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A multi_Purpose Utility Model for Urban Areas in Northern Khartoum Using GIS

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Abstract

This paper presents the design and the development of a multi-purpose utility model for Northern Khartoum area using techniques of Geographical Information System (GIS). Moreover, the study aims to investigate and identify the operational development of systems employing integrated utility databases for facilities including water pipelines networks, sewerage network, electric networks, and telephone and telecommunication networks and roads services. The second goal is to establish multi-purpose utility model to aid management and development of future plans as well as providing a requisite accuracy in a multi-purpose utility model case by design and avoid errors which can be expensive.The methodology of this paper intends to establish a mutual global and a local datum base map comprising all utility services in the study area and to apply the GIS analysis techniques for the management and planning of these networks with the ultimate aim of achieving easy and fast operation, updating and maintenance of these networks. The paper concludes that a common control body such as National Geographical Information Committee should be established to maintain and manage the utility services network by using the multi-purpose utility model. The benefits of using this model system is feeding the exact location of problem and manage to solve the problem in the study area; then in the Khartoum state and all other states eventually.

Keywords: *The method of analysis used to select the ideal site of the utility networks is the spatial analysis methods. The benefits of using these methods are feeding the exact location of problem and manage to solve the problem in the study area.*

1. INTRODUCTION

The role of Geographical Information Systems (GIS) as a multi–purpose tool for making intelligent decisions based on integration of information encourages the adoption of GIS analysis techniques for the management and planning of the utilities and resources world–wide.[1] This is especially true of the ever- increasing developments made in principle in general and in the computer and its related peripherals together with the GIS application software, in particular.

The main objective of this paper is to design a successful model for such project starting from a conceptual model, through a logical model to a physical model. This project will also meet how to pave the way to a standard procedure for the national Geographical Information Systems (GIS) of the Sudan. To make use of these procedures and practices the area of northern Khartoum was taken as a sample of the study area.

For this chosen area the research was to develop, implement and test a multi-purpose utility model in urban areas and to investigate how it operates and what it lack. Also the research will create a standard to be implemented in other urban areas.

This paper attempts to contribute in solving major problems of multi- purpose utility model system in Northern Khartoum area in water supply, sewer, and electrical networks, and other street services.

The current utility system was designed for the older Khartoum to satisfy the needs of a much smaller population so; the depreciation of elements of services through use was the result. Also, no digital maps were available for this area. [2].

Several investigations and interviews which were carried out with the staff of Khartoum State Water Corporation (KSWC), pointed out the major problems of the network, which are caused by many factors such as:

a) Insufficient water supply in the summer season;
b) High water pressure in the pipes in the winter

season;
c) Technical specification of pipe materials;
d) Network design;
e) Maintenance and following-up problem;
f) Depreciation of materials; and
g) Data is presented on many scattered maps sometimes with some confliction…etc.

2. MATERIALS AND METHODS

2.1 Study area

In this paper, the base map of study area was selected. An urban area (Fig. 1) from general Khartoum map which was prepared by Dr. M. A. Gorani in 1980 and printed by Sudan National Survey Authority at a scale of 1:25000. An urban study area is demarcated by the Nile Avenue from the north, Alimam alhadi road from the south,the Armed forces bridge from the east and the white Nile bridge from the west.

The urban study area of (6.473) km^2 was selected is northern Khartoum area.

Utility services of study area are many but the most important five utilities which are considered to be the fundamental data set are:

- Roads;
- Water Network;
- Electrical Power lines and cables;
- Sewerage systems; and
- Telephone and telecommunication networks.

In the study area there are 14 streets running east / west and 25 streets running north / south. Because of its importance, it generates a great deal of concern all around the state and it had been developed and updated to cope with the rural and civil development.

Figure 1: Study area (Northern Khartoum).

2.2 Materials

Two major software packages (ArcGIS 9.3 and Microsoft excel) were employed for the processing and analysis of the paper results.

ArcGIS 9.3 software packages (ArcCatalog, ArcMAP) were used for the following:

- Database design and viewing metadata. (ArcCatalog).
- Mapping and editing tasks (ArcMap).
- Review all utility services on the study area (ArcMap).
- Creation of a digital model of these services and performing analysis (ArcMap).

2.3 Methodology

The methodology adopted in this paper may be summarized in the following:

- Data preparation (Data collection and input);
- Design a successful model of Northern Khartoum main utility services data;
- Processing of Northern Khartoum main utility services data.(See fig.2); and
- Assessment of Khartoum State Water Corporation (KSWC) problems.

2.3.1 Data collection and input

The basic components of the multi-purpose utility GIS model of study area are:

(a) Graphic data of Northern Khartoum which consists of the study area base map, water pipeline network, sewer line and drainage system network, electric supply network, Telephone networks, telecommunication network, and roads network.
(b) Attributes data of these networks;
(c) Software (ArcGIS 9.3, and AutoCAD version 2009);
(d) Hardware (Computer, Scanners, and plotters); an
(e) Decision-makers and the operator of the systems.

Different sources of data are used to update this map. The sources of updating this map include the followings:

1- Ikonos image 2006 multi-spectral 4m resolution.
2- 1:10000 Khartoum map 2007 provided by UNMIS GIS Unit Agency.
3- Free data provided by Arm map Explorer version 1.0B may-2009 and Google Earth pro version 4.2.

A sample of one layer after data collection and preparation for analysis tasks involved in preparing data for analysis include:

- Checking data quality (making sure the data is accurate and up-to-date).
- Automating data by digitizing, scanning, converting.
- Converting data to common formats.
- Defining coordinate systems.
- Projecting layers to a new coordinate system.
- Merging adjacent layers.

2.3.2 Design a successful model of Northern Khartoum main utility services data

One of the major objectives of this study is to design a conceptual model, through a logical model to a physical model. In this paper five utilities of network services for

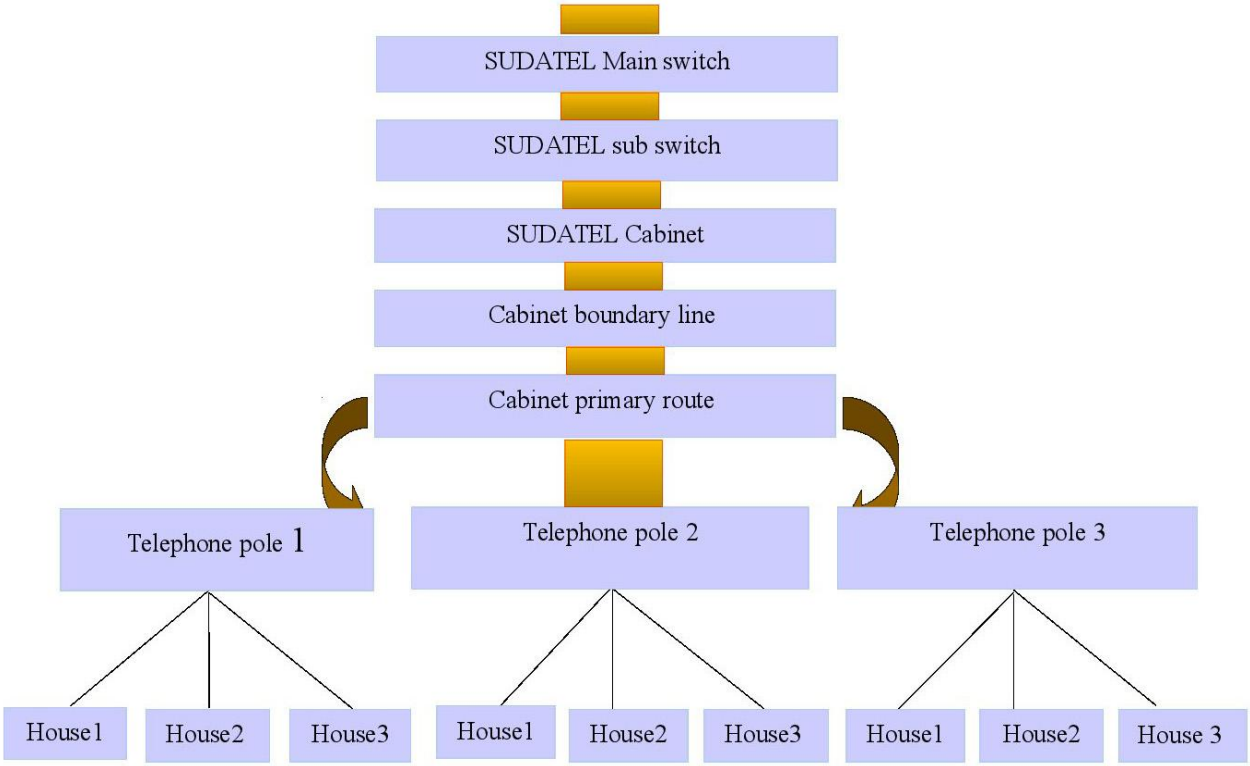

Figure 2: .The conceptual model of Entity Relationship diagram of Khartoum Telephone system.

the study area are modeled. These utilities are established through the conceptual, logical and physical models.

For example, Fig. 2 shows the conceptual model of Entity Relationship diagram of Khartoum Telephone system.

2.3.3 Processing of Northern Khartoum main utility services data

By on-screen digitization, the main project data were derived from different scales utility base maps of Northern Khartoum urban area which include:

(a) Topographic base map.
(b) Khartoum State Water Corporation (KSWC) base map, this map is prepared by (KSWC).
(c) Sudan telecommunication corporation (SUDATEL) base map, this is prepared by (SUDATEL).
(d) Sudan National Electricity Corporation (SNEC) Khartoum state base map, this is prepared by (SNEC).
(e) Khartoum Water and Services Company, drainage section base map, this is prepared by (Khartoum drainage section).

There are some methods for processing data such as scanning of graphic data, carrying out map transformation, transfer of data from raster to vector, display of building layers, editing digitizing errors, producing analytical geometry by topology and add attribute data to establishing multi purposes utility model of the study area. These methods are detailed in the following :

(1) Scanning Project Data.
(2) Georefrencing of Scanned Project Data.
(3) Map Transforming from Raster to Vector.
(4) Display of Building Layers.
(5) Data Editing and Quality Assurance.
(6) Adding attribute data.
(7) Integration between different layers to establish a multi-purpose utility model of study area.

Using ArcGIS9.3 digitizing facilities including the line command, the maps were converted into digitizer manually.

There are some drawing errors that occur in the process of scanning and tracing raster data. The expected errors which may occur are:

a. Small lines created due to smudges.
b. Under shoots incomplete lines or arcs.
c. Over shoots or excess parts of lines or arcs.
d. Duplicated lines.

The above mentioned errors should be topologically corrected before the analysis process is carried out. Fig.(3) shows a flow- chart diagram for the methodology of the research comprising data collection, database building, scanning, vectorization, editing, constructing topology, adding attribute data, analyzing data, laying out, and plotting.

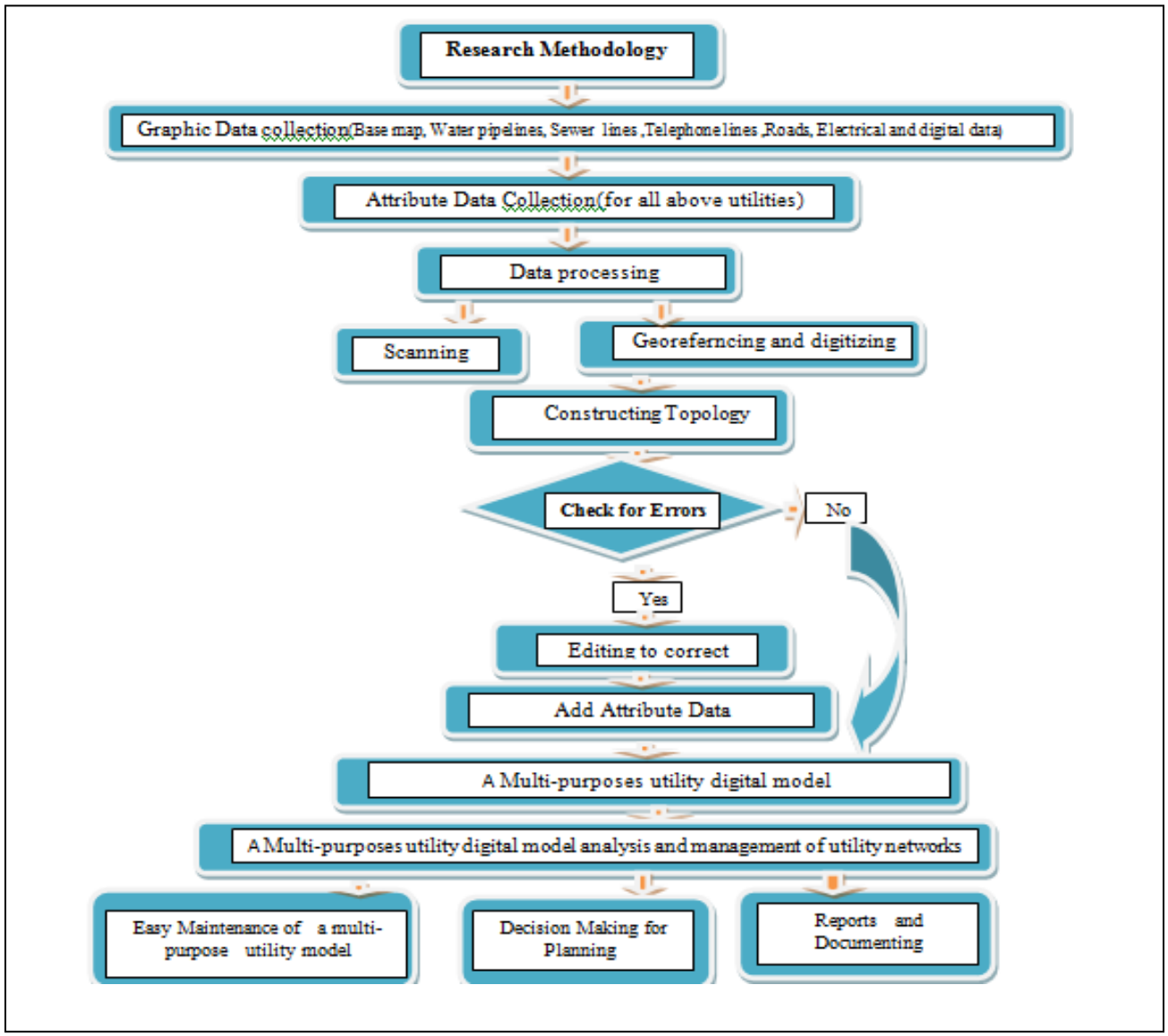

Figure 1: Paper methodology flow chart.

2.3.4 Assessment of Khartoum State Water Corporation (KSWC) problems

The case of Khartoum is one of the strangest cases, since its geographic location lies between two large rivers and at the same time subject to chronic water supply shortage. Surface water may be transmitted from remote areas to meet the large demand of a city located far from lakes or rivers.

The water sources in Khartoum State consist of two main types: surface (Rivers) and Sub-surface (boreholes). At present, in Khartoum centre sub-surface water is no more used. Sub-surface water sources are scattered in some local residential areas around the centre, with a total supply of 125000 m^3/day production. Table 1 show the supply of the five treatment plants, which indicates that the total supply of Greater Khartoum is 541000 m^3 /day. A proposed Water Treatment Plant (WTP) at Suba (south of Khartoum) is used to feed the network by 300000 m^3 /day. When this is finalized, the total supply will satisfy 80% of the real need. According to the feasibility study named as" Khartoum Area Water Project" conducted by Gannet Fleming Corddy and Carpenter Inc under financial Corporation of the world bank released in 1978-1979 (simply called "the 1979 study report"), the water demand was estimated as 165900 m^3/day in 1988. The population at that time was 995000. At the present, the population is estimated as 6.2 millions .The water demands is estimated as one million m^3/day, which signifies chronic water supply shortage in Greater Khartoum [3], [4].

The study report covered the analysis of existing facilities and forecasting the future water demand, establishment of project design criteria, preliminary design, cost estimate and financial planning with a minimum cost water supply target in the year 1993. After the 1979 study report, several studies were conducted for rehabilitation and / or expansion. (See Table 2 and Figures 4, 5).

Town	*plant*	*Establishment date*	*Total Capacity* m^3/day	*Supply area*
Khartoum	Burri (Blue Nile)	1922	18,000	Khartoum
	Mogran (Blue Nile)	1964	90,000	*Khartoum & Omdurman*
Khartoum North	Khartoum North Old (Blue Nile)	1952	11,000	*Khartoum North*
	Khartoum North New (Blue Nile)	1979	180,000	*Khartoum North & Omdurman*
Omdurman	Omdurman (River Nile)	1928	16,000	*Omdurman*
	Khartoum North New(Blue Nile)	1979	11,000	
Total Supply			326,000	

Table 1: Exiting treatment Plants.

Centre % Demand	Centre Demand m^3/day	Total State Demand m^3/day	Domestic Demand $m^3/capita/day$	Population of the centre of greater Khartoum area	Year
15.8%	167472	1,060,000	200	797250	2000
12.1%	182207	1,500,000	215	847476	2005
9.4%	207199	2,200,000	225	900866	2010
7.5%	239406	3,200,000	250	957622	2015
5.9%	279937	4,750,000	275	1,017,952	2020
4.6%	324625	7,000,000	300	1,082,083	2025

Table 2: An Estimation of water Demand in the years 2000-2025 for the study area

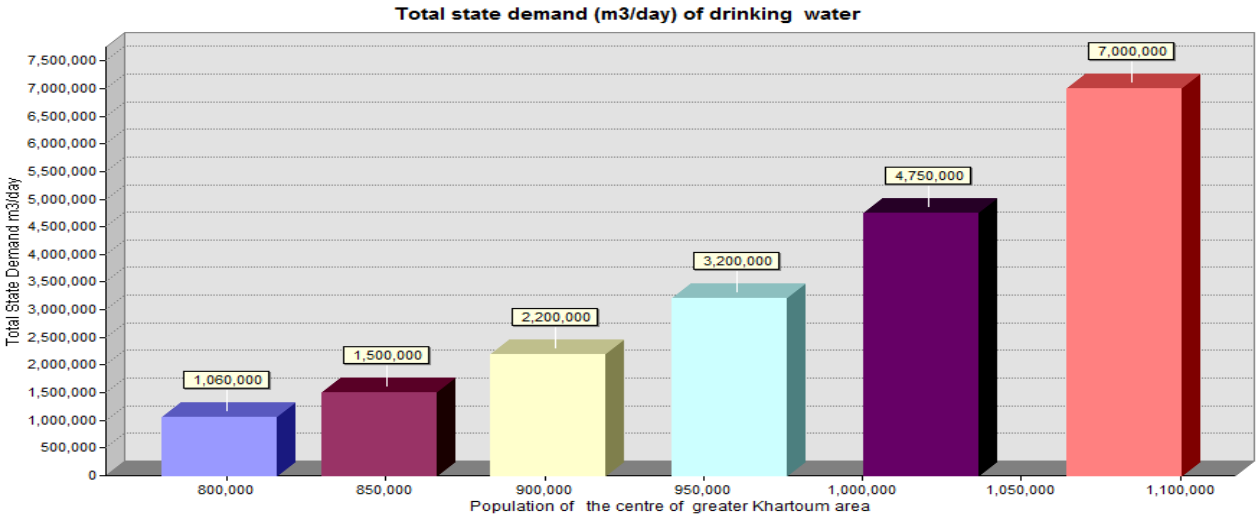

Figure 4: Total state demand of drinking water/ Population of the study area.

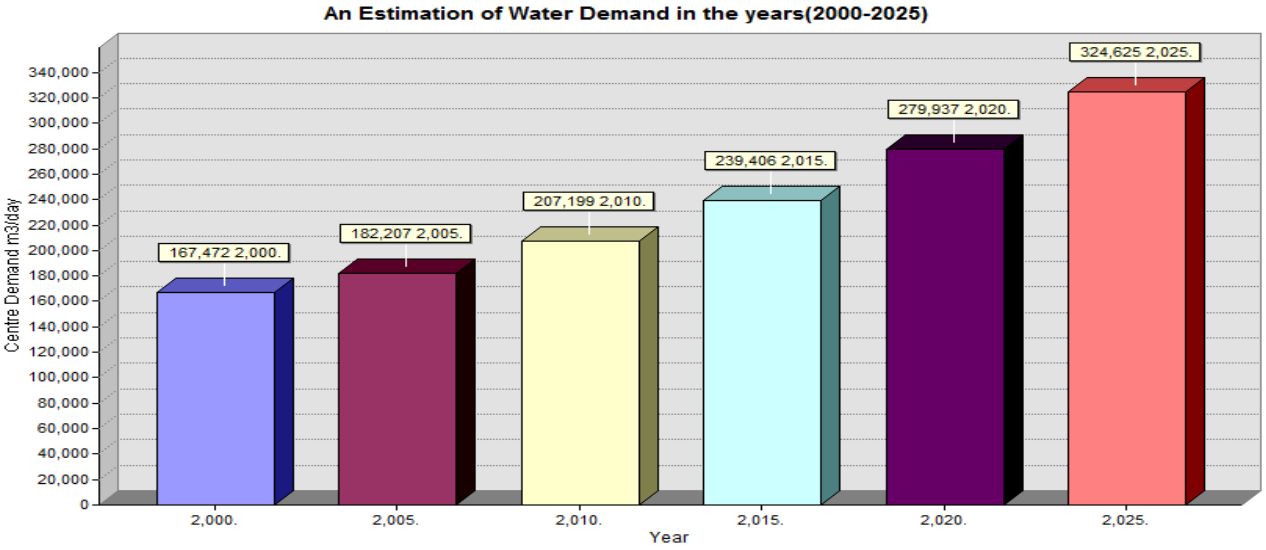

Figure 5: An Estimation of water Demand in the years 2000-2025.

Owing to the rapidly changing social situation, the Khartoum metropolitan area has witnessed many alterations after the study report was provided. The serious situation of the water supply system in the area was observed mainly because of insufficient supply capacity of the existing facilities.

3. RESULTS AND DISCUSSION

Analysis of geographic data is most important in GIS in order to answer the questions of the project requirements. Before commencing geographic analysis, one needs to assess the problem and establish an objective. The analysis requires step-by-step procedures to arrive at the conclusions. Actual problems which faced the researcher and were solved are:

(1) The main problem solved using this model was recording the graphics and attributes in digital form of northern Khartoum urban area.

(2) The GIS system will reduce the possibility of loss and damage of drawings and records of customer details, because the database will be in digital format. For these reasons, the customers can locate the site and reduce the time and total cost of maintenance Khartoum utility model.

(3) The digital model helps the decision–makers to print out reports and charts of analysis to make plans for the future.

(4) The present problems in Khartoum center in the sewerage network create a number of environmental problems like air, and water pollution and transmission of different diseases. After establishing this multi- purposes utility model, these problems were solved.

(5) The problems of the sewerage network and water pipelines network breakdowns while constructing new engineering projects because of the lack of as-built drawings can be solved by preparing updated maps, using the GPS (Global Position System) instrument RTK to establish a map showing the coordinates of start and end of the pipes. For example, we can use the digital model of these coordinates to avoid the problems of water network, pipelines, and telephone cable networking, electrical cable networking and sewer line networks. The engineers will take a map of the required area before leaving to the site.

(6) Most of the public services are found, with bad traffic jam especially during the peak hours. After using the Geographic Information System to analyze the data improvement to the routing and instituting policies will minimize the traffic jams in Khartoum streets Traffic Jams this problem is solved.

(7) The need for more education, all reputed schools and universities are placed in Khartoum, which leads to increase in the number of schools, universities and other collogues. All these aspects leads to bad traffic jam especially during the day time. After using the Geographic Information System to design small bridges in crowded junction roads this problem is solved.

In order to build a proper multi-purposes utility services database of northern Khartoum system it is essential to know all the component and feature of this utility. In this paper the basic component of Khartoum utility services distribution Network are to be stated. The other information related to Utility Information System (UIS), such as customer account can be fed to the system by specialist staff in each section according to their requirement, which is outside the scope of this study. The UIS should be flexible such that it can satisfy the needs of all sections of Khartoum utility companies, for more information about the system control and implementation. At the side the engineers can check and view data regarding the maintenance of study area of multi-purposes utility model such as the nearest water safety valve,

manhole, cabinet, overhead transformer, etc.

3.1 Setting up the Analysis

Analysis start by installing in the ArcCatalog, adds a new personal geodatabase, add a new datasets, and add a new topology or network data set. Then add command to analysis for digital model of Northern Khartoum urban area.

Geodatabase of Northern Khartoum area is established in Arc Catalog and ArcMap. Preparing data for analysis, one needs to reopen them and reopen the Khartoum multi-purposes project digital map. The digital map of study area includes the utility services, polygon, streets, and contours layers. The researcher added data from several locations during the analysis viewing the Catalog tree (see Fig. 6), navigate to and open the project folder so one can see the water pipelines layers, electrical area geodatabase. Open each subfolder and the geodatabase so that you can see the contents of each.

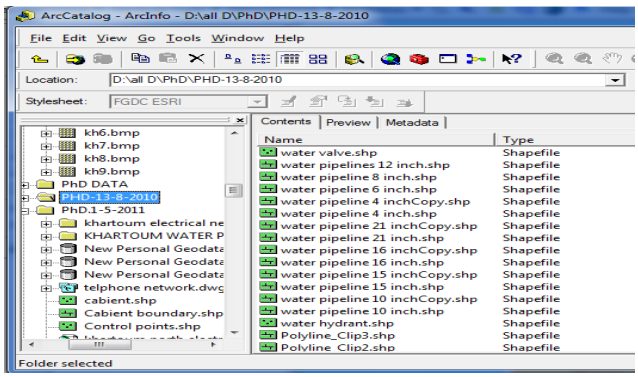

Figure 6: Arc Catalog tree.

Here are some examples of data manipulation and analyses are applied in Northern Khartoum urban area:

3.1.1 Delineating the Area the Plant Site should be within

One step of this phase of the analysis, a buffer should be created to delineate the areas the wastewater treatment plant should be within (i.e.areas within 300 meters of the river). In multi purposes utility model, a 300-meter buffer around the river is created by the researcher (see Fig.7)

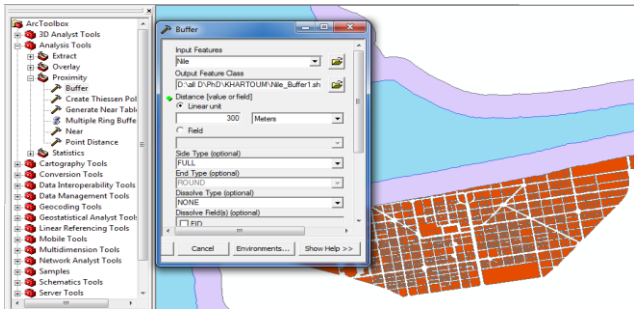

Figure 7: A 300-Meter Buffer around the River.

3.1.2 Finding the Water Pipeline (12inch diameter) that Intersect the Location of Roads

In this analysis, the Select by Location command is used to select water pipeline (12inch diameter) that intersect the roads layer. The selected water pipeline 12inch diameter is show in figure 8

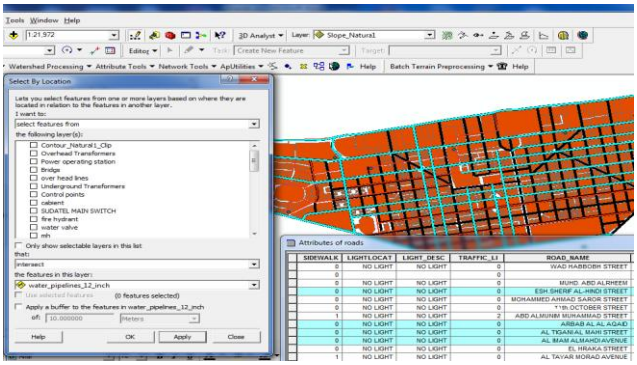

Figure 8: Select by location analysis command.

This system, which retains GIS data about Khartoum Water and sewer pipelines facilities and composed to add continuously maintenance data by the managers of the facilities. The system will enable the efficient and integrated management of the continuous maintenance data and will also enable a visual representation of the situation. These features will help to identify items which require inspection and will help with the establishment of maintenance plans.

Water and drainage leakage accidents of large-size pipelines caused a serious damage to the local communities including human lives, assets and agriculture. Since the number of pipes which have passed their working life span will increase in the future, it is challenging task to develop a method to establish optimum improvement plans for multi- purposes utility model facilities within a limited budget. Therefore, this study aims to establish a record management system in which maintenance data is continuously updated. This will support the development of maintenance plans for irrigation pipelines. This study also aims to develop a manual for establishing the system.

After adopting a computerized data base system many advantages are pointed below:

1) This system is composed of a database system and a series of programs for analysis and output of information which works on the ArcGIS produced by ESRI. The system enables the integrated management of locations and attributes of the facility required to establish the maintenance plans such as the facility specifications, the service life, the water hammer pressure, the designed flow volume, the failure rate distributions, etc.
2) Produce multi–purpose utility model of study area can show all changes in the frequency of

accidents and the repair costs by continuously recording the information about water and drainage leakage incidents, repairs, inspections and investigations. The system enables support for decision making on the timing of functional diagnostics at the facilities by monitoring changes in the facility's condition with time.

3) This system produces a program which can show a vertical cross-section view of the pipeline by selecting the pipeline on the map display screen. The vertical cross-section view can show the pipeline's vertical shape, hydrostatic pressure, water hammer pressure based on empirical rules, the places where water leakage incidents have occurred and the places where repairs, inspections and investigations have been conducted. It is also possible to understand the pressure distributions and the pipeline structure at each point.
4) The system using multi–purpose utility model of study area can show a vertical cross-section view of the pipeline by selecting the pipeline on the map display screen. The vertical cross-section view can show the pipeline's vertical shape and so on.
5) The system can operate in the pilot districts and a manual can be published to provide the directions. This will enable the system to be easily developed and also technical knowledge about GIS will not be necessary for the operation of the system.
6) Using multi–purpose utility model of study area can establish the accurate positions of the items of these networks, with respect to the national coordinates system.
7) This multi–purpose utility model system of study area can be operated with the ultimate aim of easy application land use for non-specialized persons.

Utilization of the results and points to be considered:

- The manual to develop the system and the developed programs can be provided to the land improvement districts which are in charge of the management of facilities and the related administrative departments.
- It is possible to produce and display more effective indicators for the establishment of functional maintenance plans by adding the layers of information from the functional diagnostics and the calculation results and cost.

4. CONCLUSIONS

The work presented in this paper gives a review of the important contributions of GIS Spatial Analysis (GIS-SA), GIS. Using modern information technology for analysis that enhances and make the process of planning easy. major aim is produced plans that will be useful to some users.

The tests carried out in the thesis investigated the possibility of applying GIS analysis techniques for multi-purpose utility model processes. The effort made in the thesis clearly revealed the potentiality of applying modern GIS analysis methods for a multi-purpose utility model in urban study area. Then nature of the source data was also considered. In this study the source data were existing hard copy maps which include:

(a) A base map of study area.
(b) Sewer lines map.
(c) Water pipelines map.
(d) Electrical network map.
(e) Telephone and telecommunication network map.

Digitizing the hard copy was carried out on screen using ArcGIS9.3 digitizing facilities.

Digitizing contributed significantly to the overall difficulties experienced in the project data capture and manipulation. There is no doubt that the validity of these tests would be increased and such difficulties would be less if data is available in a digital form.

The type of GIS system used should also be considered. In this study the tests were carried out using the user interface tools available in different GIS technology supporting programs. Moreover the validity of these tests would be increased if a multi-purpose utility model customized GIS and digital data base were adopted. The reason for this is twofold. Firstly, it is possible to share and exchange data between the different bodies supporting the multi-purpose system and secondly, there is a possibility of creating a multi- purpose digital data base to be used for different applications. Applications are varied such as site selection, operating and managing system, and presentation in specific location by graphs and histograms, plotting maps for site location, updating spatial and non-spatial data and applications in different fields and for different purposes. This saves the effort of the duplication of data capturing and manipulation and ensures a more integrated decision making process based on the integration of all the data layers related to the site selection decision process involved.

It is certain that the author had gained an enormous personal experience in conducting the investigation. The study has involved practical experience in digital data capture, manipulation, processing, and production of graphical output to assist in the analysis of results. Experience has also been gained in the understanding of the process of a multi-purpose system, in the creation of the base models and using many GIS application software's, such as Arc Map and ArcCatalog.

Taking into consideration the summary of the thesis above, the new tools, procedures and methodologies developed; the seven main findings of the study are:

- Current GIS need more modules in order to accomplish GIS-SA;
- Gathering of the functional requirement of the system to be modeled and developed by interviewing the

users and stakeholders; and

- ❖ Selection of database schema with appropriate data either directly or from the visual tool should be developed.
- ❖ Khartoum multi-purpose utility model is very easy to apply and also be used by non- specialized persons; and
- ❖ One official multi- purpose utility can be used by all utility authorities after verification in order to control the system, and keep it in tact.

The contributions to knowledge as a result of this research are:

(a) Development of spatial data analysis and network Analyst; and
(b) Digital Documentation of a methodology for Khartoum multi-purpose utility visualization in future.

The findings and contribution of this paper are applicable and useful to:

- GIS software developers as they seek to incorporate analysis functions.
- The multi-purpose utility model is very easy to use and is very useful for planners as they seek to ensure that activities do not conflict and help making the people live in harmony and in a healthy society.

Additional conclusions are:-

(a) The government should invest in base maps as no maps means no GIS; and
(b) There should be one organization for making base maps, distribute them to all users to ensure a common base; otherwise GIS operations will be extremely difficult.
(c) The study is concluded that the corporation is strongly in need of updating the old master plan, taking into consideration both the present and future conditions and the undertaking of feasible magnitude to be implemented within 5 years as the first stage program in the earliest possible date.

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