GIS: A theoretical background

4.1 Introduction

In this chapter, the third research objective is addressed: “To identify and conceptualize the requirements for an effective conceptual model of a spatial information system (GIS) for Disaster Risk Management in the Tlokwe Local Municipality". In this min-dissertation, the Spatial Information System used is a GIS.

According to literature GIS is utilised as an effective tool to complement conventional methods in all aspects of disaster risk management, disaster management, recovery and reconstruction (Bahuguma, et.al. 2013: 5632; Gruber, 2009:Online; Samadi & Delavar, 2009:Online; Zanariah, et al., 2009:Online; Harman, et al., 2008:Online; Kumar, et al., 2008:Online; Vargas, et al., 2008:Online). Based on the latter overwhelming support for GIS as a tool in disaster risk management and disaster management, the utilisation of the application cannot be ignored and the potential application of GIS in disaster risk management and disaster management should be explored and considered.

It can be argued that as an information systems, any GIS developed needs to accommodate all levels of users, including those responsible for capturing and processing data and those managers and other professional staff that needs information that will enable them to make effective strategic, tactical and operational decisions needed to ensure effective disaster management.

The aim of this chapter is therefor to introduce the basic concept GIS, the components thereof and factors that must be taken into consideration when considering this solution.

In this chapter, a brief discussion is provided of the concept GIS, the spatial projecting of the earth, the different types of spatial data and the basic relationship between a GIS and an Information system.

The first section discusses the concept GIS. This is followed by a concise discussion of geographical data that include raster and vectors data. A discussion of the GIS as an information system then follows. This includes the important components of an information system, namely, data, people, processes, networks, hardware and applications. Finally, a summary is provided of the important components that must be considered in the design of an information system.

In Figure 16 the outline of Chapter 4 is given.

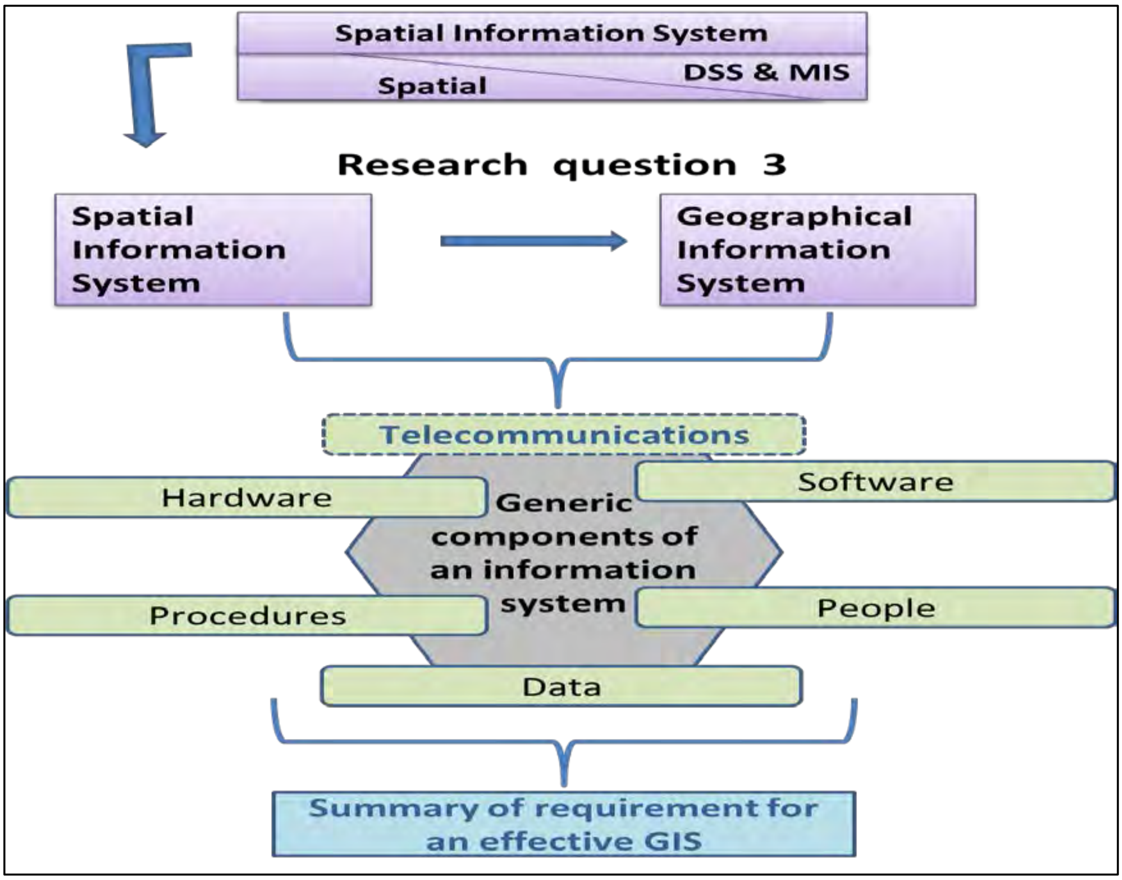


Figure 16: Outline of Chapter 4

In the next paragraph the concept, Geographical Information System is discussed.

4.2 The GIS

4.2.1 Conceptualising of a GIS

When considering the term GIS there are arguably three important concepts that should be considered, namely the GIS as a spatial information system, the concept information system and the concept system.

The definitions in the literature describing a Geographic Information System (GIS) include the following:

A GIS is a system that integrates hardware, software and data for capturing, managing, analysing and displaying of all forms of geographical referenced information. This information assists in providing answers and solutions, through the understanding, interpretation and visualization of data in ways that reveal relationships, patterns and trends in form of maps, globes, reports and charts. (ESRI, 2014:Online). This definition emphasises the collection, processing, managing and analysing of geographical reference data to provide information that can be visualised in the form of maps, graphs, reports, etc.

According to Bolstad (2012:1) a GIS is a computer-based system that aids in collecting, manipulating, storage, analysis, output and distribution of spatial data and information.

Athan *et al*., (2010:7) define a GIS as a collection of software that allows a person to create, visualize, query and analyse geospatial data. In this definition, the focus is on the process used to provide information.

Huisman & Rolf (2009:32) describe a GIS as a computer-based system, in which geo-referenced data is captured, manipulated, analysed in various ways to provide presentations of the data in various ways including maps and other types of geospatial information. In this description, the focus is on the process of data capture, preparation, management, manipulation, analysis and presentation.

According to GIMS (2006:3) a GIS is a complex data system capable of holding and using data describing places on the earth surface. In this definition, the focus is on the type of data, namely geographic.

O'Brien and Marakas, (2006:331) describe a GIS as a Decision Support System that uses a geographic database to combine and display maps and other graphic displays that support the decision that affects the geographic distribution of people and other resources. In this definition, the focus is on the type of support that the geographic system must provide, namely decision support.

Bernhardsen (2002:4), a GIS is generically any computer-based system with the capacity for the manipulation of geographical data. The system includes hardware, software and other devices that can be used to input maps and to create map products, together with the communication systems needed to link the various elements.

Stair and Reynolds, (1999:669) define a GIS as a computer system capable of assembling, storing, manipulating and displaying Geographically referenced data that is data identified according to their location. In this definition, the focus is on the processing of data.

Dash (1997:136-137), describes a GIS as a system that uses both geographic data and non-geographic data that has the ability to link these two dataset types into a single integrated system. This system provides support for spatial analyses, data manipulation and the display of the data as information in various forms such as large-scale maps, tables and charts. The importance of this description of a GIS it recognises the system's ability to link geographic or spatial data and other data into a single integrated system.

Considering the above, a Geographic Information System:

Is an integrated computer-based system (ESRI, 2014:Online; Bolstad, 2012:1; Huisman & Rolf, 2009:32; Bernhardsen, 2002:4; Stair and Reynolds, 1999:669).

Is a decision support systems (O'Brien & Marakas, 2006:331), a class of information that helps with decision support, and therefore as an information system, it has the generic components of all information systems, namely, people, hardware, software, data, telecommunications and processors (O'Brein & Marakas, 2006: 26-29; Stair & Reynolds, 1999:17-21).

Utilises spatial date that is geo- referenced data, and data that can be linked to the geo-referenced data (ESRI, 2014:Online; Bolstad, 2012:1; GIMS, 2006:3; Bernhardsen, 2002:4; Stair and Reynolds, 1999:669; Dash,1997:136-137). A coordinate system is normally used to geo-reference the data.

Is a system where the data is processed through the collection, capturing, verification, management, storage, manipulation and analysis is converted into information (Bolstad, 2012:1; Athan *et al.,* 2010:7; Huisman & Rolf, 2009:32; Bernhardsen, 2002:4; Stair and Reynolds, 1999:669).

Is a system where the information, can be in the form of maps, reports, graphs, charts, tables, other graphic displays and geospatial information (Huisman & Rolf, 2009:32; GIMS, 2006:3; O'Brien and Marakas, 2006:331; Bernhardsen, 2002:4; Dash, 1997:136-137). The information output can assist in providing solutions to problems (O'Brien and Marakas, 2006:331), and can assist management with planning, leading, organising, control & organisation, communication and decision support (*Neman & Bennett, 2006:89, 93, 99,103;* Cronje, *et al.,2005:122-124 Van Der Waldt & Du Toit, 2005:181,188, 196, 201 2006*).

Figure 16 is a conceptualisation of a GIS based on the above analyses integrated with production process of data (Riekert, 1999:62).

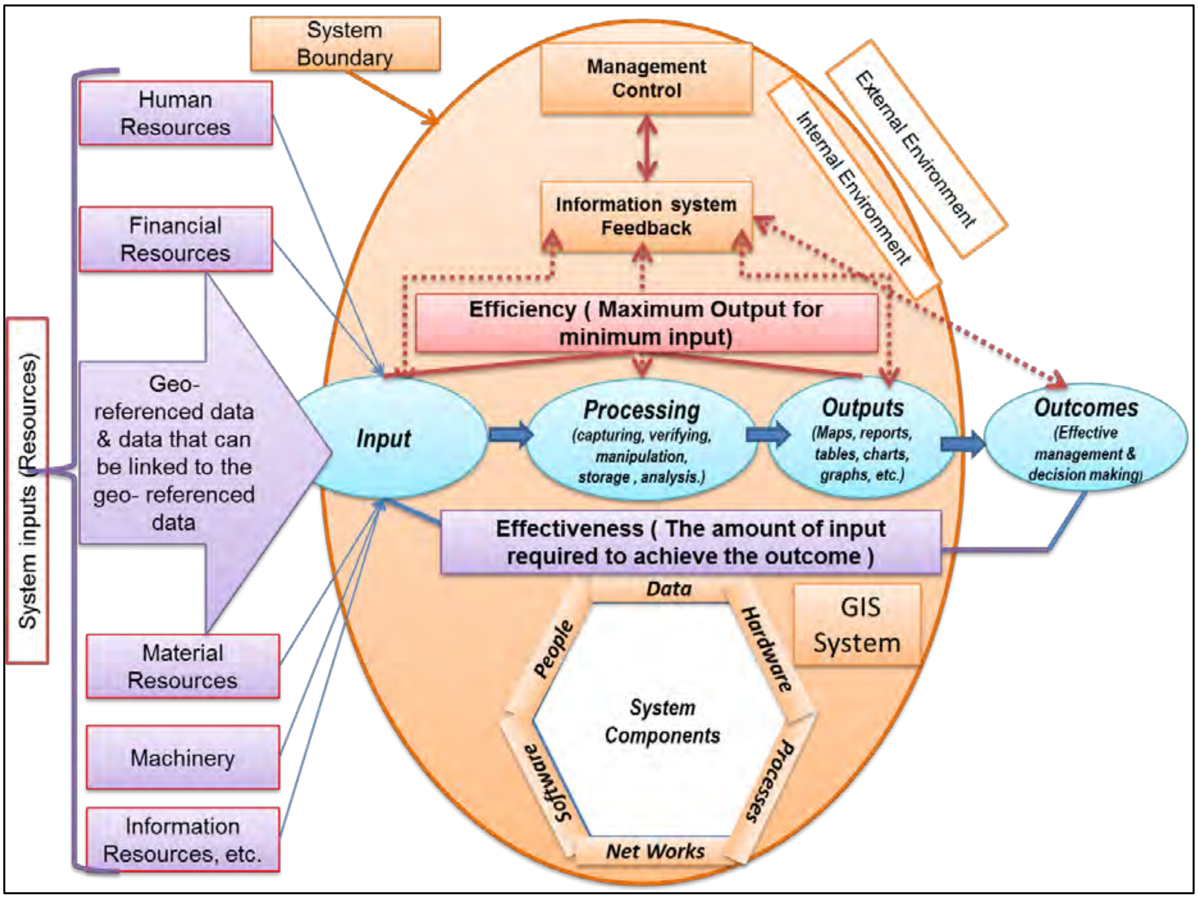


Figure 17: A systems conceptualization of a GIS

Based on the above a GIS for the purpose of this study can firstly be described as a spatial information system utilising data describing places on the earth surface. Secondly, the GIS is an Information System, comprising the basic components generic to all information systems. These components are people, software, hardware, procedures, data and telecommunication (GIMS, 2006:3, O'Brien & Marakas 2006:26, Stair & Reynolds, 1999:18-24).These component are discussed in paragraph 4.5. Thirdly, as a system it can be defined as a group of interacting components, with a clearly defined boundary and working towards a common goal. This common goal is achieved by accepting inputs and producing outputs in an on-going process, where input is the activity of gathering, formalising and capturing of data (Stair & Reynolds, 1999:15) and data processing is the conversion of data into useful outputs namely information (Stair & Reynolds, 1999:15*).* The information processing systems provide for a continuous feedback mechanism to make the necessary changes into the input, process and outputs, continuously improving the quality of information produced (Stair & Reynolds, 1999:16). Fourthly, as the systems output is based on supporting all levels of managers and knowledge workers, it can be classified as a management support system (O'Brien & Marakas, 2006:12). In this case, the GIS can provide routine management information that serves as a Management Information System, and support managers in making informed decisions in advance; thus a Decision Support System (Stair & Reynolds, 1999:25).

The GIS as a geospatial data model representation of the earth (Ormsby *et al*, 2009:2; GIMS, 2006:5) is discussed below.

4.2.2 GIS as a geospatial data model representation of the earth

The challenge with a model of the earth is that (with exception of a physical model of the globe) it is mostly represented in two dimensions (for example a map), while the real earth is a spheroid planet (See Figure18).

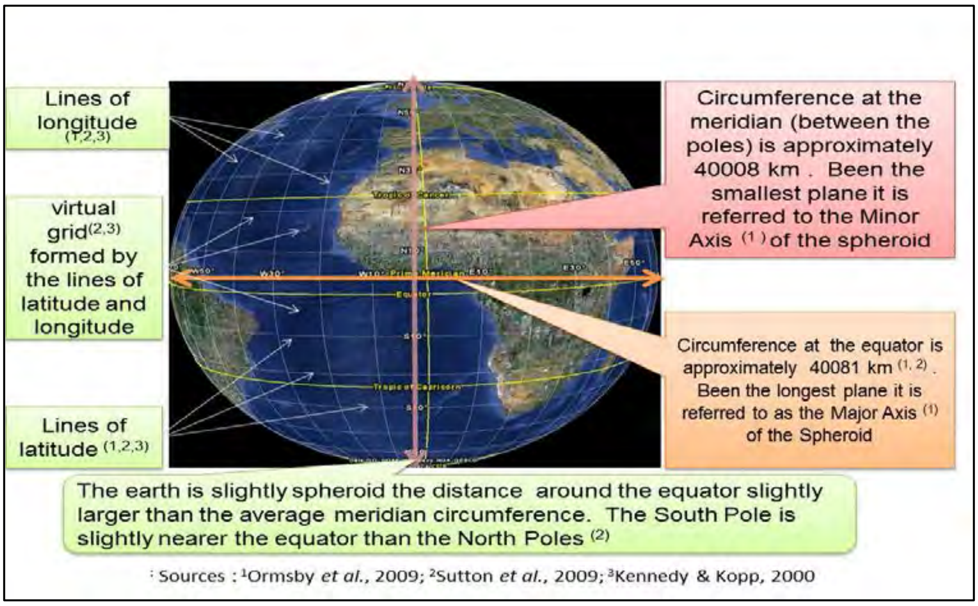


Figure 18: Representation of the earth with some important features.

The earth can be mathematically represented by a spheroid (Ormsby, *et al.*, 2009:345). This is further highlighted in the coordinate system (lines of latitude and longitude) of the earth that are measured as degrees of deviation from the centre (core) of the partially spheroid planet earth (See figure 18). To conceptualise the earth as a spheroid it is ideal to visualise two sets of planes through the partially spheroid planet, a horizontal plane being represented by the X- axis, and a vertical plane being represented by the Y - Axis.

Therefore, when projecting the earth from a spheroid into a two-dimensional surface, distortions can occur.

The next paragraph provides a concise discussion of planes of X - Axis known as the lines of latitude.

4.2.3 Lines of latitude

The lines of latitude, parallels or X- planes are virtual horizontal planes with the equator as 0^o (degree). The equatorial plane represents the horizontal centre plane of the earth. The lines of latitude are divided into 90 units from the equator (0^o) to the North Pole (90^o) and 90 units from the equator (0^o) to the South Pole (90^o). A positive sign is used to indicate the planes lying in the North (Northern Hemisphere) and a negative sign is used to indicate the planes lying in the South (Southern Hemisphere). To determine the latitude (parallel), the angle between the centre of the earth and the horizontal plane going through the equator as 0^o degrees (the reference point that is used), is used to determine the line of latitude. Being angular distances they are normally measured in degrees, minutes and seconds (where 60 minutes are equal to one degree and one minute is equal to 60 seconds). These angular distances can also be represented in other unit formats, including decimal.

4.2.4 Lines of longitude

The lines of longitude, meridians or Y - Planes, are virtual planes normally with the Greenwich meridian at 0^o degrees, and are the minor axes of the earth. The Greenwich meridian represents the vertical centre plane of the spheroid planet earth. The lines of longitude are then divided into 180 units from the centre meridian (Greenwich Meridian) towards the east (Eastern hemisphere) and 180 units from the centre meridian (Greenwich Meridian) to the West (Western Hemisphere).

A positive sign is used to indicate the vertical planes lying east of the Greenwich Meridian and a negative sign is used to indicate the vertical planes lying west of the Greenwich Meridian. To determine the longitude (meridian), the angle between the centre of the earth and the vertical plane going through the Greenwich meridian at O^o as the reference point is normally used. To determine any position on the surface of the earth as discussed earlier, both its horizontal (latitude) and vertical positions (longitude) are required. The earth surface can therefore be visualised as having virtual horizontal and vertical lines projected on its surface, forming a gridded network known as a graticule (Kennedy & Kopp, 2000:2).

The position of the object of interest on the surface of the earth can be determined by the location on the virtual graticule that is the intersection of its latitude and longitude position indicated as (x,y) where x represents the latitude and y represents the longitude. For example, (0,0) would indicate where the horizontal plane (equator) and the vertical plane (Greenwich meridian) intersect. The mathematical transformation of the three-dimensional surface of the planet into two-dimensional map is referred to as map projection (Kennedy & Kopp, 2000:11). This representation of the partially spheroid globe into two dimensions can cause shape, area, direction and distance distortions (Kennedy & Kopp, 2000:11). In attempt to provide a two dimensional model of the earth, a number of models have been developed, and are still being used, which to a certain extent are able to address one or more of the distortions encountered with modelling (Kennedy & Kopp, 2000:11). These model projections include Conformal, Equal Area, Equidistance, True Direction, Conic, Cylindrical, Planar etc. (Kennedy & Kopp, 2000:12-21).

Since 1999 the coordinate system standard use in South Africa has been the Hartebeesthoek 94 Datum details of which are outlined in Table 4; it replaced Cape Datum, which was a modified Clarke 1880 ellipsoid.

Table 4 : Standard Projection for South Africa	
Name	Haartebeesthoek94Datum
Abbreviation	Hart94
Reference Ellipsoid	WGS84 (World Geodetic System 1984 ellipsoid)
Reference Frame	ITRF91(International Terrestrial Reference Frame 1991)
Reference Epoch	1994
Date Implemented	1 January 1999
Origin of the system	Hartebeesthoek Radio Astronomy Telescope
Heights	Referenced to the mean sea level at Cape Town and verified at tidal gauges in Port Elizabeth, East Londen and Durban
Reference : NGI,2010:1-2	

The above provides a concise description of how entities and regions on the surface can be represented on a two dimensional model of the earth through the use of a suitable projection transformation model; in the case of South Africa this will be Haarteesthoek94 Datum. The projection datum will normally be included with the coordinates on the spatial database. The entity/object/surface on the global model is now projected as features/surfaces/etc. on the two dimensional map in the form of spatial data. The layers/surfaces/features etc. used in a GIS are described in the next paragraph. GIS software packages have the ability to project on the fly various projections, thus it is important to have the projections as part of the spatial data.

4.3 GIS layers, surfaces and features

On a GIS, the maps are made of one or more layers or collection of geographic objects that are similar. These layers may contain vector features or raster surfaces (Ormsby *et al.*, 2009:3; Sutton *et al.*, 2009:9).

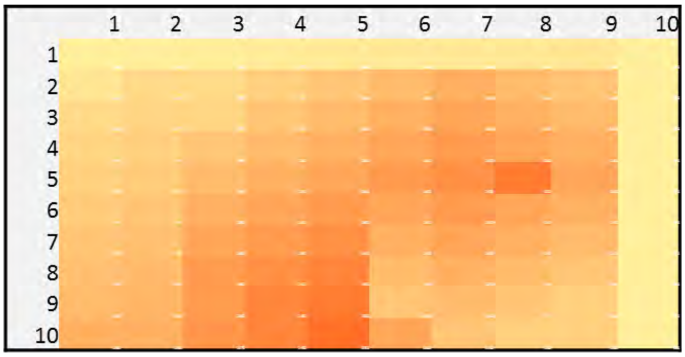
4.3.1 Raster Layer

In figure 19, an example of raster layer is provided.

10 x 10 cell raster with values representing height above sea level

	1	2	3	4	5	6	7	8	9	10
1	950	955	960	970	980	985	985	990	995	950
2	1000	1050	1050	1100	1150	1200	1250	1200	1150	950
3	1050	1075	1075	1150	1200	1250	1300	1250	1200	950
4	1075	1100	1150	1200	1250	1300	1350	1300	1250	950
5	1100	1125	1200	1250	1300	1350	1400	1500	1300	950
6	1125	1150	1250	1300	1350	1300	1350	1300	1250	950
7	1150	1175	1300	1350	1400	1250	1300	1250	1200	950
8	1175	1200	1350	1400	1450	1200	1250	1200	1150	950
8	1200	1225	1350	1450	1500	1150	1200	1150	1100	950
10	1250	1250	1375	1450	1550	1300	1150	1100	1100	950

The same 10 x 10 cell raster as above with values and with colour grading to represent the height above sea level



A 2.5 H dimension of the surface represented in the above raster

Ii should be noted that the above including the 2.5 Hd Representation was designed using Microsoft Office Excel 2007

Figure 19: An example of a raster representing a surface

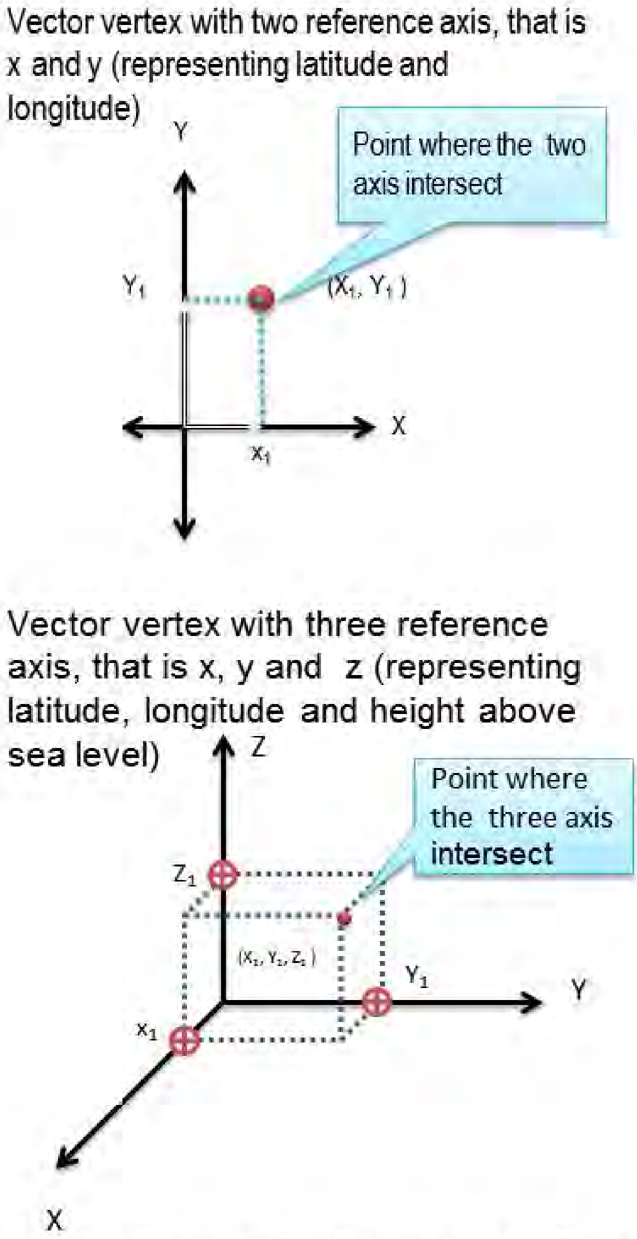
Some of the layers can be visualised as a continuous expanse where they only change from one point to another in the expanse for example, the depth of the sea (Ormsby *et al* 2009:3-4). These expanses are called surfaces with the most common kind of raster being a matrix/grid of rows and columns having identical sized squares (grid cells or pixels (Ormsby *et al.*, 2009:4; Sutton *et al.*, 2009:47-53; GIMS, 2006:7). Each square contains numeric and/or colour estimation for that location (Ormsby *et al.*, 2009:4). In Figure 19, the author provides three graphic representations: the first an example of 10x10 matrix composing of a 100 cells, each cell has a value indicating its height above sea level. The second demonstrates how the first matrix can be represented by a colour gradient for the values for example, the gradient of the brown on a surface map of the surface to indicate the mean level above sea level. The third is a 2.5 dimensional representation of the surface in the matrix. To achieve more detail, the area that each cell in the matrix represents must decrease. For example, a cell representing an area of $10m^2$ will have 10 times less detail than a cell representing $1m^2$. To be able to reflect more detain, more data memory will be required, as the size of the data will increase.

4.3.2 Vector layers

The second class of spatial data is Vector data. Vector data provide a way to represent the real-world as vector diagrams on maps (Sutton, *et al.*, 2009:9) Vector features have the following characteristics:

Firstly, all vector features can be represented using one or more points (vertices) describing the position in space. Each of the vertex's uses at least two axes (X, lines of latitude and the Y, line of longitude) and an optional third axis (Z or height above sea level) to indicate the feature's spatial position (Sutton *et al*, 2009:9).

Figure 20, below, provides an illustration of vector vertices with two and three reference points.



Based on the work Sutton *et al.*, 2009: 18, 24; Ormsby *et al.*, 2009: 5; Kennedy & Kopp, 2000: 25.

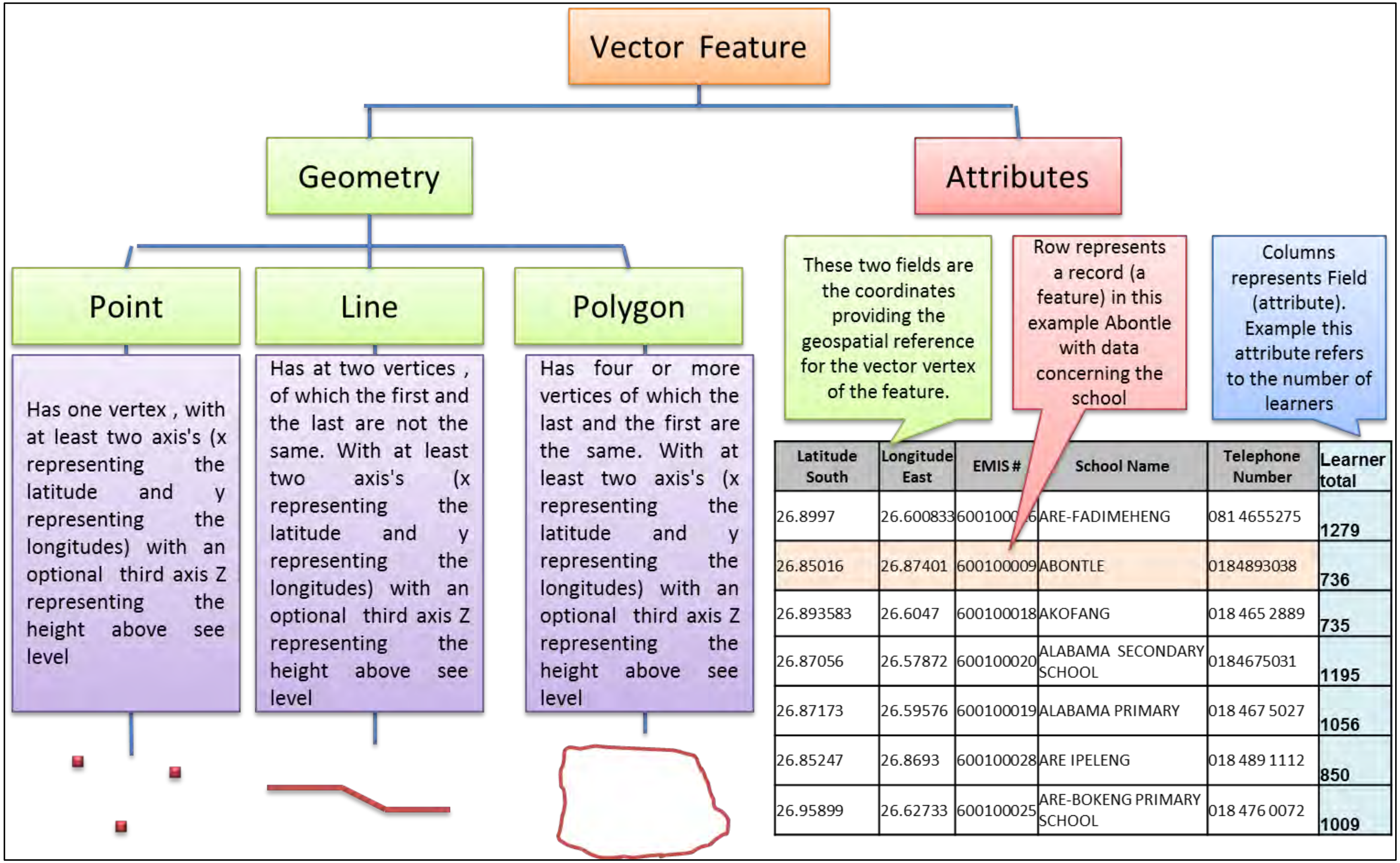
Figure 20: Vector vertex with two and three references.

When the geometry (See Figure 21) representing a feature is only one vertex it is a point, If the geometry consists of two or more vertices where the first and the last are not the same, it is a line. When the geometry consists of four or more vertices, with the last vertex the same as the first, it is an enclosed polygon; polygons can be squares, circular, spheroid, rectangular, etc.

Vector features have locations (Ormsby, 2009:4) that link the vector features to the real-world global position using a set of coordinates (X axis the latitudes and Y-Axis the longitudes).

Vector features are linked to data (numeric, alpha numeric and text) that provide information related to the feature (Ormsby, 2009:7; Sutton *et al.*, 2009:35-38) (See Figure 21).

The data in respect of the feature on the map are stored in a table, with a row known as the record for each feature, where each category of data (e.g., age, race, and gender) for the feature is arranged in columns or fields. The categories of data called fields in the table are the attributes of the feature (Ormsby, 2009:7; Sutton *et al.*, 2009:35-38) (See Figure 21).



Latitude South	Longitude East	EMIS #	School Name	Telephone Number	Learner total
26.8997	26.600833	6001000[illegible]6	ARE-FADIMEHENG	081 4655275	**1279**
26.85016	26.87401	600100009	ABONTLE	0184893038	**736**
26.893583	26.6047	600100018	AKOFANG	018 465 2889	**735**
26.87056	26.57872	600100020	ALABAMA SECONDARY SCHOOL	0184675031	**1195**
26.87173	26.59576	600100019	ALABAMA PRIMARY	018 467 5027	**1056**
26.85247	26.8693	600100028	ARE IPELENG	018 489 1112	**850**
26.95899	26.62733	600100025	ARE-BOKENG PRIMARY SCHOOL	018 476 0072	**1009**

Figure 21: Characteristics of vector features.

The type, and quality of spatially linked data sets are important in that these data sets must allow for all the levels of queries that are required for spatial analysis that will provide management supporting information and decision support information. The latter emphasises the need to consider the data and data sources that will be required to produce the necessary management support and decision support information in the early stages of systems development.

Features have spatial relationship, in that they are linked to vector vertices, this therefore enables spatial association with other objects on the map (features and surfaces) (Ormsby, *et al* , 2009:9). For example, this can be used, to highlight all buildings that could be in a new flood zone created by an expected change in the natural flow of water.

The spatial data discussed above is only one of the components of a GIS. The other remaining components that should be considered in the design of a GIS are outlined and discussed in the next paragraph.

4.5 GIS as an Information System

An information system involves the transformation of data (raw facts) into information, which is a collection of facts organized and processed so that they have value beyond the individual facts (Stair & Reynolds, 2011:5).

In a modern computer based information system, this process is achieved through the integrated and coordinated activities of six components (See Figure 22). The six components are people, data, software, hardware, telecommunication and procedures (Stair & Reynolds, 2011:5; GIMS, 2006:3; O'Brien & Marakas 2006:26; Davis & Olson, 1985:29-33).

As the aim of the system is to produce information for management and decision support, it is firstly necessary to distinguish between the data input into the process and information as the output of the process, and the role of the users' knowledge in effectively using the processed data, namely information.

4.5.1 Data

Data can be described as raw facts or observations about a physical phenomenon or an event (e.g. a business transaction). More specifically, data are objective measurements of attributes (characteristics) of entities such as people, places, things and events that have not been organised (Stair & Reynolds, 2011:5; O'Brien & Marakas 2006:554; Whitten *et al.*, 2004:758; Rob & Coronel, 2004: 6; Stair & Reynolds, 1999:666).

Data types include alphanumeric (numbers, letters and characters), date/time, currency, logic values, OLE (Object Linking and Embedding), visual, audio, video and hyperlinks (Stair & Reynolds, 2011:6; Rob & Coronel, 2004:754; Dowling, 2004:212).

Information can be described as processed data (value added data) that have been arranged in a meaningful context for the user in order to facilitate decision making (Stair & Reynolds, 2011:5; O'Brien & Marakas 2006:559; Dowling, 2004:216; Rob & Coronel, 2004:769; Whitten *et al.*, 2004:764). Data are stored in a database, which is a collection of logically related data elements organised to meet the need of the user or users. The database contains data elements describing elements (end user data) and data describing data characteristics and relationships (metadata) among entities (O'Brien & Marakas 2006:142; Rob & Coronel, 2004:763; Adamski & Finnegan, 2004:AC5; Dowling, 2004:6). The data in a relational database are represented as rows and columns in the form of a table (Dowling, 2004:20), where the rows are the records and the columns are the fields. The value of the information is the extent to which it helps decision makers to achieve organisation goals (Stair & Reynolds, 2011:12). It is a process of the user applying his/her knowledge to the provided data to enable the user to make informed decisions.

Knowledge in relation to information processing can be described as the awareness and understanding of an information set and how that set of information can be made useful to support a specific task. It includes diagnoses, describing, analysing, instructing, decision-making, planning and scheduling (Stair & Reynolds, 2004:671; Davis & Olson 1985:409).

4.5.2 People

The users and decision-makers are part of the human component of the system. People who form part of the system are the system users (managers, knowledge workers, and stakeholders) and information communication specialists, who include personnel responsible for the development, implementing maintaining and operating of the system (Stair & Reynolds, 2011:10). People therefore interact with hardware, software and telecommunication systems to access, capture, maintain and process data and interpret information, guided through a set of procedures.

4.5.3 Hardware

Hardware is the physical component of the system that performs input, processing and output activities. The hardware functioning is dependent on software (Stair & Reynolds, 2011:10). These are machines and media, physical equipment, mechanical, magnetic, electrical, electronic or optical devices (O'Brien & Marakas 2006:558). This includes main frame, desk tops, lap top, graphic tablets, hand held computers, printers, scanners, remote sensors, speech and finger print recognition systems, digital cameras, monitors, storage hardware, CD & DVD writers, memory sticks, GPS, etc. (O'Brien and Marakas 2006:68-97).

4.5.4 Software

Software enables hardware to process, store and communicate data (Stair & Reynolds, 2011:11). The software includes systems software that governs the operations (Windows, UNIX, Linux, Apple Mac) of the hardware and application software which enables the user to manipulate and process data and information,

Applications allow the computers to accomplish specific tasks. They include GIS, documentation (Microsoft Word, Star), presentation (Microsoft Power Point), relational database (Access, Oracle My SQL, Visual DBase), statistical and mathematical processing systems, enterprise management system (Oracle, SAPS), spread sheets (Lotus, Excel). Specialist software used during this study for processing of spatial information include Google Earth©, Global Mapper 12 ©, ArcGIS ©, Grass 6.4.1©, Map Windows GIS ©, Microsoft Virtual Earth ©, Quantum GIS © and Planet GIS ©.

4.5.5 Procedures

These are the strategies, procedures and rules for collecting, collating, verifying and processing data and for using the information system, including the operating and maintenance of the system (Stair & Reynolds, 2011:16).

4.5.6 Telecommunications

Telecommunication is that function of the information system that involves the transmission of signal over distances (in some cases extreme distances). Presently, the telecommunications are not only limited to the transmission of data, but can be used for images, video (streaming), sound, voice etc. It includes the use of wireless technologies, (Wi-Fi, terrestrial microwaves, radio and satellite transmissions), coaxial cables, fibre optics, etc. (O'Brien & Marakas 2006:567). It enables exchange of data/information and collaboration over long distances and between many users, who can be using different types of telecommunicating hardware, such as smart phone, cell phone, desktop, note book and palm top computers, electronic white boards, graphic pads, electronic sensors, satellite signals, etc. When designing, implementing and maintaining a GIS system it is necessary that all the components, there role, and ability to enhance the effectiveness of the systems are considered. The component mix, and ability must be that which will contribute most effectively to the systems output. The people component is a critical component, and strategies must be considered that will motivate, and enhance the abilities of the people involved to maintain a quality system that will assist in realising the goals of the organisation.

Figure 24, is a visual conceptualisation of the components that must be considered and utilised in enhancing the effectiveness of a GIS.

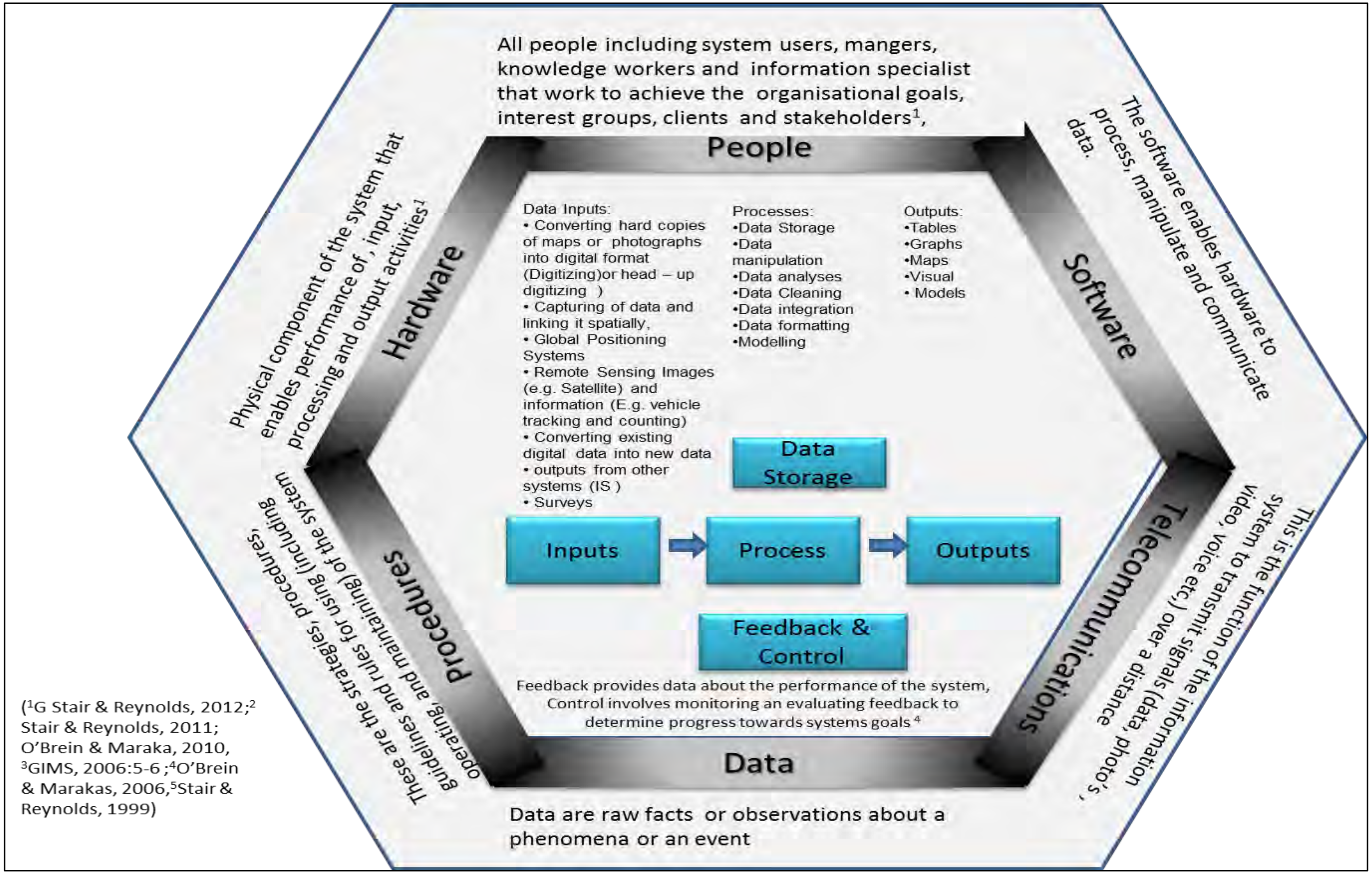


Figure 22: The components of a Geographic Information System.

The summary of the chapter is provided below.

4.6 Summary

A spatial information system provides a spatial representation of an object or event that occurs on the planet earth in a two-dimensional format. It is important to note that data, images, etc. can be linked to the object or event, although it is spatially represented in two dimensions. This will require that all data must have fields that will enable them to be linked to the spatial object.

As an information system, the components of the system must be considered at all times to ensure effectiveness and sustainability. These are the data, hardware, software, telecommunication, process and arguably the most important, the people (human) component.

As a system, it has a specific outcome to achieve, namely a spatial system that will enable the effective management of disaster risks and disasters.

The information therefore required for the system will be determined firstly, according to the output and outcomes the system must provide for, this includes disaster management and risk reduction, effective sustainability projects, Integrated Development Planning and Service Delivery Planning. Secondly, the data must enable the Tlokwe Local Municipality to monitor its progress towards complying with its Constitutional and legislative obligation. Thirdly, operational data that will enable the Tlokwe Local Municipality to effectively respond to any hazardous event or disaster must be considered and included, for example, the risk and vulnerability analysis. Fourthly, historical data and records of events (knowledge base) that will be required to enhance future operations and planning must be processed so that they can be used to enhance effective decision making and scenario planning.

Fifthly, the system must serve three purposes: as a strategic decision support system, as operational and tactical support system, and as a management information system for all generic levels of management, including, planning, leading, organising, control and communication. To prevent data redundancy and ensure data accuracy it should be integrated to existing systems, and finally the effective use of existing technology interfacing with the system must be considered.

In the next chapter the requirements for an effective conceptual model GIS for Disaster Risk Management by the Tlokwe Local Municipality in its municipal area are provided.