

Chapter 1: Introduction

Introduction

Electricity is an essential part of everyday lives often taken for granted. Electricity plays such an important role that it seems the world comes to a standstill when there is no electricity for one reason or another. Hardworking people behind the scenes ensure that distributed electricity/energy is clean, safe and reliable. They ensure that the appropriate current is received that is necessary to power vast varieties of devices, and that the supply is available when it is needed (Meyers *et al.*, 2001).

Geographical Information Systems (GIS) can be used to develop a database that can visualize information with regard to electrical systems for use by utility executives, managers and operators. The system will model the electrical utility infrastructure inside two buildings and will contain a list of the assets, their location, their condition and the relationships of the assets between each other and to their surroundings. These together with the utility IT framework will provide a solid structure for electrical utilities in the future (Meehan & Dangermond, 2009). The use of the proposed model could potentially streamline implementation, repairing and testing issues and assist in the development of various new power distribution solutions (Brar *et al.*, 2006).

According to Harder (1999) electricity is distributed to consumers through some of the most complicated networks ever engineered. These networks consist of a variety of components such as wires, transformers, meters and poles. It is very important to regulate all of these components in a system for maintenance, upgrading and the most important of all, to keep the network operational.

The capabilities of a GIS can make it substantially easier to model every component forming an electrical network. Information regarding these components is stored in attribute tables linked to the spatial features captured through digitizing (Harder, 1999).

1.1 Problem statement and motivation

Universities consist of a variety of different buildings used for different purposes. Certain buildings contain laboratories with specialized equipment used for research purposes. The research done inside these buildings are greatly dependant on reliable electrical distribution. Electrical blackouts can cause significant threats to the research done which can result in delays or even failure to attempted projects. An electrical management structure should be in place to solve electrical problems quickly to prevent complications. This electrical management structure should provide information about the location, connections and relations between electrical utilities on different floors inside a building.

Electrical information describing the electrical utilities is in most cases not located in one place. A reason for this could be that several individuals or departments were responsible for the information over the years. This resulted in the absence of a centralized storage location and structure containing all the needed electrical information for certain buildings.

Electrical utility management becomes a difficult task when trying to derive electrical information for certain buildings from different locations and sources. Some buildings were even built before the age of computers. Electrical information was stored as hardcopy printouts of electrical utilities inside buildings. These printouts take a lot of storage space and are difficult to maintain. The challenge becomes even greater when information about related features has to be gathered and put together. The hardcopy nature of the stored information makes it difficult to receive the bigger picture of the connections and relations between the electrical components forming a network on different floors inside a building.

Geographic Information Systems can be used to perform location related analysis of those components at different scales (Peachavanish *et al.*, 2006). A geodatabase can be created using the software package called ArcGIS10 that is a registered trademark of the Environmental Systems Research Institute (ESRI). A geodatabase has the ability to contain feature datasets and network datasets to describe the infrastructure components on campus with spatial reference. The use of network datasets in the geodatabase will enable the user to perform network analysis that can be used for the determination of the best route for electricity flow through a vast network of cables, switches and distribution boxes (Ashby & Baker, 2008).

GIS offers a range of functions that can be utilized as a management tool for the electrical infrastructure at the campus. The GIS allows the user to organize data more efficiently using a geodatabase containing feature and network datasets. Information regarding electric utilities can be saved in attribute tables that will allow the user to perform related queries for electrical problems on the network. The physical electrical components is geospatial in nature and GIS can be used to simulate electric distribution devices, switches, circuits and even customer information in the form of a map (Collier, 2009). Changes made on the network due to repairing, maintenance and upgrading can be recorded in the database by different users.

Designing a database will allow the user to run relevant queries to solve electrical utility problems that may occur. Network analysis can also determine which buildings will be affected during electrical blackouts for alternative route planning. Determining the shortest routes from one electrical component to another can be useful in calculating the exact length of cable needed and the costs linked to it.

Network analysis can also be used to find the closest facilities from a certain point. An example can be to find the closest distribution board during the installation of new electrical plugs inside a building. The optimal positions of electrical lines, transformers, switches and distribution boxes can also be determined for future developments.

According to Mandloi (2007) geographic information systems are widely used to model utility infrastructure as the system provides the user with powerful tools for the management, visualization, presentation and analysis of data. For the purpose of this thesis the model can be used for the digital representation of objects in 2D, from which a network data model can be created to digitally represent a network consisting of basic geometric entities such as points, lines and polygons in a vector GIS.

Finding the shortest route is an effective tool to determine the path from a source point to an end point in a network. It highlights the path and shows the user through what types of devices the network runs until it reaches its endpoint. The shortest route can also be used to find sources shared by different components in the network. According to ESRI (2011) a source can be seen as the location or group of locations used as the starting point for distance analysis.

GIS has various applications that allow the user to find and extract information about certain objects. The SQL query language is implemented by GIS and is used as an effective tool for the location of components in the model by means of the “Select By Attributes” option. The information tool can also be used to select and identify features in the GIS data model as well as to view the different relationships between the features and to obtain the descriptive information.

Modelling utility networks inside buildings is complex because of their 3D nature (Mandloi, 2007). The vector GIS data model enables the storage of z-coordinate values in the geometry of vector entities. Topology relationships are an important consideration in a vector database to maintain data integrity. According to Mandloi (2007) such vector data models is useful for the purpose of visualizing features in a 3D environment, however, they are unable to determine topology relationships such as connectivity in 3D.

The different electrical components forming the electrical network on campus is grouped into different feature classes representing objects with different behaviour. The use of subtypes and domains plays an important role to cancel out redundancy in the geodatabase. After the digitizing process, relationship classes are assigned between the different feature classes and descriptive tables. Through this application the user can receive a good picture of all the different connections between the features and tables in the database. The information tool allows the user to access these connections by means of a single mouse click on one of the modelled components on the network.

This thesis presents an object orientated GIS data model defined by ESRI (2011) as a data management structure that captures data in the form of objects and groups them in instances of a class instead of rows and tables. The data model is used for the creation of an information model of two multi-storey buildings. The model will be derived using existing Computer Aided Design (CAD) data and spreadsheet data from which a prototype of an electric utility network will be built. An electric utility network will be modelled using a generic building model consisting of several polygon feature classes as a basis.

In most cases, the utility networks inside multi level buildings are composed out of vertical connections between several floors. In order to represent the electric utility network inside the compartments on each floor level, the data model has to be 3D in nature. The user has to

view the different levels as well as the vertical connections of the network between the floors to receive a good understanding of the hierarchical electrical flow inside a building on micro level. This visualization has to be in 3D.

The model presented in this thesis uses a network dataset to model feature connectivity on different levels inside buildings through the use of commercial off the shelf ArcGIS10 software provided by ESRI.

The effectiveness of the data model is illustrated through a 3D shortest route application created in Modelbuilder. The route model is created using the network dataset consisting of all the participating feature classes. Modelbuilder can be used to simulate different network problem scenarios and to present possible solutions for the building managers.

The prototype in this thesis is developed in such a way that it allows for further expansion of the project. Should the user decide to model several more buildings on the campus, it will be possible.

1.2 Research Objectives

The aim of this project is to design and develop a 3D data model to provide a management system for electrical utilities inside buildings. The 3D model should prove to be a useful system providing integrated information between different electrical components forming the network inside the specified buildings in the study area. The model should also provide a realistic 3D view of electrical utilities. Possibilities of 3D analysis have to be researched to determine to what extent it can be performed.

For practical reasons the most accurate and available data will determine the type of electrical utility to represent in the prototype model. The electrical data will be used as a basis to create a geodatabase that contains feature datasets and network datasets. Therefore the research objectives include the following:

- To obtain the necessary knowledge through the literature review.
- To collect the relevant data.
- To design and develop an effective 3D data model.

- To test the 3D analysis and query capabilities of the 3D data model.

1.3 Research Methods

1.3.1 Literature Study

To obtain the necessary knowledge, the literature study will consult different sources consisting of scientific articles, books, journals and case studies that will be used to get an overview of database design and network analysis. By using the information gathered from the literature, ideas can be formulated to start planning and building the electrical database. Different case studies will also be used to get an integrated overview of problems faced, objectives that were set, methods used, requirements that had to be met, advantages and disadvantages as well as the software that was used to solve the problems.

1.3.2 Empirical Study

The starting point for this project will be to gather the needed information for all the different feature classes to be modelled. The digital or printed information representing the features will be studied, sorted and utilized for the data model called the PUK geodatabase. The information gathered from the various sources will be applied in the object orientated 3D GIS model. This will enable the user to visualize the various infrastructure components with a direct link to descriptive attribute tables that have analysis capability.

In order to collect the relevant data, the first step of the empirical study will be to conduct interviews with personnel from the technical department at the Potchefstroom Campus as well as the personnel responsible for the CAD drawings in relation to the infrastructure of the university. The objective of these interviews will be to fully understand how the electrical network runs on campus and which methods are used to record changes that are made on the network during repairs, maintenance and upgrades.

To aid both the design and develop processes of the database, utility data that doesn't exist has to be captured manually by digitizing and completing attribute tables. The new data will be integrated with the existing CAD files which contain the layouts of buildings E4 and E6.

The electrical geodatabase containing feature and network datasets will be designed, taking the possible challenges obtained from the interviews into consideration.

The expected outcome of the research should prove that an effective 3D GIS data model can be utilized to solve electrical utility problems inside buildings. It should serve as an effective information system linking the different features to one another. The potential output and capabilities of 3D analysis must prove to be useful in the management of the electrical network of the two specified buildings in the study area.

1.4 Background of the NWU and study area

The North West University (NWU) is a combined university consisting of three campuses called Potchefstroom, Vaal-Triangle and Mafikeng. According to the NWU (2011b), the Potchefstroom campus is the largest campus with 38,784 registered students for 2011. The Potchefstroom campus hosts a large number of buildings that are interconnected with each other through substations and mini- substations. This is connected to the main substation forming the macro electrical campus network. Each building contains various electrical components such as main distribution boards, sub-distribution boards, lights, plugs, switches and air conditioning, forming the micro network which runs through the different levels. The Potchefstroom campus supports eight faculties with 32 departments and schools excluding administration and management (NWU, 2011a).

The E6 and E4 buildings in the study area are two multi-level buildings that host the Department of Environmental Sciences and Development. Several zoology, botany, microbiology and computer laboratories are located inside these two buildings. The object orientated GIS model in this thesis serves as a prototype model to provide an information system with 3D analysis capabilities for the electrical utilities inside the two buildings. Figure 1.1 shows the location of the buildings forming the study area. Buildings E4 and E5 were recently upgraded and combined to form a new building called the E4.

Building E6 is called the J.S van der Merwe building. This building has five levels consisting of a sub level underground followed by four levels upwards. The building hosts the Department of Environmental Sciences and Development. It consists of the schools for Zoology, Botany and Micro Biology.

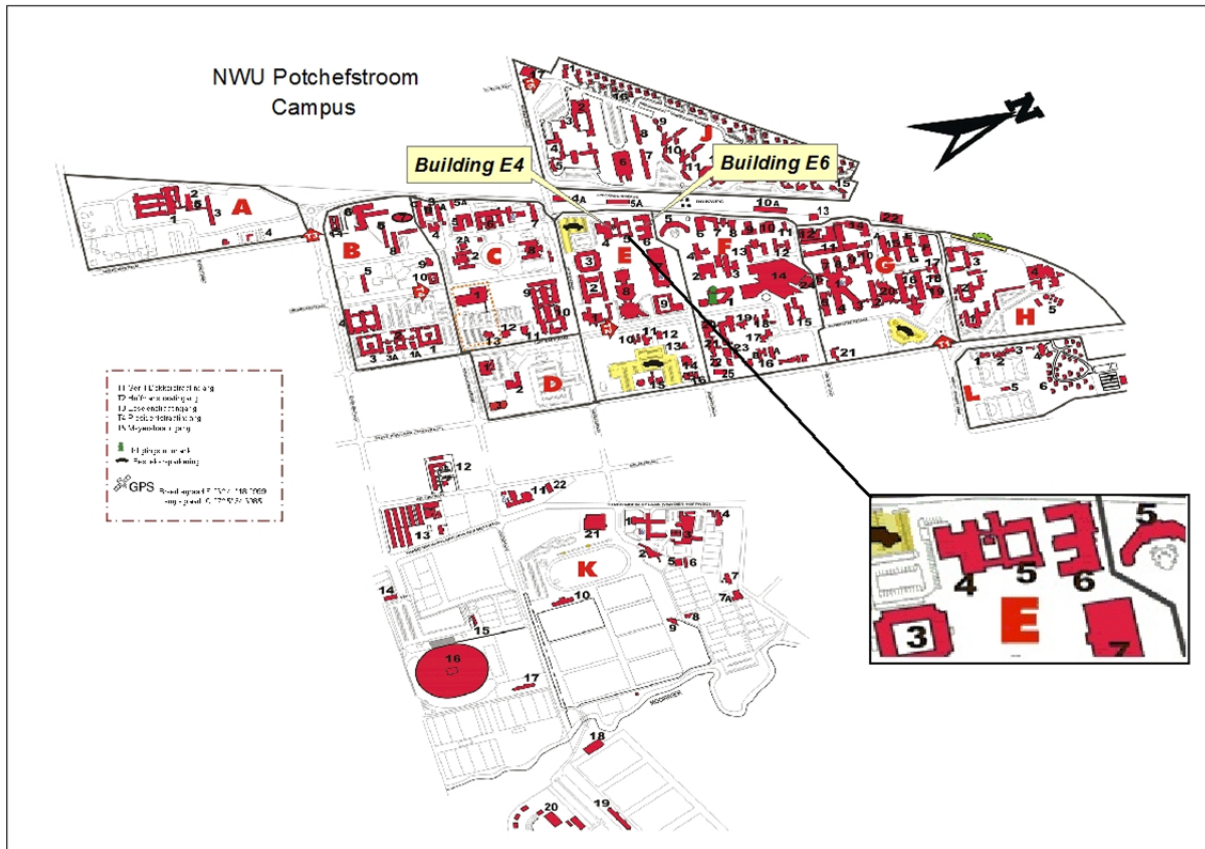


Figure 1.1: Buildings E4 and E6 located in the study area (NWU, 2011a).

Building E4 is a combination of two buildings called the Lettie du Plessis and the De Klerks Huis. The two buildings are alongside each other, sharing the wall on the boundary between them. From an aerial perspective, the two buildings are under the same roof as described in Figure 1.2 below. This is due to the recent upgrade of the two buildings. The De Klerks Huis part of the building consists of two levels while the Lettie Du Plessis part of the building only has a ground level.

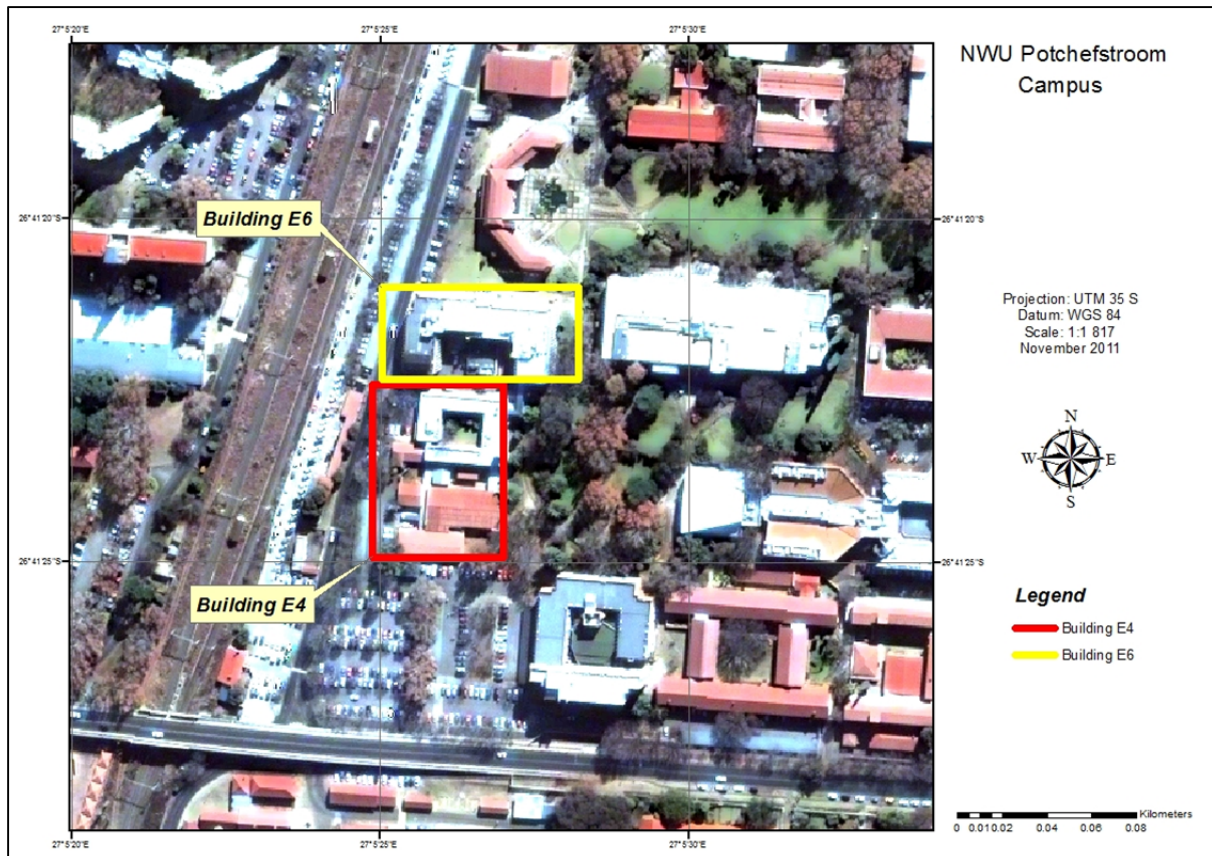


Figure 1.2: Aerial photograph of buildings E4 and E6 (QuickBird, 2008).

The electrical network serving these two buildings on the macro scale is called the “Ring 2 Feeder” network. It consists of a 70 mm paper insulated steel wired armored cable running from the main substation feeder on campus to the J.S. van der Merwe substation and mini-substation located near the buildings. From these stations, the feeder cables containing lower voltage runs to several main distribution boards inside the two buildings. The network runs through all the sub distribution boards until it reaches the utility endpoints. The utility endpoints can be modelled as lights, air conditioning or heaters. The most accurate and available data for the utility endpoints represents the electrical plugs. Therefore the scope of this study is to model the different plugs inside the buildings.

1.5 Chapter Layout

The chapters of this thesis are organized as follows. Chapter 2 provides a theoretical framework to all the different GIS concepts used in this thesis. It serves as a theoretical overview to some of the decisions that lead to the development of the electric utility data

model. The chapter also explains why a set of data model design steps were chosen that forms the main structure of Chapter 3.

Chapter 3 reviews all the different techniques that were used to design the object orientated GIS data model. The chapter is based on the different design steps that are involved to create a robust GIS data model. The chapter also presents the different modelling elements such as the feature datasets, feature classes, tables, relationship classes, topology, images and network datasets to create the data model in ArcGIS10.

Chapter 4 serves as the methods and implementation chapter. This chapter describes the process and methods in which the necessary information for the geodatabase was gathered, organized and utilized. Chapter 4 walks the reader through the process of building the PUK geodatabase from start to finish. All the different techniques for digitizing and capturing the required data are discussed and reasons are given for decisions that had to be made for the 3D data model.

Chapter 5 explains the different analysis possibilities that can be performed by the model and the solutions to the different potential network problems relevant to the electrical utilities. Chapter 6 provides the conclusions and recommendations of this thesis.

1.6 Conclusion

The use of GIS is introduced and the possibilities of integrating it with an electrical network are suggested. A research aim was identified, explained and combined with motivations regarding the capabilities of GIS in electrical networks. The background of the study area was given along with a figure to represent the two buildings used for the prototype model. A quick summary of the different chapters were given followed by the research objectives, methods and preliminary chapter layout. The following chapter represents the relevant theory covering the important GIS concepts used in this research project.