

Chapter 3: Design

Introduction

The chapter reviews the conceptual and logical design steps presenting all the techniques that were used during the design of the geodatabase. According to Mandloi (2007), a GIS has a common database structure containing all the necessary data needed for a project. The GIS has many processing functions that allow the user to process and analyze the data stored in the database. The underlying spatial database plays a critical part in the successful implementation of a GIS. Thus in order to achieve return for the hard work put in the GIS, a good database design is very important.

According to Munsys (2008), the user can retrieve data from the database by category, geographic location or user specific criteria. The previous chapter reviewed different steps to effective database design by different authors. The proposed steps to designing geodatabases by Actur & Zeiler (2004) is a good combination of the various steps and serves as a comprehensive guide to design an effective geodatabase. Therefore the underlying structure of this chapter is based on steps one to seven in designing geodatabases proposed by Actur & Zeiler (2004). The first three steps is the conceptual design phase of the project and steps four to seven is the logical design phase. Each step is discussed in this chapter that lead to the final proposed geodatabase. The following topics are listed as the different steps in the two design phases proposed by Actur and Zeiler (2004), illustrated in Figure 3.1.

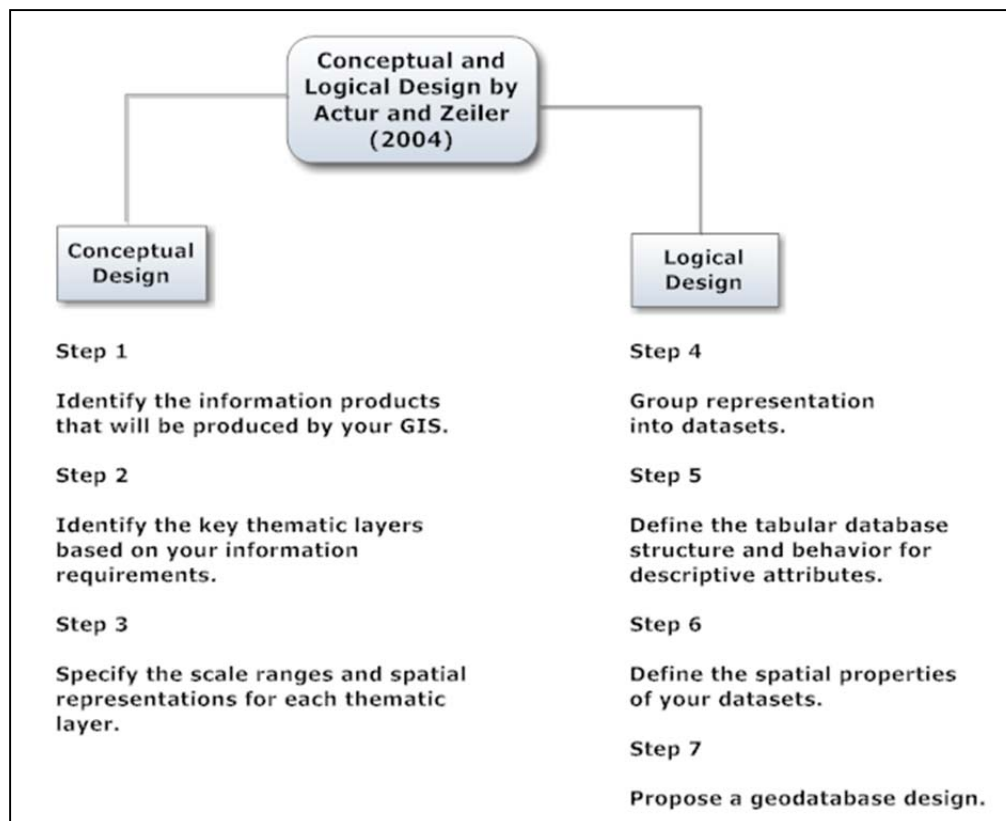


Figure 3.1: Conceptual and Logical Design (Actur & Zeiler, 2004).

3.1 Identify the information products that will be produced with your GIS

In this step the user must identify the final product that has to be produced by the geodatabase. In this thesis the final output of the geodatabase must contain the following:

The final product that will be produced consists of a file geodatabase that must be developed to contain multiple infrastructure datasets. The prototype model will be designed to handle a feature dataset that contains information regarding the electrical network that serves the two specified buildings in the study area. The geodatabase consists of polygon, line and point features captured from raster images and CAD drawings. Spatial accuracy in the digitizing process is not crucial to this application and therefore no accuracy tests were conducted. The database can be divided into two parts. The first part is the polygon features in the database containing information about the study area itself which is building E6 and E4 on campus. The reason for creating generic polygon features is to enable future researchers to use the same feature classes to expand the project. It is not possible for different persons to digitize

the study area in exactly the same way. There will be differences. The generic polygon features cancels out redundancy and dissimilarities in the digitizing process.

The second part of the geodatabase models the electrical utilities that form a macro and micro network running from the main substation on campus until it reaches the endpoints of the network such as the plugs. The macro electrical network models the utilities outside the buildings and the micro network models the utilities inside the two specified buildings. The electrical utilities will be organized in the electrical feature dataset forming a connected network to perform network analysis.

The geodatabase design must not be limited to the two specified buildings in the study area. Should the user want to expand the project in the future to model more buildings on campus, it must be possible to do so. Therefore the model must have the capacity to model more buildings. The utilities model must also form a connected network between buildings that will be modelled in the future in order to create a connected utilities network for analysis.

A “File Geodatabase” has to be presented to the building managers working with the electrical utilities of the Potchefstroom campus. The model should be able to provide a prototype of a centralized spatial database containing information about the electrical infrastructure utilities with analysis possibilities. The model should provide the user with the following:

1. The user must be able to obtain a three dimensional view of the study area’s building layout. The model must provide a 3D visualization of the building layouts, the rooms inside the two buildings as well as the different floors inside the buildings.
2. The user must be able to visualize the electrical utility network flowing inside the two buildings on the different levels as well as the vertical connections between the levels.
3. The model should provide extra information from non-spatial tables such as the owners for each room, the contractor personnel working on the utilities and the maintenance table keeping record of the maintenance done on the utilities.
4. The electrical network consisting of cables and connection points must be modelled in such a way that it forms a connected network for analysis.

A geodatabase model has several tools that enable the user to derive important information quickly and effectively (ESRI, 2011). To achieve this objective the following applications is used in the geodatabase for the electrical infrastructure:

1. The information tool can be used to derive attributes regarding the components as well as the associated relationship connections between the features.
2. The SQL query language can be used to solve frequently asked questions regarding the network as well as potential network problems that might occur.
3. Network analysis can be implemented to find the shortest route between features and to determine which features share a common source.
4. Should someone call regarding a utility problem, the user can track the phone number in the spatial database and identify the exact location of the problem inside a building with multiple levels.

3.2 Identify the key thematic layers based on your information requirements

In this step the different thematic layers that have to be represented must be identified in order to achieve the information products that will be produced by the GIS. The spatial data will be of vector or raster format. The vector data shall receive specific geometry types in the next geodatabase design step by Actur & Zeiler (2004). Thematic layers are illustrated to achieve the information requirements for the generic part as well as the utilities part of the geodatabase. The following thematic layers are important for the generic part of the geodatabase.

1. The NWU Potchefstroom campus is divided in alphabetical zones to distinguish certain areas from each other. The two specified buildings are located in zone E of the campus. Therefore the study area buildings are named E6 and E4. A layer called PUK_Zones has to be digitized to enable the user to locate the zones in the spatial database.
2. Each zone on campus contains many buildings, each of them numbered according to the specific zone. Each building's layout is digitized and forms the layer for the visualization of the buildings in 3D.
3. The next important thematic layer identified is the rooms inside the buildings. The user must visualize the rooms inside the buildings on the different levels and have a

good understanding of the location of the rooms as well as the associated attributes of the rooms.

4. Non-spatial data like extra information tables is also needed to provide the user with sufficient information regarding the zones, buildings, rooms and the utility network running inside the buildings.

The utilities part of the geodatabase contains all the electrical components forming the electrical network that runs all the way from the main substation along the network until inside the specified buildings where the endpoints are reached. The electrical utilities network is divided into two networks called the macro network and the micro network. The first two layers represent the macro network. The layers presented after that illustrates the micro network inside the study area buildings.

1. According to De Beer (2011b), the NWU Potchefstroom Campus receives its electrical current from the Gamma substation located near the campus. The main substation receives overhead electrical power lines from the generating plants. From here the electricity is distributed to the campus. The main substation called the Gamma substation will be represented as a layer as it is the primary electrical source from which the electrical network runs.
2. From the main substation the electrical network connects to several substations and mini-substations in different parts of the campus. The substations and mini-substations feed power to the buildings allocated in their area. Therefore the substations and mini substations will be represented as one layer as it forms the final part of the macro electrical network.
3. The micro electrical utilities network starts when the network runs inside the buildings originating from the substations or mini-substations outside. According to De Beer (2011b), each building contains several main distribution boards that distribute electrical current to the different levels inside a building. The main distribution boards will serve as a layer.
4. The sub-distribution boards on the different levels of a building receive the electrical network from the main distribution boards. These boards contain two types of distribution called single- or three-phase electricity. These sub-distribution boards feed an electrical current to the endpoints of the electrical network where the power is consumed by the customer.

5. One of the most important features in the electrical network is the electrical cables or conductors connecting all the components to one another. The electrical cables will be represented as one layer.

There are many different endpoint components in the electrical distribution network. For practical reasons and data availability only the different plugs inside the two specified buildings are modelled. The two buildings contain two types of plugs. The normal plugs can be seen as the white coloured plugs while the dedicated plugs can be seen as the red coloured plugs. The dedicated plugs are used to power appliances with heavier load such as computers, laboratory equipment and industrialized fridges inside the E6 building. These plugs are normally also connected to the power generators in case of power outages (De Beer, 2011a).

The two primary data sources from which the object-orientated database will be digitized is a Quick Bird Image with a pixel size of 0.6m by 0.6 m of the NWU Potchefstroom campus and the digital CAD drawings in printed or digital format obtained from the responsible building manager.

3.3 Specify the scale ranges and spatial representations for each thematic layer

The features contained in the geodatabase represent spatial variation between the different components. Therefore the features can be represented as vector shapes and as mentioned by Zeiler (1999), these shapes can be classified by dimension in points, lines and polygons.

The spatial representation of the generic geodatabase will consist out of polygon features representing the zones, buildings and the rooms inside the multiple-level buildings with descriptive attribute tables. The polygon geometry is chosen because the components represented contain a series of segments that enclose an area.

The extra information regarding the owners for each room, the list of contractor personnel working on utilities and the maintenance information for the infrastructure will be available in the form of information tables inside the generic geodatabase. The following features will be represented as polygon features:

1. Puk_Zones
2. Puk_Buildings
3. Puk_Rooms

The components forming the junctions in the electrical utilities network are too small to be depicted as lines or polygons. They represent zero-dimensional shapes stored as single x;y and z coordinates with descriptive attribute tables. The following features are represented as point features:

1. Main Substation Feeder
2. Distribution Station Feeder
3. Distribution Station Transformer
4. Distribution Boards
5. Utility endpoints

The electrical cables or conductors connecting the junctions in the electrical utilities network represent features too narrow to be depicted as areas. They can be seen as one dimensional shapes stored as a series of ordered x;y and z coordinates with attributes (Zeiler, 1999).

Table 3.1 summarizes the scale ranges and spatial representations for each thematic layer.

Table 3.1: Scale ranges and spatial representations for each thematic layer

Name	Raster or Vector data	Scale	Spatial representation
PUK Zones	Vector	1:100	Polygon
PUK Buildings	Vector	1:100	Polygon
PUK Rooms	Vector	1:100	Polygon
Main substation feeder	Vector	1:100	Point
Distribution station feeder	Vector	1:100	Point
Distribution station transformer	Vector	1:100	Point
Cables	Vector	1:100	Line
Main distribution boards	Vector	1:100	Point
Sub distribution boards	Vector	1:100	Point
Utility endpoint components	Vector	1:100	Point
Quick Bird Image	Raster	1:100	Grid
Fishnet	Raster	1:100	Grid

3.4 Group representations into datasets

There are several approaches that can be taken to represent a 3D network of electrical utilities inside a multi-storey building. Each approach has its advantages and disadvantages. Three approaches were considered in this thesis until a final approach was adopted. The aim of each approach is to cancel out data redundancy and have the capacity to allow further expansion of the project. The following approaches were considered:

3.4.1 Approach 1

The first approach for the data model design was to create a geodatabase for each building. Each building's information would be organized in a database that would be easy to manage and extract data from. The databases for each building have separate feature datasets representing the different floor levels.

The idea behind this geodatabase design layout was fine for the purpose of an organized layout of utility data in one building but several questions arose:

1. If the user wanted to see a connected system between several buildings, would it be possible to connect the geodatabases to each building on campus?
2. Can the user visualize the connections between the different floors in a building?
3. Does the layout enable the user to turn different floors on and off during analysis?
4. Should two geodatabases be able to connect to each other, is it possible that the databases share the same set of topology rules and relationship classes?

According to ESRI (2011), it is not possible to connect several geodatabases to each other using ArcGIS software. However, it is possible to store multiple geodatabases in other database management systems (DBMS) such as SQL Server, Oracle, DB2 and Informix.

An Oracle DBMS can be used to store multiple geodatabases. There are two options the user can follow to obtain this objective. According to ESRI (2011), the user can install separate instances of Oracle. In each instance a geodatabase can be stored. Another option is to create a master database in Oracle and store several dependant geodatabases in that same instance.

The first option requires the user to install multiple instances of Oracle. By using ArcSDE to connect to the geodatabases the user will need one connection service for each geodatabase stored in an Oracle instance. Each of the geodatabases can be updated, maintained, deleted and uninstalled independently. Figure 3.2 illustrates how multiple geodatabases can be stored in separate Oracle instances.

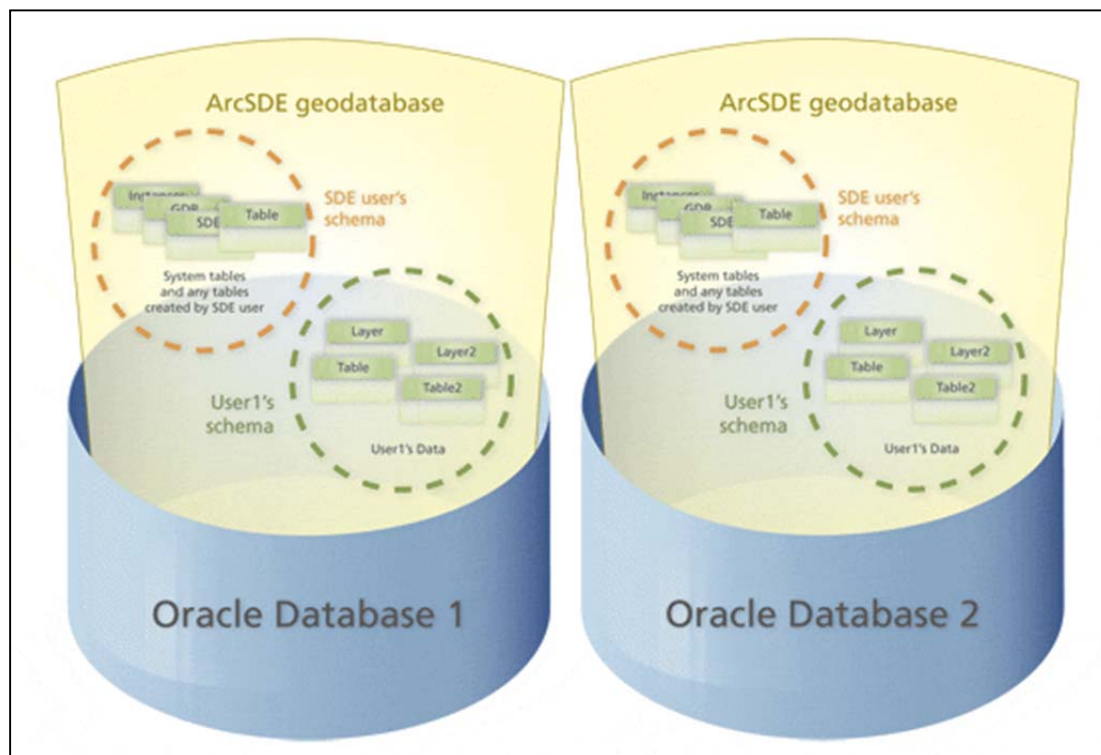


Figure 3.2: Multiple geodatabases in separate Oracle instances (ESRI, 2011).

The second option requires the user to install one Oracle database that will serve as a master database, one ArcSDE installation and one service connection. This option also requires the use of multiple users to the database. Each of these users must be granted ArcSDE administration privileges to enable them to install, manage and upgrade their own database schema (ESRI, 2011). Figure 3.3 illustrates the use of a single Oracle instance containing several geodatabases through the connection of ArcSDE.

The project presented in this thesis will serve as a prototype for a centralized geodatabase containing information for the electrical utilities network on the Potchefstroom campus. ESRI software is available for use to complete the project. The use of other software is not available and too expensive for the scope of this project.

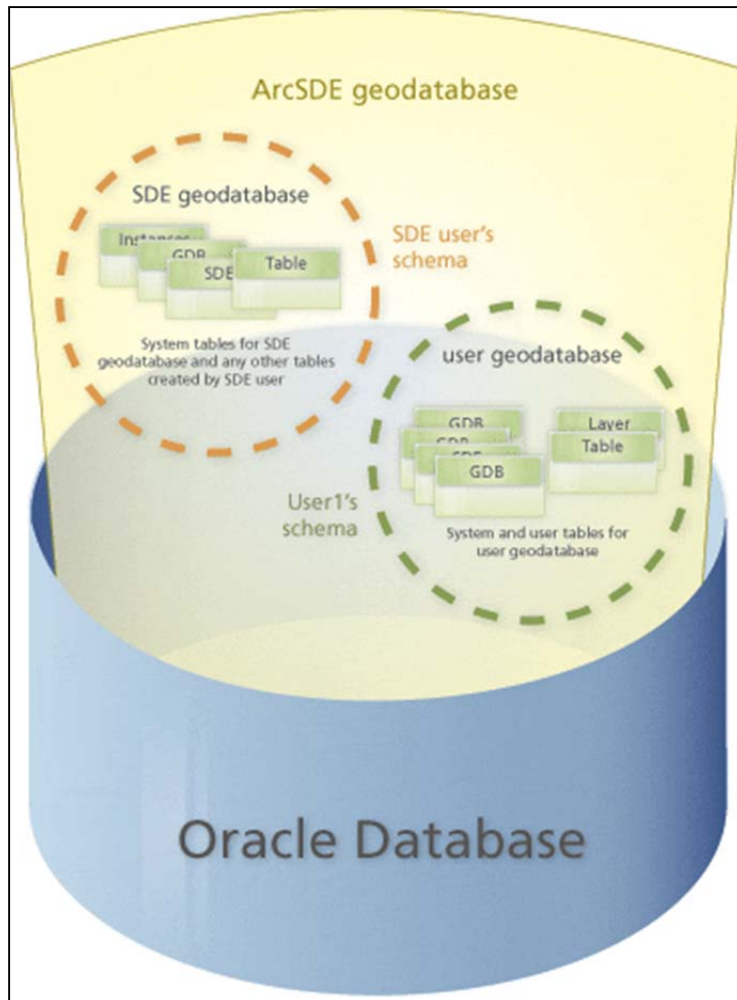


Figure 3.3: A single Oracle database instance containing several geodatabases (ESRI, 2011).

The research also showed that should the user want to create topology rules, relationship classes, geometric networks and network datasets, the participating data had to be in the same feature dataset (ESRI, 2011). This approach groups the utilities information into several feature datasets, forbidding the user to model a connected network between the different floors of a building.

The prototype of a utility geodatabase must have room for further expansion. It had to be designed in such a way that all the buildings on campus with their networks can be added to the geodatabase and be connected to each other for analysis. This approach to the geodatabase layout would not enable the user to do so.

3.4.2 Approach 2

A second approach had to be considered for the geodatabase layout. The next idea was to create a single geodatabase containing multiple infrastructure utilities in separate feature datasets. This approach was investigated to determine the future possibilities to expand the project. Possibilities were investigated to model and combine different infrastructure utilities such as water, information technology and electricity. This approach aimed to create a feature dataset for each of the infrastructure utilities to cancel out the possibility of confusion between the different utility components. This is evident especially when assigning topology rules, network datasets and relationship classes. Each feature dataset contains a large quantity of data. Combining the different datasets into one would be confusing. The different feature datasets will be built using the generic geodatabase polygons as a basis. At this stage of the design, the problem to represent the multiple floors in each building was still evident. A geodatabase had to be developed that may contain more than one dataset and have the capacity to display features on several levels inside a building.

The second approach was to create a feature class for each floor level in the two specified buildings called E6 and E4. Table 3.2 illustrates the layout idea that contained the following:

Table 3.2: First idea to model different floors for the generic geodatabase model

Geodatabase:	PUK geodatabase
Feature dataset:	PUK electrical infrastructure
Feature class:	PUK Zones
Feature class:	PUK Buildings
Feature class:	E4 Ground floor
Feature class:	E4 Level 1
Feature class:	E6 Sub Level
Feature class:	E6 Ground Level
Feature class:	E6 Level 1
Feature class:	E6 Level 2
Feature class:	E6 Level 3

This idea could work because all the data is in one feature dataset. This enables the user to define topology rules, assign relationship classes and build network datasets that forms a connected network system across the multiple levels inside buildings.

The next idea for approach 2 was to simplify the feature dataset even further by creating separate feature classes that each represented a level for all buildings on the campus instead of representing separate levels for each building. There has to be separate feature classes for the different levels because two floors on top of each other from a CAD drawing perspective are not always exactly the same in one building. For example, the feature class representing the first level will show all the rooms, steps and corridors for every building across campus. Table 3.3 illustrates a proposed geodatabase layout for this approach:

Table 3.3: Second idea to model different floors for the generic geodatabase model

Geodatabase:	PUK geodatabase
Feature dataset:	PUK electrical infrastructure
Feature class:	PUK Zones
Feature class:	PUK Buildings
Feature class:	PUK Rooms Sub Level 1
Feature class:	PUK Rooms Sub Level 2
Feature class:	PUK Rooms Ground Level
Feature class:	PUK Rooms Level 1
Feature class:	PUK Rooms Level 2
Feature class:	PUK Rooms Level 3

In this approach the total number of feature classes representing the multiple levels will be equal to the highest number of floors for all the buildings on campus. This idea works better than the previous one due to the fact that the total number of feature classes is reduced. A problem occurred when assigning relationship classes. The user starts off by creating relationship classes for all the components connected to the “PUK Rooms Sub Level 2” feature class. This step takes a while and there are a number of relationship classes to assign, especially when all the feature classes for the utilities are involved. After the user has finished assigning relationship classes for the first feature class, the exact same amount of relationship connections must be assigned for the following feature class representing the next level in the building. Therefore, in this approach the number of relationship classes for each level is multiplied by the highest number of floors for all the buildings on campus.

3.4.3 Approach 3

The case study by Mandloi (2007) discussed in Chapter 2 presents another approach for a geodatabase design layout. The idea is to model all the different floors for the buildings in a single feature class. The vertical connectivity can be illustrated by placing each floor level in a separate subtype. Each subtype is assigned to a different floor level. According to Mandloi (2007), this approach requires the use of a single feature class to represent the entire floor network of every building to be modelled. Thus, it is much more efficient at the database level. The different floors represented by the subtypes can be turned on and off by the user, cancelling out the possibility of confusion between the different levels in 2D. The layout also reduces the total amount of relationship classes to assign and the possibility of many feature classes containing only a few features. This idea will be adopted and modified according to the research and will serve as the final approach to the generic geodatabase layout.

The final approach to the generic polygon layout contains the following:

- PUK geodatabase
- Electrical Infrastructure feature dataset
- PUK Zones polygon
- PUK Buildings polygon
- PUK Rooms polygon
- Owners Table
- Maintenance Register table
- Contractor details table
- Subtypes represents different floor levels
- Faculty domain
- Department domain
- Space types domain

The subtypes in the final generic geodatabase layout will be grouped to model the different floor levels inside the buildings on campus. The three domains specified in Table 3.24, 3.25 and 3.26 will serve as a specified drop down list of the different faculties and departments on

the NWU campus. The “Space_type” domain is a list of the different room types inside the buildings.

The domains are used to cancel out the possibility of human error and it serves as a way to maintain data integrity. Table 3.4 illustrates the final geodatabase layout for the different feature classes contained in the feature dataset to model the electrical utilities network on campus:

Table 3.4: Feature classes for the electrical utilities geodatabase layout

Feature class	Geometry type	Subtypes	Domains
PUK Zones	Polygon	No	No
PUK Buildings	Polygon	No	Yes
PUK Rooms	Polygon	Yes	Yes
Main_Substation_Feeder	Point	No	No
Distribution_Station_Feeder	Point	Yes	Yes
Distribution_Station_Transformer	Point	No	No
Distribution_Board	Point	Yes	Yes
Utility_endpoints	Point	Yes	Yes
Cables	Line	Yes	Yes

3.5 Define the tabular database structure and behaviour for descriptive attributes

In this step by Actur & Zeiler (2004), all the different attribute fields for each feature class are specified according to the information requirements. Domains and subtypes are added to control behaviour in the geodatabase and relationship classes are assigned to the different feature classes by means of primary and foreign keys in the attribute tables. This step can be divided into two parts. Part one describes the polygons created for the PUK geodatabase. These polygons will be used as the basis on which the feature classes representing the utilities are designed. The second part of this step describes the attributes assigned for the feature classes representing the electrical utilities. This step is combined with the electrical theory associated with the different fields.

The “Object ID” field is a field generated by default each time a feature is added to the attribute table. This particular field stays unique throughout, even if a feature is deleted and added again into the attribute table. Each feature class attribute table has an Object ID field with unique values that is perfect to be used as primary keys in relationship classes.

The “Shape” fields are also a default field for all types of feature classes. It represents the geometric entity of each feature added. To cancel repetition, the “Shape” field is not included in the following tables describing the attribute fields for each feature class.

Each feature class attribute table also contains a Unique ID field used to locate a specific feature through the use of the SQL query language. The field contains a unique code for each feature. The code enables the user to know exactly in which zone, building, floor level, room and from which particular distribution board an endpoint component is located. Table 3.5 illustrates an example of a Unique ID for a plug inside a room of a building. The idea for the unique identification code was derived from the case study presented by Glos (2008).

Table 3.5: An example of a Unique ID field for the Utility endpoints feature class

Feature class name	Zone	Building	Floor	Room	Distribution Board	Utility component	Unique ID
Plugs	ZE	E4	F01	G35	SDB2	P12	ZE/E4/F01/G35/SDB2/P12

The following tables show the list of attribute fields for the different feature classes inside the geodatabase. Each attribute field is described by means of:

- Identifying the field type
- Giving a short description
- Specifying if the particular field has subtypes or domains
- Specifying if the particular field takes part in a relationship class
- Identifying the cardinality of the participating relationship class

3.5.1 Part 1: Polygons representing the study area

The “PUK_Zones” feature class represents the different alphabetical zones in which the NWU Potchefstroom campus is divided. This feature class will enable the user to orientate him or herself according to the zones and will be able to locate desired buildings quickly and effectively. The “Number of buildings” field in Table 3.6 indicates the amount of buildings in each zone on campus. This enables the user to get an idea of the size of the electrical network contained in each zone.

Table 3.6: Attribute fields of the PUK Zones feature class

Field name	Field type	Domain	Subtypes	Relationship key:	Cardinality
Object ID	Long Integer	--	--	Primary Key	1 – M
Unique ID	Text	--	--	--	--
Number of buildings	Long Integer	--	--	--	--

The “PUK_Buildings” feature class is a single feature class that has the capacity to represent all the buildings on campus. Buildings E4 and E6 are contained in this feature class. More buildings can be added to the feature class to allow further expansion.

The “Zone ID” field in Table 3.7 is part of the relationship class between the “PUK Zones” and “PUK buildings” feature class. It serves as the foreign key between the two and a list of the “Object ID” values contained in the “PUK Zones” feature class. The “Name of buildings” field is a description of the common names used by locals to identify the buildings on campus. The “Faculty” and “Department” fields are two domains used to ensure database integrity. The domains represent a drop down list of the different faculties and departments on campus. This prevents human error and is much faster to list in the table. The “Number of floors” field is an indication of the height of the different buildings. This field enables the user to extrude buildings according to their heights in 3D in order to distinguish height levels between different buildings.

Table 3.7: Attribute fields for PUK Buildings feature class

Field name	Field type	Domain	Subtypes	Relationship key:	Cardinality
Object ID	Long Integer	--	--	Primary Key	1 - M
Unique ID	Text	--	--	--	--
Zone ID	Long Integer	--	--	Foreign Key	M - 1
Name of building	Text	--	--	--	--
Faculty	Long integer	Faculty	--	--	--
Department	Long integer	Department	--	--	--
Number of floors	Long integer	--	--	--	--

Each building has a certain amount of floor levels, offices, corridors, stairs and many other types of spaces. Therefore, the “PUK_Rooms” feature class is used to visualize and provide information about the different spaces and levels inside the various buildings.

In Table 3.8 the “Building_ID” field is a list of the “Object ID” values in the “PUK Buildings” feature class. This list of values is needed to create the relationship class between the two feature classes. The “Space_Type” field uses a domain called “Space_type” to present a drop down list of different types of spaces inside a building. This allows the user to

identify certain spaces on different levels inside a building. The “Owner_ID” field is used as a foreign key and contains the values of the “Owner_ID” field inside the Owner_Table. This field contains each employee’s unique personnel number that occupies an office. The relationship class between the “Owner_Table” and the “PUK_Rooms” feature class enables the user to determine which offices belong to whom. The user also has access to extra information about the occupants of each office inside a building. Each room’s approximate capacity for the maximum number of persons is listed in the “Capacity” field. The “PUK_Rooms” feature class contains subtypes to represent the different floor levels inside the building. The “Floor” field uses a drop down list to distinguish between the different levels inside the campus buildings. Due to the fact that the GIS model presented in this thesis must have room for further expansion, the amount of floor levels are determined to support future developments for new buildings. The number of floors for the subtype is also calculated taking into consideration the highest buildings on campus as well as the buildings with the most underground levels.

Table 3.8: Attribute fields of the PUK Rooms feature class

Field name	Field type	Domain	Subtypes	Relationship key:	Cardinality
Object ID	Long integer	--	--	Primary Key	1 – M M – N 1 – 1
Unique ID	Text	--	--	--	--
Building ID	Long integer	--	--	Foreign Key	M – 1
Space type	Long integer	Space type	--	--	--
Owner ID	Long integer	--	--	Foreign Key	M – 1
Capacity	Long integer	--	--	--	--
Floor	Long integer	--	Floor subtypes	--	--

3.5.2 Part 2: Point and line features representing electrical utilities

This part describes the attributes assigned to all the feature classes forming the electrical network. Each attribute field is described along with the combined theory associated with it. Interviews were conducted with two individuals from the technical department at the Potchefstroom campus of the NWU. They are responsible for electrical management and maintenance on the campus. The information regarding attributes for electrical utilities was derived from them.

The “Main_Substation_Feeder” feature class represents the three main electrical feeders that receive electricity either from the municipality or from the generators in case of electricity outage.

The “Job_ID” field in Table 3.9 represents the specific jobs done by the maintenance personnel on the electrical network. All the utility components in the network have a “Job_ID” field in their attribute tables. The “Job_ID” field is linked to the “Maintenance_Table” through a relationship class to present extra information about the maintenance done on a specific utility.

The following descriptive fields are used in both the “Main_Substation_Feeder” and the “Distribution_Station_Feeder” feature classes. Although it seems that the two feature classes have exactly the same descriptive attributes, they are in fact not the same and cannot be grouped under a single feature class. The “Distribution_Station_Feeder” feature class uses subtypes to distinguish between the two types of distribution stations allocated to various locations on campus.

The “Label” field represents the specific name given to an electrical feeder on the NWU Potchefstroom campus. The description in this field can either be a descriptive code or a local name to distinguish between different electrical stations. Each feeder can have one of three circuit breaker types. The “Circuit_Breaker_Type” field uses a domain to present a drop down list of the three circuit breaker types used on the campus. According to De Beer (2011a), a circuit breaker is used on an electrical network for two purposes. Firstly, the breaker can be used to isolate a whole electrical line for maintenance purposes. Switching off the breaker will ensure that it is safe for maintenance personnel to proceed. Secondly, the breaker can be used to trip the electrical flow in case of a sudden increase in current due to lightning or a network malfunction.

Each circuit breaker is made by a certain company. Therefore, the “Circuit_Breaker_Make” field describes the company make of each breaker. The “Current_Rating” field indicates the amount of current each breaker receives and handles. Under normal circumstances the received amount would be 11 kV or 11 000 volts which would be 630 Ampere for the circuit breaker. According to De Beer (2011a), the fault level of each electrical component is very important. The fault level can be seen as a certain potential of electrical current in a network.

This can be determined by the source from which the electricity originates such as the generating plants. For example: If there is a big generating plant that distributes electricity through big cables or conductors, the potential for electrical current will also be big at the receiving point.

If the big generating plant distributes electricity through smaller cables or conductors, the potential for electrical current will be much smaller. The “Fault_Level” field represents the result of a chain of calculations from the electrical source to the point of utilization. There are three determining factors to calculate the fault level. It depends on the size of the electrical source, the manner in which it is distributed and the potential amount that is available. The “Voltage_Rating” field represents the amount of voltage in the network.

Table 3.9: Attribute fields for the Main Substation Feeder feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	Primary key	M – M
Unique ID	Text	--	--	--	--
Job ID	Long integer	--	--	Foreign key	1 – 1
Label	Text	--	--	--	--
Circuit Breaker Type	Long inter	Circuit breaker type	--	--	--
Circuit breaker make	Text	--	--	--	--
Current Rating	Text	--	--	--	--
Fault Level	Text	--	--	--	--
Voltage Rating	Text	--	--	--	--

A distribution station feeder is as an electrical component containing several circuit breakers and it can have more than one transformer. The “Distribution Station Feeder” feature class represented by Table 3.10 has two subtypes in the electrical network of the campus. A distribution station feeder can be categorized under a substation or mini substation. The difference between the two is that a substation distributes a heavier load of electricity than a mini substation. The two types have exactly the same characteristics, therefore the attribute fields are the same. This enables the user to sub categorize the two types under one feature class. The “Type” field provides the subtypes to be chosen during the digitizing process. Each distribution station feeder has different sizes of cables entering from the primary supply. The size of the cable varies and is determined according to the demand for electrical supply that has to be distributed from the distribution station feeder to the participating buildings.

Table 3.10: Attribute fields for the Distribution Station Feeder feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	Primary key	M – M
Unique ID	Text	--	--	--	--
Job ID	Long integer	--	--	Foreign key	1 – 1
Type	Long integer	--	Type	--	--
Label	Text	--	--	--	--
Circuit Breaker Type	Long inter	Circuit breaker type	--	--	--
Circuit breaker make	Text	--	--	--	--
Current Rating	Text	--	--	--	--
Fault Level	Text	--	--	--	--
Voltage Rating	Text	--	--	--	--

There is a transformer in every distribution station on campus responsible for the transformation of the high primary voltage to a lower secondary voltage. After the voltage is transformed to a lower current, it is ready to be distributed to the participating buildings receiving their electricity from the distribution station. The “Label” field present the descriptive name used to distinguish between the different transformers in various distribution stations. Each distribution station transformer receives a primary voltage amount that is transformed to a secondary voltage amount.

The “Primary_Voltage” field indicates the voltage amount entering the distribution station and the “Secondary_Voltage” field shows the voltage amount after it has been transformed. The “Rating_kVA” field stands for the capacity of each transformer. “kVA” is an acronym for kilo volt ampere. The amount in each field indicates the maximum amount of kVA the transformer can handle before it burns out. The “Vector_Group” field indicates a certain type of distribution vector evident in the transformer. For example, if the value in the field is “DYN”, it stands for delta, star and neutral. The delta wires are the first part of the transformer that receives the high voltage current before it is passed on to the star wires on which the electrical current is transformed to a lower current or voltage. The neutral connection receives no current under normal circumstances in a balanced scenario. It will be safe for a person to put a hand on the connection because there is no electricity running through it.

The value captured in the “Impedance” field is an important factor to determine the fault level value for the network. The impedance is basically the amount of copper wire windings in the transformer. Calculations can be made to determine the exact length of copper wire in each transformer. Each transformer descends from a certain company manufacturer. The

“Make” field indicates which factory is responsible for the manufacturing of the specific transformer. The “Year_of_manufacture” field indicates the year in which the transformer is produced. The “Oil_level” field represents a component in the transformer. The oil levels are checked on a monthly basis. A transformer does not use much oil under normal circumstances. If there is a drop in the oil level, it is usually an indication of a broken seal. The silica gel is also a component of a transformer. Silica gel is a type of crystal that has characteristics to absorb moisture. The crystals change colour when exposed to water. A transformer uses air during the operational process. A container of silica gel is attached to the air pipe entering the transformer. The silica gel extracts water from the air, keeping it from mixing with the oil in the transformer. Table 3.11 describes the attribute fields for the Distribution Station Transformer feature class.

Table 3.11: Attribute fields for the Distribution Station Transformer feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	Primary key	M – M
Unique ID	Text	--	--	--	--
Job ID	Long integer	--	--	Foreign key	1 – 1
Label	Text	--	--	--	--
Primary voltage	Long integer	--	--	--	--
Secondary voltage	Long integer	--	--	--	--
Rating (KvA)	Long integer	--	--	--	--
Vector group	Text	--	--	--	--
Impedance	Text	--	--	--	--
Make	Text	--	--	--	--
Year of manufacture	Date	--	--	--	--
Oil level	Text	--	--	--	--
Silica gel	Text	--	--	--	--

The “Distribution_Board” feature class represents the main electrical distribution boards inside various buildings. Each building has two types of distribution boards called main distribution boards and sub-distribution boards. Buildings can have more than one main distribution board according to the energy requirements of the specific building. Each main distribution board also transforms the received electrical voltage to a lower voltage before the energy is allocated to the different sub distribution boards inside the building.

Each room feature that was edited has a unique object identification field in the “PUK Rooms” feature class. These values are listed in Table 3.12 under the “Room ID” field in the “Distribution_board” feature class to enable the relationship class connection. The user clicks on a specific utility component and has the ability to see the different relationship classes between the cables, utility components and the space types involved by means of the

identification tool. The “kA_Rating” field represents the voltage rating calculated from the electrical source all the way to the endpoint utility. This determines the amount of energy available at the specific point.

Under normal circumstances, the kA value is 6 kA at the sub distribution boards. The main distribution boards have a higher kA value of 10. The kA value is determined by two factors: the distance from the distribution station transformer and the impedance of the system. The different phases of the distribution boards are represented by the “Phase” field. It is useful to the technical personnel to know which phase connects which utilities inside a building. The different phases in a distribution boards have to be balanced. For example: If the Red phase runs a big machine, the White and Blue phases can have several small utilities connected using the same electricity load. Indicating the different phases can be useful in situations where there is a problem with a phase. A simple query can be run to locate all the different utilities connected to the specific phase. The “Phase_Rotation” field is also implemented. This indicates the direction in which the phases rotate inside the distribution boards. It can be either clockwise or anti-clockwise. The NWU campus uses mainly clockwise rotations. There are cases in municipality networks where anti-clockwise rotations are used. The “Type” field shows the subtypes of the “Distribution_Board” feature class.

Table 3.12: Attribute fields for the Distribution Board feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	Primary key	M – M
Unique ID	Text	--	--	--	--
Job ID	Long integer	--	--	Foreign key	1 – 1
Room ID	Long integer	--	--	Foreign key	M - 1
kA_Rating	Long integer	--	--	--	--
Phase_Rotation	Long integer	Phase_Rotation	--	--	--
Phase	Long integer	Phase	--	--	--
DB_Location	Long integer	--	Floor subtypes	--	--
Board_Type	Text	--	--	--	--

The “DB_Location” field use subtypes to distinguish between the different floor levels. This is useful because the subtypes can be turned off during digitizing to cancel out confusion between features. The “Board_Type” field lists the different types of distribution boards inside the buildings as described in Table 3.12. Each building has several sub-distribution boards on the different floor levels. Each sub-distribution board hosts several electrical utility endpoints on a different electrical phase.

The “Cables” feature class represents the vast network of cables that runs through the campus from the main substation feeders to the utility endpoints where electricity is utilized. The “Cables” feature class connects all the electrical components in the macro as well as the micro electrical network of the campus. The feature class connects six relationship classes, enabling the user to see what type of electrical components are connected on either side of an electrical cable or conductor in the network. The “Cables” feature class has four fields called Sup_DB, Sup_MS_Feeder, Sup_DS_Feeder and Sup_DS_Transformer that take part in relationship classes to enable the user to identify from which connection the specific cable originates. The cardinality of the relationship classes are all “many – many”. By using the information tool, the user can visualize the two connections on either side of a specific cable to determine its origin and destination.

The main substation feeder on campus distributes electricity through 14 ring feeder switches inside the substation. There are seven main electrical feeder rings that run on campus. Each feeder cable ring has two ring feeder switches attached to it. Each feeder ring supports a number of substations and mini substations. The “Ring_Feeder” field represents which feeder ring is present that supports the specific electrical cable. According to De Beer (2011a), there are different types of cable materials. This is represented by the “Cable_material” field. The field uses a domain to select the type of cable material. There are many different cable sizes involved in an electrical network. This depends on the amount of current that has to be distributed from point A to point B. The “Cable_size” field uses a domain to show all the different cable sizes to choose from in a list. Each electrical cable in a network is composed out of different materials. Table 3.13 explains the different abbreviations used for the cable compositions. The “Cable_composition” field distinguishes between different cable compositions through the use of a domain.

Table 3.13: Abbreviations for different cable compositions

Abbreviation	Description
PILSWA	Paper Insolated Steel Wired Armored
XLPE PVC	Cross Linked Polyethylene Polyvinyl Chloride
PVC RUBBER	Polyvinyl Chloride Rubber
PVC	Polyvinyl Chloride
Al Conductor	Aluminum cable/conductor
TCUV	Three Core Unarmored Vultex
PVC PVC	Polyvinyl Chloride Polyvinyl Chloride
PVC NITRILE	Polyvinyl Chloride Nitrile
Cu Conductor	Copper cable/conductor

Each cable has to be connected to an electrical utility on its endpoint. The manner in which this connection is performed without causing electrical shortages, is described by the termination of the specific cable. There are two different types of termination, e.g. dry type and compound type. These types of termination are designed in such a way to prevent electrical shortages in the network because of certain characteristics. The “Termination” field represents this information. According to De Beer (2011a), the “Outside_Diameter” field is important because this information determines if the cable can fit into the service routes for several areas. Service routes can be in the form of steel pipes inside buildings walls, cable skirting along the walls and cable trenches in the ground. The “Cable_Position” field use subtypes to distinguish the features between the different levels of the building. Each feature is assigned to a subtype that can be turned off during digitizing to cancel out possible confusion by viewing all the features at once as described in Table 3.14.

Table 3.14: Attribute fields for Cables feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	Primary key	1 – M
Unique ID	Text	--	--	--	--
Job ID	Long integer	--	--	Foreign key	1 – 1
Ring_Feeder	Long integer	Ring_Feeder	--	--	--
Sup_DB	Long integer	--	--	Foreign Key	N – M
Sup_MS_Feeder	Long integer	--	--	Foreign key	N – M
Sup_DS_Feeder	Long integer	--	--	Foreign key	N – M
Sup_DS_Transformer	Long integer	--	--	Foreign key	N – M
Electricity categories	Long integer	--	Electricity categories	--	--
Cable material	Long integer	Cable material	--	--	--
Cable size	Long integer	Cable size	--	--	--
Cable composition	Long integer	Cable composition	--	--	--
Outside_Diameter	Text				
Termination	Text	--	--	--	--
Cable_Position	Long integer	--	Floor subtypes	--	--

The “Utility_endpoint” feature class represents the endpoints of the electrical network. These points are in fact the areas where the electricity is used to power appliances through the plugs.

The “Cable ID” field in the “Utility endpoint” feature class is a list of the “Object ID” field values in the “Cables” feature class as described in Table 3.15. This enables the relationship class connection between the two feature classes. The user can click on a utility endpoint connection and see which cable is connected to that feature and which connections are connected to the cable upstream. The “Type” field enables the user to specify the type of

utility endpoint evident. Even though only the plugs are modelled in this project, the name of the “Utility_endpoint” feature class stays the same. This will enable the user to use the same feature class when modelling and capturing other types of utility endpoints inside buildings such as lights and air conditioning. The “Phase” field represents the phase to which the specific utility endpoints are connected to. This information is useful to trouble shoot problems in case of electricity outages to find out if the problem occurs on one of the phases. The “Level” field use subtypes to distinguish between features on different levels. These features assigned to the different subtypes can be turned off to view only the features on a desired level during digitizing.

Table 3.15: Attribute fields for the Utility endpoint feature class

Field name	Field type	Domain	Subtypes	Relationship key	Cardinality
Object ID	Long integer	--	--	--	--
Unique ID	Text	--	--	--	--
Cable ID	Long integer	--	--	Foreign key	M – 1
Job ID	Long integer	--	--	Foreign key	1 – 1
Room ID	Long integer	--	--	Foreign Key	M – 1
Type	Text	--	--	--	--
Phase	Long integer	Phase	--	--	--
Level	Long integer	--	Floor subtypes	--	--

3.5.3 Non-spatial table attribute fields

The non-spatial data serves as extra information tables outside the feature dataset that takes part in the relationship classes between all the participating feature classes. In this prototype model there are three extra information tables that describe the different owners for each room that serves as an office, maintenance information for utilities on the network and a list of contractors responsible for maintenance on network utilities. Table 3.16 describes the “Owners_Table” in the PUK_geodatabase.

The “Object_ID” field serves as a unique code for the each entry in the owners table. Each time an entry is deleted, the following entry has a new object id. The “Owner_ID” field represents each unique personnel number of the employees working for the NWU. The “Owner_ID” field in the owners table is the primary key for the relationship class between the table and the “PUK_Rooms” feature class. This relationship class enables the user to receive extra information about a person occupying an office in a building. The “Owner_Name” field describes the names and surnames of employees. The contact

information of each person is listed under the “Tel_number” and “Email” fields in the table. The “Owner_Table” also uses the “Department” domain to categorize employees under the different departments.

Table 3.16: Attribute fields for the Owners Table

Field name	Field type	Domain	Relationship key	Cardinality
Object ID	Long integer	--	--	--
Owner ID	Long integer	--	Primary key	1 – M
Owner Name	Text	--	--	--
Tel number	Text	--	--	--
Email	Text	--	--	--
Department	Long integer	Department	--	--

Table 3.17 describes the “Maintenance_Register” that is used as an extra information table to keep record of the maintenance done on each utility on the network. The “Object_ID” field is automatically generated each time a new entry is made in the table. This makes the field ideal to be used as a primary key in relationship classes between the different utility components. The “Contractor_ID” field describes a unique identification code for each person working as an electrical contractor on the utility components. The particular field is also used as a foreign key in the relationship class between the “Maintenance_Table” and the “List_of_contractors” tables. The “Install_date” field represents the first time a specific utility is installed. The purpose of this field is to determine the lifespan of a specific utility on the network and to calculate the optimum time when replacement is needed. There are many components participating in an electrical network. Every time maintenance is done, it is important for the user to know on which specific types of components were worked on. Therefore the “Utility_Component” field specifies between the electrical components. The “Last_updated” field shows the last time a person recorded maintenance done on a specific utility in the campus electrical network.

Table 3.17: Attribute fields for the Maintenance Register

Field name	Field type	Domain	Relationship key	Cardinality
Object ID	Long integer	--	Primary key	1 – 1
Contractor ID	Long integer	--	Foreign key	M – 1
Install date	Date	--	--	--
Utility component	Text	--	--	--
Last updated	Date	--	--	--

The “List_of_contractors” table described by Table 3.18 presents a list of extra information about the persons working as electrical contractors on the campus. The “Contractor_name”

field represents the names and surnames of the persons while the “Occupation” field distinguishes between the types of electrical expertise between the different persons. The “Contractor_Tel_nr” and the “Email” fields are used the present contact information for the specific persons. The “Company” field refers to the specific company the person works for. The North-West University is composed out of three separate campuses. Therefore it is important to distinguish between the three in the “Campus” field. The “Fax_number” field presents a contact number if there is a need to send a fax to the specific person.

Table 3.18: Attribute fields for List Of Contractors Table

Field name	Field type	Domain	Relationship key	Cardinality
Object ID	Long integer	--	Primary key	1 – M
Contractor name	Text	--	--	--
Occupation	Text	--	--	--
Contractor Tel nr	Text	--	--	--
Email	Text	--	--	--
Company	Text	--	--	--
Campus	Text	--	--	--
Fax number	Text	--	--	--

3.5.4 Relationship classes between the spatial and non-spatial attribute fields

The relationship classes are used to generate connections between the different electrical components as well as the information tables. This enables the user to view a connected infrastructure system from the main substation feeder through the campus zones, buildings and rooms until the network ends at the utility endpoints. Table 3.19 describes all the relationship classes participating in the GIS prototype model.

Every relationship class has a distinct name indicating the feature class or information table participating in the connection. According to ESRI (2011), each relationship class has an origin and a destination class. The origin and destination class must not be confused with each other because getting this right is critical. Objects in the origin table match objects in the destination table through the use of primary and foreign keys. The values in the fields participating as key fields are important for the relationship class connection. The cardinality determines the number of objects in the origin class that relate to a number of objects in the destination class (ESRI, 2011).

Table 3.19: Relationship classes between attribute fields of different tables

Relationship class name	Origin table	Destination table	Primary key	Foreign key	Cardinality
Zone_has_Building	PUK_Zones	PUK_Buildings	Object_ID	Zone_ID	1 – M
Building_has_Room	PUK_Buildings	PUK_Rooms	Object_ID	Building_ID	1 - M
Room_has_DB	PUK_Rooms	Distribution_Board	Object_ID	Room_ID	1 – M
Room_has_UE	PUK_Rooms	Utility_endpoints	Object_ID	Room_ID	1 – M
DB_has_Cables	Distribution_Brd	Cables	Object_ID	Sup_DB	M – M
MSS_Feeder_has_Cables	MSS_Feeder	Cables	Object_ID	Sup_SS_Feeder	M – M
DS_Feeder_has_Cables	DS_Feeder	Cables	Object_ID	Sup_DS_Feeder	M – M
Transformer_has_cables	DS_Transformer	Cables	Object_ID	Sup_Transformer	M – M
Cables_has_Utility_EP	Cables	Utility_End_Points	Object_ID	Cable_ID	1 – M
OT_has_Rooms	Owner_Table	PUK_Rooms	Owner_ID	Owner_ID	1 – M
MR_has_DB	Main_Register	Distribution_Board	Object_ID	Job_ID	1 – 1
MR_has_Cables	Main_Register	Cables	Object_ID	Job_ID	1 – 1
MR_has_UT_endpoints	Main_Register	Utility_endpoints	Object_ID	Job_ID	1 – 1
MR_has_MSS_Feeder	Main_Register	MSS_Feeder	Object_ID	Job_ID	1 – 1
MR_has_DS_Feeder	Main_Register	DS_Feeder	Object_ID	Job_ID	1 – 1
MR_has_Transformer	Main_Register	DS_Transformer	Object_ID	Job_ID	1 – 1
LOC_has_MT	List_contractors	Maintenace Table	Object_ID	Contractor_ID	1 – M

3.5.5 Attribute fields subtypes

The subtypes for the “PUK_Rooms” feature class represent the different floor levels above and under the ground level of the different buildings. The user is able to switch the subtypes on and off during analysis and visualization to view only the desired rooms of a specific building. According to ESRI (2011), subtypes are used to categorize data that has the same descriptive attributes. Categorizing the “PUK_Rooms” feature class is an effective manner to distinguish between different floor levels. Table 3.20 shows the different subtypes used for the “PUK_Rooms” feature class. The number of subtypes indicating floor levels are chosen in such a way that the user has enough subtypes to work with even when expanding the database to model buildings with a higher number of floors in the study area.

Table 3.20: Subtypes for PUK Rooms feature class

Code	Dropdown list	Description
0	Sub_Floor_01	Underground level one
1	Sub_Floor_02	Underground level two
2	Ground_Floor	Ground floor
3	Floor_01	First floor level
4	Floor_02	Second floor level
5	Floor_03	Third floor level
6	Floor_04	Fourth floor level
7	Floor_05	Fifth floor level
8	Floor_06	Sixth floor level
9	Floor_07	Seventh floor level
10	Floor_08	Eight floor level
11	Floor_09	Ninth floor level
12	Floor_10	Tenth floor level

The distribution station feeders on campus can be categorized under substations and mini-substations. The two types of distribution stations share exactly the same descriptive attributes. Therefore the possibility exists to create subtypes for the feature class. Table 3.21 describes the two subtypes of the “DS_Feeder” feature class.

Table 3.21: Subtypes for Distribution Station Feeder feature class

Code	Dropdown list	Description
0	Sub Station	Standard sub station
1	Mini Substation	Standard mini sub station

The subtypes for distribution boards and utility endpoints inside buildings represent the different floor levels. The features representing the distribution boards and utility endpoints are each assigned to a subtype representing a specific floor level that can be turned off during digitizing. Table 3.22 illustrates the two subtypes for the “Distribution_Board” and “Utility_endpoint” feature classes.

Table 3.22: Subtypes for the Distribution Board and Utility endpoints feature classes

Code	Dropdown list	Description
0	Sub_Floor_01	Underground level one
1	Sub_Floor_02	Underground level two
2	Ground_Floor	Ground floor
3	Floor_01	First floor level
4	Floor_02	Second floor level
5	Floor_03	Third floor level
6	Floor_04	Fourth floor level
7	Floor_05	Fifth floor level
8	Floor_06	Sixth floor level
9	Floor_07	Seventh floor level
10	Floor_08	Eight floor level
11	Floor_09	Ninth floor level
12	Floor_10	Tenth floor level

Electrical cables or conductors are distributed along many paths outside buildings either overhead or underground. The distribution continues across the different levels of each building until the cable reaches its endpoint. The subtypes used to represent the “Cables” feature class distinguishes the features between the different floors of buildings and outside the buildings as described in Table 3.23.

Table 3.23: Subtypes for Cables feature class

Code	Dropdown list	Description
0	Sub_Floor_01	Underground level one
1	Sub_Floor_02	Underground level two
2	Ground_Floor	Ground floor
3	Floor_01	First floor level
4	Floor_02	Second floor level
5	Floor_03	Third floor level
6	Floor_04	Fourth floor level
7	Floor_05	Fifth floor level
8	Floor_06	Sixth floor level
9	Floor_07	Seventh floor level
10	Floor_08	Eight floor level
11	Floor_09	Ninth floor level
12	Floor_10	Tenth floor level
13	Outside	Outside buildings

3.5.6 Attribute field domains

Certain domains are created to maintain database integrity and to eliminate the possibility of human error. These domains present a drop-down list with specific values to choose from. A domain can be either coded or range. All the domains used in this prototype model use coded values to provide a list of accurate possibilities to choose from (ESRI, 2011). The NWU Potchefstroom campus has eight faculties listed in Table 3.24. The purpose of this domain is to present a correct list of the different faculties to the user. Each code represents a faculty. If new faculties are developed, the new entry can simply be added to the list contained in the domain.

Table 3.24: Domain for faculties on campus

Code/Range	Drop down list
0	Arts
1	Natural Sciences
2	Theology
3	Education Sciences
4	Economic and Management Sciences
5	Law
6	Engineering
7	Health Sciences

The information in Table 3.25 was mostly derived from the CAD drawings which represent the different types of spaces on different levels inside a building. These different types were used to generate a list of possible generic space types inside a building described in Table 3.25. This helps the user to distinguish between the various room types evident in the study area.

Table 3.25: Domain for different space types inside buildings

Code/Range	Drop down list	Code/Range	Drop down list
0	Office	9	Utility Room
1	PC Labs	10	Empty Room
2	Laboratory	11	Lobby
3	Class room	12	External Area
4	Corridor	13	Elevator
5	Steps	14	Library
6	Kitchen	15	Staff Room
7	Bathroom	16	Exhibition
8	Storage	17	Seminar

Every faculty is divided even further into schools, departments and centres. According to NWU (2011b), there are more than 30 schools and centres on campus, excluding the administration departments. The “Department” domain is created to present a generic drop-down list of the different schools to maintain database integrity. Table 3.26 presents the code for each department or centre listed by NWU (2011b).

Table 3.26: Domain for different school departments on campus

Code/Range	Drop down list	Code/Range	Drop down list
0	School of Languages	17	Potchefstroom Business School
1	School of Social and Government studies	18	School of Accounting Sciences
2	School of Music	19	School of Economics
3	School of Communication Studies	20	School of Business Management
4	School of Philosophy	21	School of Human Resources Sciences
5	School of Physical and Chemical Sciences	22	Centre for Community Law and Development
6	School of Environmental Sciences and Development	23	Potchefstroom Electronic Law Journal (PER)
7	School of Computer, Statistical and Mathematical Sciences	24	School for Chemical Engineering
8	Centre for Business, Mathematics and Informatics	25	School for Electrical, Electronic and Computer Engineering
9	Centre for Environmental Management	26	School of Mechanical Engineering
10	Centre for Human Metabonomics	27	Post- graduate School of Nuclear Science and Engineering
11	School for Biblical Studies and Bible Languages	28	School of Biokenetics, Recreation and Sport Science
12	School for Ecclesiatical Studies	29	School of Pharmacy
13	School for Education	30	School of Physiology, Nutrition and Consumer Sciences
14	School for Continuing Teacher Education	31	School of Psychological Behavioural Sciences
15	School for Curriculum Based Studies	32	School of Nursing
16	Research Focus Area: Teaching – Learning Organizations	33	Administration

Electrical cables can be composed out of different materials. There are variations between aluminum and copper materials. Table 3.27 presents the drop-down list used in the “Cable_materials” domain. This provides important information to the user due to the fact that the cable materials have specific characteristics dividing them from each other. The type of cable material determines the termination method when a cable is connected to an endpoint.

Table 3.27: Domain for different cable materials

Code/Range	Drop down list
0	Al conductor
1	Al single core
2	Al 2 core
3	Al 4 core
4	Cu conductor
5	Cu single core
6	Cu 2 core
7	Cu 4 core

As mentioned earlier, the cable sizes vary between certain areas in an electrical network depending on the availability of electricity and the manner in which the electricity is distributed. According to De Beer (2011a) the electricity demand also plays an important role when choosing cable sizes to place in the distribution network. If there is a high demand for electricity in point A, this demand can only be met according to the availability of electricity at the generating plant and the size of the cable distributing this energy. Should there be enough electricity at the generating plant but the distribution cable is too small, the demand for energy in point A will not be met. The fault level discussed earlier is determined by these important factors. Different cable sizes support different electricity categories. The main electricity categories are extra high voltage, high voltage, medium voltage and low voltage. The cable sizes are valid for both the copper and aluminum cables used in the network. Table 3.28 represents the different cable sizes in the “Cable_sizes” domain.

Table 3.28: Domain for cable sizes

Code/Range	Drop down list	Code/Range	Drop down list
0	1.5 mm ²	8	50 mm ²
1	2.5 mm ²	9	70 mm ²
2	4 mm ²	10	95 mm ²
3	6 mm ²	11	120 mm ²
4	10 mm ²	12	150 mm ²
5	16 mm ²	13	185 mm ²
6	25 mm ²	14	240 mm ²
7	35 mm ²	15	300 mm ²

Each of the seven ring feeders are composed out of two ring feeder switches inside the main substation feeder and multiple cables connecting the various electrical components on the campus network. The “Ring_Feeder” domain in Table 3.29 represents the “Ring_Feeder” field in the “Cables” feature class. The user will be able to identify the specific cable ring

supporting each cable on the network. The domain presents the code value for each ring feeder in the drop down list.

Table 3.29: Domain for different ring feeders from Main Substation Feeder

Code/Range	Drop down list
0	Ring_1_Feeder
1	Ring_2_Feeder
2	Ring_3_Feeder
3	Ring_4_Feeder
4	Ring_5_Feeder
5	Ring_6_Feeder
6	Ring_7_Feeder

There are three circuit breaker types used in the campus network. According to De Beer (2011a), it is beneficial to standardize to a certain circuit breaker type in a network. This can be useful when there is a need for spare parts in case of an emergency. In cases where a circuit breaker malfunctioned, it is necessary to remove a circuit breaker from one box to be installed where it is more needed. Table 3.30 illustrates the domain used for the different circuit breaker types through the use of coded values.

Table 3.30: Domain for circuit breaker types in network

Code/Range	Drop down list
0	Oil
1	Vacuum
2	SF6 Gas

According to De Beer (2011a), there are many material combinations to compose electrical cables. It is important for the technical personnel to list these cable compositions in the descriptive data for the “Cables” feature class. Each cable composition is used for specific objectives or areas it would work best. Aberdare (2011) lists the different cable compositions available used in the campus electrical network. Figure 3.4 shows the different cable compositions with describing pictures:

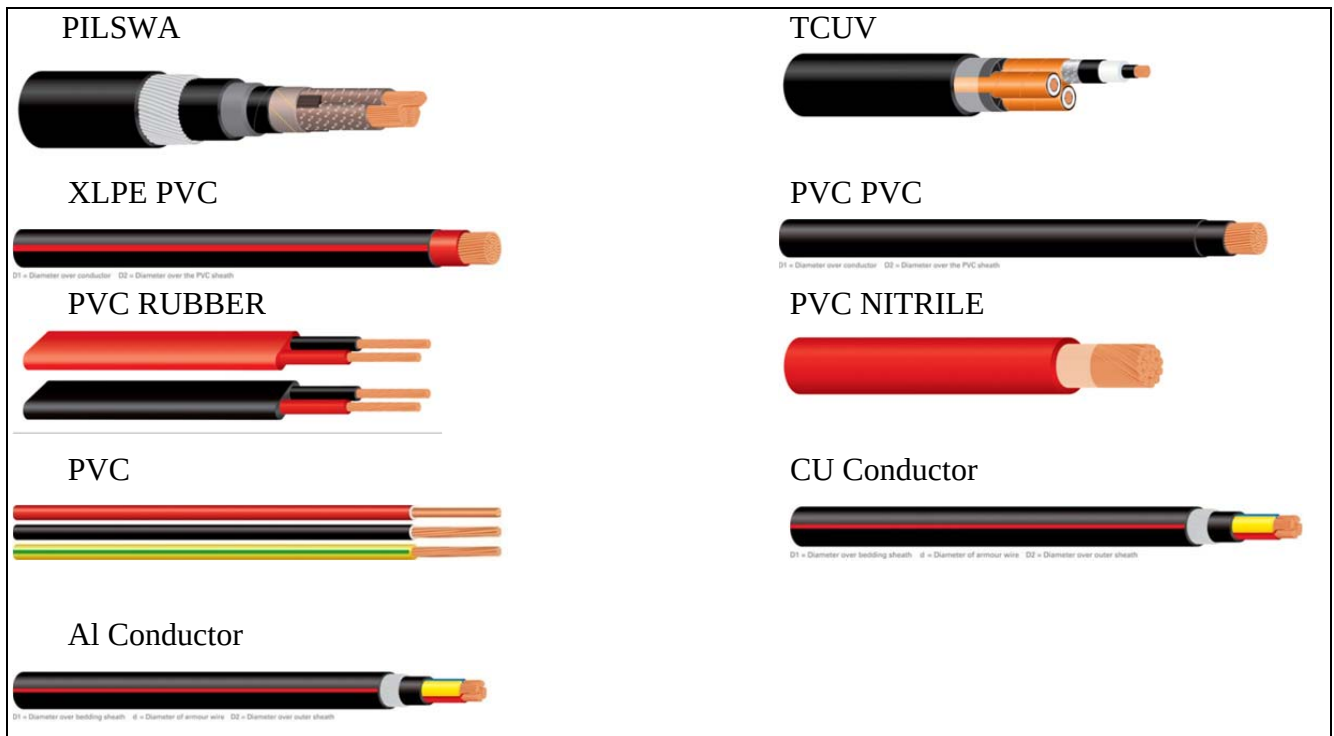


Figure 3.4: Types of cable compositions (Aberdare, 2011).

To make a drop down list of the different cable compositions, a domain is used to assign the different compositions with a code. This enables the user to choose the correct option when digitizing cable features in the geodatabase. Table 3.31 describes the domain for the different cable compositions used in the campus electrical network.

Table 3.31: Domain for cable composition

Code/Range	Drop down list
0	PILSWA
1	XLPE PVC
2	PVC RUBBER
3	PVC
4	Al Conductor
5	TCUV
6	PVC PVC
7	PVC NITRILE
8	Cu Conductor

Every electrical utility is connected to an electrical phase. Each phase inside a distribution board supports a number of electrical utilities until the maximum is reached. Knowing which phase supports which utilities can help determine problems in case of an electrical outage. Table 3.32 describes the domain for the different phases.

Table 3.32: Domain for different phases

Code/Range	Drop down list
0	Red
1	White
2	Blue
3	Three Phase

Every distribution board inside a building is subject to a type of phase rotation. Knowing the type of phase rotation helps the electrical technician to sort out possible problems on the electrical network. There are two types of phase rotations known as clockwise rotation or counter-clockwise rotation, as described in Table 3.33.

Table 3.33: Domains for different phase rotations

Code/Range	Drop down list
0	Clockwise
1	Anti Clockwise

3.6 Define the spatial properties of your datasets

In this step by Actur and Zeiler (2004) the different map projections, topology rules and the consideration between geometric networks and feature datasets are discussed. Three map projections were considered for the datasets. Each projection is discussed in Chapter 2 to motivate why one was chosen. A number of relevant topology rules were considered and tested to enforce spatial integrity and shared geometry. The networks modelled in the geodatabase used vertical connections between the different floor levels of buildings. This forms a connected system of features inside the two specified buildings. The use of geometric networks and feature datasets were considered in order to model connected networks efficiently for analysis.

3.6.1 Projection

After considering the three types of map projections and comparing the characteristics with each other in Chapter 2, it was determined that the UTM projection would work best for the project presented in this thesis. The data in this thesis consists mainly out of small shapes inside buildings. The study area is also a small area on the NWU campus. The UTM projection is well suited to represent small shapes very accurately with minimal distortion.

The distortion of larger shapes is also minimal within the zone. The UTM 35 S zone will be used in this thesis.

3.6.2 Topology

Topology rules are an important aspect that plays a vital role in the digitizing process of different features due to the fact that it maintains spatial integrity in the geodatabase. According to Rhaman (2005) the use of topology rules forms the base of calculations in a geodatabase.

Due to the fact that the connected networks in this thesis are viewed in 3D, the topology rules are limited. The digitized features forming the connected network use z-values in their geometry. These z-values are also used to establish vertical connections between the different floors of a building. Gillgrass (2010) explained that 3D-topology is not yet implemented, therefore only 2D-topology can be used. The use of z-values limits some of the current topology rules because the topology sees the features on top of each other in 2D.

Six types of topology rules were considered for the project in this thesis. Each rule was tested to determine the viability of the rule towards the features in 2D. The following figures illustrate the different topology rules considered for the feature classes in the PUK geodatabase:

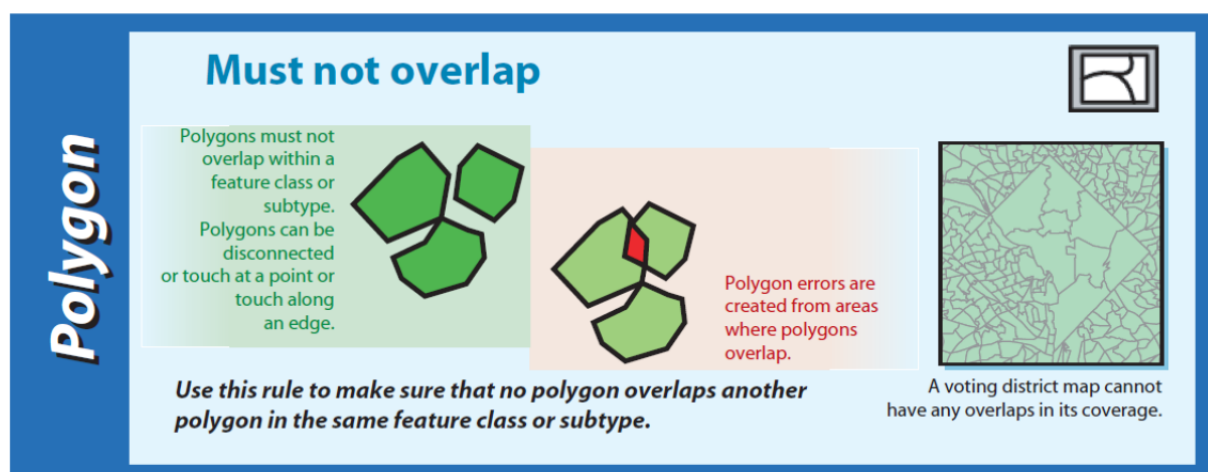


Figure 3.5: The “must not overlap” topology rule (ESRI, 2011).

The topology rule described in Figure 3.5 is used for the “PUK_Buildings” feature class and the “PUK_Zones” feature class. Both of the feature classes function mainly for 2D purposes. The “must not overlap” rule ensures that the different zones and building outlines don’t overlap themselves to maintain spatial integrity.

The “must not overlap” topology rule was tested for the “PUK_Rooms” feature class and encountered a problem. This particular feature class uses z-values in its geometry to model the different floor levels. The room outlines on the different levels of the buildings are not the same. From a 2D perspective, the rooms would overlap each other. Therefore this topology rule cannot be used due to the use of z-values.

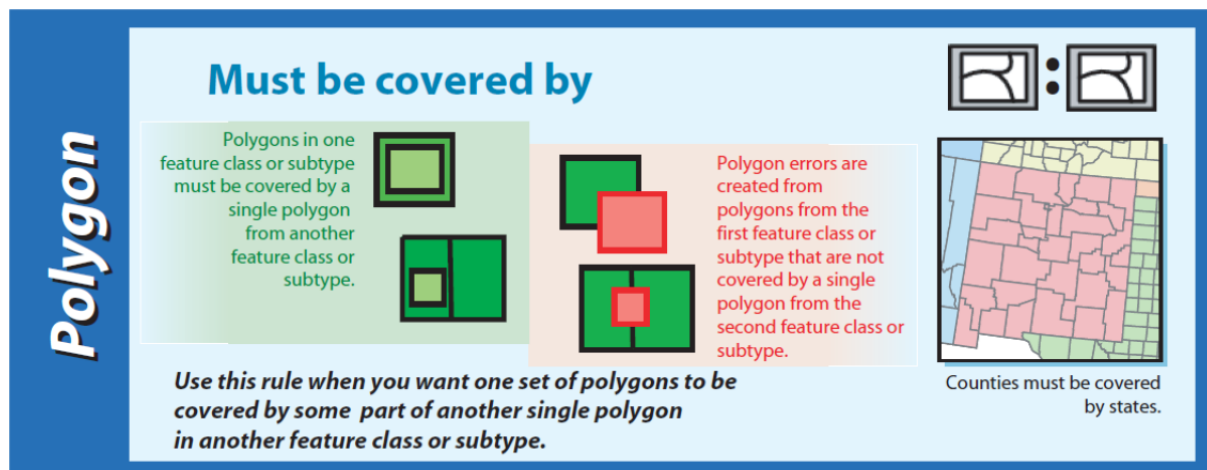


Figure 3.6: The “must be covered by” topology rule (ESRI, 2011).

The “PUK_Rooms” and “PUK_Buildings” feature classes participate in the topology rule described in Figure 3.6. This topology rule ensures that there are no rooms outside the particular building and another problem was identified. The “PUK_Rooms” feature class uses a domain to distinguish between the different types of spaces inside the buildings. One of the types describes the external areas inside the buildings such as gardens and socializing areas. These areas touch the boundary of the “PUK_Buildings” feature class causing a topology error. This particular error for all the external areas is in fact not wrong. The external areas are inside the “PUK_Buildings” feature class even though they touch the boundary. Therefore exceptions were made to cancel these errors.

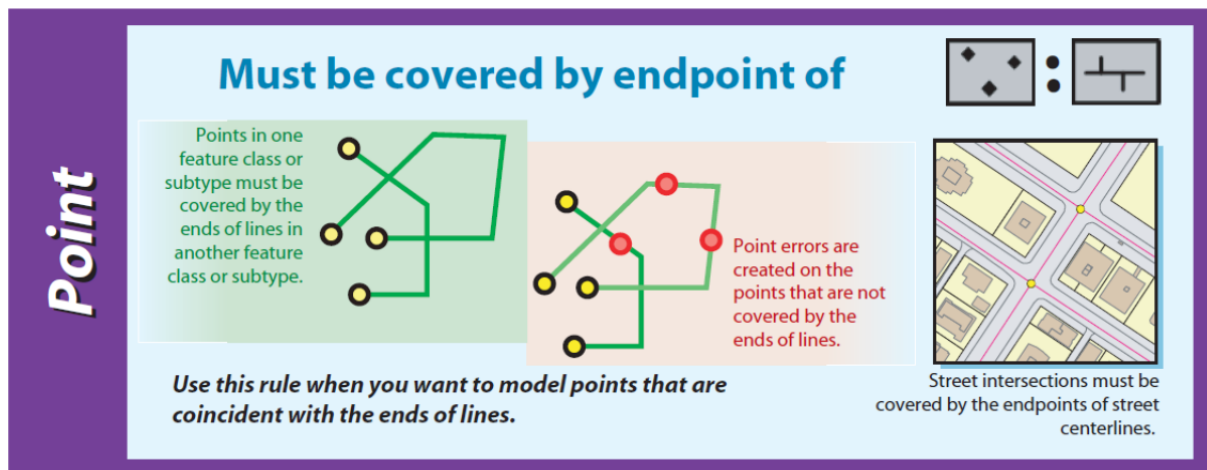


Figure 3.7: The “must be covered by endpoint of” topology rule (ESRI, 2011).

The topology rule illustrated in Figure 3.7 is assigned for all the point feature classes participating in the geodatabase. The main reason for considering this topology rule is to identify possible areas where point features are not connected to the endpoints of cables. This can help to ensure that all participating features are connected before running a network dataset.

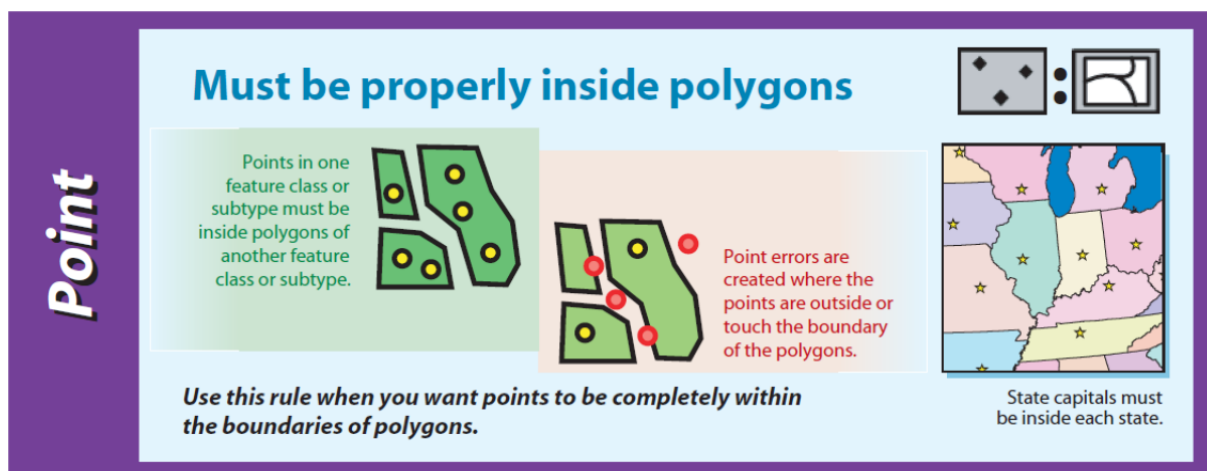


Figure 3.8: The “must be properly inside” topology rule (ESRI, 2011).

The topology rule described in Figure 3.8 is assigned for the micro network point feature classes inside the buildings. It ensures that the particular point feature classes are not outside the boundary or the “PUK_Buildings” feature class.

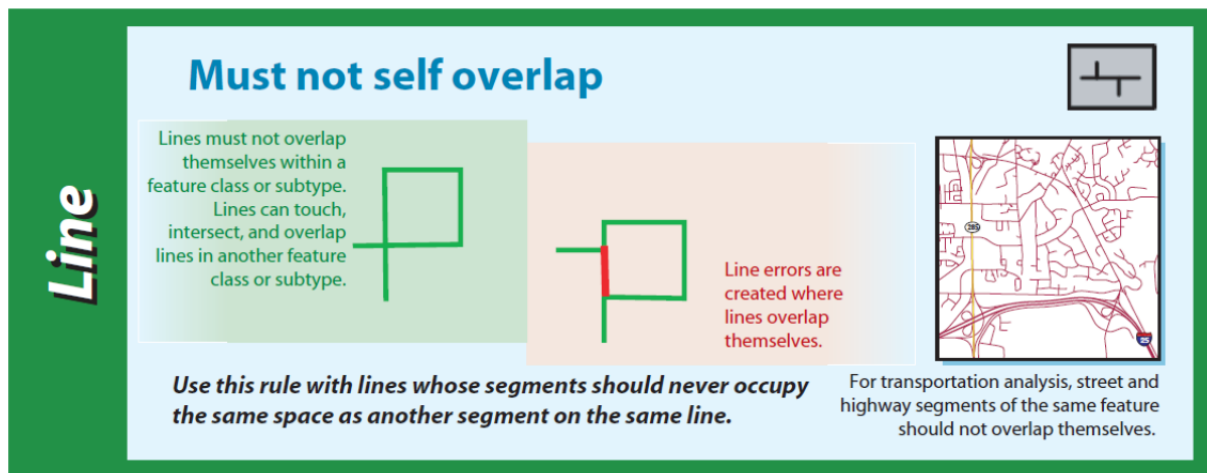


Figure 3.9: The “must not self overlap” topology rule (ESRI, 2011).

The purpose of the topology rule described in Figure 3.9 was to identify possible areas where electrical cables overlapped themselves. The electrical cable network in this thesis divides into two types called the ring network and the endpoint network. In both these networks there should not be any areas where electrical cables overlap themselves. The “must not self overlap” topology rule was tested but problems occurred. The z-value geometry caused errors on every vertical line in the network. Electrical lines on different floor levels are seen as on top of each other from a 2D point of view. This causes the topology rule to generate errors on all those areas. Therefore, this topology rule was considered but could not be implemented.

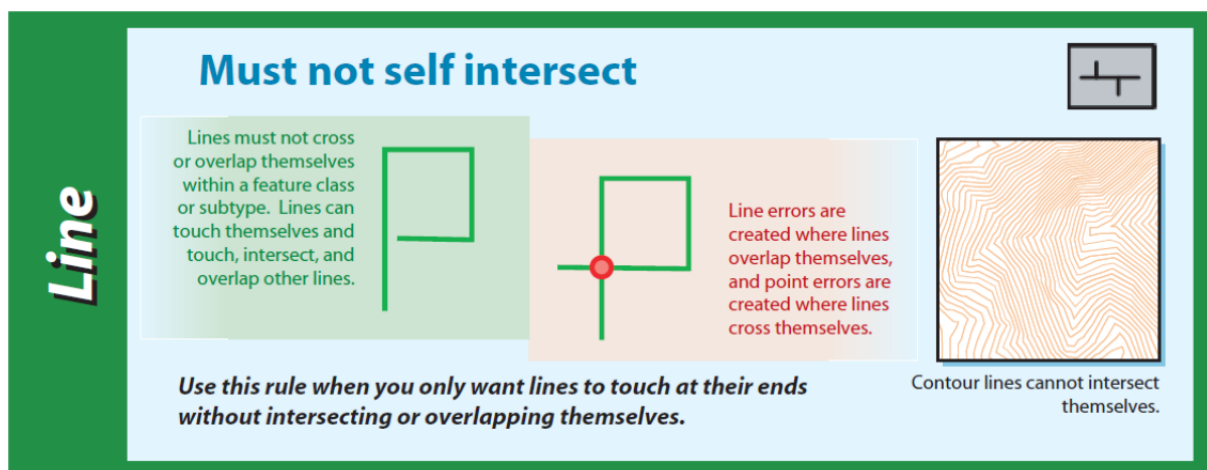


Figure 3.10: The “must not self intersect” topology rule (ESRI, 2011).

The rule described in Figure 3.10 was considered for the same reasons as the “must not self overlap” rule. The cables in the macro and micro network are not supposed to intersect

themselves due to the ring and endpoint nature of the networks. This topology rule encountered the same problem with the z-value geometries. The electrical cables on different levels and the vertical connections cause errors in the topology. Therefore, this topology rule was also considered, but could not be implemented. Six types of topology rules were considered and those suited were assigned in the geodatabase. Table 3.34 lists all the topology rules implemented in the prototype model.

Table 3.34: Topology rules implemented in the prototype model

Feature class	Topology rule	Feature class
PUK_Buildings	Must not overlap	
PUK_Zones	Must not overlap	
PUK_Rooms	Must be covered by	PUK_Buildings
Distribution_board	Must be covered by endpoint of	Cables
Utility_endpoints	Must be covered by endpoint of	Cables
MS_Feeder	Must be covered by endpoint of	Cables
DS_Feeder	Must be covered by endpoint of	Cables
DS_Transformer	Must be covered by endpoint of	Cables
Main_DB	Must be properly inside	PUK_Buildings
Utility_endpoints	Must be properly inside	PUK_Buildings

3.6.3 Geometric networks and Network Datasets

The model presented in this thesis represents a connected network of electrical utilities in two specified buildings in the study area. This connected electrical network flows through the different floor levels of the buildings. Vertical connections in the network are established by digitizing the participating features through the use of z-values. Analysis has to be done on these z-value features to determine if the prototype model can be used to solve electrical utility problems on the campus network. It should prove that the prototype model can run analysis not only for the macro network but also for the micro utilities network on campus. Therefore a consideration had to be made to choose which model works best to represent the micro electrical utilities on different floor levels of a building.

According to ESRI (2011), two core models are implemented to represent networks called a geometric network and a network dataset. Geometric networks are designed to represent networks with directed flow such as electrical networks or river networks. Network datasets are better suited for networks with undirected flow such as transportation networks in multiple directions.

The two models used to represent connected systems contain geographic features from which a graph is derived. In this graph, elements are grouped to form a logical network and a set of element and connectivity tables. Geometric networks and network datasets differ from each other in the way their features are defined (ESRI, 2011). Figure 3.11 represents an illustration of the conceptual abstraction of a graph from geographic elements.

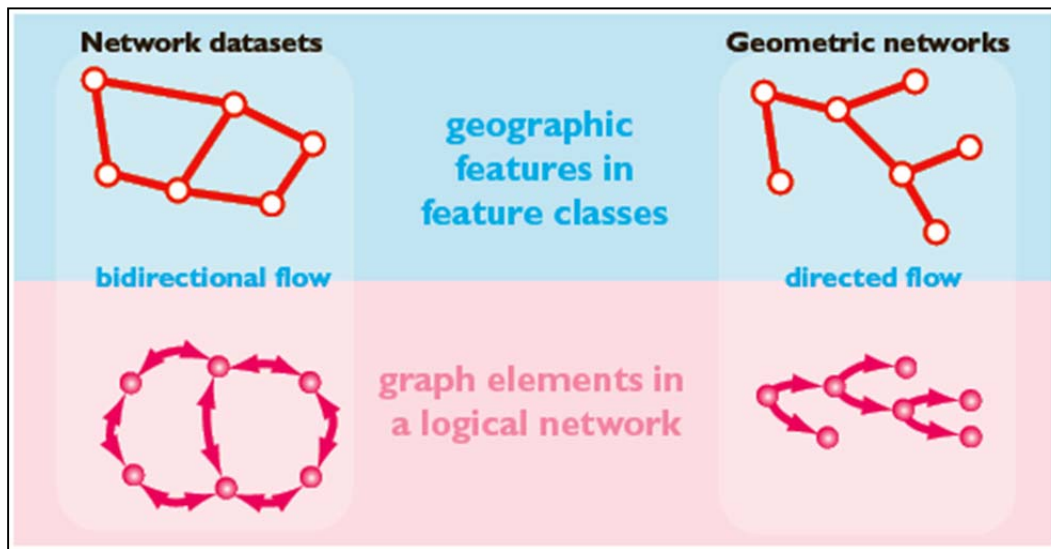


Figure 3.11: Graph from geographic elements (ESRI, 2011).

The two types of models were considered and it was determined that geometric networks are better suited for network analysis of electrical features in two dimensions. The problem occurred when z-value features were introduced in the geometric model to be represented in 3D. Van Maren (2011) states that the ESRI software does not support 3D geometric networks in ArcGIS10 as discussed in Chapter 2 of this thesis. Network datasets have the ability to perform analysis in 3D and is suited to achieve the objectives set for this project.

3.7 Propose a geodatabase design

In this step by Actur and Zeiler (2004), informed decisions were made through group discussions on applying all the different elements participating in the geodatabase. The existing design by Mandloi (2007) was studied for an example to provide different methods to the database design. A geodatabase design is proposed after considering steps one to three of the conceptual design phase and steps four to six of the logical design phase by Actur and Zeiler (2004).

Figure 3.12 represents a schematic drawing of the proposed geodatabase design showing all the feature classes under the “PUK_Electrical_Infrastructure” feature dataset. The relationship classes between the feature classes are also illustrated. The relationship classes with one arrow head indicate a “one-to-many” relationship. The arrow heads in both directions shows “many-to-many” relationships and the connections without arrowheads are “one-to-one” relationship classes.

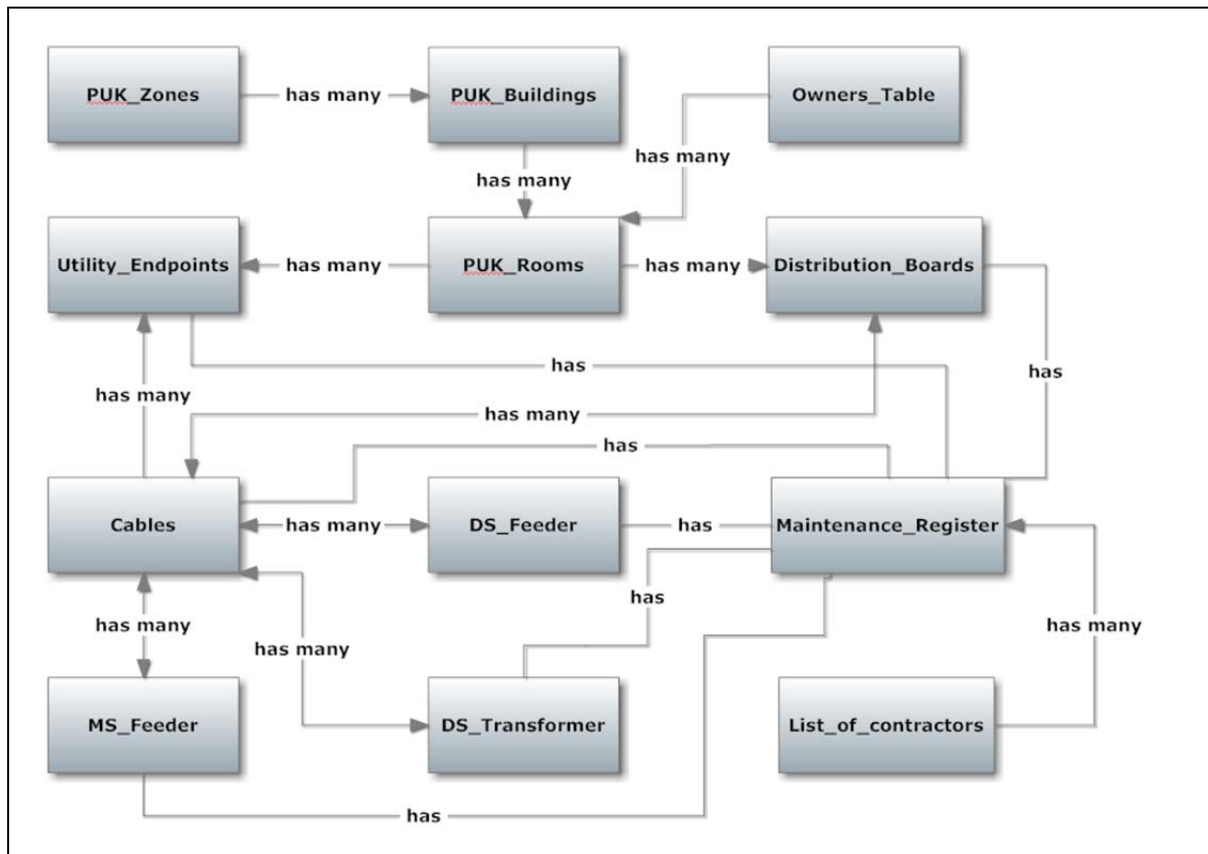


Figure 3.12: Participating feature classes and tables in the feature dataset.

Figure 3.13 illustrates the layout of the “PUK_geodatabase” showing all the components forming the structure of the prototype model.

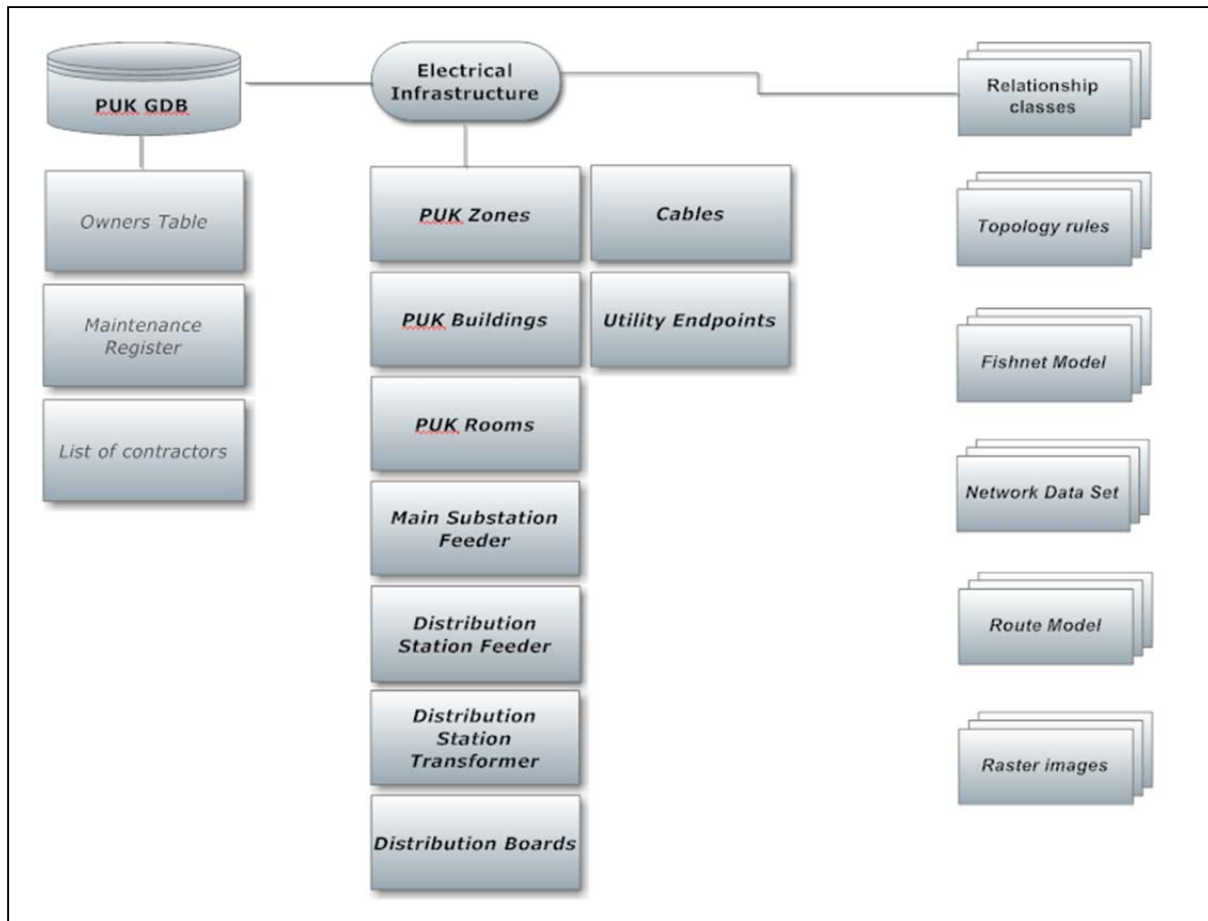


Figure 3.13: The basic layout of the PUK geodatabase serving as the prototype model.

3.8 Conclusion

Chapter 3 described the conceptual and logical design phases of the geodatabase design steps proposed by Actur and Zeiler (2004). Key thematic layers were identified that forms the basic framework to build the information system based on the requirements for the network. After each thematic layer was identified, the scale ranges and spatial representations were assigned to each layer. Raster and vector data are used and each thematic layer was divided into point, line and polygon feature according to the geometry.

Three approaches were considered to determine the most effective geodatabase structure. The case study by Mandloi (2007) discussed in Chapter 2 provided a solution to the final design of the geodatabase structure. Attribute fields were listed for each utility in the campus electrical network. A final geodatabase structure was proposed taking all the steps of the conceptual and logical design into consideration.

Chapter Four covers the physical design phase of the proposed geodatabase design by Actur and Zeiler (2004). The chapter discusses the physical implementation of the geodatabase and illustrates screenshots of the digitizing process. ArcGIS10 software is used to build the prototype model for the “PUK_geodatabase”, modelling the electrical utility infrastructure components.