1                    varchar,
TCH2                    varchar,
TCH3                    varchar,
TCH4                    varchar,
TCH5                    varchar,
TCH6                    varchar,
TCH7                    varchar,
TCH8                    varchar,
TCH9                    varchar,
TCH10                   varchar,
TCH11                   varchar
)
```



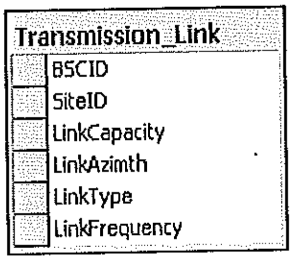
A cell is configured for so many parameters, the table includes the very limited one that may encounter frequent changes and update. A single BTS may support and configured for the coverage of one, two or three.

```
create table BTS_Configuration
(
ConfID              varchar(15)        NOT NULL,
SiteID              varchar(15),
ConfType            varchar(20),
TRXName             varchar(20)
)
```



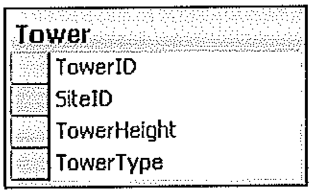
BSC – the BSC provides all the control functions and physical links between the MSC and BTS

```
Create table BSC
(
BSCID                  varchar(15)        not null,
 BSCName               varchar(20),
 mode                  varchar,
 SystemType            real
 )
```



Transmission_Link table carries information about the radio link between BSC and BTS. It is also used to relate the two tables. In this database it is also used relate BTS and BSC table.

```
Create table Transmission_Link
(
 BSCID                        varchar(15),
SiteID                       varchar(15),
    LinkCapacity                 varchar,
    LinkAzimth                   real,
    LinkType                     varchar,
    LinkFrequency                varchar)
```



Tower table contains the two fields TowerHeight and TowerType and has a relation with BTS. Towers are erected at elevated place with height over 40 meters. The code used to create this table is:

```
Create table Tower
(
TowerID         varchar(15)        not null,
SiteID          varchar(15),
TowerHeight     real,
TowerType       varchar
)
```

3.1.2. Constraint and Data Integration

In SQL Server 2000, you can enforce data integrity by using a variety of methods. These methods enable you to make sure that the data users add or modify in your databases is valid. You can enforce data integrity by using either of two methods: declarative or procedural. With declarative data integrity, you enforce integrity as part of the object itself; the integrity becomes part of the database and table definitions. You use constraints, defaults, and rules to enforce declarative data integrity. You enforce procedural data integrity through the use of programming. You can use triggers and stored procedures to implement procedural integrity.

As it is discussed by William O. Ingle in the book Microsoft SQL Server 2000 - Database Design, since programming can add considerable overhead to your server's workload, Microsoft recommends that you primarily implement data integrity through declarative methods wherever possible instead of through procedural methods. For this reason and its simplification, this research focuses on declarative data integrity and also performed in that way like the data type discussed above.

3.1.3. Defining Primary Key Constraints

You can define a *primary key* that consists of one or more columns in a table; you use the primary key to uniquely identify each row in a table. Because you use a table's primary key to search for records, SQL Server requires that each row's primary key be unique throughout the table. So, by using a primary key, you can protect the integrity of the data in a table. In addition, by specifying a primary key when you create a table, you create an index for the table that's based on the primary key. Because the primary key is used for indexing the table, SQL Server requires that you configure the columns in the primary key to not accept null values. SQL Server doesn't permit duplicate entries in the primary key column(s) for a table.

Most of the tables that are created in the database have primary key constraints. The following code of statements can be used to create a primary key constraint for the table Base_Transceiver_Station by considering SiteID as a unique value.

ALTER TABLE Base_Transceiver_Station
ADD CONSTRAINT PKStation *PRIMARY KEY* (SiteID)

Similarly, a primary key constraint is defined for tables requiring it using Query analyzer window of SQL server.

3.1.4. Defining Foreign Key Constraints

As we talked earlier, about normalizing your tables in order to avoid duplicating data across multiple tables. After you split up your tables, you use relationships between those tables to link them together. If you create one or more columns in one table that are identical to the primary key for another table, you can link these columns by defining a foreign key constraint.

You must define the primary key before you can link a foreign key to it. After you've defined the foreign key constraint, data integrity prevents you from changing the value of a primary key if you have any matching rows in the foreign key table. Likewise, you can't delete a row from the primary key table if it has matching rows in the foreign key table

The syntax used in defining foreign key constraint is written below. Defining the foreign key constraint also assure the possible relationship exist in the database.

```
ALTER TABLE table_name
ADD CONSTRAINT constraint_name FOREIGN KEY
(column_name) REFERENCES ref_table(ref_column)
```

The result of the above task is to link the above tables with the possible relationship.

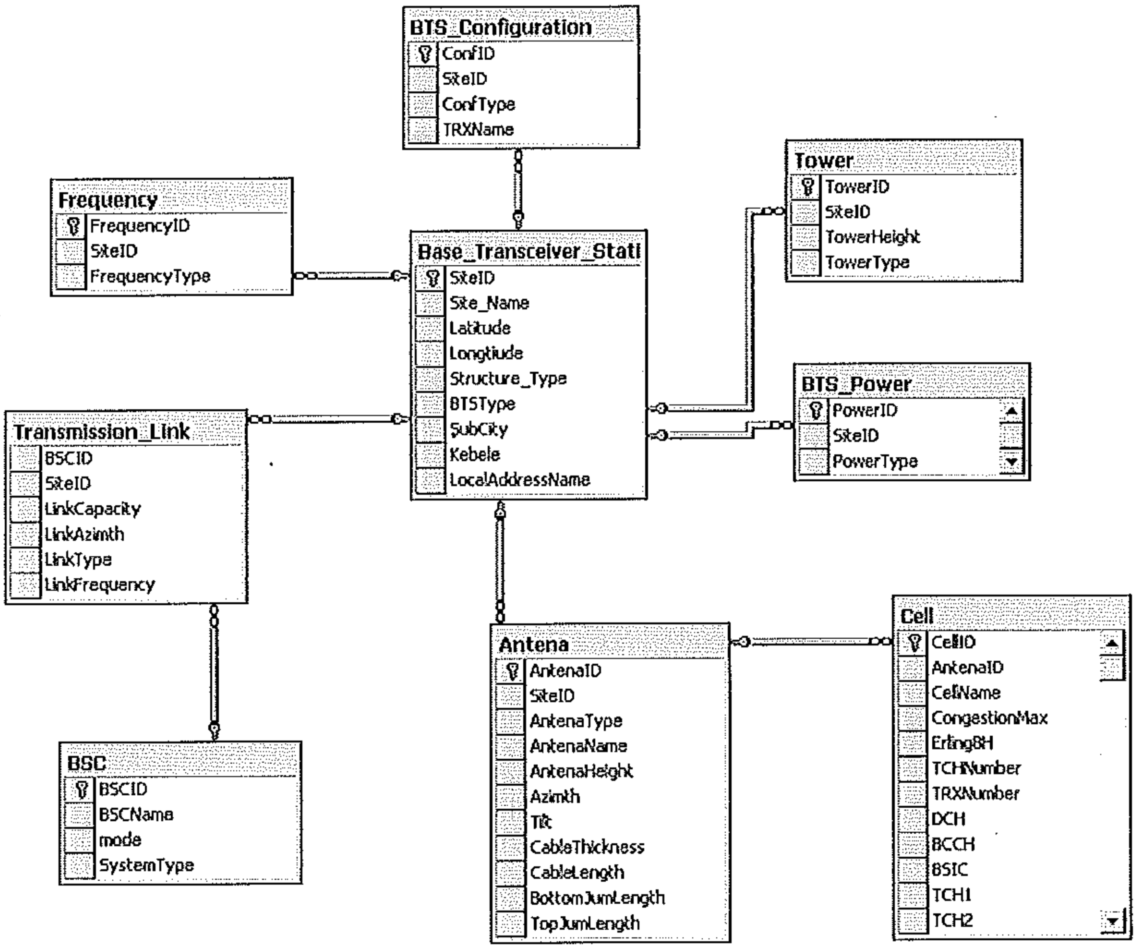


Figure7: Relationship among tables

3.1.5. SQL Server Security

Although managing security is primarily a database administrator's task, as a database developer, the researcher tries to show how SQL Server's security works. SQL Server's security consists of three layers:

- ✓ Login security, which enables you to control who can log in to the SQL server.

- ✓ Database access security, which enables you to control who can access each database on your server.
- ✓ Permissions security, which enables you to control what a user or group of users can do to a database

In SQL Server Enterprise Manager, in the console tree, expand your server's Security folder. Select the Logins object to view a list of the login accounts on your SQL server in the details pane. By default, SQL Setup creates a SQL login account named sa (system administrator) with full permissions to manage the server.

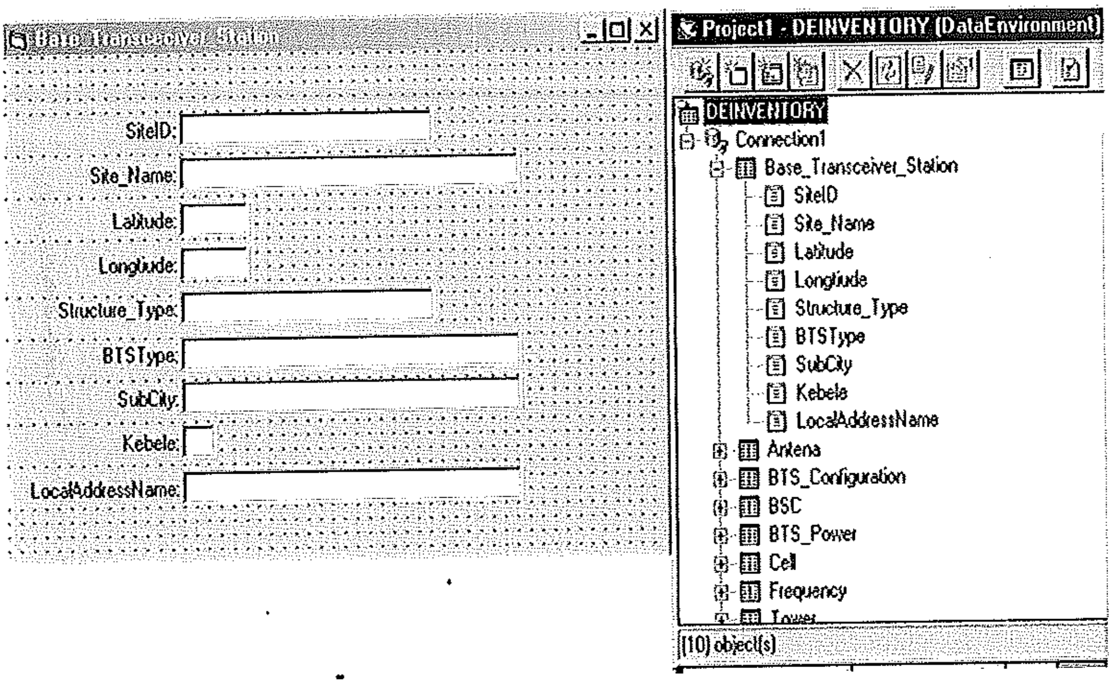
In addition, Setup creates a login account for the Windows user account for the service account (this is the account the SQL Server services use to log in to your server). Finally, Setup creates a Windows login account for the Windows 2000 Administrators group. As a result, all members of the local Administrators group on your SQL server can log in to your SQL server.

3.2. Visual Basic forms: A user interface for SQL database

Visual Basic is a programming language that enables a programmer to accomplish about any task he can imagine. In this thesis, it is implemented to create a users interface to access data from the SQL server. So it is required to link the table created in the SQL server with the form created in Visual Basic and to access the data stored.

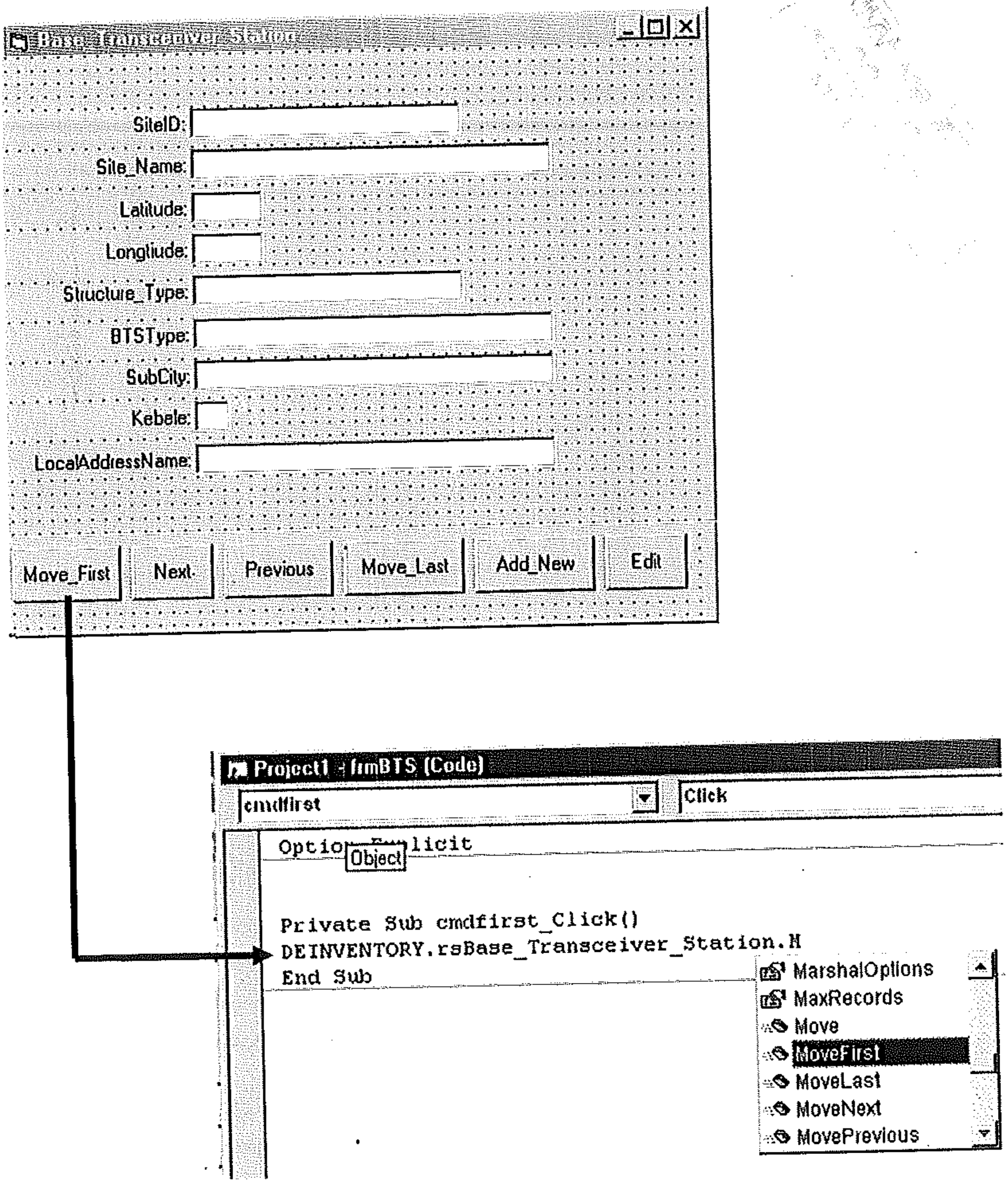
An application can choose from a variety of data access techniques available for managing and maintaining data. These include Open DataBase Connectivity (ODBC), Data Access Objects (DAO), Remote Data Objects (RDO), ActiveX Data Objects (ADO) and Object Linking and Embedding DataBase (OLE DB). Some of the important factors that govern the choice of these technologies are Functionality, Programming ease, Deployment issues and Performance.

ADO connection is adopted in the paper. The ADO Connection object is the highest-level object in the ADO object model and it makes a connection between your application and an external data source. The Connection object lets you specify all the necessary parameters (for example, the server and the database names, the user's name and password, and the timeout) before they serve as containers for transactions. Each connection belongs to a given client application and is closed only when you explicitly close it, when you set the object variable to Nothing, or when your application ends.



A Connection object represents a unique session with a data source. In the case of a client/server database system, it may be equivalent to an actual network connection to the server. Depending on the functionality supported by the provider, some collections, methods, or properties of a Connection object may not be available.

The above picture shows how connection is created with Visual Basic form. The form created for each table can be made friendly by adding some command button and code. The command button can be prepared for viewing data (Like Next and Previous), adding data, and editing data.



Base Transceiver Station
SiteID:
Site_Name:
Latitude:
Longitude:
Structure_Type:
BTSType:
SubCity:
Kebele:
LocalAddressName:
Move_First
Next
Previous
Move_Last
Add_New
Edit
Project1 - frmBTS (Code)
cmdfirst
Click
Option Explicit
Object
Private Sub cmdfirst_Click()
DEINVENTORY.rsBase_Transceiver_Station.M
End Sub
MarshalOptions
MaxRecords
Move
MoveFirst
MoveLast
MoveNext
MovePrevious

3.3. Creating a geodatabase using ArcGIS

The geodatabase—short for geographic database—is the core geographic information model used to organize GIS data into thematic layers and spatial representations. The geodatabase is a comprehensive series of application logic and tools for accessing and managing GIS data. The geodatabase application logic is accessible in client applications (ArcGIS Desktop), server configurations (ArcGIS Server), and logic embedded in custom applications (ArcGIS Engine).

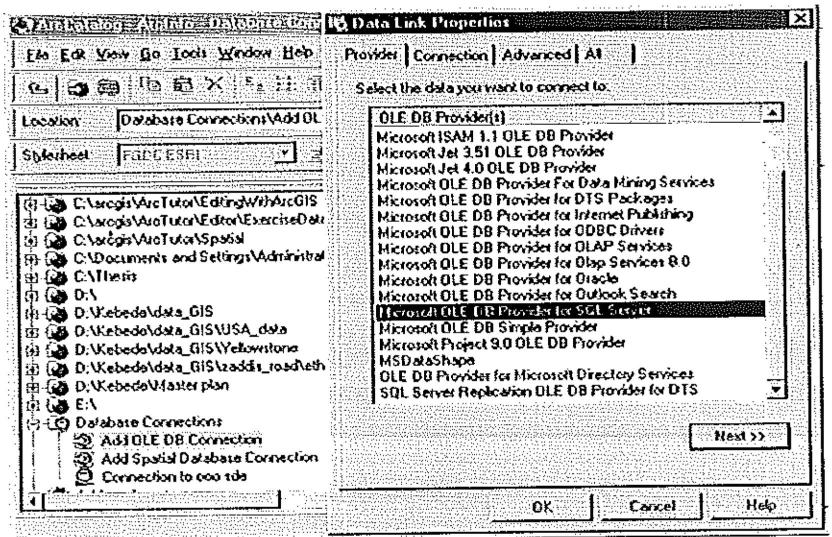
The geodatabase is a GIS and DBMS standards-based physical data store and is implemented on a number of multiuser and personal DBMSs and in XML. Geodatabase application logic is used to work with datasets in hundreds of formats and data structures, and it is also used to implement advanced GIS data objects, such as topologies, networks, raster catalogs, relationships, and domains.(ESRI)

3.3.1 Creating BTSs Point Map

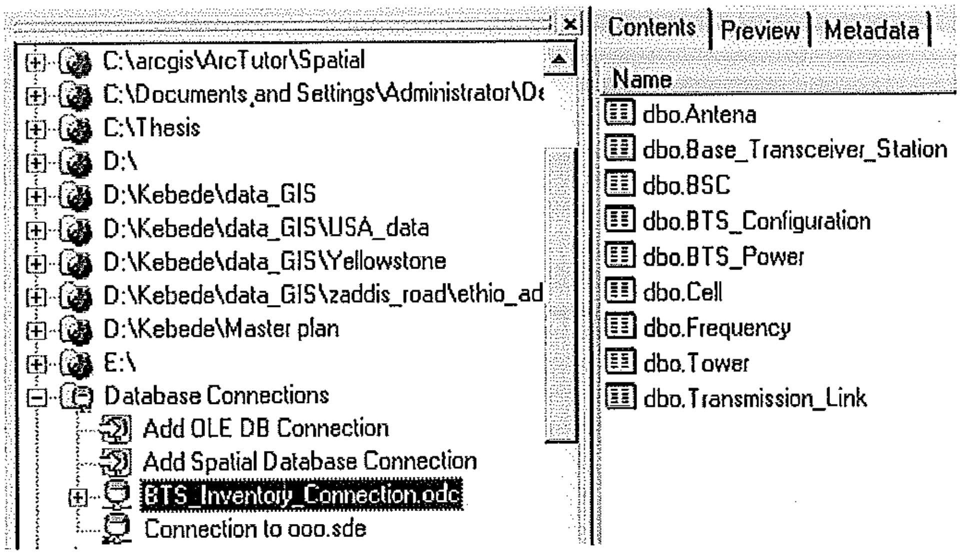
In the discussion above, the RDBMS is created and one of the table Base_Transceiver_Station, that contains the location information (latitude and longitude) of each BTS. The Table can be linked to ArcGIS to get point map of the BTS.

The connection can be created using ArcCatalog. In the ArcCatalog table of content there is OLE DB connection that contains option to select for different DBMS software providers. One of this software is a SQL, so it is possible to provide connection with the database created above.

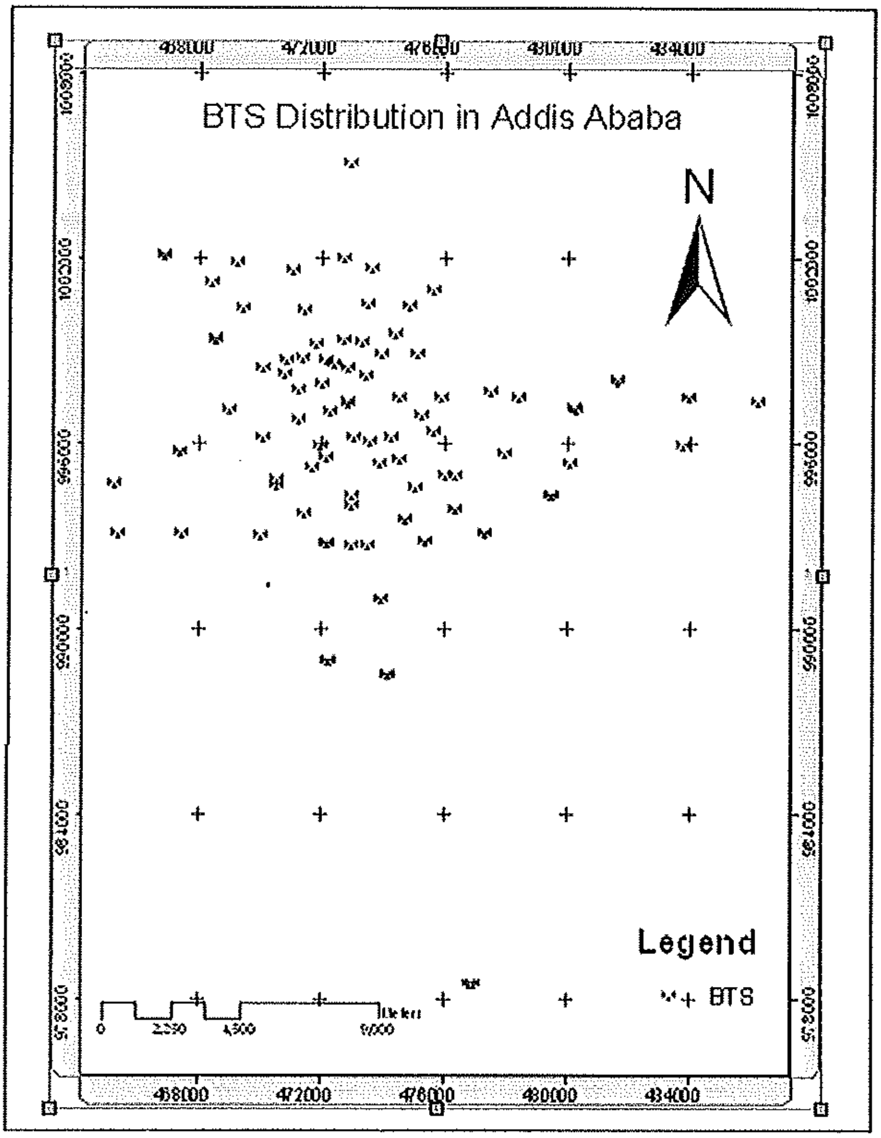
The pictures depict the connection.



After following the procedure the output will be dbf tables connected to ArcGIS.



When you add the Base_Transceiver_Station table that contains location data on ArcGIS window, you can get BTS point map as depicted in map2. The points shown have got their own intelligence, displays the information stored in the BTS table. This is one of the outputs of this research. It alleviates one of the problems stated in the thesis.



Map2: BTS distribution in Addis Ababa

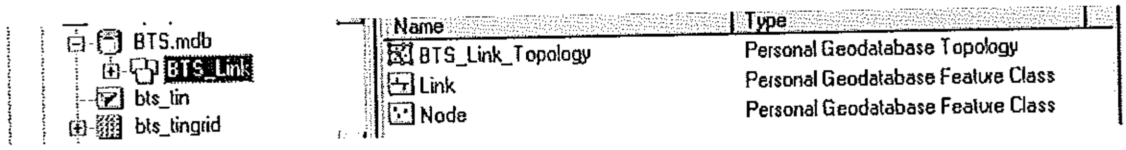
3.3.2 Creating Link-to-Node using Topology

Topology is used most fundamentally to ensure data quality and to allow your geodatabase to more realistically represent geographic features. A geodatabase provides a framework within which features can have behavior, such as subtypes, default values, attribute domains, validation rules, and structured relationships to tables or other features.

This behavior enables us to more accurately model the world and maintain referential integrity between objects in the geodatabase. Topology may be considered an extension of this framework for behavior that allows you to control the geometric relationships between features and to maintain their geometric integrity. Unlike other feature behavior, topology rules are managed at the level of the topology and dataset, not for individual feature classes. (ESRI)

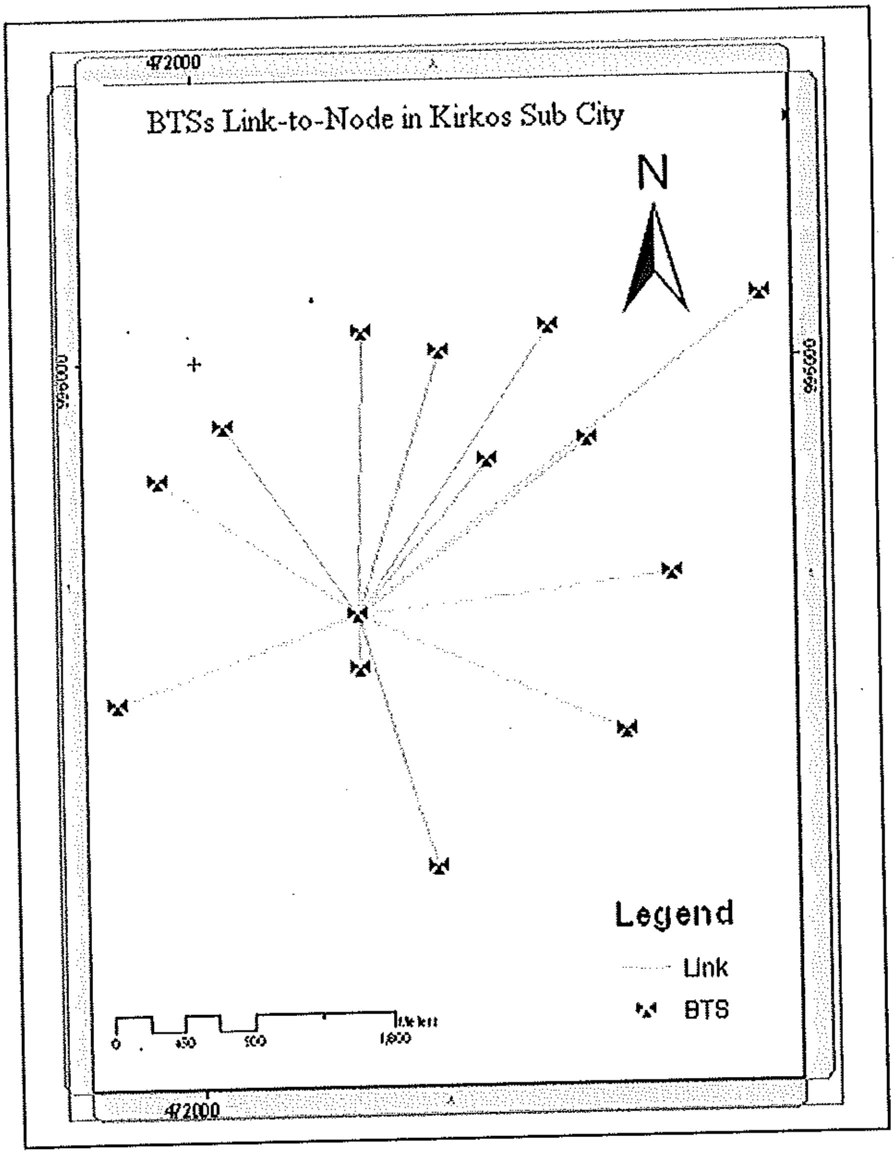
For this project topology is applied to link the BTSs (Node) with the BSC, the controller of the BTS using transmission radio (link). The nodes(BTSs location) are generated above (Map1) and the link is generated using the procedure below.

In ArcCatalog, with in the exist geodatabase or by creating a new geodatabase, it is possible to create a new dataset. Then in the created dataset, a new line shape file (for the link) is created and the existing point data (BTS location for the node) is imported and also a new topology is created.



In the process of creating topology, topology rule, cluster tolerance, rank assignment which is appropriate to the task is defined. The appropriate topology rule for the task is "Node must be covered by end point of link". In rank assignment higher rank (1) is assigned to node (existing location) and the lower is assigned to the link (that is created in ArcMap). Cluster tolerance is taken the default value.

After making ready the dataset for editing, the next step is to add it in the ArcMap. Using Editor Menu and its snapping and editing functionality it is possible to produce the link-to-node map as shown below in map3.



Map3: Link-to-Node map of BTSs located in Kirkos sub city.

CHAPTER IV

BTS CAPACITY VIS-À-VIS POTENTIAL CUSTOMERS

4.1. BTS capacity

One of the expected results of this thesis is to make analysis about BTS capacity in provisions customer number with the potential customers in the area. The number of customer supported by a BTS depends on so many parameters as it is discussed in the second chapter of this paper. So, the number of customers supported can be derived as follows using traffic formula and standard Erlang-B Traffic table .

Traffic refers to the numbers of subscribers the network can support and is usually described as follows:

$$A = n \times T/3600$$

Where n- calls made by a subscriber within an hour

T- average duration of each call (in seconds)

A- Traffic, in Erlang

If call is made by a subscriber and last 120 seconds, the traffic is calculated as:

$$A = 1 \times 120/360 = 33\text{mErl}.$$

In the case of Ethiopia, 30mErl is taken per subscriber. This result is one of the input to determine the capacity of each BTS. In addition, the number and capacity of channel dedicated in each BTS is a basic parameter to derive the number of customers supported. Having the standard table with the combination of Traffic data and number of channels (TCH) you, it is possible to calculate the actual customer supported by a given BTS with 0.02 Grade of Service.

Grade of Service (GOS) refers to the degree of network congestion or call loss rate. GOS = 2% means that 98% of subscribers can make calls successfully and 2% of subscribers will end up with unsuccessfulness.

Erlang-B Traffic Tables For P.02 Grade of Service	
TCH	Erlangs
10	5.08
20	13.2
30	21.9
40	31
50	40.3
60	49.6
61	50.6
62	51.5
100	88

Table1. Sample table for Erlang Traffic Tables

If a BTS has TCH number 40, then the respective value of Erlang is 31. The actual customer supported at time can be calculated by dividing the derived value(31Erl) by 30mErl (Ethiopian case).

Customer supported by one cell = 31/ (30/1000)

=(31/ 30) x 1000

=1033

If the BTS has three cells with equal number of channels, the total number of customers supported by the BTS will be 3100.

Using the same formula and calculation, it is possible to get the number of customers supported by all BTSs'. The following table shows some of the BTSs' cell name, Erlang and the respective customers supported by each cell.

The table that shows the calculated figure of the number of customer supported by each cell is attached at appendix 1.

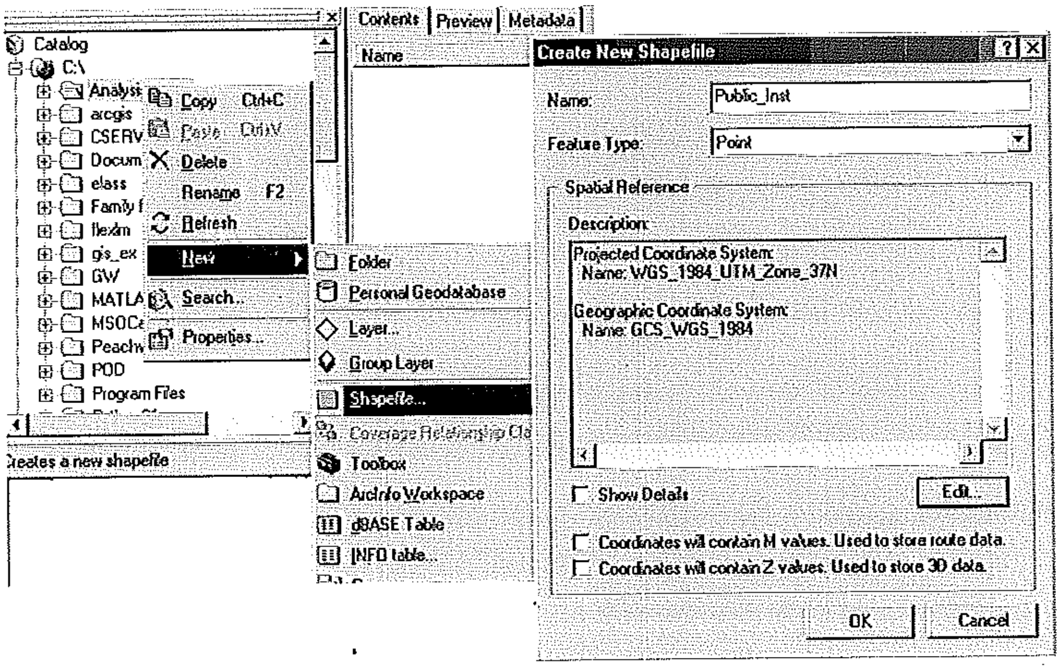
After calculating the number of customers for all BTSs', it is possible to add additional column on the BTS table by the name customers and populate with the data above. This data will be used later in the research to make some kind of analysis.

4.2. Potential customers

The researcher tries to identify 'some of the potential users of cellular phone. The potential users can be the residents in the area, the public institution, international organizations, secondary schools and higher institutes. For simplicity, the analysis is done on Kirkos sub city. In this area all the parameters indicated by the researcher are available.

The population size for each parameter with respect to their location is collected and prepared for analysis. The technique implemented in preparing the data for the analysis is discussed as follows:

The first step is to create a point shape file in the arc catalogue to represent each parameter. These are Resident, Public Institutions, International Organizations, Secondary schools and Higher Institutions.



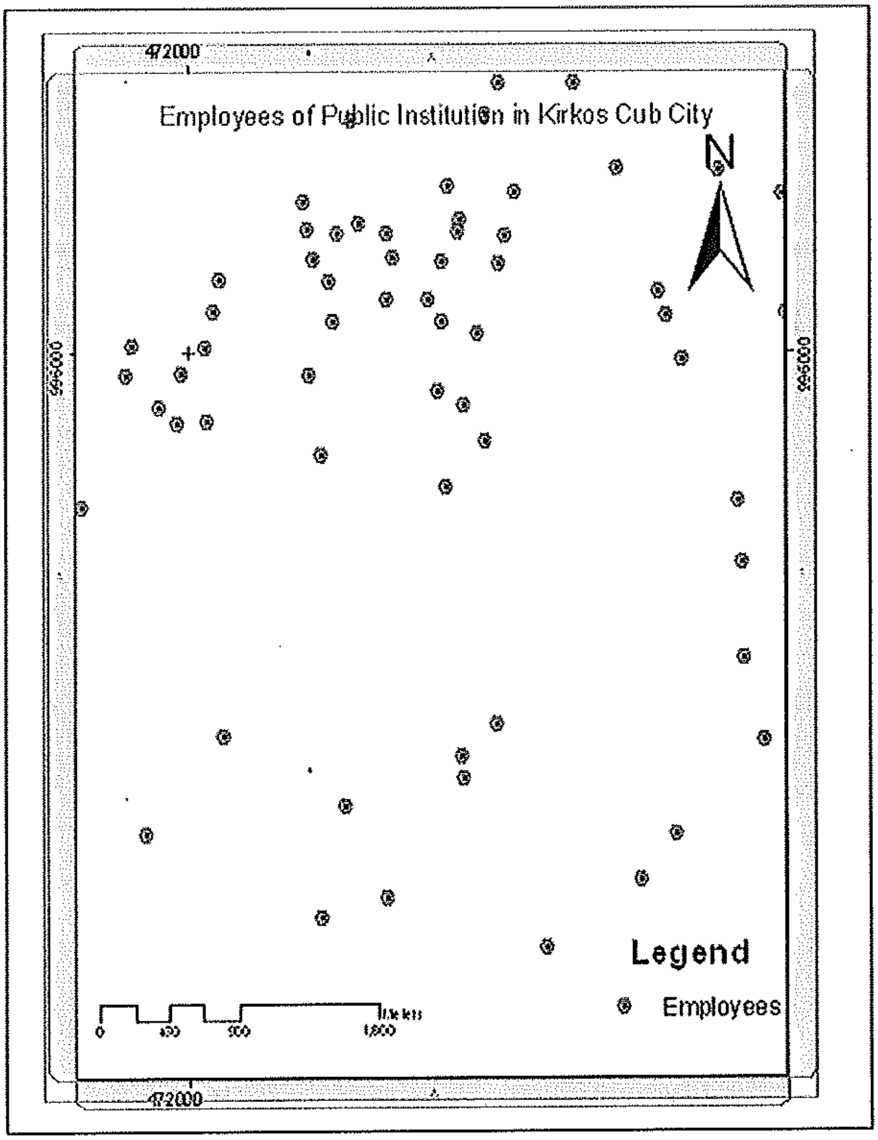
The above picture shows the steps involved in creating a point feature for Public Institutions. The creation of point feature includes projection of the features in to UTM geographic projection.

Using the above steps it is also possible to create a point feature for the International Organizations, and college /schools.

After creating the point features, you need to add in to ArcGIS. By adding location and population fields for each layer then populating with the respective data. So the output, for example for the public institution, of this process is a point employee map. It indicates the number of employees in each institute with the respective location.

Map4 below depicts the distribution of public institution in the Kirkos sub city. The public institution in this paper represents state ministry, state organizations and factory, private companies like factory or large business that may have impact on the users of mobile phone in the area.

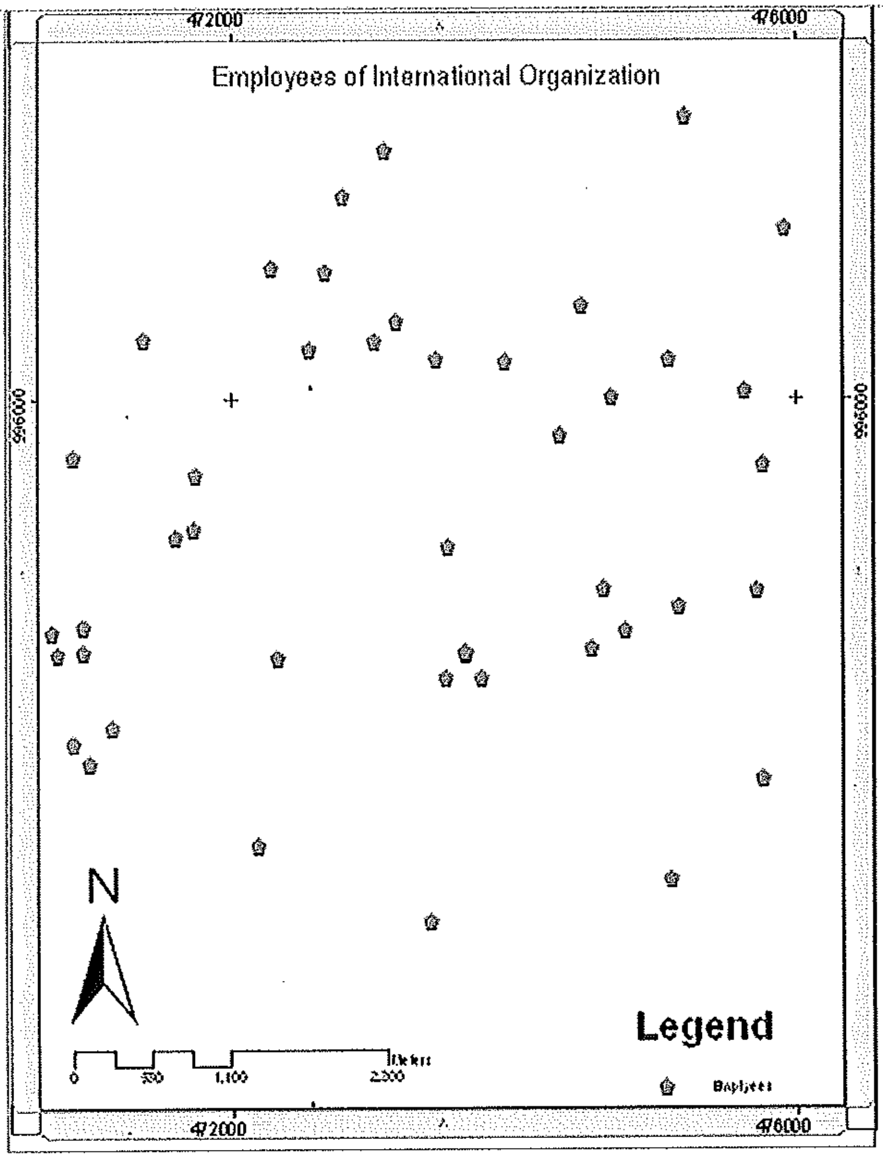
Employees in the public institutions are potential users of cellular phone. These employees call/receive telephone in their working place in the working hours. Though, these employees live some where outside from the study area, when they are at work they use their cellular phone in the area.



Map4: The distribution of employees of public institutions in Kirkos sub city

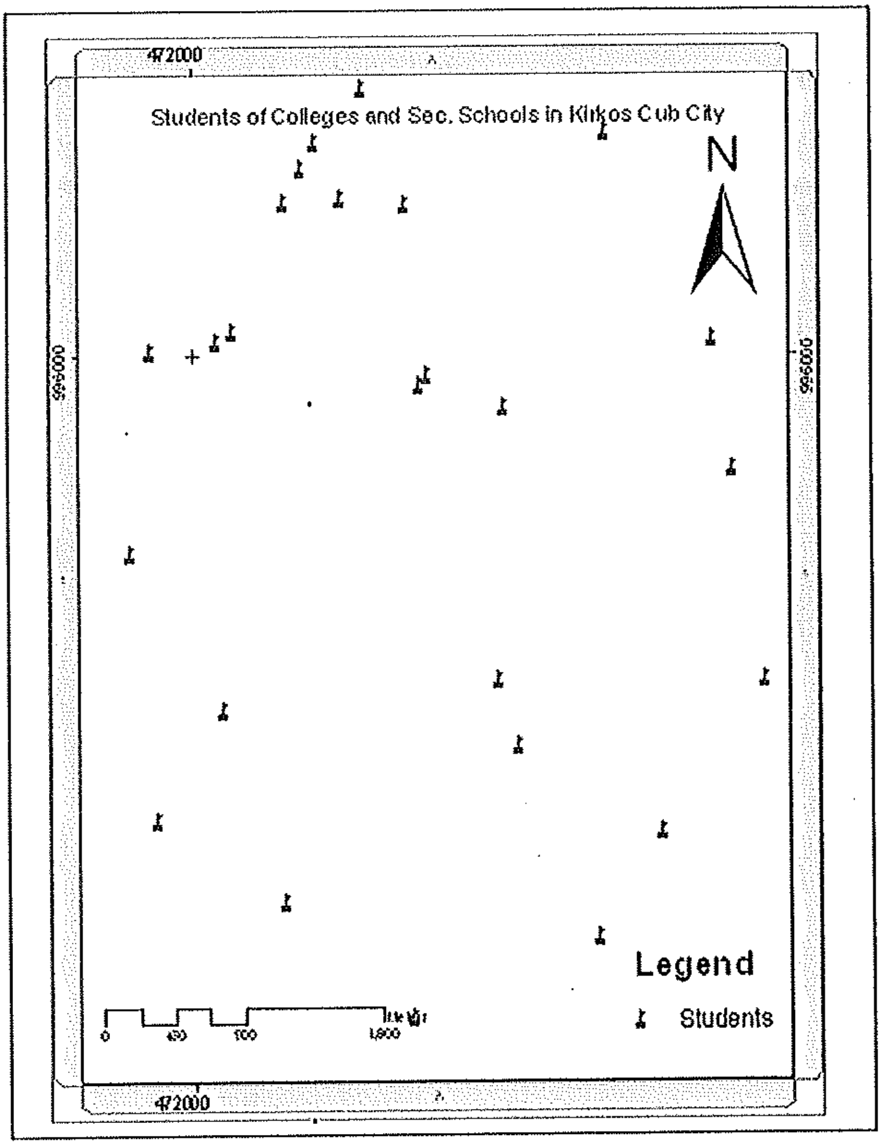
Employees of international organizations are other potential customers of cellular phone (mobile). With the same justification above they dial/receive their cellular phone in the study area.

Following the same procedures and steps used above for the case of public institution, it is possible to produce a distribution map for employees of international organizations available in the study area.



Map5: Distribution of employees of international organizations in Kirkos sub city

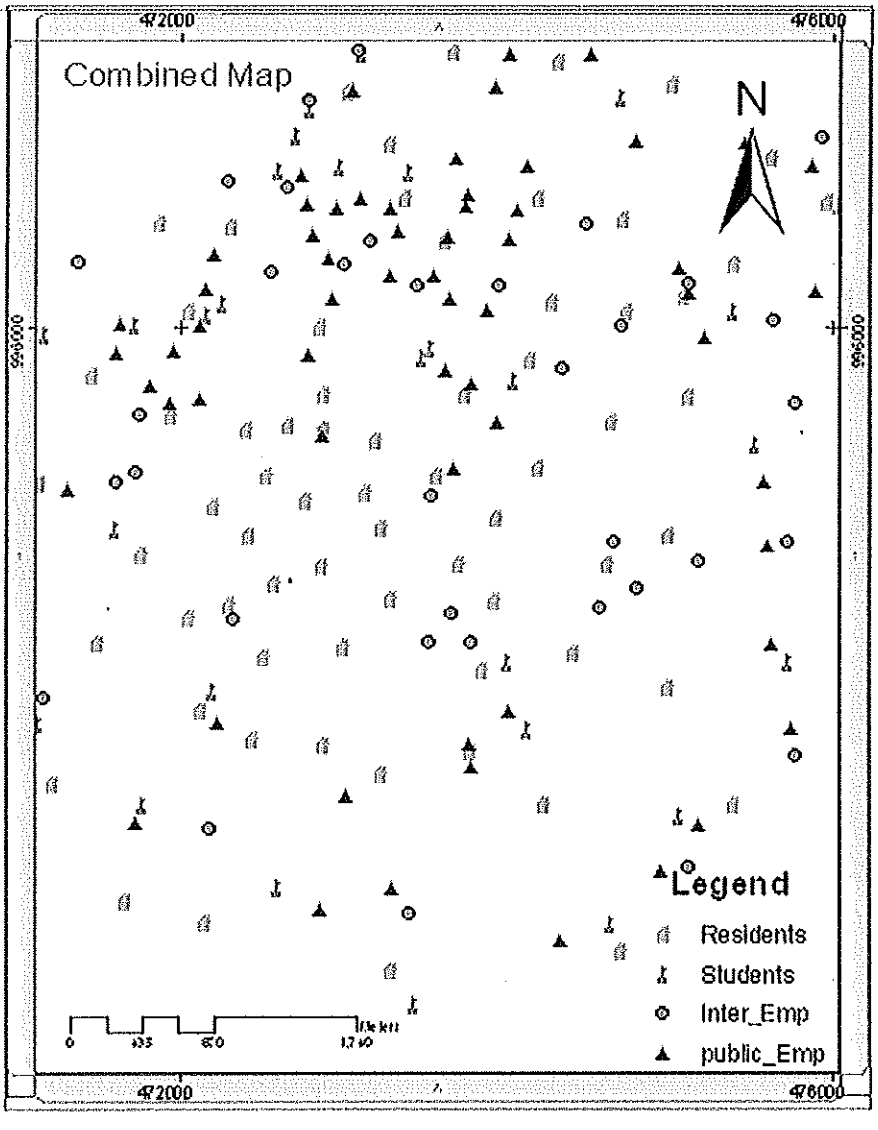
The third parameter considered as potential users of cellular phone are students enrolled in colleges/universities and secondary schools. Map6 shows the distribution of students enrolled in colleges/universities and secondary schools in the Kirkos sub city.



Map6: Distribution of students enrolled in colleges/universities and sec. schools in Kirkos sub city.

When you add the four layers the resulting map explains that public institutions, schools and international organizations are concentrated in similar area and similarly residents are concentrated in another area. This should coincide with the capacity of the BTS distribution.

In dense areas, the BTS capacity should be better than in sparse areas. The weightage given to residents should be greater than to the weightage given to other parameters. This is done due to the capacity of potential to afford cellular phone expenses.



Map8: Distribution of Public institutions, international organizations, schools and residents in Kirkos sub city (Employees and students)

4.3. Interpolating to Raster

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data: elevation, rainfall, chemical concentrations, noise levels, and so on.

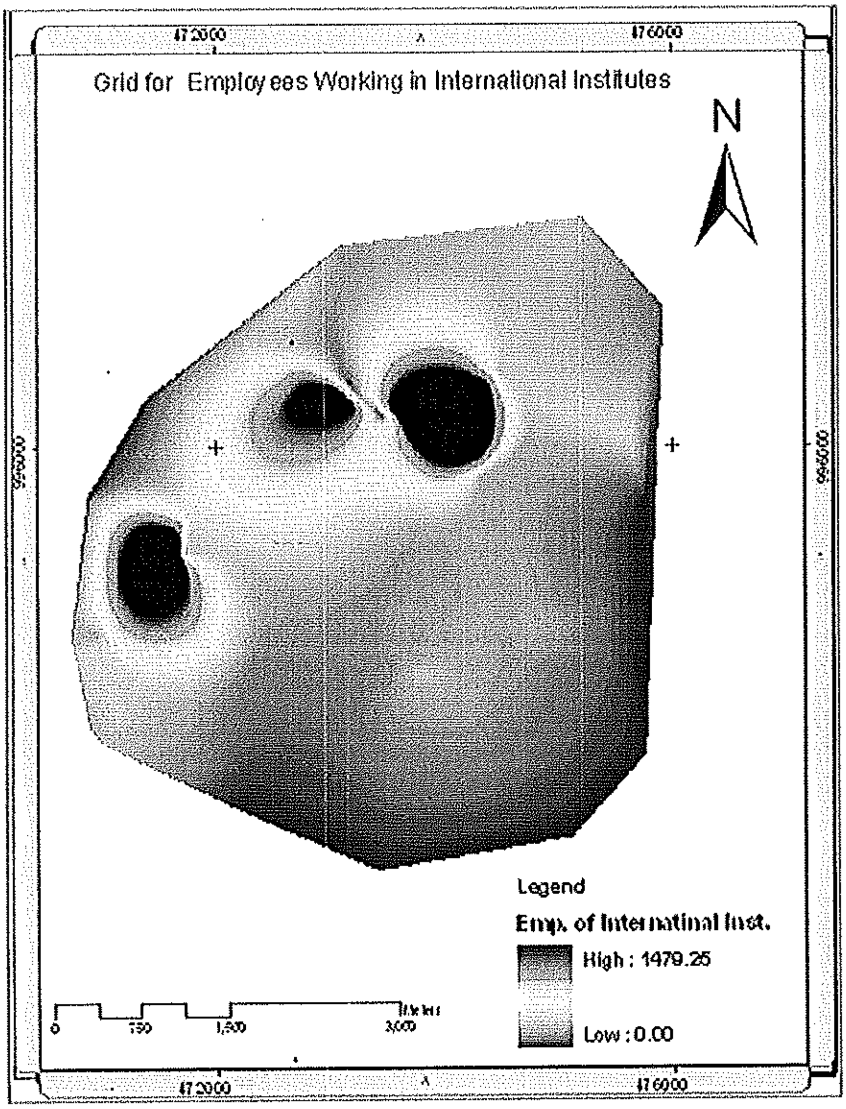
Surfaces of continuous data are usually generated from samples taken at points across the area. For example, the irregularly spaced weather stations in a region can be used to create raster surfaces of temperature or air pressure. The resulting surface is a regular grid of values.

Interpolation is based on the assumption that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics. For instance, if it is snowing on one side of the street, you can predict with a high level of confidence that it is also snowing on the other side of the street. You would be less sure if it was snowing across town and less confident still about the state of the weather in the next county

Visiting every location in a study area to measure the height, magnitude, or concentration of a phenomenon is usually difficult or expensive. Instead, dispersed sample input point locations can be selected, and a predicted value can be assigned to all other locations. Input points can be either randomly, strategically, or regularly spaced points containing height, concentration, or magnitude measurements.

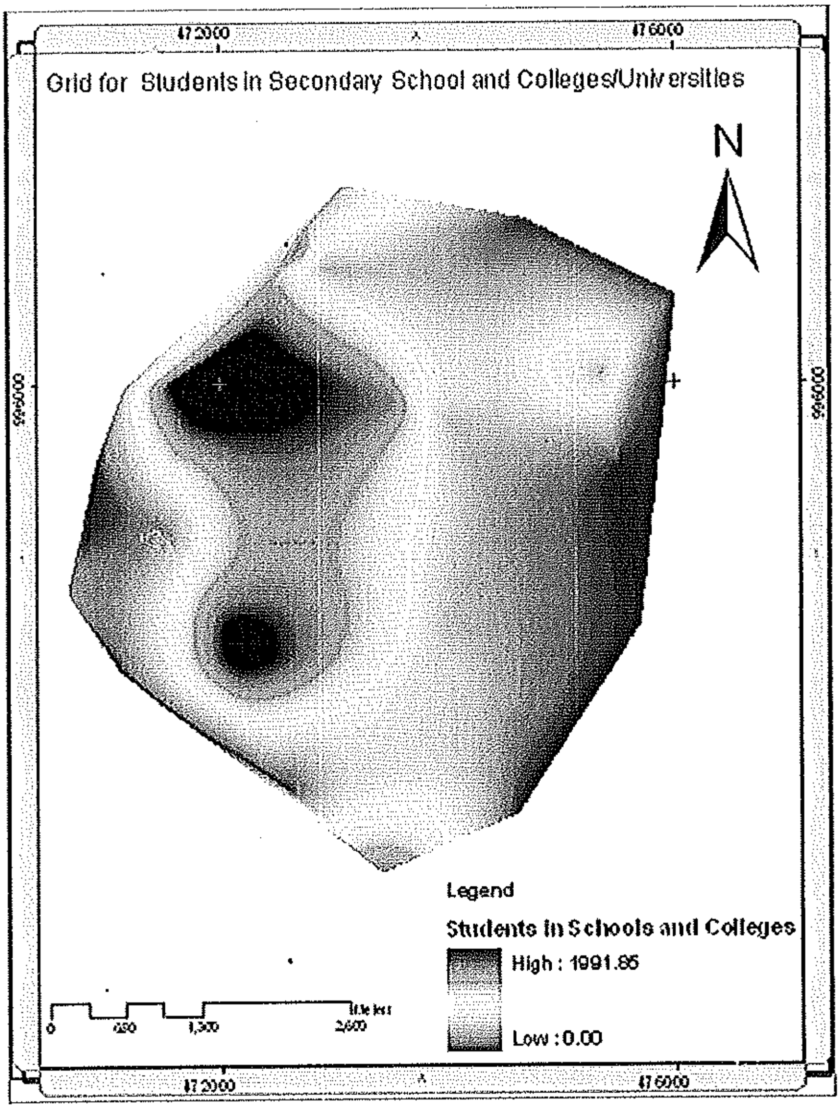
The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics. For instance, if it is raining on one side of the street, you can predict with a high level of confidence that it is also raining on the other side of the street. You would be less sure if it was raining across town and less confident still about the state of the weather in the next country. Using this analogy, it is easy to see that the values of points close to sampled points are more likely to be similar than those that are further apart. This is the basis of interpolation. (ESRI)

Among the factors considered as potential users of cellular phone are International organizations. Their distribution in the area is shown in Map3. To make ready the layer for the analysis, this point feature has to be converted to raster surface. The number of employees engaged in each organization is taken as a height source



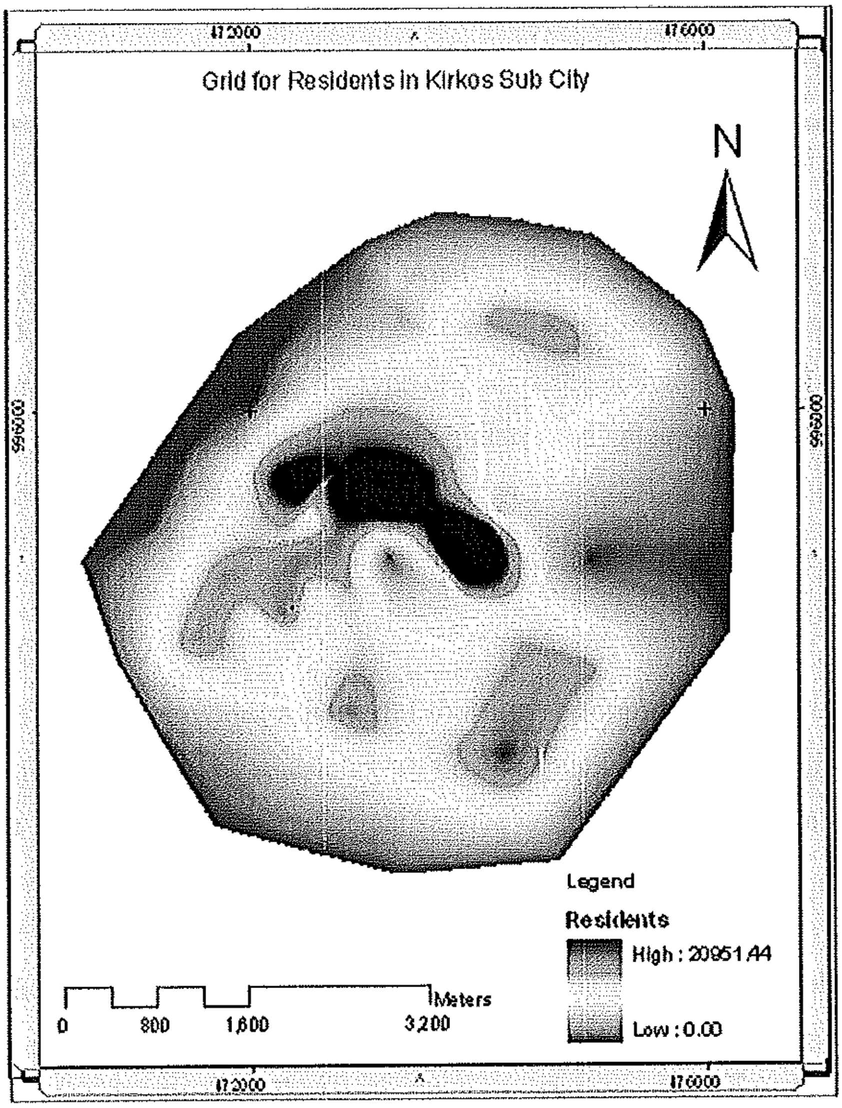
Map10: Raster surface of employees' of international organizations in Kirkos sub city.

The other factor taken as potential customers of cellular phone are pupils of secondary schools and college/university available in the area. So Map11 below shows the raster surface that has been taken pupils a height source.



Map11: Raster surface of students of secondary schools and colleges/universities.

In the process of converting residents point distribution in to Raster surfaces, population per Kebele is taken as a height source. Map13 shows the interpolated raster surface of residents in Kirkos sub city.



Map13: Raster surface of residents in Kirkos sub city.

Using this weightage for the classified layer and by subtracting the potential customer layers from the actual customer supported by the BTSs in the area may give us the actual service provided by ETC.

Using the following expression in the map calculator the resulting map shows the actual service. This result is in the assumption that users of cellular phone may require the service like dial/receive according to the given weightage at least at the congestion time.

[bts_class - bts_class] - (0.2* [Res_class - Res_class] + 0 .8* [inter_class - inter_class] + 0 .25 * [coll_class - coll_class] + 0.6 * [pub_class - pub_class])

Where -
- [bts_class - bts_class]-capacity of BTSs supported
- [Res_class - Res_class]- Residents
- [inter_class - inter_class]- Employees of international organization
- [coll_class - coll_class]-Students of secondary schools and colleges/universities-Employees of public institution

Therefore, the resulting map explains that the darkest region implies poor service at least at conjunction time and the brighter area shows good service or at least minimum call drop at conjunction time.

6.2. RECOMMENDATION

ETC is a sole service provider in Ethiopia with a motto of "Connecting to the future". One of its services is providing mobile telephony to customers with reliable and affordable prices. In implementing the service throughout the country, there is a huge amount of data that flows from one region to another or from one department to another or even from system to person. Manual data flow and work flow usually may not make any system efficiency. One of the reasons to solve the observed problems, which are stated in the first part of this paper, could be because of the failure of not using GIS with the integration of other systems.

Therefore, to alleviate the stated problems and to make the work flow of the department more efficient and effective and to satisfy the customers need, the researcher recommends the following points.

1. It is better to store BTSs' information in Relational Database Management system like Microsoft SQL server. SQL server able can manage huge data; easy to access and update data; supports multiusers and also has high security option.
2. There is also a suggestion to use GIS to get the following advantages from the technology:
    a. Able to get intelligent point map that shows the distribution of BTSs throughout the country. The digital point map displays not only the location of the BTSs but also other attributes of the BTSs stored in the database.
    b. Able to get node-to-link map information. It is possible to get information like which BTS has a radio link to which BSC or which BSC joins BTSs through which BTSs.
    c. Able to make decision on system expansion. With the help of ArcGIS it is possible to identify which areas have good coverage and which areas have no. It is also possible to identify where the potential customers are located.
3. As a component of GIS, this study advocates the training of staffs who implement and work with GIS environment.

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