Chapter 4: Methods and Implementation

Introduction

The implementation chapter reviews the physical design phase which includes steps eight, nine and ten proposed in the ten steps to designing geodatabases by Actur and Zeiler (2004). Figure 4.1 illustrates the physical design phases. This chapter guides the user through the process of building the prototype geodatabase using commercial ArcGIS10 software. The implementation and methods used during the design of the prototype geodatabase that models the electrical utilities inside buildings E4 and E6 is described from start to finish.

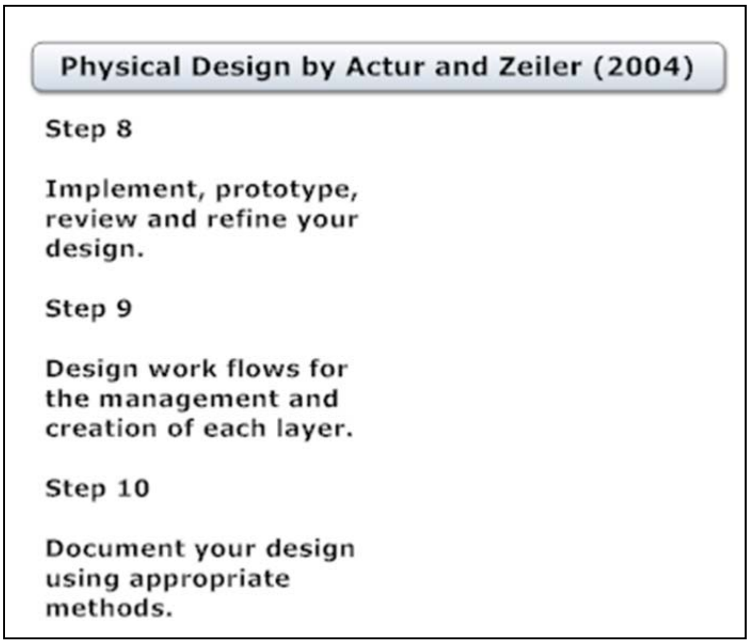


Figure 4.1: Physical design phase (Actur & Zeiler, 2004).

4.1 Implement, prototype and review your design

In this step by Actur and Zeiler (2004), the designer uses the ideas from the conceptual and logical design phase to build a geodatabase. The acquired data is loaded into the database, tested and refined. This step starts the physical design phase of the project.

4.1.1 List of required data

It is necessary to gather the required data and tabular information before implementing the geodatabase. A list of data requirements and tabular information was composed and sent to the technical department of the NWU Potchefstroom campus. The list contained the following data requirements to be used in the PUK geodatabase.

- A schematic representation of the **macro electrical network** on the Potchefstroom campus preferable in georeferenced CAD format. This representation shows the location of the main substation feeder as well as the distribution station feeders and the distribution station transformers.
- A schematic representation of the **macro electrical connections** on campus. This data indicates which cables are connected to which macro electrical utilities before entering the specified buildings.
- CAD data indicating the locations of the different **zones** in which the Potchefstroom campus is divided.
- CAD data showing the **outlines of the buildings** in the study area. This data will be used as the basis on which to digitize the building outlines in ArcGIS10.
- CAD data serving as blue prints for the different **floor levels** of each building.
- CAD data representing the **micro electrical network** inside the specified buildings in the study area. This data will be used to locate and digitize the specific electrical utilities. The designer will be able to view connections between the different utilities as well as the cable connections. This data must be up-to-date in order to provide the correct information in order to be useful to the building managers responsible for specific buildings on campus.
- Tabular information describing the **different utilities** to be modelled. This information must indicate which fields are important to list in the attribute tables. The required tabular information should also describe the different fields of the electrical features to provide the user with a useful understanding of the represented features.
- Tabular information **describing each floor level** of the specified buildings. This data must show useful information regarding the different space types on each level. Information about office occupants is also necessary for the database to derive personnel identification and contact information.

- It is necessary to keep track of the **maintenance** done by different external contractor personnel on the electrical utilities of the campus. Therefore tabular information representing a list of contractors should prove to be very useful to the building managers. If there is a malfunction on one of the electrical components; the person responsible for the previous maintenance can be contacted.
- It is also important to keep a **maintenance register** for each electrical utility. Tabular information indicating the maintenance record of each utility is vital to determine the lifespan of certain products.
- **Personal interviews** must be conducted to provide the designer with the necessary ideas and knowledge about the electrical network on campus. This information is used to identify which features are represented by which feature classes. This also provides the designer with information about which electrical utilities is more important to model than others.

A building manager and two individuals in the technical department of the Potchefstroom campus were identified. The list of data requirements was sent to them to obtain the data. Oral interviews were also conducted to receive information about the functionality of the electrical network. These interviews provided sufficient information about each electrical utility to list in the descriptive attribute tables. It was not possible to obtain all the data listed in the data requirements. Some exceptions were made and most of the data was obtained.

4.1.2 Obtaining data

4.1.2.1 Satellite Image

A satellite image of the study area inside the Potchefstroom campus formed the basis on which referencing took place. A satellite image with a decent resolution had to be used due to the size of the features modelled in this project. Finer resolution results in a more detailed image of the study area to enable the designer to reference features more accurately. A Quickbird (2008) satellite image obtained from the satellite application centre in Pretoria was used to form the predefined base data on which CAD drawings is referenced for digitizing purposes. This particular Quickbird image has a resolution of 60 cm by 60 cm and is referenced according to the WGS 84 UTM Zone 35 S projection. Figure 4.2 shows an example of the Quickbird (2008) satellite image in ArcMap10.

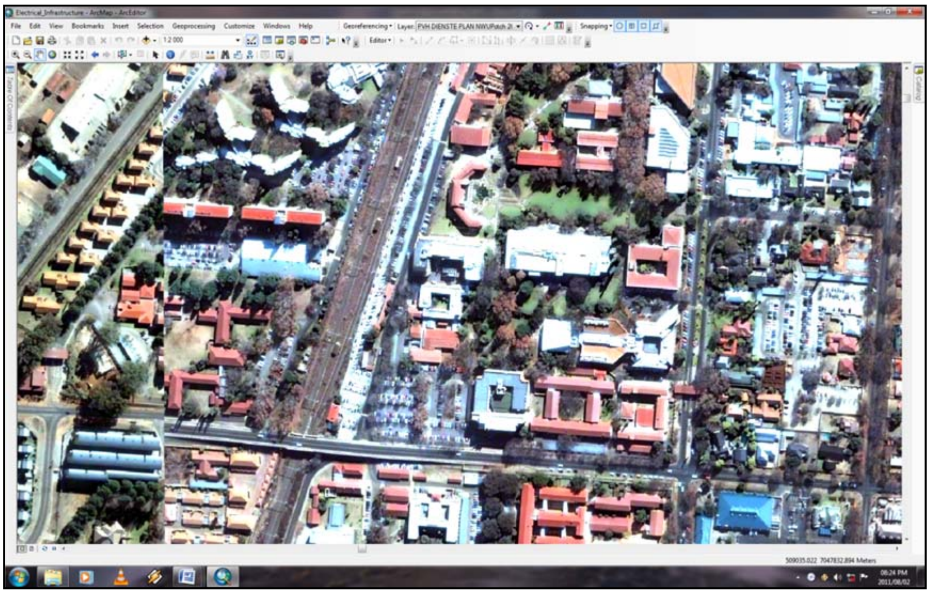


Figure 4.2: Quickbird 2008 satellite image of the study area.

4.1.2.2 Data for PUK Zones feature class

Unfortunately, there were no referenced data indicating the boundaries of the different zones of the Potchefstroom campus. There is, however, CAD data showing the polygon features of the entire campus without the zone indications. The only available data indicating the different zone boundaries is a bitmap image that can be obtained from the NWU (2011a). This image was used as a point of reference to digitize the different zones in which the campus is divided. Figure 4.3 illustrates the bitmap image obtained from the NWU (2011a).

Figure 4.3: Bitmap image of the different zones on the Potchefstroom campus (NWU, 2011).

4.1.2.3 Data for PUK buildings and PUK Rooms feature class

Digital CAD drawings were available for both the PUK buildings and the PUK Rooms feature classes. The "as-built" data were obtained from the building managers responsible for the two buildings. These digital CAD drawings are suitable for digitizing purposes because of their accuracy. The "as built" CAD drawings represented the E4 and the E6 building more commonly known as the "Lettie Dup" and the "J.S vd Merwe" buildings. Figure 4.4 illustrates the CAD drawing for building E4 on the different levels.

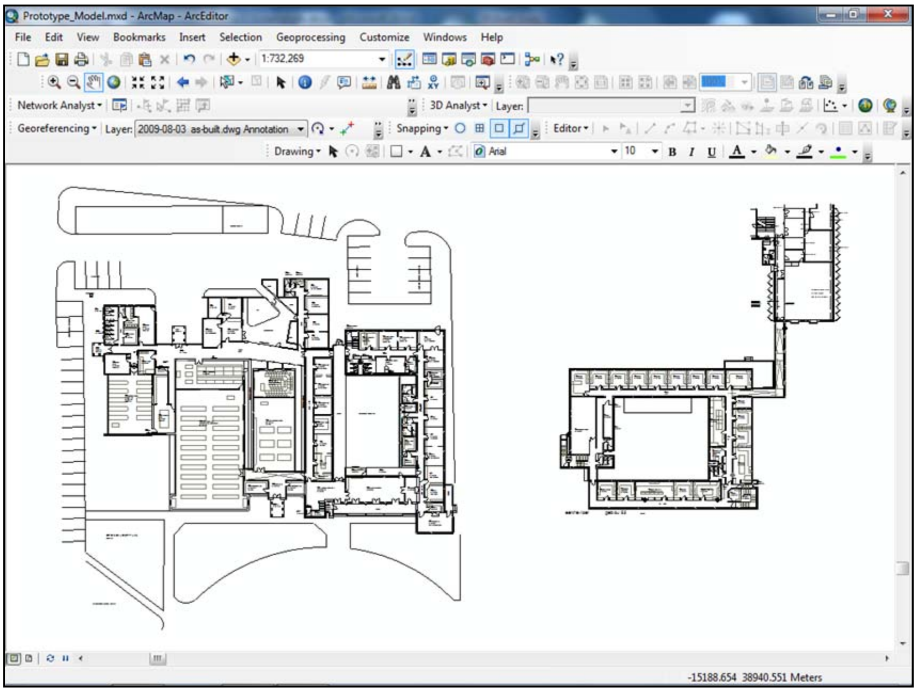


Figure 4.4: CAD drawing indicating two levels of building E4.

The CAD drawing of building E6 contained all the levels on one drawing next to each other. Figure 4.5 shows the CAD drawing for the J.S vd Merwe building obtained from the technical department of the Potchefstroom campus.

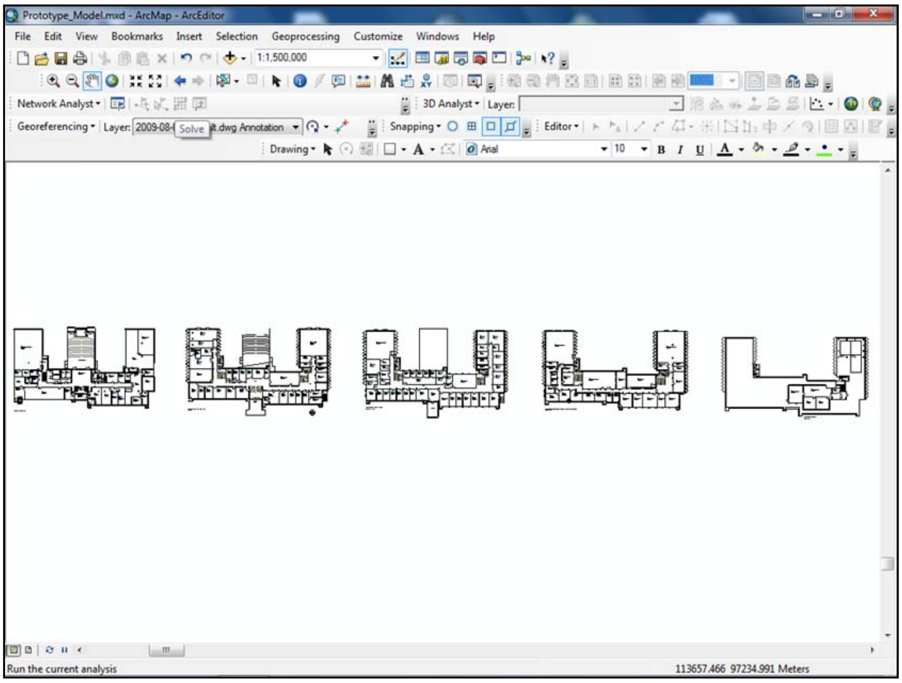


Figure 4.5: CAD drawing indicating the different levels of building E6.

4.1.2.4 Obtaining data for the Distribution Boards and Utility Endpoints

A recent CAD drawing representing the electrical utilities on the ground level for building E4 was available. The digital image can be used to locate the different distribution boards and utility endpoints on the ground level. The data also indicated which endpoint utilities are served by which distribution board. The main and sub distribution boards can be seen from this particular CAD drawing. Figure 4.6 shows the CAD drawing representing the ground floor utilities of building E4.

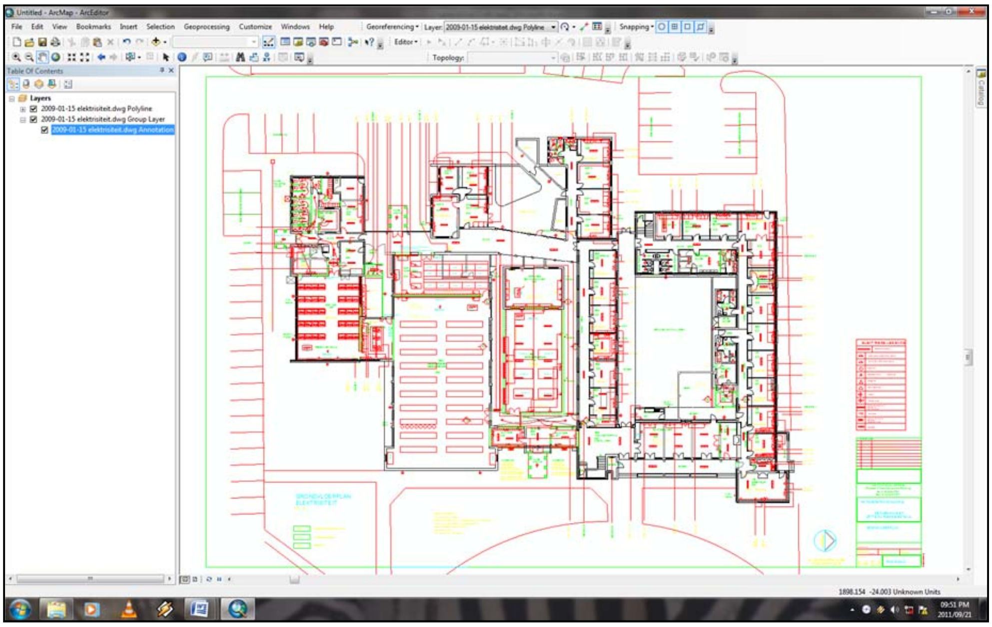


Figure 4.6: CAD drawing representing the ground floor utilities of building E4.

No recent digital data were available for the first floor of building E4. The location of the distribution boards as well as the utility endpoints on the first floor had to be located manually and added to the "as built" data representing the E4 building. Assumptions had to be made regarding which utilities in the different rooms are served by which distribution board.

The only available digital data for building E6 represented the utilities in the first floor and the third floor. Some of the data could be captured from old CAD hardcopy drawings showing the locations of the electrical utilities in the rooms of the different levels. The rest of the utilities in the remaining floors had to be located manually by walking through each room and capturing the utilities on an empty "as built" drawing of the participating floor.

4.1.2.5 Macro cables, electricity feeders and transformers

The location of the Main Sub Station Feeder was obtained after conducting an interview with De Beer (2011a) from the technical department of the Potchefstroom campus. A file showing the macro electrical connections between cables, feeders and transformers were also obtained from De Beer (2011a). This drawing showed which distribution station feeders and transformers supported which buildings. The digital drawing also showed the connections formed by the different ring feeders running from the main substation.

Another CAD drawing was obtained from the technical department indicating the locations of the macro network cables on campus. Although these drawings are not accurate, it was still used as reference to locate the positions where the cables enter the two buildings. Figure 4.7 shows the CAD drawing indicating the locations of the macro network cables entering the two buildings.

Figure 4.7: Locations of the macro network cables entering buildings E4 and E6.

4.1.2.6 Micro network cables inside buildings

No data was available to indicate the locations of the different electrical cables running through the two buildings. The available CAD drawings only showed the cable skirting on certain parts of the buildings. The rest of the locations as well as the amount of cables had to be assumed. Some of the cable locations could be retrieved by walking through the different floor levels following the skirting containing the cables. This could be done until the skirting reaches rooms not accessible or the skirting continues above the ceiling of the rooms.

4.1.2.7 Owners Table

The information necessary to complete the “Owners Table” was gathered from the administration personnel working in the two buildings. The administration personnel did not have all the information and the rest had to be gathered elsewhere. The building manager responsible for maintenance and technical tasks had listed information that was used to complete the “Owners Table”.

4.1.2.8 Maintenance Register

The Maintenance Register had to be generated from the information gathered from interviews due to the lack of data describing the maintenance done on electrical utilities inside the two buildings. A possible reason is that there are many electrical technicians working on the utilities at different times. These electrical technicians also work for different companies. This results in the absence of generic record keeping to describe the maintenance done on electrical utilities. The idea would be to complete a mandatory register to keep track of jobs done on specific electrical utilities with information about the person who did the job. Therefore a list of possible electricity related jobs were listed in the maintenance register to show the idea of its functionality.

4.1.2.9 List of contractors

The information about recent electrical contractor personnel was not easy to come by. A variety of sources had to be used to gather sufficient information to generate a list of technical people who worked on utilities. This information was mainly gathered from the head office of the technical department running operations on campus.

4.1.3 Building the geodatabase

4.1.3.1 Folder connections

The first step is to create folders containing all the data. These folders will be used to create folder connections to Arc Catalog. The purpose of these folders is to store data in one central location to make it easier to copy the whole database to other sources if needed. The Data folder contains the CAD drawings, images, world files, layer files and information tables. This makes it easier for the user to drag and drop data from the Catalog tree to the table of contents in ArcMap10 or ArcScene10. The NWU electricity folder contains the PUK geodatabase. All features created and edits that took place are stored in this folder directory. During editing sessions the saved files are stored inside the PUK geodatabase.gdb file inside the NWU electricity folder. Figure 4.8 illustrates the folder connections made in the Catalog tree.

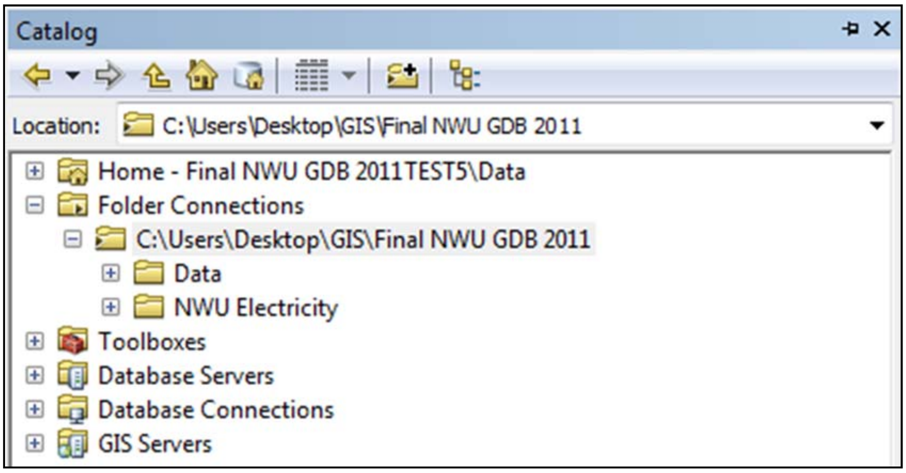


Figure 4.8: Folder connections made in the ArcCatalog tree.

4.1.3.2 Geodatabase

The PUK geodatabase is created in the NWU Electricity folder. After naming the geodatabase, the designer assigns the different domains to be used throughout the database inside the database properties option. Only coded domains are used in this particular geodatabase as illustrated in Figure 4.9. Each domain is created along with its description.

The next step is to define the properties for the participating domain. Field and domain types as well as the split and merge policies are listed. The final step is to create the coded values with their descriptions. These descriptions will be presented in a drop down list when completing the attributes of digitized features. Figure 4.10 shows the option for creating a new file geodatabase.

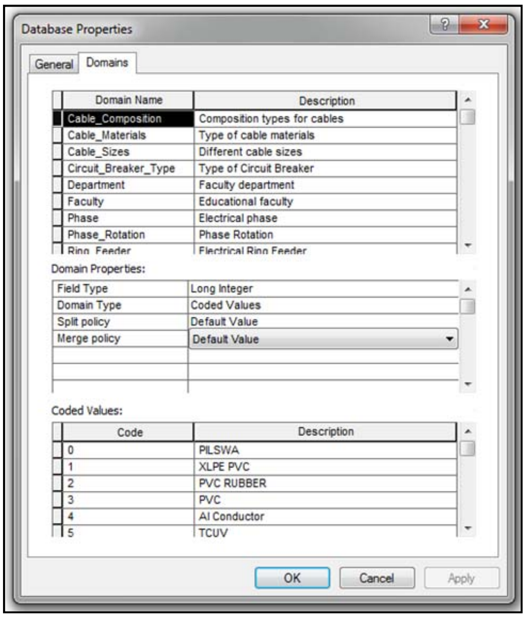


Figure 4.9: Assigning database domains.

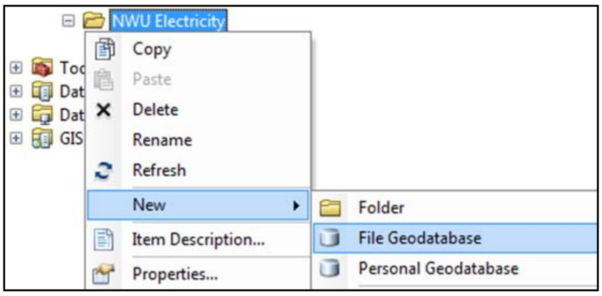


Figure 4.10: Creating a new file geodatabase.

4.1.3.3 Feature dataset

A feature dataset is created inside the PUK geodatabase used to store the feature classes, topologies, relationship classes and network dataset. The predefined coordinate system is imported from the Quickbird (2008) satellite image. This will ensure that all the features created inside the feature dataset contain the same coordinate system. Figure 4.11 illustrates the option where the user imports the predefined coordinate system from a specified source.

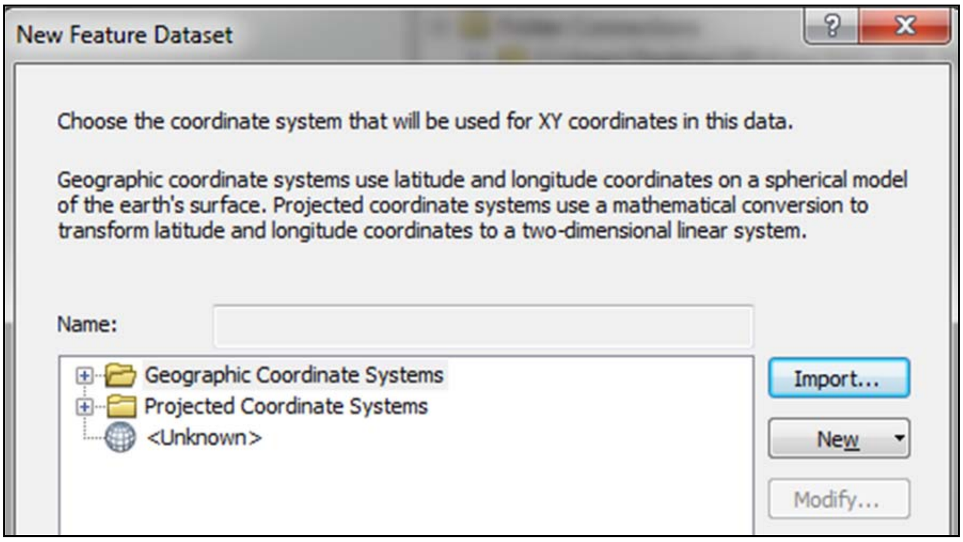


Figure 4.11: Importing a predefined coordinate system from a specified source.

4.1.3.4 Referencing techniques

Three techniques were tested to determine the best way to reference the CAD drawings as accurate as possible. The best technique was chosen and used to reference the rest of the CAD drawings according to the Quickbird Image (2008). Problems occurred during this process and the designer had to accept that the CAD drawings will not fit perfectly over the satellite image. This was caused by the image not being taken at ninety degrees directly from above. By looking at the image, the user can see that the image is taken from an angle facing the right hand side of the building.

- Spatial Adjustment

Kasianchuk (2003) states that in order to do accurate GIS analysis, accurate spatial information is needed. Therefore it is a necessity to integrate existing data with new data and to update less accurate data. It is also necessary to convert raw digitizer coordinates into geo-referenced coordinates.

In this particular project, the raw CAD layout drawings of buildings E4 and E6 will be converted to shapefiles in ArcGIS10. The shapefiles will be imported into a file geodatabase after editing and digitizing has taken place.

One of the methods of converting raw CAD layout drawings is commonly known as spatial adjustments. According to Kasianchuk (2003) familiar methods of spatial adjustment is through "adjust", "edge-snap" and "transform" commands. The spatial adjustment toolbar contains tools and commands that help you improve the quality of your data. This toolbar enables the user to edge snap, rubber sheet and transform spatial features. It also transforms attributes from one feature to another. This particular adjustment toolbar works only during edit sessions so that advantage can be taken of editing tools such as the snapping environment or the magnifier window while editing.

The problem with the spatial adjustment method is that human error can occur frequently. The reference points are used to overlay the CAD drawing to the desired position of the real world data. Common mistakes can be made by the user, e.g. not placing the reference points at the correct location from the CAD drawing to the referenced data. The result is that the image is not correctly aligned over the referenced data causing the image to be disfigured or skew. Another common mistake can be to neglect to place the reference points in an order clockwise or counter-clockwise. If it is not done properly, the result will be a disfigured image. The research indicated that this method works and can be used, but there are less time consuming and more accurate methods for transforming CAD drawings to referenced data.

- World file

A second method of transforming CAD data to be viewed in ArcMap10 is by means of a world file document. In this method the user creates his/her own world file in a word pad saved as a txt.document. The world file enables the user to move the CAD data from the current location to the same coordinate space as the other GIS data. ESRI (2008b) explains that this process does not work if there are spaces in the name of the CAD files. After the world file process is complete, no permanent changes were made to the CAD file itself. As mentioned earlier, if the CAD dataset has more than one feature layers, the user has the option to use only one of those feature layers. In most CAD transformations the polyline feature layers are used because this particular feature type makes the transformation process more efficient.

According to ESRI (2008b) it is important to set the map units to the units in which the CAD file was created. The units are often in feet or meters. In RSA meters will be more likely.

Should the units used for the CAD file be unknown, it is suggested to select “meters” as a default unit.

In order to create a world file, a CAD layer must be compared with a reference layer. The reference layer can be a shapefile, geodatabase feature class, coverage or even a referenced image. By comparing the CAD polyline layer with the reference layer, two points can be determined to be used for the transformation. These points must be as far apart as possible, e.g. if one reference point is in the northeast corner of the CAD data, the second point must be in the southwest corner. By using the “zoom-in” tool, the user can get a more clearer view to set marker points in the CAD data.

The marker points in the CAD data contains x;y coordinates. These x;y coordinates can be retrieved by double-clicking on the marker symbol. The size and position tab is used to display the x;y coordinates.

The world file is created by copying the digits for the marker points in a Notepad document. The format for the Notepad document file can be parcel02364.wld for example. After the Notepad document with all its coordinates from the marker points is constructed and saved it is possible to transform the CAD data. This can be done by using the transformations tab to overlay the CAD data with the other GIS data in a real-world coordinate system. The CAD layer can be exported to a shapefile or geodatabase feature class. In order for the new dataset to match the other data, the projection has to be defined (ESRI, 2008b).

This technique is a much more accurate method for transforming CAD drawings to referenced data than the spatial adjustment method. The only problem with this technique is that it is very time consuming to create world files manually to reference the CAD drawings to real world data. Although this is a more accurate method than the spatial adjustment method, there is an even better and faster method for transforming CAD datasets.

- Georeferencing

The georeferencing technique is a method in which the user does not have to create a world file manually. Using two reference points as far apart from each other as possible, the georeferencing toolbar creates its own world file to be saved as a notepad document at a location of the user's choice.

According to ESRI (2008a) ArcGIS introduces new techniques for transforming CAD data through the georeferencing toolbar in ArcMap. This tool enables the user to transform CAD datasets into GIS. These CAD transformations are based on the similarity transformation method. Similarity transformations are two-point transformations that support rotation and scaling. Only two points or links are used to define the transformation. This will always keep the aspect ratio, e.g. uniform scaling. CAD layers can be rotated, shifted and scaled with the georeferencing toolbar. Most of the raw CAD drawings that are imported into ArcMap have no projection and referencing at all.

Maher (2010) states that in a perfect world, every GIS dataset would have the correct coordinate system and the information about that coordinate system would be reflected in the metadata. Dealing with data that should display correctly is a common aggravation for GIS users. The georeferencing toolbar has a fit-to-display option to position the CAD drawings in the current map extent. Control points can be created to define the destination coordinates of the transformation. This transformation can be saved to and from world files.

According to ESRI (2010), a world file is a text file containing information about where an image should be displayed in real-world coordinates. When an image has a properly configured world file, GIS software can use the information to accurately overlay the image with any other data already in a projected or geographic coordinate system. Figure 4.12 shows an example of a world file created automatically from the georeferencing toolbar by means of the two-point transformation.

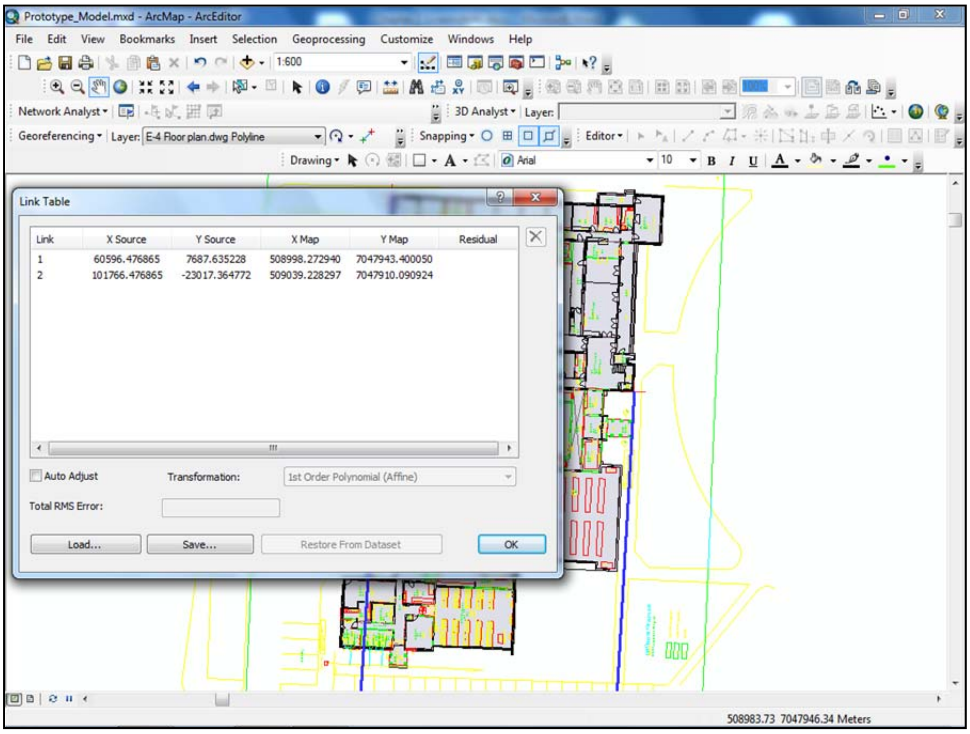


Figure 4.12: The world file created automatically from the georeferencing technique.

The georeferencing toolbar has a drop down menu list that indicates the available layers for georeferencing. CAD and raster layers can be seen at the same time in the drop-down list. Raster transformations differ from CAD transformations because of specific menu choices. The user will notice that there are specific menu choices for raster transformations and that the options are not available for CAD transformations. For example: the Rectify, Transformation and Flip Horizontal/Vertical menu choices are not available for CAD layers. On the link table dialog box, no values will be reported for Residual and Total RMS error, and the transformation drop down box will be disabled. The rest of the options will be available for use.

According to ESRI (2008a) CAD transformations apply to the entire CAD dataset. In this particular project there is a lot of unnecessary information when an entire CAD dataset is transformed. Should there be more than one CAD feature class layer in the CAD dataset, the user has the option to use only one of those feature layers. Therefore it doesn’t matter which CAD feature class of the CAD feature dataset is transformed, the transformation will apply to the entire CAD dataset. All transformation options will be applied to the target layer.

ESRI (2008b) states that CAD files can be displayed in Arc Map whether the files are in (.dwg) or (.dxf) format. Most CAD drawings are created in a local coordinate system. In order to align these drawings in Arc Map it must be transformed or moved to overlay with GIS data in a real world coordinate system.

This referencing technique is the most accurate of the three. It is the fastest method with less possibility for human error compared to the spatial adjustment and world file technique. This technique will be used as the referencing method for transforming CAD drawings to real world referenced data in GIS. Figure 4.13 indicates the result of a CAD image referenced by means of the georeferencing toolbar.

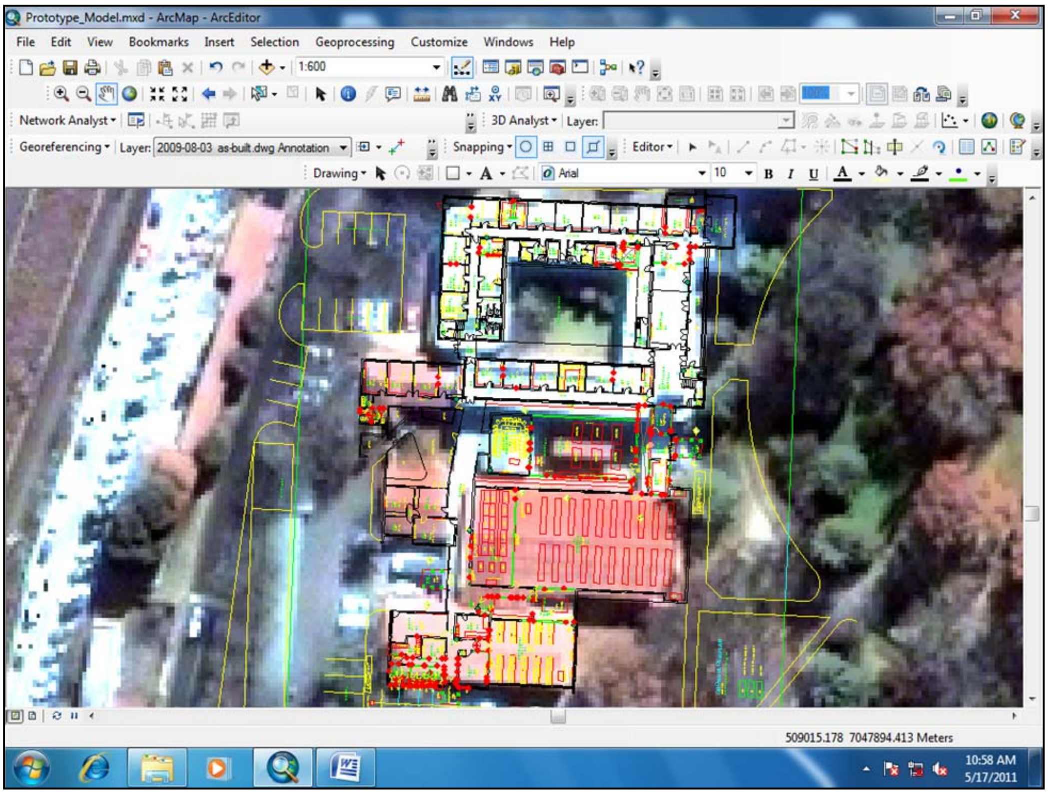


Figure 4.13: CAD drawing of building E4 referenced to the Quickbird Image (2008).

4.1.3.5 PUK Zones

The PUK Zones feature class is created inside the Electrical Infrastructure feature dataset. The designer specifies the name of the feature class as well as an alias if needed. The type of feature is selected and the geometry properties are further specified, e.g. if coordinates include z-values used to store 3D data. The database storage configuration is set by default which presents the user to use default storage for the new table or feature class. The next step is to list the attribute fields for the participating feature class. The designer add the fields and specifies each field's data type. Each field's properties can be seen and domains can be selected for each field. After each attribute field is listed the designer ends the session by clicking "Finish". Each feature class is created this way. Figure 4.14 shows a screenshot where the designer creates a new feature class in the network dataset.

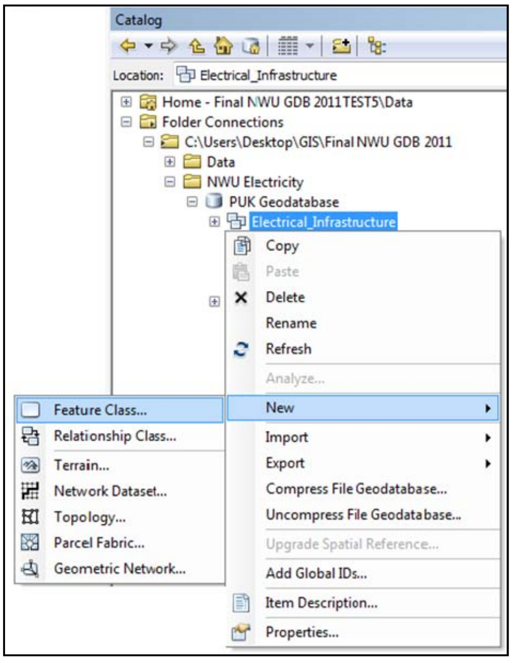


Figure 4.14: Creating a new feature class inside a feature dataset.

After creating the PUK Zones feature class inside the feature dataset, data capturing can take place. The designer starts off by enabling the editing environment and using the "Create features" tool to digitize the different campus zones. The "Organize templates" option is selected inside the "Create features" tool. The next step is to select the "New Template" option to add layers needed to create templates. The designer selects "Next" and "Finish".

The necessary templates are added to the "Create features" tool and editing can take place. Figures 4.15 and 4.16 illustrate the option of selecting and adding templates used for editing.

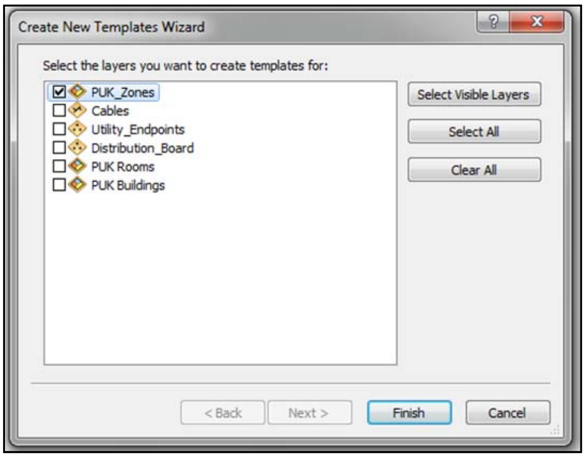


Figure 4.15: Selecting templates for editing.

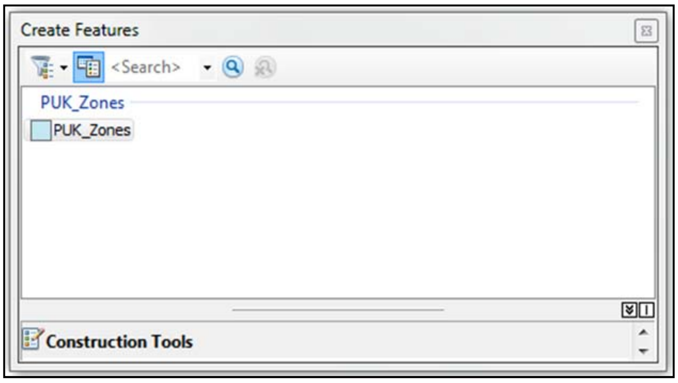


Figure 4.16: Using templates for editing.

Each polygon feature created generates a row inside the attribute table of the PUK Zones feature class. After all the necessary features are digitized inside the feature class, the attributes must be completed. Figure 4.17 shows the features digitized in the PUK Zones feature class using the Quickbird (2008) image. The CAD drawing is georeferenced over the satellite image to provide reference for the digitizing process.

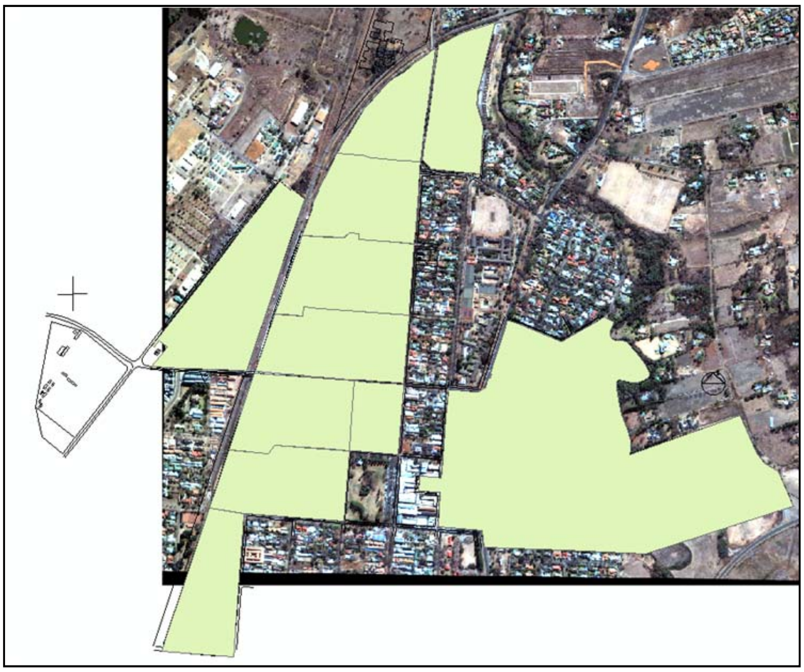


Figure 4.17: Features digitized in the PUK Zones feature class.

4.1.3.6 PUK Buildings

The PUK Buildings feature class is created inside the Electrical Infrastructure feature dataset. The feature class is added to the table of contents in ArcMap. The designer starts off by enabling the editing environment and digitizing the outline of each building using the georeferenced CAD drawings as guidance. The outside lines of the CAD drawing are used for the snapping environment. Figure 4.18 illustrates the snapping tool.

Figure 4.18: Snapping tool used to snap features to the CAD drawing.

A CAD image for each building was georeferenced over the Quickbird (2008) image by means of the georeferencing toolbar. Figure 4.19 illustrates the georeferenced CAD drawing over the satellite image.

After the outline of each building is digitized, a new row is added to the attribute table of the feature class. The next step is to complete the attribute information with the editing toolbar still active. The designer ends the editing session after all the needed features are digitized and the attributes are completed.

The PUK Buildings feature class shows the outline of each building. The purpose of this feature class is to represent relationship classes between the PUK Zones and PUK Rooms feature classes. It is also used to enforce topology rules between the participating features. The PUK Building feature class contains a field in the attribute table called the "number of floors". This value is used in a simple calculation to extrude the feature class in order to view

3D images of buildings in ArcScene10. No features containing z-values in their geometry were used in this feature class. Figure 4.20 illustrates the digitized features of the PUK Buildings feature class.

Problems encountered during the digitizing of this feature class are the shadows and trees on the satellite image covering the building. This made it a challenging task to place the referencing points on exactly the right positions. The pixel sizes of the satellite image cause the image to become distorted when zooming in. The camera angle of the image makes it difficult to align it exactly according to the CAD drawing. Referencing is done in the best manner possible although the alignment seems skew.

Figure 4.19: Georeferenced CAD image of building E4.

Figure 4.20: PUK Buildings.

The PUK Buildings feature class is used in ArcScene10 to get a realistic view of the buildings in the study area. This is done by extruding the feature class according to the number of floors listed in the attribute table as described in Figure 4.21. The results of this extrusion are showed by Figure 4.22.

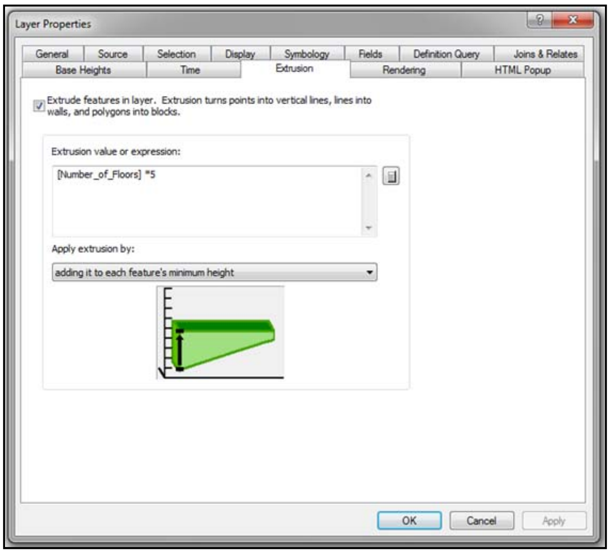


Figure 4.21: Extruding the PUK buildings feature class.

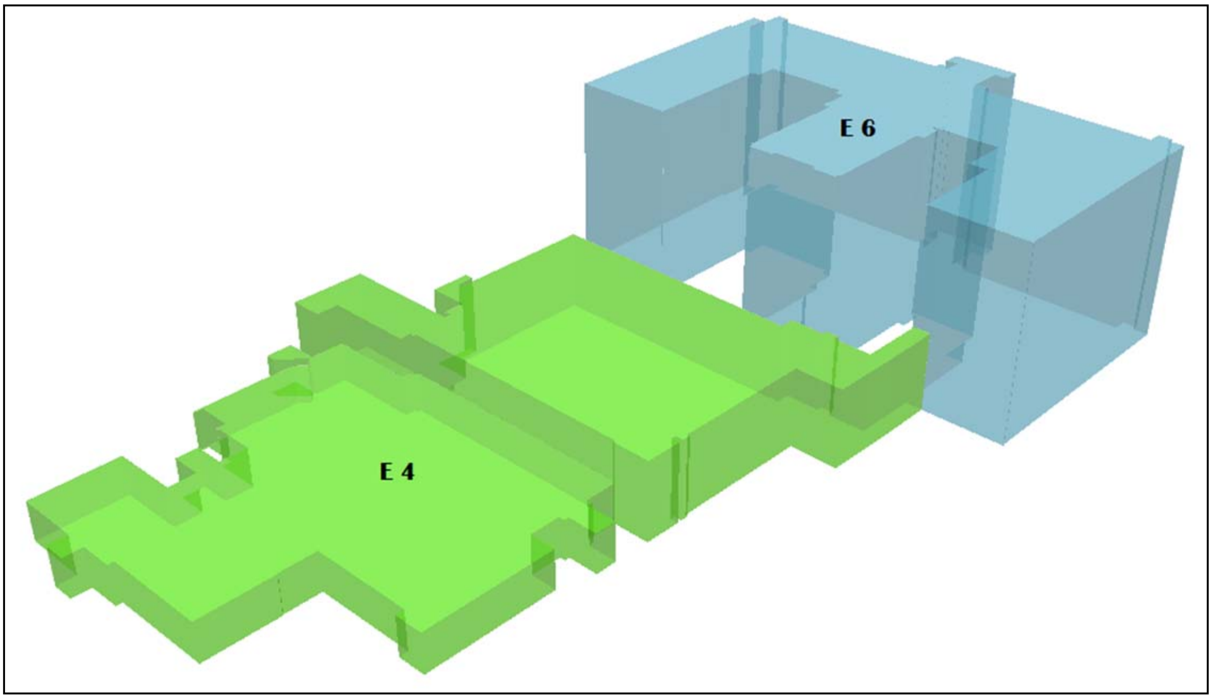


Figure 4.22: PUK Buildings feature class in 3D.

4.1.3.7 PUK Rooms

The PUK Rooms feature class was created in the Electrical Infrastructure feature dataset. This feature class makes use of subtypes in the attribute table. The designer assigns subtypes in the "properties" option of the PUK Rooms feature class in ArcCatalog10. The "subtypes" tab is selected under the feature class properties dialog. The subtype field is selected in the drop down list of all the fields in the feature class attributes. A default subtype is selected in the next step. The different codes along with their descriptions are specified and will serve as a drop down list in the attribute table of the feature class. The features assigned to a particular subtype can be turned on or off during the digitizing process. Under the default values and domains option the "space_types" domain is assigned to the feature class. After assigning the subtypes and domains, the feature class is dragged over to the table of contents in ArcMap10.

The designer starts the editing session to digitize the features. The same CAD drawings used to digitize the PUK Buildings feature class are used as reference for the snapping tool. Digitizing takes place by snapping features on the inside lines of the CAD drawing for the sake of topology. The PUK Rooms features must be properly inside the PUK Buildings features.

Z-values were used in the feature geometries to enable the user to visualize the different levels of the PUK Rooms feature class in ArcScene10. Z-values are assigned by means of the "sketch properties" tool as described in Figure 4.23. Each vertex added to a feature during the digitizing process is assigned a z-value to specify which level the features represent. The z-values are assigned in increments of five which is easy to remember when digitizing becomes complicated. The increments cannot represent actual measurements between the different levels of the buildings due to the fact that ArcGIS10 does not assign values to vertical features. The features created in the sub floor levels uses negative z-values.

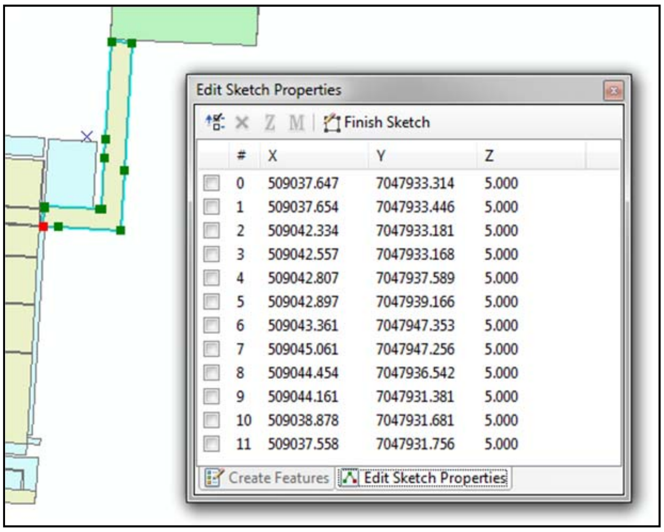


Figure 4.23: Assigning z-values to vertexes of digitized features.

The staircases which connect the different floor levels of the buildings are digitized using an increment of 2.5 to represent the part between the floors as described in Figure 4.24 and 4.25.

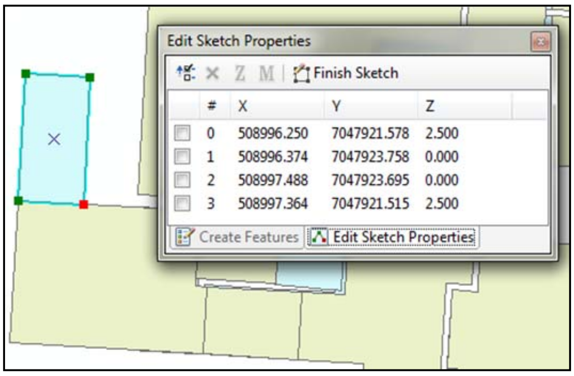


Figure 4.24: Digitizing the staircases.

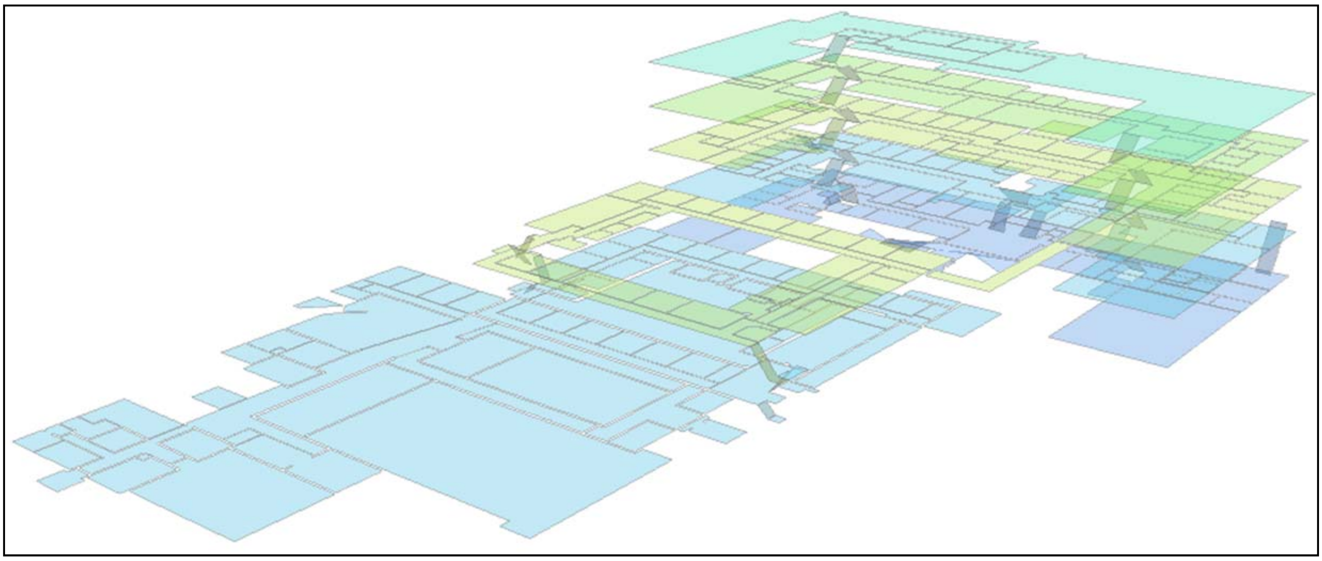


Figure 4.25: Visualizing staircases and floors in ArcScene10.

Some of the attribute information could be retrieved from the CAD drawings by means of the annotation. This information included the room numbers on each level, the owner names of certain rooms and, in some cases, the room type as described in Figure 4.26.

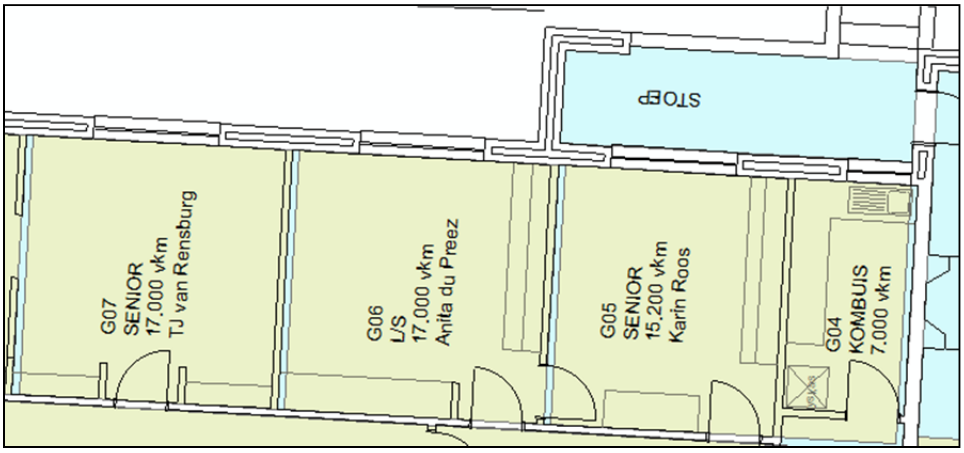


Figure 4.26: Retrieving data from the CAD drawings.

4.1.3.8 Feeders and Transformers

The Main Substation Feeder, Distribution Station Feeders and Distribution Station Transformers are created as point features inside the Electrical Infrastructure feature dataset. The locations of these features were determined through an interview with De Beer (2011a) from the technical department on the Potchefstroom campus. The Distribution Station Feeder feature class use subtypes to distinguish between substations and mini- substations located across campus. Subtypes are assigned by means the feature class properties inside ArcCatalog10. The three separate feature classes where created and dragged over to the table of contents in ArcMap10. An editing session was started and the different feeders and transformers were captured according to their locations on campus. Each feature is edited and the attributes are completed. Figure 4.27 illustrates the locations of the JS vd Merwe Mini Sub and the JS vd Merwe MS Transformer next to the E4 and E6 buildings in the study area.

Figure 4.27: Locations of JS vd Merwe Mini Sub and JS vd Merwe MS Transformer.

4.1.3.9 Distribution Boards and Utility Endpoints

The distribution boards feature class and the utility endpoint feature class forms part of the micro electrical network that runs inside the buildings. The two feature classes were created in the Electrical Infrastructure feature dataset as point features. Both of the feature classes use subtypes to distinguish between the different levels of the buildings in the study area. Subtypes enables the user to turn features on and off during digitizing. During digitizing, the user can assign features to the participating level so that only those features can be seen when editing. This cancels out possible confusion especially when, for example, the features on the third floor is digitized while all the features are visible from the sub levels of the building. Figure 4.28 and 4.29 illustrates the ability to turn the visibility of feature on and off by means of subtypes.

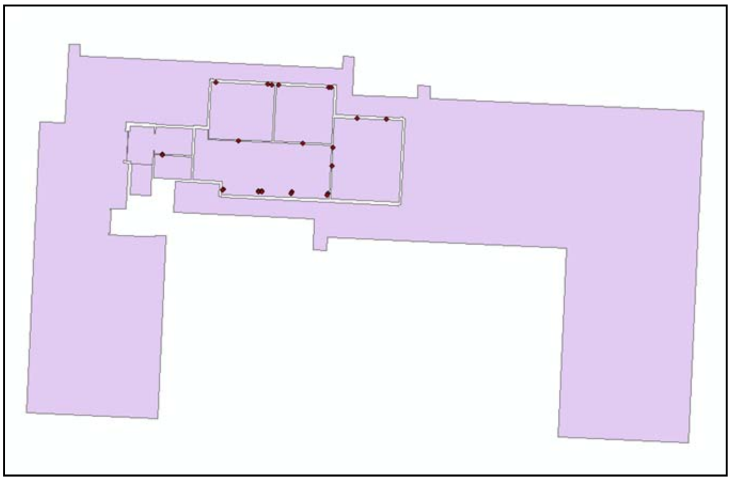


Figure 4.28: Third floor features visible.

Figure 4.29: All features visible.

In order to turn subtypes on or off, the user enters the properties of the desired feature class and selects the “symbology” tab. The value field is selected and all the unnecessary subtypes are removed until only the desired are left as described in Figure 4.30.

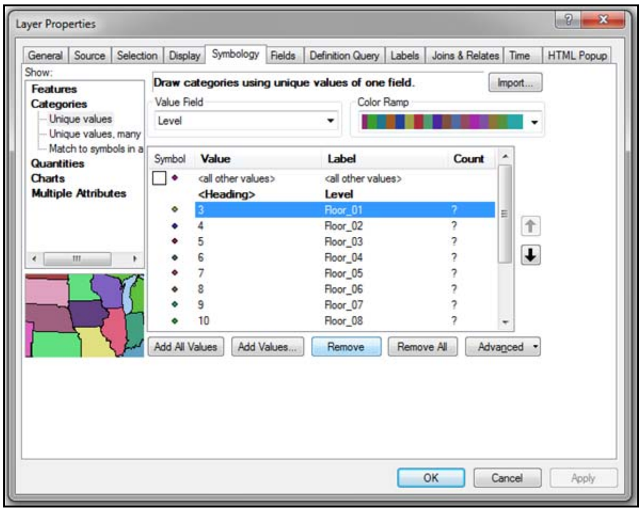


Figure 4.30: Layer properties dialog for removing and adding subtypes.

Z-values are also used in the geometry of the point features representing the distribution boards and utility endpoints. The z-values are added to the geometry by means of the sketch properties tool in ArcMap10. In order to digitize a point feature, for example, on the first level of a building, the “point at end of line” option is used under the “create features” toolbar as described in Figure 4.31. The point feature is created by double-clicking on one location to receive two sets of identical coordinates. The second set of coordinates receives a z-value.

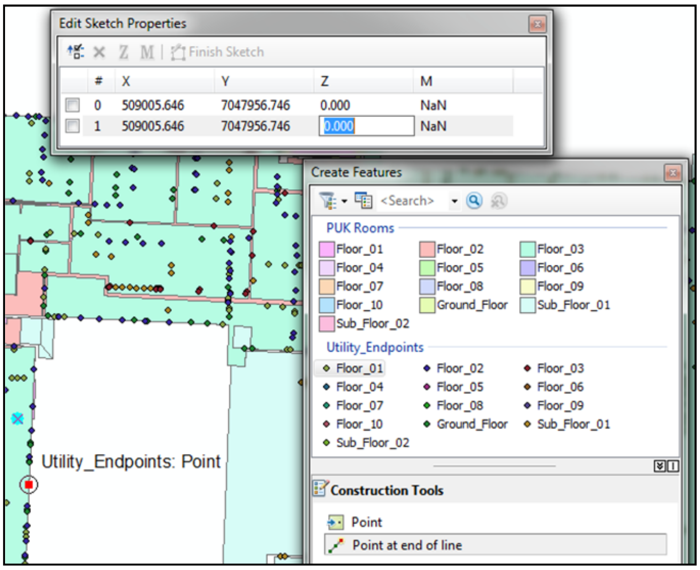


Figure 4.31: Assigning z-values to point features.

Each distribution board and utility endpoint is captured on the different levels according to the available data. The digital CAD drawings provide a very efficient way of pinpointing each feature because of the accuracy in which it is created. Georeferenced CAD drawings prove to be very accurate when it comes to digitizing features inside buildings. Figure 4.32 illustrates the distribution boards and utility endpoints as seen in ArcScene10.

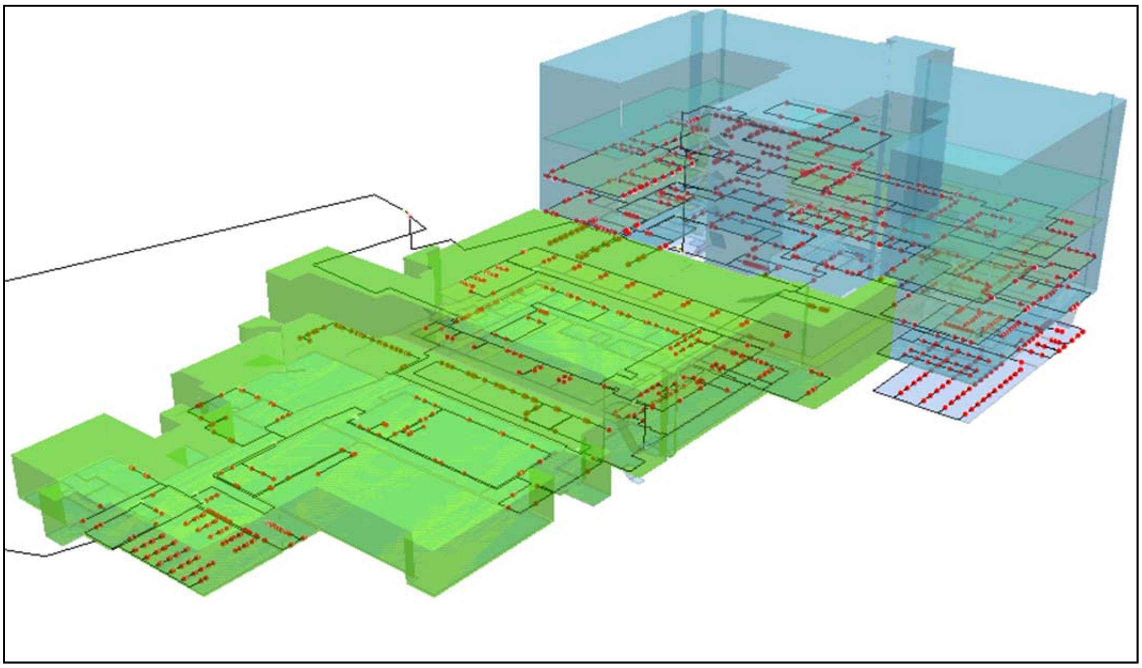


Figure 4.32: Distribution board and utility endpoints in ArcScene10.

4.1.3.10 Cable features

The Cables feature class is created inside the Electrical infrastructure feature dataset. This feature class also uses subtypes to distinguish between the different cable positions between the different levels and outside the buildings. After creating the feature class, listing the attribute fields, assigning domains and specifying subtypes to be used, the Cables feature class is dragged over to the table of contents in ArcMap10.

The Cables feature class plays a very important role in the electrical network. This feature class forms the entire connected electricity network running from the Main Sub Station Feeder all the way to the individual utility endpoints inside the different buildings.

The Cables feature class has the most relationship classes connected in its attribute table, adding up to a total of six. The "Ring_Feeder" domain is also used in this feature class to represent which ring feeder running from the Main Sub Station Feeder is supporting the buildings in the study area.

To create a connected system between the cables and the point features, it is important to create connected cable segments between features each with their own "object id" as described in Figure 4.33. Failing to do so will result in stand-alone features when creating a network dataset.

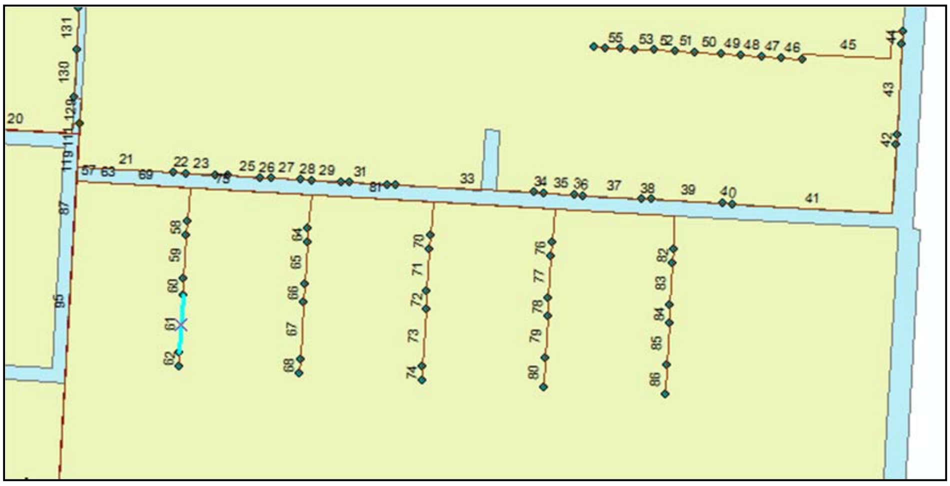


Figure 4.33: Cable segments forming a connected network.

The different line segments in the Cables feature class are necessary to form a connected network. In reality, an electrical cable network does not have individual cable segments between features. A number of cables run from a distribution board to the different locations where several endpoint utilities are connected to them. These cables are connected to trip-switches inside the distribution boards. If a switch trips inside the distribution board, none of the endpoint utilities will receive electricity. Therefore, the unique id's of all the different cable segments forming an actual cable is the same to simulate a realistic cable running from the distribution board to the utility endpoints, as illustrated in Figure 4.34.

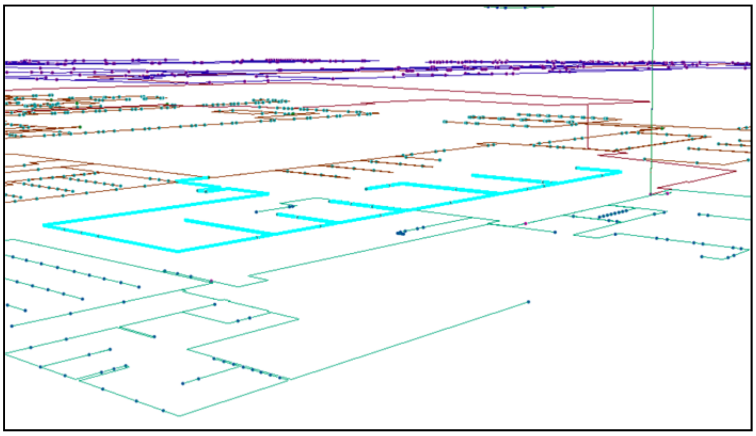


Figure 4.34: Selecting a single electric cable.

The Cable feature class makes use of vertical lines to establish connections between features on different levels of a building. These vertical lines usually run from a distribution board on one level to another distribution board located on a different floor level. Vertical lines are created in an active editing session. The snapping tool is used to snap on a point feature or any other vertex or edge of a feature. The vertical line is created by double-clicking on that same location so that two sets of identical coordinates are derived in the sketch properties tool as illustrated in Figure 4.34. Z-values are determined by the location of the vertical cable between the different floor levels. The z-values in Figure 4.35 create a vertical cable from the ground level to the first level of the participating building.

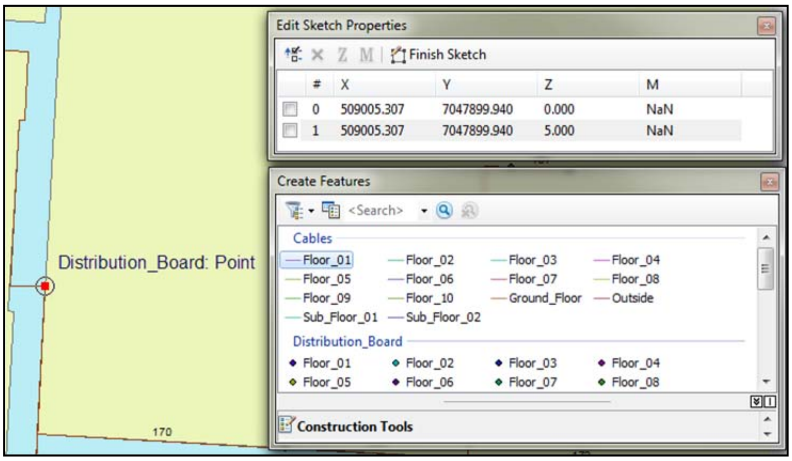


Figure 4.35: Creating vertical line features.

The length of vertical lines cannot be measured in ArcGIS10 yet. Therefore the “Shape_length” value for vertical lines is listed as zero in the attribute table for the Cable feature class. This is one of the reasons for using an increment of five when assigning z-values for different levels in buildings. Actual measurements do not matter at the moment. Figure 4.36 illustrates the value of zero for vertical lines in the attribute table while Figure 4.37 shows a vertical line as seen in ArcScene10.

Outside_Diameter	Termination	SHAPE_Length	Cable_Position
9 mm	Dry	0.344156	Ground_Floor
9 mm	Dry	4.697912	Ground_Floor
9 mm	Dry	0.421907	Ground_Floor
9 mm	Dry	9.261457	Ground_Floor
9 mm	Dry	4.395958	Ground_Floor
9 mm	Dry	6.268833	Ground_Floor
9 mm	Dry	0.410196	Ground_Floor
9 mm	Dry	2.903032	Ground_Floor
55 mm	Dry	0	Floor_01
55 mm	Dry	1.695678	Floor_01
55 mm	Dry	29.154542	Floor_01
55 mm	Dry	24.490377	Floor_01
9 mm	Dry	7.690437	Floor_01

Figure 4.36: Shape_length value for vertical lines.

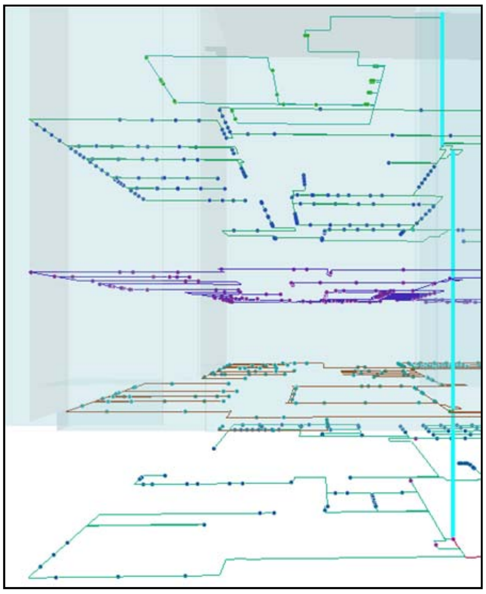


Figure 4.37: Vertical lines between floor levels.

4.1.3.11 Owners Table, Maintenance Register and List of Contractors

The three tables serve as additional information to the PUK geodatabase. Each table is created inside the geodatabase and not in the feature dataset. These extra information tables can be linked to the features inside the feature dataset by means of relationship classes. A new table is created by right-clicking on the geodatabase and selecting “New” and “Table” as described in Figure 4.38. The table name is specified and an alias is also created if necessary. The database storage configuration is set by default. The next step is to add all the fields participating in the table and setting the data type of each field. Domains can also be assigned to the necessary fields illustrated in Figure 4.39.

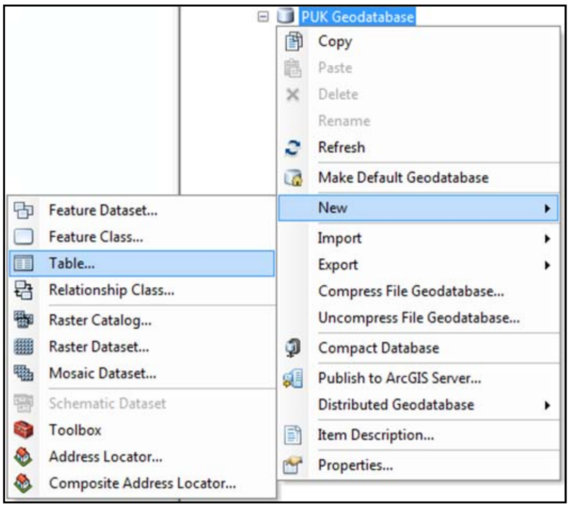


Figure 4.38: Creating a new table.

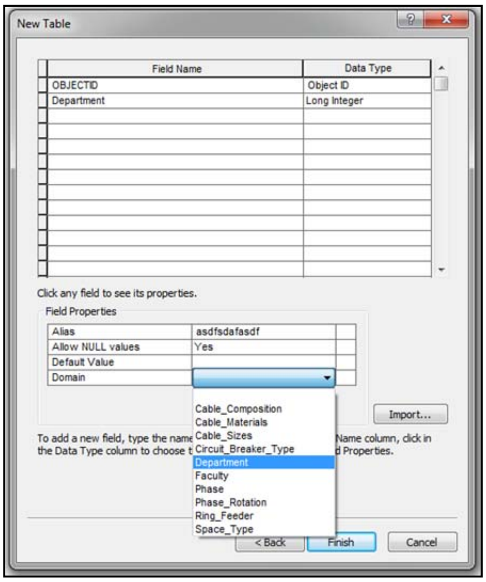


Figure 4.39: Adding fields and domains to a table.

The new tables are created in ArcCatalog10 and added to the table of contents in ArcMap10. Attributes are added to the tables by enabling an editing session and typing in the information.

4.1.3.12 Relationship classes

A total of 17 relationship classes were used in this geodatabase. Three types of relationship classes were used: "one-to-one", "one-to-many" and "many-to-many". Relationship classes connect the different features to each other through primary and foreign keys in the attribute tables. The point, line and polygon features are connected through relationship classes created inside the feature dataset. The extra information tables are connected to the point line and polygon features through relationship classes created inside the geodatabase and not the feature dataset. Relationship classes are created by right-clicking either on the geodatabase or on the feature dataset and selecting "New" and "Relationship class" as described by Figure 4.40. No editing sessions must be active in the attempt to create a relationship class. Otherwise an error might occur as illustrated by Figure 4.41.

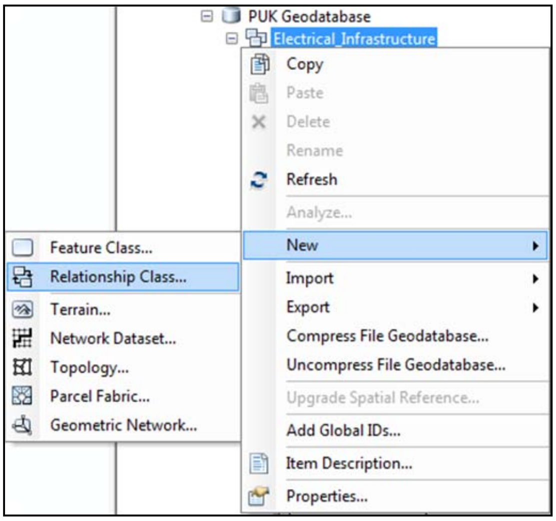


Figure 4.40: Creating a new relationship class.

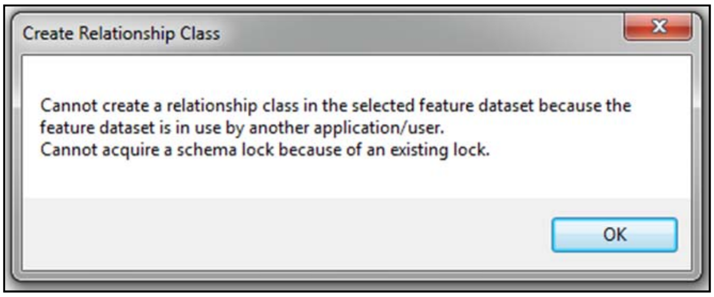


Figure 4.41: Error occurring because of an existing lock.

4.1.3.13 Creating "many-to-many" relationship classes

This type of relationship class is created by right-clicking either on the geodatabase or on the feature dataset depending on where the participating features are located. A new relationship class is created. The next step is to specify a name for the new relationship class. The origin and destination table/feature class is selected and the option to click on "Next" becomes active. The type of relationship is selected. All relationship classes in this geodatabase are simple (peer to peer) relationships. These types of relationships can exist independent of each other which means when objects in the origin table/feature class are deleted, the objects connected in the destination table/feature class are not deleted by default. Labels for the relationships are specified as they are navigated through from the origin table/feature class or otherwise.

The next step is to specify the direction of the messages to be propagated between the objects related in the participating relationship class. After clicking "Next" the cardinality of the relationship class is selected. The next option asks the designer if additional attributes can be added to the relationship class. The answer was "No" for all the relationship classes created. The next step is to select primary keys used in the origin and destination tables/feature classes. The values in the primary key fields will be used to link the two features together and to create the many-to-many relationship classes. The names of the foreign keys in the relationship tables that refer to the primary key field in the origin and destination table/feature class is specified as illustrated in Figure 4.42. The next option provides a summary of the relationship class to be created and the "Finish" option is selected.

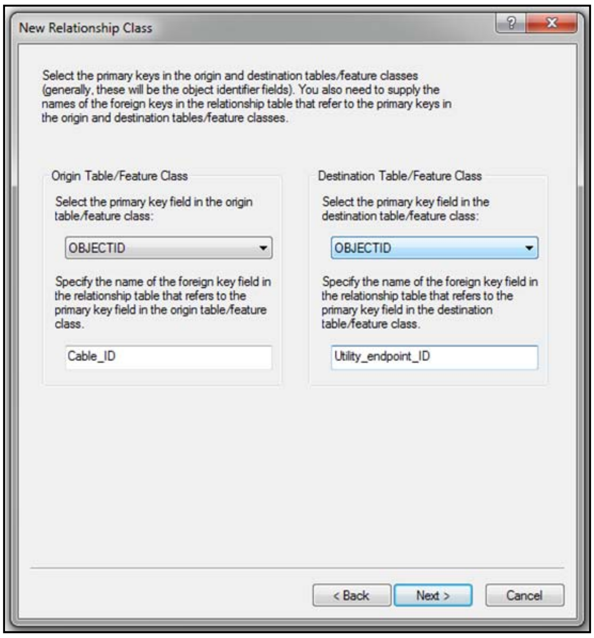


Figure 4.42: Selecting primary keys for the many-to-many relationship classes.

The many-to-many relationship class is created in ArcCatalog10. The relationship class is then added to the table of contents in ArcMap10 where a new added table is visible. Three empty fields are visible after opening the new table in the table of contents. The next step is to open the attribute tables of the two participating feature classes. Three opened attribute tables are visible. In order to create the many-to-many relationship classes, the primary field values in both the participating feature classes has to be selected in their attribute tables and added to the empty fields in the relationship class table. After starting an editing session and selecting the two primary key values that links to each other, the "Attributes"-option on the editor toolbar is selected. A many-to-many connection is created by expanding the features added to the Attributes dialog and right-clicking on the last expanded layer to add the selected features to the empty fields in the relationship table as described in Figure 4.43.

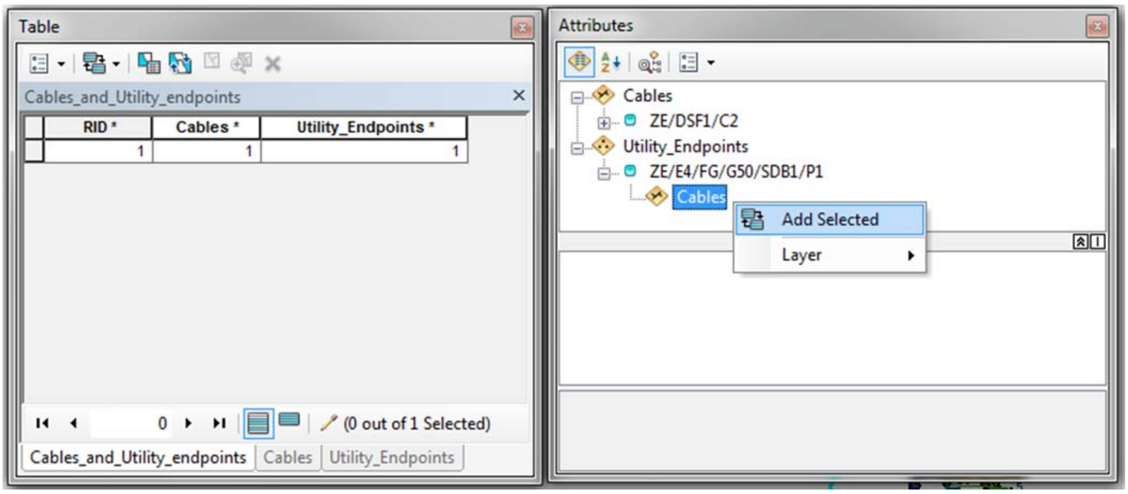


Figure 4.43: Selecting and adding primary key values to the relationship class table.

Each many to -many connection between the participating feature classes is created this way. After completing all the needed connections, the editing session is ended and the many-to-many relationship class is completed.

4.1.3.14 Creating "one-to-one" and "one-to-many" relationship classes

These relationship classes are created in the same way many to –many relationship classes are created. The only difference is that these types of relationship classes do not use the primary key values in the attribute tables of the participating features. Only the primary key and foreign key fields are specified that connects the two feature classes as described in Figure 4.44.

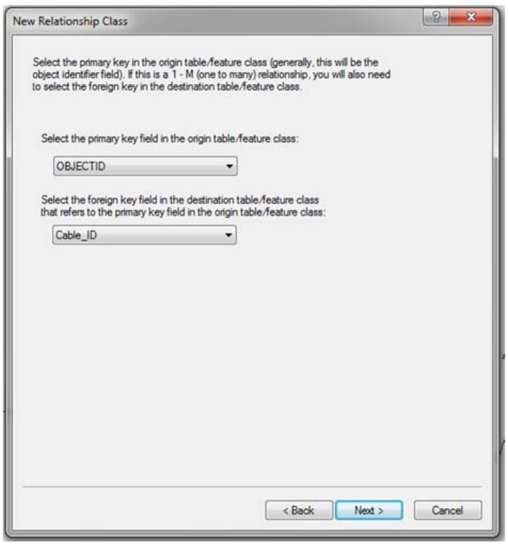


Figure 4.44: Selecting primary and foreign key values.

After the primary and foreign key values are selected the next option provides a summary of the relationship to be created. The "Finish" option is selected and the new relationship class is added to the catalog tree in ArcCatalog10.

4.1.3.15 Topology

The topology is created in the feature dataset of the PUK geodatabase as described in Figure 4.45. After selecting to create a new topology, the first window appears introducing the functions of topology. By clicking "Next" the following window presents an option to enter a name for the new topology. A name is specified and a cluster tolerance is selected which represents a distance range (in meters) in which all vertices and boundaries of the participating features are considered identical or coincident. This means that vertices and endpoints falling within the cluster tolerance are snapped together.

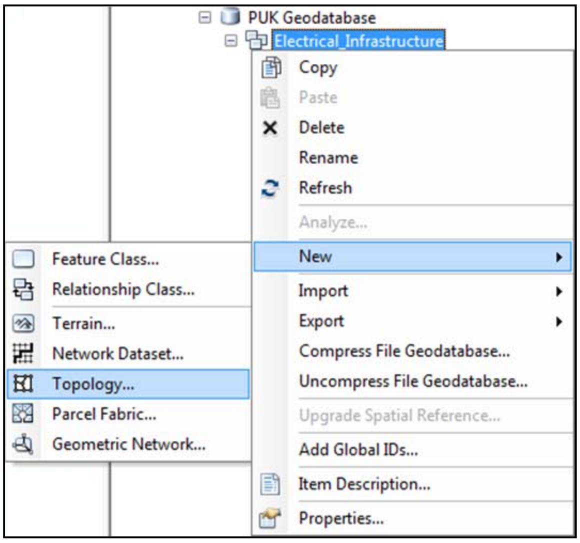


Figure 4.45: Creating a new topology.

The next window presents the options for selecting all the feature classes participating in the topology. After all the selections are made, the "Next" button becomes active to proceed to options where different ranks can be assigned to the feature classes. The ranks vary from one to five (one being the highest) to control how much the features will move when topology is validated.

The next window presents the options for adding the topology rules to be used in the PUK geodatabase. The "Add rule" button is selected and a dialog appears where different topology rules can be created for the geodatabase as described in Figure 4.46 and 4.47.

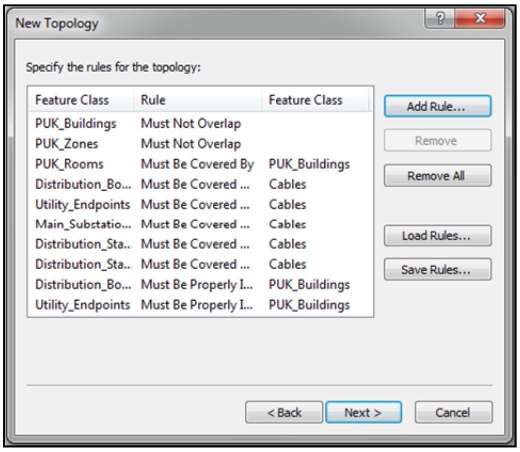


Figure 4.46: Adding topology rules.

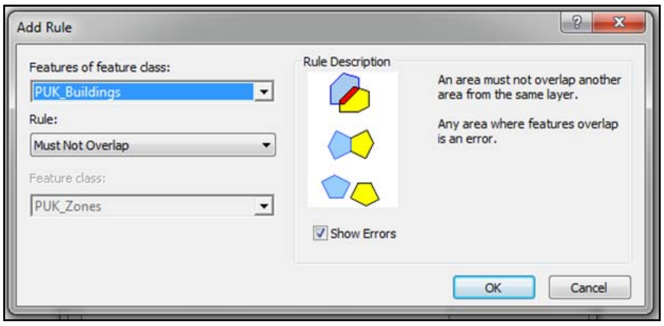


Figure 4.47: Creating topology rules.

After creating all the needed topology rules, the "Next" button is selected and the next window appears providing a summary of the newly created topology for the feature dataset. The new topology is added to the Electrical Infrastructure feature dataset by clicking on the "Finish" button. The process becomes active for creating the new topology and a prompt appears asking if the topology can be validated as illustrated in Figure 4.48.

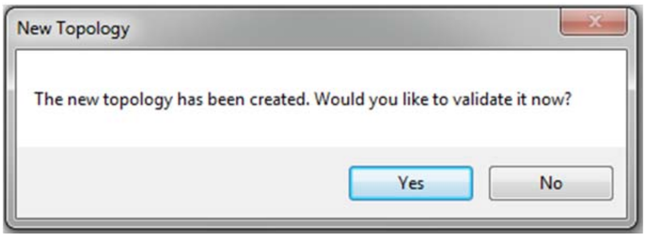


Figure 4.48: Validating a new topology.

The next step is to add the topology to the table of contents in ArcMap10. A prompt will appear asking if all the features participating in the new topology must be added to the map. The "No" tab is selected to cancel out redundancy of adding extra unnecessary features to the map. The topology will display the area, point and line errors in red occurring on the features inside the Electrical Infrastructure feature dataset as illustrated by Figure 4.49.

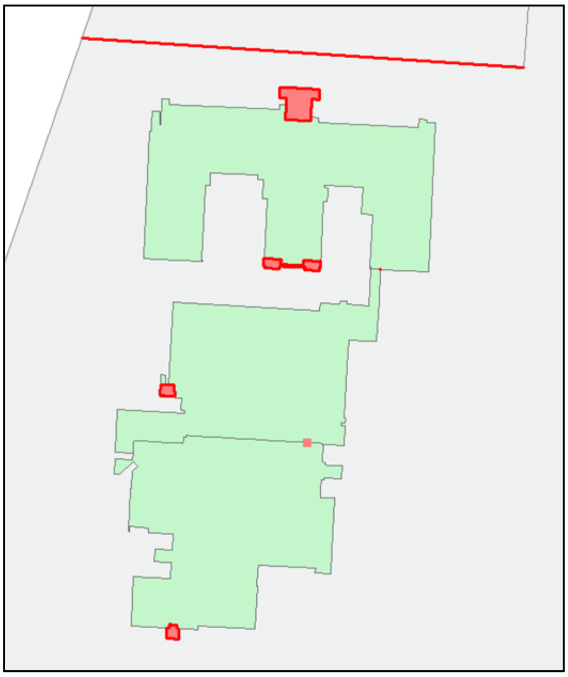
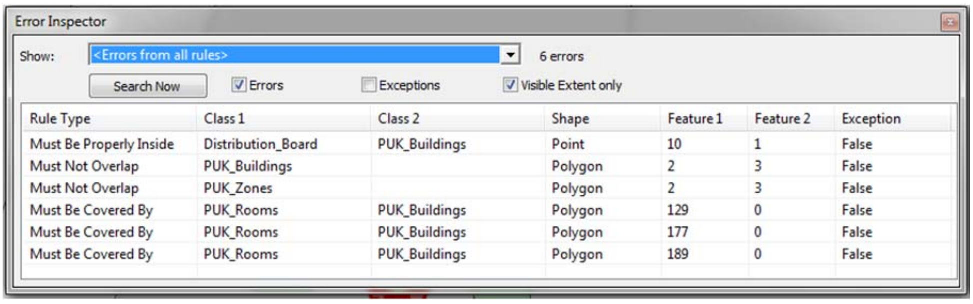


Figure 4.49: Topology errors displayed.

The topology errors can be fixed by enabling the topology toolbar and starting an editing session. The topology toolbar will become active and the "error inspector" button is selected which opens the error inspector window. Inside the error inspector window is a drop down bar providing options for selecting the different topology rules. The "Show errors from all rules" bar is selected and the "Search now" button is used to select all the topology errors into the list of the error inspector window as illustrated in Figure 4.50.



Rule Type	Class 1	Class 2	Shape	Feature 1	Feature 2	Exception
Must Be Properly Inside	Distribution_Board	PUK_Buildings	Point	10	1	False
Must Not Overlap	PUK_Buildings		Polygon	2	3	False
Must Not Overlap	PUK_Zones		Polygon	2	3	False
Must Be Covered By	PUK_Rooms	PUK_Buildings	Polygon	129	0	False
Must Be Covered By	PUK_Rooms	PUK_Buildings	Polygon	177	0	False
Must Be Covered By	PUK_Rooms	PUK_Buildings	Polygon	189	0	False

Figure 4.50: Error inspector window showing all topology errors.

In order to fix the errors where polygon features are not supposed to overlap, the specific errors listed in the error inspector window is selected, right-clicked upon and the "Merge" option is selected. A prompt will appear asking which of the two polygons must be merged with the other. Any of the polygons can be selected and the overlap error is fixed. The "Must Be Covered By" errors between the PUK rooms and PUK buildings feature classes appear because the PUK rooms feature class is digitized on the boundaries of the PUK buildings feature class. This is not actually a topological error and therefore these errors are marked as exceptions. The error where one of the distribution boards has an error is because the distribution board is also located on the boundary of the PUK buildings feature class. This is also not actually a topological error and therefore it is also marked as an exception. After all the errors are corrected, the use of topology helped to enforce database integrity.

4.1.3.16 Network dataset

The network dataset is created inside a feature dataset by selecting “New” and “Network Dataset”. A window appears presenting an option to choose a name for the network dataset to be created. In the next window the feature classes that will participate is selected and the “Next” button is clicked. No turns will be modelled in the network dataset for the PUK geodatabase. The next window presents an option to check the connectivity settings. The setting is set to default which means that the network dataset only establishes connectivity at coincident endpoints of line features during the build process. The connectivity policy of the line features is set to “endpoint” and the point features is set to “honor” as described in Figure 4.51.

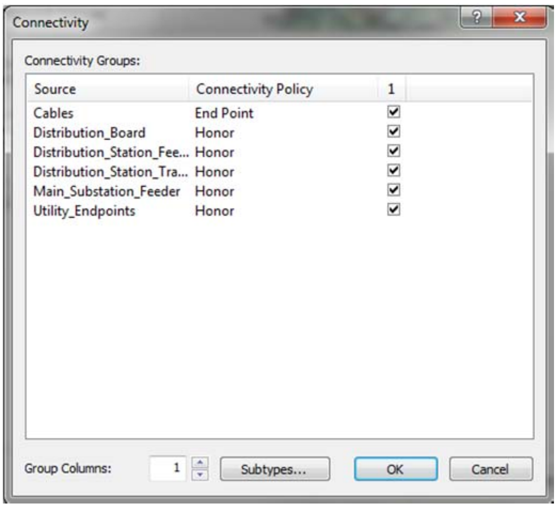


Figure 4.51: Checking connectivity settings in the network dataset.

In the next window a selection is made on how to model the elevation of the features in the network. The option for “Using z-coordinate values from geometry” is selected and the “Next” button is clicked. The attributes for the network dataset is selected in the following window. In this window the designer clicks on the “Next” button and a prompt appears asking to add a cost attribute based on the shape length as illustrated in Figure 4.52.

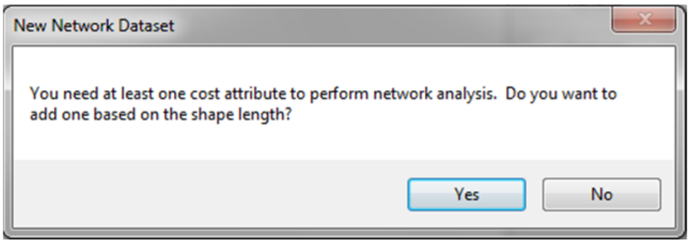


Figure 4.52: Selecting a default cost attribute for the network dataset.

The “Yes” button is selected. No driving directions are used for the network dataset and the next window provides a summary of the new network dataset. By clicking on the “Finish” button, the network dataset is created and a prompt appears asking to build the network dataset. The “Yes” button is selected and another prompt appears asking to add all the feature classes that participate in the network dataset to the map. The “No” button is selected to cancel out redundancy of unnecessary features being added to the table of contents. After all the steps are completed, the newly created network dataset is added to the table of contents and the route model can be built.

4.1.3.17 Route model

The route model used for the PUK geodatabase can be created in ArcScene10 to determine the shortest route between features. The route model is started off by opening the ArcToolbox and Modelbuilder window at the same time. The network analyst tools in ArcToolbox are used to make a new route layer in Modelbuilder. The network dataset created previously is used as the analysis network in the new route layer.

The next step is to add locations into the route layer. Only the point feature classes participate in this route model, otherwise the model won’t run. The “Add locations” tool is dragged over from ArcToolbox to Modelbuilder. The designer right-clicks on the “Add locations” tool and make a variable from parameters in order to input locations. The first participating feature is selected into the “Input locations” window as illustrated in Figure 4.53.

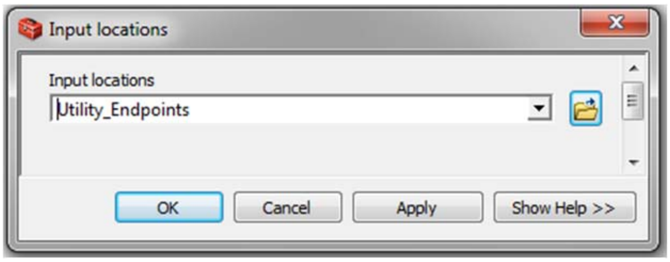


Figure 4.53: Selecting feature classes to input locations.

The designer right-clicks on the “Add locations” bubble and select the previously created route for the option to input a network analysis layer. The properties of the feature class added in the “Input locations” bubble are selected and the data type is changed from Table view to Feature set. The “Add locations” step is repeated for all the point feature classes participating in the route model.

The next step is to drag the “Solve” tool over to the Modelbuilder window. The designer clicks on the “Solve” bubble and selects the last route created into the option to input a network analysis layer as described in Figure 4.54.

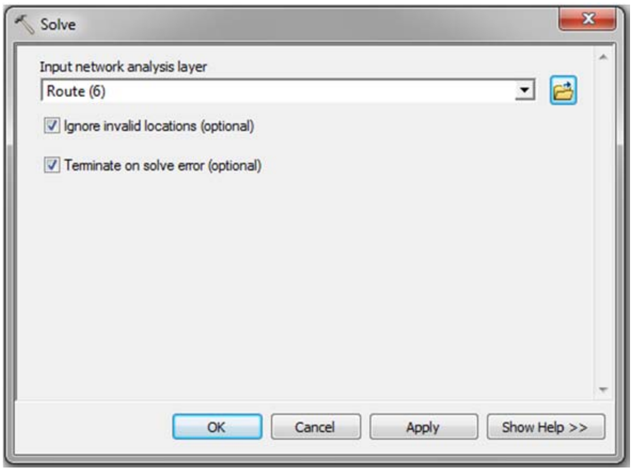


Figure 4.54: Selecting a previously created route into the Solve tool.

Symbology is added to the map under “Data Management Tools”. The “Layers and Table Views” toolbox is expanded and the “Apply Symbology From Layer” tool is dragged over from the ArcToolbox window to the Modelbuilder window as described in Figure 4.55.

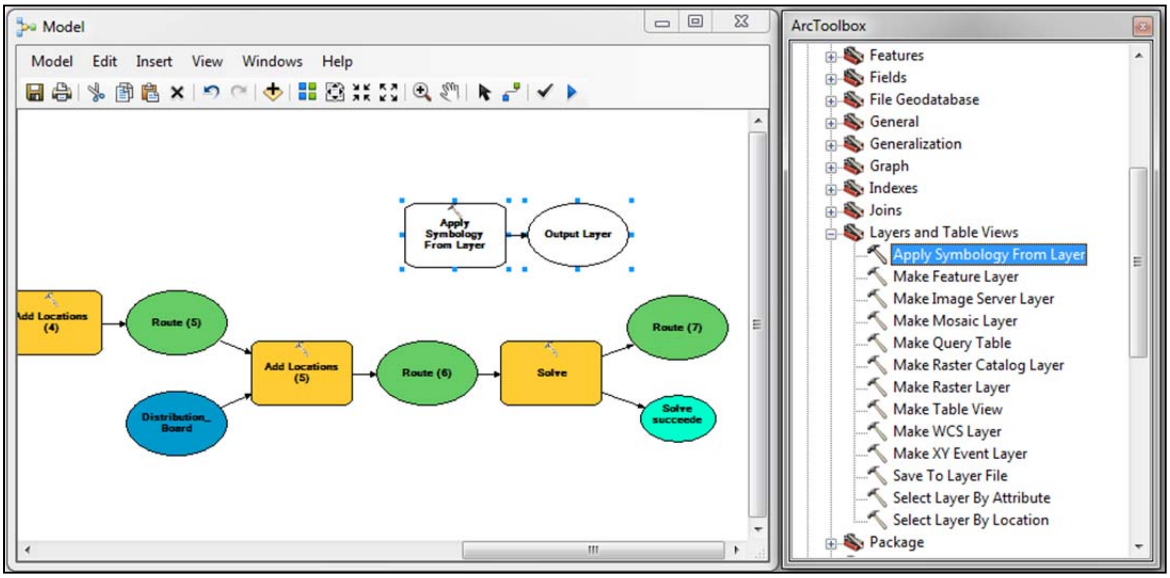


Figure 4.55: Using the “Apply Symbology From Layer” tool.

The designer clicks on the “Apply Symbology From Layer” bubble where the previously created route is selected into the option to input a layer. A previously defined route symbology layer is also added to the tool in the drop down menu. The final step is to create model parameters for all the feature classes participating in the route model. This is done by right-clicking on each of the feature classes and selecting model parameter. The answer at the end of the model is also assigned a model parameter. A new toolbox is created in the PUK geodatabase in which the model is saved as illustrated in Figure 4.56. By clicking on the model, a window will appear with options to do analysis on the features participating.

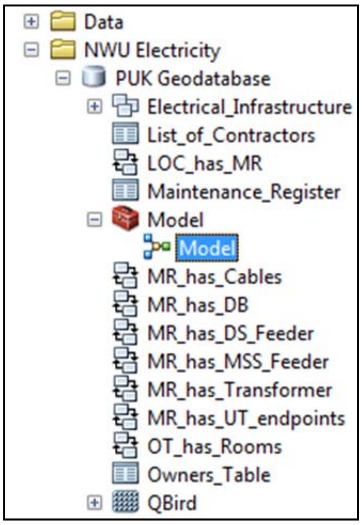


Figure 4.56: Location of the newly created route model.

4.1.3.18 Creating a Fishnet

The fishnet draped over the study area is created by using the ArcToolbox window. Under data management tools, the “Feature Class” toolbox is opened and the “Create Fishnet” tool is utilized as described in Figure 4.57.

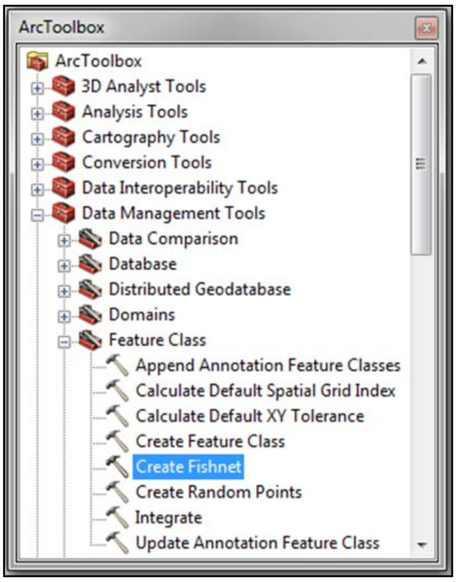


Figure 4.57: Selecting the “Create Fishnet” tool.

The next step is to open the “Create Fishnet” tool in the ArcToolbox window by clicking on the tool. A window will appear presenting options to be selected for the fishnet. The name of the fishnet is specified in the “Output Feature Class” option. The template extent is set to the same extent as the Quickbird (2008) satellite image. The cell size width and height is set to one which will create fishnet blocks of one by one meter. The number of rows is calculated by subtracting the values in the left extent from the values in the right extent. The number of columns is calculated also by subtracting the values in the bottom extent from the values in the top extent as illustrated in Figure 4.58. By selecting the “Ok” button, the process will run until the fishnet is executed and displayed as illustrated in Figure 4.59.

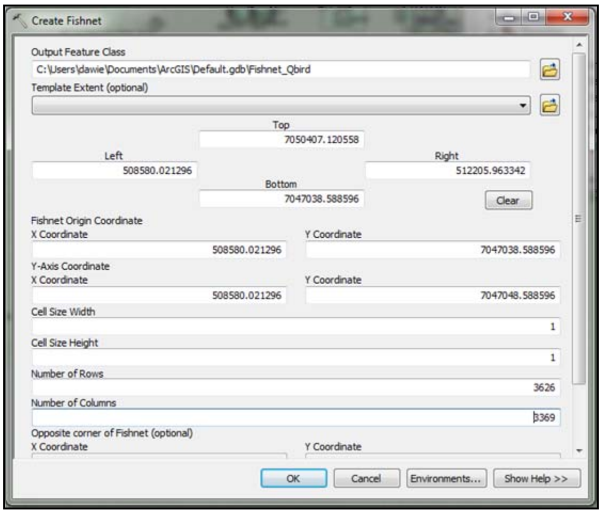


Figure 4.58: Completing options for the fishnet.

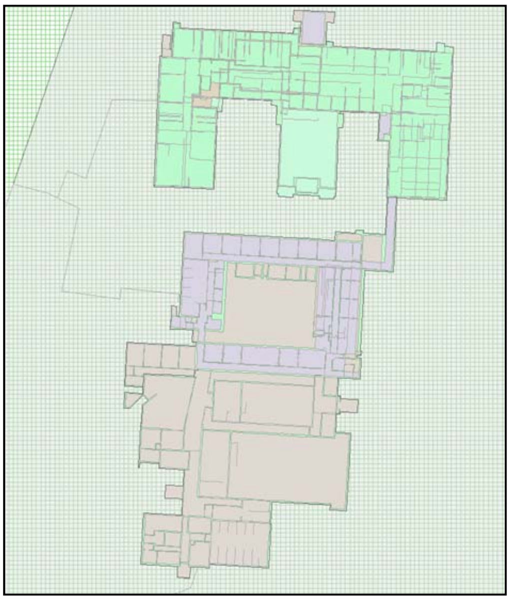


Figure 4.59: Fishnet draped over the study area.

4.2 Design workflows for building and maintaining each layer

Step nine of the ten steps to designing geodatabases by Actur and Zeiler (2004) suggests that work flows has to be defined to conform to business practices, in this case, the management of the two specified buildings for which this prototype model is built. This should guide the person who is responsible for the management of the buildings when it comes to updating the geodatabase. The previous steps explained how the geodatabase was built. These steps forming the standard operating procedure should provide support in the process of updating and maintaining the geodatabase.

4.2.1 Storing data

First of all, it is important to store all the data used for the geodatabase in folders that are easy to access and easy to locate quickly. For example, all the data used for this project is located under the folder called “Final NWU GDB 2011”. This folder contains all the data as well as the geodatabase used for this project. Storing data in well managed folder will also make it easier to backup important files. It is very important to create backups when creating and maintaining a geodatabase.

4.2.2 Standard Operating Procedure

GIS operations require the use of certain items and equipment combined with skills and abilities to perform related tasks. The following illustrates an example of equipment, abilities and skills needed to establish a GIS and perform operations on participating features as described by ANON (2006):

4.2.2.1 Hardware

- Personal computer or laptop with sufficient memory to run GIS software.
- An appropriate output device such as a printer or plotter with sufficient ink.
- Appropriate connection cables and power supplies.
- An external portable hard drive is suggested.

4.2.2.2 Software

- Standard and current versions of commercial “off-the-shelf” GIS software installed on the computer.
- Appropriate licenses to run the software.
- The needed software extensions and tools.

4.2.2.3 Infrastructure

- Internet connection and service is required.
- Uninterruptable power supply such as battery-backup is suggested.
- Access to the work site where features has to be modelled.

4.2.2.4 GIS knowledge, skills and abilities

It is important that the person performing GIS operations has basic knowledge about the system and the software. This will enable the responsible person to achieve goals set for specific projects. The following abilities and skills are recommended as described by ANON (2006):

- Effectively use the commercial “off-the-shelf” GIS software.
- Work with a variety of spatial data types such as raster and vector data.
- Understand Global Positioning data and be able to download, process and incorporate the data.
- Understand the use of a variety of datums and projections including geographic coordinates and be able to re-project data.
- Troubleshoot hardware and software problems to keep the GIS running.

4.2.2.5 Updating and deleting data in the PUK geodatabase

The following describes the basic procedure that has to be followed when features in the PUK geodatabase has to be updated or deleted. It serves as a basic guideline for the responsible GIS manager using and maintaining the PUK geodatabase.

It is important to make sure the network analyst and 3D analyst extensions are checked by clicking on the “Extensions” option under the “Customize” tab. This will enable access to edit features like creating a network dataset.

PUK Zones

Updating	**Deleting**
List the information for each updated feature in the related attribute table. Run topology rules to validate errors.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

PUK Buildings

Updating	**Deleting**
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. List the correct foreign key values for PUK Zones.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

PUK Rooms

Updating	**Deleting**
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. Make sure features contain the needed z-values. Z-values can be changed using the editing toolbar. List the correct foreign key for PUK Buildings. List the correct foreign key for Owners Table. Create features according to subtypes.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data. Make sure features from the correct floor level are deleted.

Use default values in subtypes that generate attributes automatically.	

Main Sub Station Feeder

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. List the correct foreign key values for Maintenance Register.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

Distribution Station Feeder

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. List the correct foreign key values for Maintenance Register. Create features according to the subtypes.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

Distribution Station Transformer

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. List the correct foreign key values for Maintenance Register.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

Distribution Boards

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. Make sure features contain the needed z-values. Z-values can be changed using the editing toolbar. List the correct foreign key values for PUK Rooms. List the correct foreign key values for Maintenance Register. Create features according to the subtypes. Turn subtypes from other levels off during digitizing to cancel out confusion between features. Use default values in subtypes that generate attributes automatically. Make sure features do not snap accidentally to features on lower levels during digitizing.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data. Make sure features from the correct floor level are deleted.

Utility Endpoints

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. Make sure features contain the needed z-values. Z-values can be changed using the editing toolbar. List the correct foreign key values for PUK Rooms. List the correct foreign key values for Cables. List the correct foreign key values for Maintenance Register. Create features according to the subtypes. Turn subtypes from other levels off during digitizing to cancel out confusion between features. Use default values in subtypes that generate attributes automatically. Make sure features do not snap accidentally to features on lower levels during digitizing.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data. Make sure features from the correct floor level are deleted.

Cables

Updating	Deleting
List the information for each updated feature in the related attribute table. Run topology rules to validate errors. Make sure features contain the needed z-values. Z-values can be changed using the editing toolbar. List the correct foreign key values for Distribution Boards. List the correct foreign key values for Main Sub Station Feeder. List the correct foreign key values for Distribution Station Transformer. List the correct foreign key values for Distribution Station Feeder. List the correct foreign key values for Maintenance Register. Create features according to subtypes. Turn subtypes from other levels off during digitizing to cancel out confusion between features. Use default values in subtypes that generate attributes automatically. Make sure features do not snap accidentally to features on lower levels during digitizing.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data. Make sure features from the correct floor level are deleted.

Owners Table, Maintenance Table and List of Contractors

Updating	Deleting
List the information for each updated feature in the related attribute table.	Make sure fields in the attribute tables do not contain primary and foreign keys when attempting to delete data.

Network Dataset

Updating	Deleting
By altering feature classes the network dataset has to be rebuilt to accept changes made. Open the properties dialog of the network dataset. Select the "Source" tab and remove the feature classes that have been altered. Add the altered feature classes again and click "Ok". Right click the network dataset and select "Rebuild".	Deleting the network dataset will cause the route model to stop working.

Route model

Updating	Deleting
When a feature class is altered and rebuilt in the network dataset, it is automatically updated in the participating route model. Newly created feature classes are added to the route model by means of the "add locations" tool in the ArcToolbox window.	Features can be deleted from the route model by removing the locations added to it. This could result the model to not work properly.

4.3 Document your design using appropriate methods

In this step by Actur and Zeiler (2004), the design is documented using methods that include drawings, diagrams, figures, tables, layer diagrams, schema diagrams and reports. Appendix A illustrates the schema diagram for the PUK geodatabase. All the participating feature classes, subtypes and relationship classes are displayed through a connected diagram. The extra information tables and domains used in the geodatabase are displayed in Appendix B. It is also important to list metadata for the PUK geodatabase. The metadata summarizes information about each feature class created in the data model for future reference. The metadata for the PUK geodatabase is listed in Appendix C.

4.4 Problems and precautions during implementation

The following list of problems was encountered during the digitizing process. It can also serve as precautions when managing, creating and updating the PUK geodatabase.

1. The CAD drawings provided does not show the locations of the cables connected to the different utilities. The designer had to improvise to map the different cables inside the buildings.
2. The Quickbird (2008) satellite image is not taken directly ninety degrees from above. Therefore the CAD drawings georeferenced to the buildings does not align exactly. If

the user deletes the network dataset from the PUK geodatabase and tries to continue editing, an error will appear explaining that features cannot be edited because of dirty areas. This problem can be resolved by closing ArcMap10 and opening it again.

3. When the user wants to add a new domain to the PUK geodatabase to be used in the attributes of existing feature classes, the drop down list of the new domain refuses to work. For some reason, the drop down lists only works if the domain is created before the feature classes.
4. Assigning subtypes to the features on different levels enables the user to turn them off when needed to cancel out confusion and to make the digitizing process a bit easier. This enables the user to view only the features of the specific floor level. The only problem is that the snapping tool can accidentally snap to the invisible features on the floor levels below.
5. ArcGIS10 does not have the ability the perform route tracing by means of a geometric network in 3D yet. The only substitute is to create a route model to find the shortest route in 3D. Hopefully, more advanced procedures will be created in the future to enable the possibility of more complicated analysis in 3D.
6. 3D Topology rules do not exist to be used in ArcScene. The only way to enforce topology is to assign the rules for features in ArcMap. Therefore the basic topology rules are used to validate errors made during digitizing.
7. A problem occurred when trying to locate utilities forming the network outside the buildings. Most of the electrical cables run underground from the macro network features until inside the various buildings. It is important to know exactly where these cables are located underground to cancel out future problems when buildings are upgraded. One suggestion was that a GPS could be used to locate the cables but this posed a problem. Only very expensive GPS's have the ability to map positions with high accuracy. More common and less expensive GPS's plot locations anywhere within a five meter radius. It is very difficult to locate a specific cable underground. A solution to this problem was to create a fishnet over the study area drawing blocks of one meter in diameter. Cables can be located by following the blocks outside the buildings. The fishnet model has the ability to specify the extent of the area it should cover. The length and height of each grid can also be selected that calculates the amount of rows and columns generated. The created fishnet can be added as a layer in the table of contents in ArcMap10. It can be turned off according to the needs of the user.

8. The final problem encountered was the availability of data. The available data were either old or incomplete.

4.5 Conclusion

The methods and implementation chapter described the physical design phase of the ten steps by Actur and Zeiler (2004) in detail. The chapter started off by providing a list of required data to be presented to the building and electrical managers responsible for maintaining the utilities of the buildings in the study area. This process made it clear that some of the data is difficult to find due to the age of the buildings. A reason for this is that several individuals were responsible for maintaining utilities inside the buildings over the years. Each person had a unique way of keeping record of utilities and processes. Most of the people relied on knowledge and experience when managing the buildings. No effort was made to document processes regarding the maintenance, upgrading and management of utilities inside the buildings. Therefore, most of the data had to be assumed during the digitizing process. Because of this, the proposed geodatabase can only be used as a prototype model. The available data that could be retrieved was either outdated or incomplete.

The available data used for the PUK geodatabase was listed and the process of how it was utilized and where the data was obtained were explained. The implementation chapter then walked the reader through the process of building the PUK geodatabase from start to finish. Different techniques were explained during digitizing and capturing data. Reasons were also presented for some decisions that had to be made. This chapter provided insight for building a geodatabase with limited resources. The process of handling errors and making exceptions in some cases ran throughout the chapter. The following chapter will present the results of the PUK geodatabase and its capabilities for analysis. Chapter 5 will demonstrate the usefulness of the geodatabase in the management of utilities inside buildings on micro level.