APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN NAIROBI CITY WATER AND SEWERAGE COMPANY

By

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A MANAGEMENT RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF BUSINESS ADMINISTRATION (MBA), SCHOOL OF BUSINESS, UNIVERSITY OF NAIROBI

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DECLARATION

This management research project is my original work and has not been presented to any college or institution for any degree.

Signed: ……………………………………….. Date: ………………………

Francis Wahome Maina **D61/73046/2009**

This research project has been submitted for examination with my approval as the university supervisor:

Signed: ………………………………. Date: ………………………

J.T. Kariuki

DEDICATION

My dedication goes to my wife, Essie for her unwavering understanding and support for allowing me to use part of my family time to carry out my studies.

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First and foremost I wish to thank the almighty God.

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ABSTRACT

Many companies are applying GIS based applications to improve efficiency in day to day operations. The main purpose of this research was to establish the application of Geographical Information Systems in the water sector. The study aimed at examining the extent of GIS usage with focus on the benefits realized and challenges experienced with the use of GIS.

A descriptive research design was adopted for this study. The target population constituted of ICT, Technical, Commercial, Finance and Human Resources staff at NCWSC. Convenience sampling was used to collect data from 57 staff of NCWSC. The questionnaires were mainly hand delivered to the respondents. The respondents were asked about the extent of GIS use in the company, benefits and challenges of using GIS.

The results show that most of the respondents were experienced with GIS and therefore had the necessary knowledge sought for. The interpretation drawn indicates there is a moderate extent usage of GIS. Further analysis revealed NCWSC has benefited from the GIS application. Some of the benefits include reduced errors in readings of water meters, quick response in determination of water pressure and quick response in identification of leaks. Despite the benefits, it was also found that there were several challenges encountered in the use of GIS. The major challenges included, inadequate IT training on use of GIS application, lack of capturing proper workflows across contributed by users and lack of efficient appropriate network to transfer large amount data from the field.

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LIST OF ABBREVIATIONS

CCN	–	City Council Nairobi
GIS	–	Geographic Information Systems
ICT	–	Information and Communication Technology
IS	–	Information Systems
IT	–	Information Technology
NCWSC	–	Nairobi City Water and Sewerage Company
WRMA	–	Water Resources Management Authority
WSB	–	Water Services Boards
WSD	–	Water and Sewerage Department
WSP	–	Water Services Provider

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

In the age of information technology, it is increasingly important for water utilities to improve their asset management tools and philosophies surrounding growth and maintenance issues. Using a targeted approach to the digitization of assets and mapping automation, rather than a paper map library sustained within individual departments, provides for a more centralized approach saving both time and money.

Over the past decade, there has been a rapid adoption of computerized management information systems for managing organizations information, gathering, processing, transfer and dissemination for feedback and decision making purposes in water companies. Since these systems are complex and require large investments and are object of ever increasing demands by the end-users, senior managers in water companies have become concerned about their value in business.

The Butler-Cox Foundation (1990) stated that obtaining value from Information Technology (IT) is probably one of the main concerns of business managers. According to them there is unfortunately no single measure that can be used to conclusively prove the business value of IT.

Mukhopadhyay, Kekre and Kalathur (1995) found that, in a study on the business value of IT, a great deal of controversy exists regarding the impact of IT on organizational performance. They noted that while some authors have reported positive impact, others have found negative or no impact. Investment in IT puts increasing pressure on managers to justify the outlay by quantifying the business value of IT, and that major investments in IT demand an analysis of costs and benefits plus strategic considerations.

The value of an information system to a business, as well as the decision to invest in any new information system, is, in large part, determined by the extent to which the system will lead to better management decisions, more efficient business processes, and higher firm profitability. Although there are other reasons why systems are implemented the primary purpose is to contribute to corporate value.

The water sector is faced with increasing pressure to demonstrate efficiency in the delivery of all its services. In order for these efficiencies to be achieved without compromising effectiveness, it is essential that the water sector should take advantage of new techniques, toolkits and technologies. Geographical Information system (GIS) is one such technology that undoubtedly has great potential. Water utilities represent a sector within which GIS could prove extremely beneficial; in fact it has a constructive role to play in local government Hill and Mc Connachie (2001).

The ability of GIS to analyse a water reticulation network for efficiency, and subsequently aid planners, decision makers and service technicians, by means of software such as a network analyst, can potentially transform an existing water reticulation system into an efficient one.

1.1.1 Geographic Information System

Rolf (2001) defines GIS as a computerized system that facilitates the phases of data entry, data analysis and data presentation, especially in cases when we are dealing with geo-referenced data; Robertson (2004) defines GIS as a computerized database management system for capture, storage, retrieval, manipulation, analysis and display of spatial (defined by location) data. Geographic Information System is a computerized database management system for spatial data that enable storage, retrieval, analysis and support of decision making. Spatial data means a figure that has coordinate (position) data and attribute.

GIS based applications are now becoming widespread in business especially in water utilities companies, playing a role that reflects both the similarity of GIS to other forms of IT. GIS may be used to assemble, store, manipulate, and display geographically referenced information (i.e. utility assets) identified according to their real world locations (Maguire, 1991). Combining database information, utility assets, and programming, GIS tools can form the basis for a targeted and detailed approach to distribute asset information in work-order applications with emphasis on up-to date maintenance and customer service.

In general GIS provide tools to enhance communication about water resource and supply, analyse water supply data, and integration with other enterprise systems like business applications, web services and messaging that add value to business processes through efficient operation and customer satisfaction.

The huge growth in the use of these applications has brought to the forefront the need for organizations to recognize, evaluate and measure the benefits as well as costs of investing in GIS (Obermeyer 1999; Maguire et al. 2007; Tomlinson2007).

Measuring and identifying business benefits of GIS is important to ensure it continues to support the organizations vision, strategy and objectives. Benefit measurements are often essential to support directors understanding and authorization of the need for continued investment or increases in expenditure. An independent survey found only 40 percent of enterprises measured its benefits contribution to the business. It was concluded that the failure to set measurable goals is severely impacting the value being derived from their IT infrastructure (Ann All, 2007).

1.1.2 The Nairobi City Water and Sewerage Company

According to the Nairobi City Water and Sewerage Company's (NCWSC) Strategic Business Plan 2007/8-2009/10, the company, was formed in line with the Water Sector Reforms under the Water Act 2002.

The Act which emphasizes the involvement of all stakeholders in the management and delivery of water services created new institutions to manage water resources in Kenya among them being the Water Resources Management Authority (WRMA), Water Services Regulatory Board (WSRB), Water Services Boards (WSB) and the Water Services Providers (WSP).

The company was formed to provide water and sewerage services to residents of Nairobi. NCWSC achieves its objective through proper utilization of available resources in a cost effective manner. Though fully owned by City Council of Nairobi (CCN), an independent board comprising of key stakeholders from Nairobi was appointed to run the company on commercial principles in line with the water Act, 2002.

Before the Water Act 2002 came into force, water and sewerage services in Nairobi were provided by the Water and Sewerage Department (WSD) of the City Council of Nairobi (CCN). The company faced a lot of challenges in its operations, among them being complaints from customers on erroneous bills and mismatch of water meters, inadequate data on the water systems infrastructure, incomplete or missing financial records and customers took long periods queuing for services at the various service points e.g. Payment offices. To address the challenges the company acknowledged the need to have GIS as one of key success factors to improve the organization performance. One way GIS has assisted is mapping routes and grouping of water meter into manageable clusters called Itineraries.

1.2 Statement of the problem

Establishing GIS technology requires a sizable initial investment which is not likely to be approved without solid demonstration of substantial potential benefits. A study by Karikari and Stillwell (2005) applied a model of cost-benefit analysis to empirically analyze the prospect of GIS in Ghana's Lands Commission Secretariat. The business goals were first identified and then all benefits from GIS were identified, culled, and prioritized. Their benefit value was compared to the organization's potential ability to meet the goals.

The investment and use of GIS is expected to give value despite the fact that benefits are often difficult to identify or quantify in monetary terms and can take years to materialize. In order to identify benefits, an organization must first identify all GIS-applications that it will develop (Lerner, 1994). Bastedo (2008) stated that GIS are enhancing business value, which includes understanding values related to place, customer, organization (revenue), shareholders, and brand. Andronikov (2008) states that GIS functionally is enhancing the business decision making process in many area of business, such as site analysis, market analysis, analysis of demand, supply chain management, risk management, and network routine modeling.

Although GIS has been applied in various functional areas, there is very little evidence to show its use in many water utilities. GIS has the potential to act as a central resource for water utilities; planning, distribution, operation and maintenance, customer information and with its ability to integrate different data for analysis it can help in making the water companies planning process more robust.

There has been a substantial progress in evaluating benefits and challenges of using GIS since the early 1990's, but no studies have established the benefits and challenges of GIS application in water utility. The study sought to provide answers to the following research questions: What benefits are derived from the GIS? What challenges are encountered in the usage of GIS? How is GIS applied in NCWSC?

1.3 Objectives of the study

The objectives of the study were to:

i. Establish the benefits realized with the use of GIS
ii. Determine the challenges of using GIS.
iii. Extent to which NCWSC is using GIS

1.4 Value of the study

The water companies may benchmark and obtain information on the business value of GIS in provision of water and challenges that hinder full benefits.

The government can use the findings from the study to assist in policy formulation and developments of a framework that explains measurement model of the business value of GIS.

The water regulatory authority and Water trust fund will have better policies for better benefits and challenges handling. Recognize the importance of funding the, company in matters of GIS technology and feedback represents a measure of feedback from the stakeholders.

In addition, the findings of this research will contribute to the growing knowledge on the applications of GIS in organizations, particularly in the water utilities and the wider GIS community.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Over the years many organizations have come to realize that GIS not only helps manage the existing utility infrastructure, but can also help aid in the design for future expansion (Shamsi 2002, Croswell 1991). The utility industry is a major consumer of GIS because of the fact that almost all utilities can be spatially referenced.

GIS is able to provide the utility organizations with endless amounts of information about their assets, whether it is spatial or non-spatial (Environmental Systems Research Institute, ESRI, 2003). Utility organizations spend a large amount of money and time on maintaining their infrastructures. By using GIS, these organizations are able to greatly reduce the amount of time and money involved on maintenance. Many of the organizations incorporate their work order and billing systems into the GIS, which saves even more time and resources. The organizations are able to use one system to effectively manage all their utilities.

GIS is an information integration vehicle with a tremendous range of uses. It becomes more powerful, and dramatically more cost effective, the more different types of information are available for integration. The main advantage of GIS, the possibility of integrating spatial and alphanumeric data, has made it widely applicable to a variety of fields (Trubint et al, 2006). Digital geographic information, once captured, can be used for many productive purposes. The key to effective GIS use being creation of mechanisms to share that data.

GIS has various characteristics that distinguish it from other technologies. The major feature is that GIS provides and brings the management's concern in sharing the data at deferent degree of inputting, processing and presenting these data.

The implementation of GIS is an innovation contributed to the organization, which require management commitment and corporate level consideration. Organization's strategies for managing Geographic Information Systems play a fundamental role in the success of the technology within or between the organizations (Somers, 1989).

2.2 Benefits of GIS

Review studies of GIS costs and benefits in the literature (Obermeyer and Pinto 1994; Obermeyer 1999; Huxhold and Levinsohn 1994; Pick 2005) provide an overview of categories, methods, and strategies to conduct GIS benefit analysis. Several authors described classification schemes for GIS benefits: Knepper (1990) tangible and intangible benefits; Born (1992) differentiates primary and secondary benefits; Prisley (1987) and Clarke (1991) efficiency, effectiveness and intangible benefits; Antenucci (1991) Type 1 to Type 5 benefits.

A main emphasis on external benefit can be found by Smith (1992). The benefits generally are more difficult to specify, and especially when intangible benefits are involved, it's not clear how these can be quantified. Part of the cost/benefit analysis will be on investigating these. GIS benefits may be classified based on four benefit categories used (Behr, 1994): benefits due to increased efficiency; operational benefits; strategic benefits; external benefits.

Benefits due to increased efficiency are considered the easiest to quantify (Prisley 1987): Increased efficiency in managing and evaluating data and information increases in efficiency results in reduced labour costs and associated with data activities. Parcel mapping with a GIS instead of hand drafting is a typical example of increased efficiency of GIS in water utilities. Doing more with less is another example of efficiency. It can be achieved by enhancement of productivity (Antenucci 1991).

Operational benefits correspond with capacity enhancements by higher human or technical resources. Operation benefits are to a great extent independent of the selected system. The benefits may include integration of technical calculations for project engineering, use of the same geographic database by different departments and increase in amount of data, information, and knowledge in the system, the scope and utility of documented database grows while standard interfaces for search and retrieval make it accessible to a larger audience. Enhancement to data quality by placing all data into a map-based environment, data is naturally integrated and visualized, highlighting discrepancies, and spurring new insights and more creative solutions.

Strategic benefits are highly correlated with the strategic goals of the organization. Decisions can be made with more confidence and conviction based on more and better information. GIS integrate spatial and attribute information to provide analytical and decision support capabilities (Longley et al. 2005; Pick 2008). Integrated, current data on water and climate, combined with spatial-data on distribution of resources and constraints, allows a multi-criteria optimization that all stakeholders can understand and agree on as the most reasonable decision.

External benefits accrue to others who are not directly using GIS. They may be harder to quantify but often have a lasting, long-term positive effect on a company. Providing a continuous link between internal and external clients and at the same time placing projects in are global context, improves communication and relevance, increasing chances for successful programs. A benefit analysis must consider all kinds of benefits whether they are accrued by the implementing organization itself or by potential additional users of the GIS products provided. Particularly in public agencies external benefits have to be taken more closely into consideration (Gramlich 1981, cit. by Wilcox 1990).

2.3 Challenges of using GIS

Various studies done on GIS evidently show that there are various types of barriers to GIS success and which are classified into technical and non-technical. The no-technical issues have been labeled, organizational and human dimensions, institutional barriers, political climate, interpersonal and resistance to change (Kanter, 1983; Somers, 1989; Anderson, 1991; Campbell, 1992; and Medyckyj-Scott and Hearnshaw, 1993). Avoidance of the Organizational and human dimension (Campbell, 1994) of technology transfer and innovation/adoption creates critical barriers to successful implementation. Various authors have identified institutional or organizational issues as critical dimensions of GIS technology-transfer effort (Anderson and Preecs 1989; Levinsohn 1989). Five issues critical to the effort are derived; people, organizations, goals, change and technology. People are the basic elements to organizations and they reflect the behavior and values of the people who form it. Organization problems, management, operational must be solved before the GIS can reach its full potential.

Review on GIS technology adoption and use specifically targets institutional and organization factors which influence possibilities for successful GIS technology-transfer and its beneficial use (Ventura, 1994). The success or failure of the technology-transfer effort relates to the failure to define goal (Korte, 1992). The creation of goals as benchmarks and guidelines for GIS implementation is important. Technology transfer unavoidably stimulates change in a way tasks are performed. As GIS implementation experiences are examined, the impact of change caused by technology-transfer activities is more frequently recognized and addressed. GIS technology supports real time and business sensitive applications. In these cases the availability of GIS applications becomes critical. To support these requirements, the technology teams are faced with supporting and designing the underlying infrastructure with appropriate relational database systems, application servers, terminal server technologies, synchronization system, storage systems and restoration technology. Another challenge to GIS technology is the difficulty to integrate GIS with users' own models (Goodchild, 1993). The difficulty is caused by incompatibility in data structures, data input and output, user interface, and capabilities of procedure communication. The use of GIS with other models is generally time consuming and costly. Both GIS and user models are under-utilized due to the absence of a bridge between them. There is a crucial need to integrate them at the operational level.

In the business context, visualization in GIS poses a challenge to interface designers to provide facilities that meet the problem representation needs of users, while also providing convenient ways of interacting with that representation. Computer interface design generally has yet to take full advantage of the increased power of computing and the richer set of possibilities that this offers for user interaction. The complex nature of spatial data requires GIS to use sophisticated visualization techniques to represent information. It is therefore quite challenging for GIS to also to provide an interactive interface on the same screen. However, GIS applications can especially benefit from better designed human-computer interfaces which meet their specific needs (Hearnshaw & Medyckyj-Scott, 1993).Obtaining the relevant data is a significant challenge.

Data used in GIS represents something about the real world at some point in time. They are always an abstraction of reality because not every bit of data would be useful (Aronof, 1995).Aspect of data quality; accuracy, precision, time, currency and completeness. Accuracy indicates how often, by how much and predictability of the correctness of data. Precision indicates the fitness of the scale with which data was described. Time indicates point when the data was taken and usually affect the quality of data. Current how recently the data was collected and completeness the portion of the area of interest for which data is available (Aronof 1995).

Winning political support and getting its blessing for future faster and more delightful GIS development must become prerequisite in success of using a GIS application. In the same time, familiarization of politicians and decision makers through user- friendly GIS interfaces can make easy and attractive task during political relies and later when they have to translate their policies and promises into real socio-economic and physical world. In her research Budic (1994) concludes that political support, which secures commitment to GIS implementation, is expected to correlate with more effective use of GIS technology.

The time component and length of experience with GIS in its future diffusion will also play a crucial role. Any GIS success can't be achieved instantly, without well trained and placement of staffing levels. After adjusting to an automated way of working, users can take a more creative approach exploring new ways of performing the old duties (Budic, 1994). A long way forward is something expected for all who intend to exploit a full range of GIS capabilities.

2.4 GIS Application

GIS technology is being widely used in many disciplines primarily because conventional database systems do not have any information related to the geographic location of the data in relation to data taken at different locations (Oloufa and Ikeda, 1995). GIS is applied in four sections of the water infrastructure sector: asset management, distribution management, customer and outage management (Brussels, 2005).

Asset management is the collection, processing, analysis and maintenance of extensive information about various types of assets such as equipment, facilities and other resources to plan work to be executed to maintain these assets at an operational level in the most cost-effective fashion possible (Lemer, 1998). In the water supply sector this is vital for providing uninterrupted services. However, water supply assets are mostly buried underground and can only be accessed after excavation (Babovic et al., 2002). Thus it is complicated to ascertain the status of these assets and has often led to unplanned disruption of services when systems abruptly breakdown. Often major excavations are done to replace or repair broken water assets disrupting transportation and smooth conduct of business.

The engineering group within a water utility is generally responsible for facility design, construction, and mapping. The maps served the purpose in three major areas: existing location of the system infrastructure, engineering aspects of the utilities and customer connections, and the overall network of the system for analysis (Environmental Systems Research Institute, ESRI, 2003).

In distribution management, GIS is applied in the entire lifespan of water supply systems from planning to implementation, operation and maintenance to replacement (Brussels, 2005). This is because GIS provides a variety of support in asset inventory, determining and prioritizing repair and replacement works and closing valves to redirect water flow. Through GIS, the direction of flows can be established to find upstream and downstream of points to optimize water pressure so as to identify an isolated part of a network. It is essential to create systems that motivate the use of GIS in managing water systems. The adoption of such a system has the potential to improve the quality of service. The data management and display capabilities of a GIS can be used to create manage and analyze any network. This makes feasible the use of network analysis in a variety of applications, such as a water and sewer reticulation system (Lupien et al, 1987). Water quality measurements can be included in the GIS, which allow for a better understanding of where water quality problems might exist (Dangermond, 2003).

The planning and management of water supply infrastructure requires combination of a wide range of knowledge from various dimensions such as technical aspect and environmental aspect (Arnold, 2008).A technical dimension of includes the water distribution system that forms the most extensive component in the water distribution network. The technical dimension of a water supply system may be conceptually considered to have five major components (Yehuda, 1997) which include: supply source works; treatment plant and pumping stations; transmission pipes; storage facilities reservoirs and distribution system.

2.5 Cost-benefit analysis

Cost-benefit analysis is essentially a framework for structuring the decision process to invest in a project. Attempts to develop such frameworks and apply them to GIS have been undertaken by Dickinson and Calkins (1988, 1990) and DeMers and Fisher (1991). The approach suggested by Dickinson and Calkins contains the central assumption that 'GIS products' can be defined and quantified though they acknowledge that this is often not possible and they suggest two approaches to supplement the basic model. The first of these – cost performance evaluation – relates the volume of output (where it is difficult to assign an economic value to that volume) to deliver the output. The second method suggested by Dickinson and Calkins (1988) identifies how unquantifiable benefits can be incorporated using risk analysis and the concept of derived demand. These techniques have been substantially criticized (Wilcox, 1990). Wilcox questioned Dickinson and Calkins assertion that the application to Cost Benefit Analysis to GIS evaluation involves situations too complex for the basic cost-benefit model (Dickinson and Calkins, 1988) and argued that 'there are few occasions where information (on cost benefits) is genuinely unavailable, either directly or by proxy'. In many instances in water companies, the benefits are articulated in non-financial terms.

2.6 Literature review Summary

The benefits of GIS, whether examined on the basis of economies or improved service, are compelling. Any plan for GIS will encounter difficulties and will require innovative action by the parties involved to champion its successful use and implementation. The benefits and challenges of using GIS should be regularly reviewed. It is also important to mention that if the implementation of GIS system doesn't follow proper and professional planning, operating and controlling procedures, it will lead to a useless system and eventually to cost wasting and bad impression. There is limited past research done in this area. There is need for further research and contribution in exploring the benefits and challenges of using GIS and its application and implementation part. For the benefits of GIS to be realized, the challenges have to be overcome.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology that was used to carry out the study. This chapter includes the research design, population, sampling procedure, data collection tools used and data collection technique, and data analysis method and presentation.

3.2 Research Design

Dooley (2007) defines a research design as the scheme, outline or plan that is used to generate answers to research problems. A survey research design was chosen in this study since not much has been done in this area. A descriptive approach aims at getting information that describes a situation, behavior, attitudes of the individual and the community. For this study, descriptive research was appropriate because it set to find out the benefit, challenges associated with extent of usage of GIS. This was in line with the purpose of the study.

3.3 Population

The target population comprised of the Technical, ICT, Commercial, Finance and Human Resources staff of NCWSC selected because they had the knowledge sought for. The total population for the purposes of this research at NCWSC was 116 staff according to Human Resources Directorate NCWSC 2012.

3.4 Sampling procedure

Convenience sampling method was adopted for this study. A sample size of a seventy four respondents was used. As per recommendation Yamane (1967), the following formula was applied in determination of the sample size.

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size, and e is the level of precision used with a ±7 % precision. In addition, proportional allocation was used to assign sample to a strata. Strata sample sizes were determined by the following equation:

nh = (Nh / N) * n

Where nh is the sample size for stratum h, Nh is the population size for stratum h, N is total population size, and n is total sample size.

Table 3.4: Strata of the population size

Stratum	**N_i**	**Sample size (n_i)**
ICT staff	25	16
Finance staff	8	5
Commercial Staff	25	16
Technical staff	50	32
Human Resources staff	8	5
Total	**116**	**74**

Source: Research Data 2012

3.5 Data Collection method

Data was collected by the use of questionnaire. Questionnaire was used as the primary data collection instrument. The questionnaire was pre-tested on appropriateness, structure and relevance of the questionnaire to the study.

The questionnaire was divided into four sections: Section A of the captured basic demographics information about the NCWSC. Section B captures the extent of GIS use, section C benefits and section D the challenges experienced while using GIS in NCWSC operations.

3.6 Data Analysis

The completed questionnaire schedules were checked for correct entries, errors and missing data. The questionnaires were further coded and entered into the Statistical Package for Social Sciences (SPSS) version 17 computer package for analysis. Descriptive statistics (frequencies and percentages) were used to analyze demographic information whereas factor analysis was used to analyze the other aspects of the study.

CHAPTER FOUR

DATA ANALYSIS, FINDINGS AND INTERPRETATION

4.1 Introduction

This chapter presents the analysis of data collected. Seventy questionnaires in total were administered but the researcher managed to obtain 57 completed questionnaires representing 81% response rate.

4.2 Study Findings

The study findings are presented as follows.

4.2.1 Distribution of respondents by department

Majority (47%) of the respondents were from the technical department followed by those from the commercial department at 23%. The findings are as presented in Table 4.2.1.

Table 4.2.1: Distribution of Respondent by Department

Department	Frequency	Percentage (%)
ICT staff	12	21.1
Finance staff	2	3.5
Commercial Staff	13	23
Technical staff	27	47.3
HR	3	5.3
Total	57	100.0

Source: Research Data 2012

4.2.2 Distribution of Respondent by duration worked in department

Respondents were further required to indicate the duration they had worked in their specific departments. Majority (44%) of the respondents indicated that they had worked in their respective departments for between 1-2 years. Those who had worked for between 3-5 years then followed at 32% as shown in Table 4.2.2.

Table 4.2.2: Distribution of Respondent by duration worked in department

Length of Time Worked	Frequency	Percentage (%)
Less than 1 year	5	8.8
1-2 years	25	44
3-5 years	18	31.6
Above 5 years	7	12.3
Non response	2	3.5
Total	57	100.0

Source: Research Data 2012

4.2.3 Extent of GIS Use

Respondents were required to indicate the extent to which GIS was used at NCWSC. Means of between 2.63 and 3.37 were registered from the analysis based on a Likert Scale of 1 to 5, where 1- To no Extent and 5 - To a very great extent. Based on the means one can conclude that improved mapping of customer meters with corresponding account numbers (3.37), efficient asset management (3.24) and improved new customer connections (3.12) were identified as the major ways in which GIS was extensively applied at the NCWSC. The findings are as presented in Table 4.2.3.

Table 4.2.3: Descriptive Statistics on Extent of GIS Use

Aspect	No extent (%)	Small(%)	Moderate (%)	Great(%)	Very great(%)	Mean	Std. Deviation
Improved mapping customer meters with corresponding account number	10.5	5.3	10.5	56.1	17.5	3.37	0.77
Efficient assets management	7	21.1	10.5	54.4	7	3.24	0.77
Improved new customer cconnections	10.5	15.8	31.6	31.6	10.5	3.12	1
Effective detection of pipe bursts in transmission lines	12.3	29.8	45.6	5.3	7	3.05	0.86
Improved mapping of customer accounts with the land parcel	3.5	42.1	29.8	14	10.5	3	1
Accurately capturing of water meter readings	14	31.6	33.3	10.5	10.5	2.9	1.04
Enhanced prioritizations of repair and replacement of water pipes work	19.3	21.1	29.8	15.8	14	2.88	1.23
Better determining locations of the existing water lines	5.3	38.6	12.3	12.3	31.6	2.68	1.15
Improved efficiency and enhance planning of water facilities	12.3	35.1	22.8	1.8	28	2.63	1.24

Source: Research Data 2012

Further, factor analysis was applied by comparing the pattern of correlations between observed measures. Measures that are highly correlated were likely to be influenced by the same factors while those that were uncorrelated were likely to be influenced by different factors. Factor analysis produced communalities of the variables which is the proportion of the variance that each item has in common with other items. Table 4.2.4 shows the communalities of the variables with extraction method being the Principal Component Analysis. The study findings revealed that over 94% of variance is experienced in enhanced prioritization of repair and replacement of water pipes works by GIS application at NCWSC. On the other hand 74% of variance is experienced in improved efficiency and enhanced planning of water facilities by GIS application at NCWSC.

Table 4.2.4: Communalities- Extent of GIS use

Extent of GIS use	Initial	Extraction
Enhanced Prioritizing of repair and replacement of water pipes works	1	0.948
Improved mapping of customer accounts with the land parcel	1	0.909
Accurately capturing of water meter readings	1	0.826
Effective detection of pipe bursts in transmission lines	1	0.815
Better determining locations of the existing water lines	1	0.801
Efficient assets management	1	0.796
Improved mapping customer meters with corresponding account number	1	0.786
Improved new customer connections	1	0.745
Improved efficiency and enhance planning of water facilities	1	0.74

Source: Research Data

Table 4.2.5 shows all the factors extracted from the analysis along with their Eigen values, the percent of variance attributable to each factor, and the cumulative variance of the factor. The study findings revealed that the first factor accounted for 64.5% of the variance and the second factor accounted for 17.4% of the variance. Cumulatively, the two factors accounted for 81.9% of the variance with regard to the extent of using GIS application at the NCWSC. All the remaining factors were statistically not significant.

Table 4.2.5: Total Variance Explained- Extent of GIS use

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.804	64.484	64.484	5.804	64.484	64.484	5.199
2	1.562	17.352	81.836	1.562	17.352	81.836	3.954
3	.561	6.236	88.072				
4	.452	5.023	93.095				
5	.245	2.723	95.818				
6	.182	2.026	97.844				
7	.107	1.193	99.037				
8	.055	.607	99.644				
9	.032	.356	100.000				

Source: Research Data

Table 4.2.6 shows the loadings of the nine variables on the two main factors extracted. The higher the absolute value of the loading, the more the factor contributes to the variable. Component 1 contained eight factors while component 2 contained one factor.

Table 4.2.6: Component Matrix- Extent of GIS Application

	Component	
	1	**2**
Better determining locations of the existing water lines	.876	
Improved mapping customer meters with corresponding account number	.876	
Effective detection of pipe bursts in transmission lines	.870	
Efficient assets management	.854	
Prioritizing repair and replacement of water pipes works	.815	
Improved efficiency and enhance planning of water facilities	.795	
Improved new customer connections	.780	
Accurately capturing of water meter readings	.708	
Improved mapping of customer accounts with the land parcel		.729

Source: Research Data

Component 1 comprised of better determination of locations of the existing water lines, improved mapping customer meters with corresponding account number, effective detection of pipe bursts in transmission lines, efficient assets management, prioritization repair and replacement of water pipes works, improved efficiency and enhance planning of water facilities, improved new customer connections and accurate capturing of water meter readings. Component two on the other hand comprised of improved mapping of customer accounts with the land parcel as shown in Table 4.2.7. This implied that variables in component 1 had more explanatory power in explaining extent of GIS use than that in component 2.

Table 4.2.7: Summary of factor loadings- Extent of using GIS

Factor	Variables
1	Better determining locations of the existing water lines Improved mapping customer meters with corresponding account number Effective detection of pipe bursts in transmission lines Efficient assets management Prioritizing repair and replacement of water pipes works Improved efficiency and enhance planning of water facilities Improved new customer connections Accurately capturing of water meter readings
2	Improved mapping of customer accounts with the land parcel

In general, factor one represents variables that have a greater application of GIS usage and factor two represents minimal application of GIS usage in mapping customer accounts with their land parcels at NCWSC.

4.2.4 Benefits of GIS

Respondents were required to indicate the benefits of using GIS at NCWSC. Means of between 2.52 and 4.03 were registered from the analysis based on a Likert Scale of 1 to 5, where 1- To no Extent and 5 - To a very great extent. Based on the means one can conclude that reduced errors in readings of water meters (4.03), Easy access to information (3.64) and Standard procedures in contracting new customers (3.48) were identified as the major benefits of using GIS at the NCWSC. The findings are as presented in Table 4.2.8

Table 4.2.8: Descriptive Statistics on benefits of using GIS

Benefits	**No extent (%)**	**Small Extent (%)**	**Moderate Extent (%)**	**Great Extent (%)**	**Very great Extent (%)**	**Mean**	**Std. Deviation**
Reduced errors in readings of water meters	10.5	21.1	22.8	31.6	14	4.03	1.1
Easy access to information	14	24.6	14	22.8	24.6	3.64	1.22
Standard procedures in contracting new customers	17.5	17.5	26.3	14	17.5	3.48	1.19
Quick response in determination of water pressure	1.8	15.8	28.1	33.3	21	3.36	1.22
Standardized interface for searches by location and data type	10.5	31.6	22.8	21.1	14	3.36	1.22
Reduced paper work in capturing customers queries	17.5	14	40.4	7	21.1	3.3	1.31
Quick response in identification of leaks	19.3	15.8	29.8	3.5	31.6	3.21	1.29
Reduced data entry	10.5	17.5	45.6	19.3	7	3.03	1.02
Reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewerage remains and manholes	14	24.6	40.4	7	14	2.94	1.25
Enhanced computing capabilities to wide range of users	14	56.1	15.8	14	7	2.94	1.25
Quick response in readings of water meters	28.1	17.5	22.8	17.5	14	2.88	1.32
Improved asset management planning on repairs undertaken	10.5	52.6	22.8	3.5	10.5	2.7	1.1
Reduced legal cases from false information to customers	24.6	38.6	19.3	10.5	7	2.52	1.23

Source: Research Data

Further, factor analysis was applied by comparing the pattern of correlations of between observed measures. Measures that are highly correlated were likely to be influenced by the same factors while those that were uncorrelated were likely to be influenced by different factors. Factor analysis produced communalities of the variables which is the proportion of the variance that each item has in common with other items. Table 4.2.9 shows the communalities of the variables with extraction method being the Principal Component Analysis. The study findings revealed that over 95% of variance is experienced in quick response in determination of water pressure as a benefit of using GIS application at NCWSC. On the other hand 73% of variance is experienced in standard procedures in contracting new customers as a benefit of using GIS application at NCWSC.

Table 4.2.9: Communalities- Benefits of using GIS

Benefits	**Initial**	**Extraction**
Standardized interface for searches by location and data type	1	0.957
Reduced paper work in capturing customers queries	1	0.933
Improved asset management planning on repairs undertaken	1	0.932
Reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewer remains and manholes	1	0.923
Quick response in determination of water pressure	1	0.905
Quick response in readings of water meters	1	0.905
Reduced errors in readings of water meters	1	0.865
Reduced data entry	1	0.854
Reduced legal cases from false information to customers	1	0.85
Enhanced computing capabilities to wide range of users	1	0.845
Quick response in identification of leaks	1	0.774
Easy access to information	1	0.756
Standard procedures in contracting new customers	1	0.73

Source: Research Data

Table 4.2.10 shows all the factors extracted from the analysis along with their Eigen values, the percent of variance attributable to each factor, and the cumulative variance of the factor and the previous factors. The study findings revealed that the first factor accounted for 65.86% of the variance, the second factor accounted for 12.64% of the variance and the third factor accounted for 7.9%. Cumulatively, the three factors accounted for 86.4% of the variance with regard to the benefits of using GIS application at the NCWSC. All the remaining factors were statistically not significant.

Table 4.2.10: Total Variance Explained- Benefits of using GIS

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	8.562	65.863	65.863	8.562	65.863	65.863	6.909
2	1.643	12.636	78.498	1.643	12.636	78.498	6.158
3	1.026	7.896	86.394	1.026	7.896	86.394	4.515
4	.627	4.820	91.214				
5	.430	3.310	94.524				
6	.320	2.460	96.983				
7	.182	1.401	98.384				
8	.113	.868	99.252				
9	.064	.490	99.742				
10	.031	.241	99.983				
11	.002	.017	100.000				
12	1.312E-16	1.009E-15	100.000				
13	-9.238E-16	-7.106E-15	100.000				

Source: Research Data 2012

Table 4.2.11 shows the loadings of the thirteen variables on the three factors extracted. The higher the absolute value of the loading, the more the factor contributes to the variable. Component 1 contained nine factors, component 2 contained three factors and component 3 contained one factor.

Table 4.2.11: Component Matrix- Benefits of using GIS

	Component		
	1	**2**	**3**
Quick response in readings of water meters	.870		
Reduced errors in readings of water meters	.865		
Reduced data entry	.852		
Enhanced computing capabilities to wide range of users	.824		
Improved asset management planning on repairs undertaken	.823		
Reduced legal cases from false information to customers	.820		
Standardized interface for searches by location and data type		.520	
Standard procedures in contracting new customers	.805		
Easy access to information	.789		
Quick response in identification of leaks	.786		
Quick response in determination of water pressure		.560	
Reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewer mains and manholes		-.504	
Reduced paper work in capturing customers queries			.582

Source: Research Data 2012

Component 1 comprised of quick response in readings of water meters, reduced errors in readings of water meters, reduced data entry, enhanced computing capabilities to wide range of users, improved asset management planning on repairs undertaken, reduced legal cases from false information to customers, standard procedures in contracting new customers, easy access to information and quick response in identification of leaks. Component two comprised of standardized interface for searches by location and data type, quick response in determination of water pressure and reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewer mains and manholes. On the other hand component 3 comprised of reduced paper work in capturing customers queries as shown in Table 4.2.12. This implied that variables in component 1 had more explanatory power in explaining the benefits of GIS use than those in component 2 and component 3.

Table 4.2.12: Summary of factor loadings- Benefits of using GIS

Factor	Variables
1	Quick response in readings of water meters Reduced errors in readings of water meters Reduced data entry Enhanced computing capabilities to wide range of users Improved asset management planning on repairs undertaken Reduced legal cases from false information to customers Standard procedures in contracting new customers Easy access to information Quick response in identification of leaks
2	Standardized interface for searches by location and data type Quick response in determination of water pressure Reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewer mains and manholes
3	Reduced paper work in capturing customers queries

In general, factor one represents variables that explain more on the benefits realized from GIS application at the NCWSC. The second and third factors represent variables that explain less on the benefits realized from the application of GIS at the NCWSC.

4.2.5 Challenges of Using GIS

Respondents were required to indicate the extent to which GIS was used at NCWSC. Means of between 2.81 and 4.05 were registered from the analysis based on a Likert Scale of 1 to 5, where 1- To no Extent and 5 - To a very great extent. Based on the means one can conclude that inadequate IT training on use of GIS application (4.05), lack of capturing proper workflows across contributed by users (3.93) and lack of proper network connection to transfer large amount of data (3.76) were identified as the major challenges in using GIS at the NCWSC. The findings are as presented in Table 4.2.13.

Table 4.2.13: Descriptive Statistics on challenges of using GIS

Benefits	No extent (%)	Small Extent(%)	Moderate (%)	Great Extent(%)	Very great (%)	Mean	Std. Deviation
Inadequate IT training on use of GIS application	10.5	10.5	14	36.8	31.6	4.05	0.99
Lack of capturing proper workflows across contributed by users	17.5	3.5	26.3	31.6	21.1	3.93	0.87
Lack of proper network connection to transfer large amount of data	10.5	14	26.3	31.6	17.5	3.76	1.03
Lack of data integration with technical tools	7	22.8	8.8	42.1	19.3	3.76	0.9
Inadequate experienced experts in GIS	22.8	7	10.5	38.6	21.1	3.71	1.04
Lack of systems integration with existing systems	8.8	22.8	7	54.4	7	3.61	0.94
Unexpected technical problems due to incomplete implementation	17.5	12.3	21	47.4	1.8	3.5	0.89
Inadequate funds and high cost of producing spatial data	7	24.6	15.8	49.1	0	3.5	0.74
Lack of top management support in decision making	7	10.5	14	36.8	31.6	3.48	1.31
Lack of suitable infrastructure for capturing geo-based data	0	29.8	31.6	17.5	21.1	3.45	0.99
Strong resistance to change in introducing technology	7	36.8	8.8	15.8	31.6	3.43	1.43
High software costs in data loggers	8.8	31.6	21.1	26.3	12.3	3.4	1.08
Lack of technical support from GIS partners	14	14	31.6	26.3	7	3.29	1.02
Lack of defined standard and procedures to determine the cost of GIS projects	10.5	12.3	35.1	35.1	7	3.24	0.88
High cost of field equipment	14	15.8	40.4	22.8	7	3.17	0.93
Lack of copyright law in data handling	24.6	17.5	26.3	10.6	21.1	3.07	1.24
Negative staff attitude towards the use of GIS application	15.8	31.6	21.1	31.6	0	2.81	0.97

Source: Research Data 2012

Further, factor analysis was applied by comparing the pattern of correlations between observed measures. Measures that were highly correlated were likely to be influenced by the same factors while those that were uncorrelated were likely to be influenced by different factors. Factor analysis produced communalities of the variables which is the proportion of the variance that each item has in common with other items. Table 4.2.14 shows the communalities of the variables with extraction method being the principal component analysis. The study findings revealed that over 95% of variance is experienced in high software costs in data loggers as a challenge of using GIS application at NCWSC. On the other hand, 76% of variance is experienced in high cost of field equipment as a challenge of using GIS application at NCWSC.

Table 4.2.14: Communalities- Challenges of using GIS

Challenges	Initial	Extraction
High software costs in data loggers	1	0.958
Inadequate funds and high cost of producing spatial data	1	0.914
Lack of defined standard and procedures to determine the cost of GIS projects	1	0.901
Unexpected technical problems due to incomplete implementation	1	0.892
Inadequate IT training on use of GIS application	1	0.891
Inadequate experienced experts in GIS	1	0.885
Lack of top management support in decision making	1	0.883
Lack of data integration with technical tools	1	0.854
Lack of capturing proper workflows across contributed by users	1	0.852
Lack of suitable infrastructure for capturing geo-based data	1	0.85
Lack of technical support from GIS partners	1	0.837
Lack of copyright law in data handling	1	0.833
Strong resistance to change in introducing technology	1	0.833
Negative staff attitude towards the use of GIS application	1	0.83
Lack of systems integration with existing systems	1	0.813
Lack of proper network connection to transfer large amount of data	1	0.766
High cost of field equipment	1	0.758

Source: Research Data

Table 4.2.15 shows all the factors extracted from the analysis along with their Eigen values, the percent of variance attributable to each factor, and the cumulative variance of the factor and the previous factors. The study findings revealed that the first factor accounted for 31.1% of the variance, the second factor accounted for 18.8% of the variance, the third factor accounted for 12.9% of the variance, the fourth factor accounted for 8.9% of the variance, the fifth factor accounted for 7.4% of the variance and the sixth factor accounted for 6.4% of the variance. Cumulatively, the six factors accounted for 85.6% of the variance with regard to the challenges of using GIS application at the NCWSC. All the remaining factors were statistically not significant.

Table 4.2.15: Total Variance Explained- Challenges of using GIS

	Initial Eigen values			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.285	31.089	31.089	5.285	31.089	31.089
2	3.200	18.826	49.915	3.200	18.826	49.915
3	2.193	12.901	62.816	2.193	12.901	62.816
4	1.518	8.928	71.745	1.518	8.928	71.745
5	1.265	7.444	79.189	1.265	7.444	79.189
6	1.088	6.399	85.588	1.088	6.399	85.588
7	.690	4.059	89.646			
8	.676	3.976	93.623			
9	.437	2.573	96.195			
10	.215	1.267	97.462			
11	.199	1.168	98.630			
12	.144	.844	99.474			
13	.069	.409	99.883			
14	.020	.117	100.000			
15	3.710E-16	2.182E-15	100.000			
16	9.109E-17	5.358E-16	100.000			
17	-1.487E-16	-8.749E-16	100.000			

Source: Research Data

Table 4.2.16 shows the loadings of the seventeen variables on the six main factors extracted. The higher the absolute value of the loading, the more the factor contributes to the variable. Component 1 contained seven factors, component 2 contained six factors, component 3 contained one factor, component 4 contained one factor, component 5 contained one factor and component six contained one factor.

Table 4.2.16: Component Matrix - Challenges of GIS Application

	Component					
	1	2	3	4	5	6
Unexpected technical problems due to incomplete implementation	.856					
Inadequate funds and high cost of producing spatial data	.748					
Lack of top management support in decision making	.617					
High cost of field equipment	.606					
Lack of defined standard and procedures to determine the cost of GIS projects	.599					
Lack of data integration with technical tools	.575					
Lack of capturing proper workflows across contributed by users		.801				
Lack of copyright law in data handling		.718				
Lack of proper network connection to transfer large amount of data		.606				
Lack of suitable infrastructure for capturing geo-based data		.571				
Strong resistance to change in introducing technology		-.552				
Lack of systems integration with existing systems		.515				
Inadequate IT training on use of GIS application			.799			
Inadequate experienced experts in GIS				.607		
Lack of technical support from GIS partners					-.477	
Negative staff attitude towards the use of GIS application						-.416

Source: Research Data

Component 1 comprised of unexpected technical problems due to incomplete implementation, inadequate funds and high cost of producing spatial data, lack of technical support from GIS partners, lack of top management support in decision making, high cost of field equipment, lack of defined standard and procedures to determine the cost of GIS projects and lack of data integration with technical tools. Component 2 comprised of lack of capturing proper workflows across contributed by users, lack of copyright law in data handling, lack of proper network connection to transfer large amount of data, lack of suitable infrastructure for capturing geo-based data, strong resistance to change in introducing technology and lack of systems integration with existing systems. Component three comprised of inadequate IT training on use of GIS application. Component four comprised of inadequate experienced experts in GIS. Component five comprised of lack of technical support from GIS partners and component six comprised of negative staff attitude towards the use of GIS application as shown in Table 4.2.17. This implied that variables in component 1 had more explanatory power in explaining the challenges of using GIS application than components 2,3,4,5 and 6.

Table 4.2.17: Summary of factor loadings- Challenges of using GIS

Factor	**Variables**
1	Unexpected technical problems due to incomplete implementation Inadequate funds and high cost of producing spatial data Lack of top management support in decision making High cost of field equipment Lack of defined standard and procedures to determine the cost of GIS projects Lack of data integration with technical tools
2	Lack of capturing proper workflows across contributed by users Lack of copyright law in data handling Lack of proper network connection to transfer large amount of data Lack of suitable infrastructure for capturing geo-based data Strong resistance to change in introducing technology Lack of systems integration with existing systems
3	Inadequate IT training on use of GIS application
4	Inadequate experienced experts in GIS
5	Lack of technical support from GIS partners
6	Negative staff attitude towards the use of GIS application

In general, factor one represents variables that explained more on the challenges faced on GIS application at the NCWSC with unexpected technical problems due to incomplete implementation being the greatest challenge and lack of data integration with technical tools being the least challenge in factor one. Lack of capturing proper workflows contributed by users was the greatest challenge faced in factor two and lack of systems integration with existing systems was the least challenge in that factor. Factors 3,4,5,and 6 represent variables that explain less on the challenges faced from the application of GIS at the NCWSC.

CHAPTER FIVE

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the study, discussions and conclusions. The researchers then present the major limitations of the study and the recommendations for both the research and for the policy and practice.

5.2 Summary

The researcher administered 70 questionnaires in total but the researchers managed to obtain 57 completed questionnaires representing 81% response rate. The questionnaires contained questions that addressed the objectives of the study. The research sought to establish the application of GIS at the NCWSC. The research was guided by the following specific objectives; extent to which NCWSC is using GIS, the benefits realized with the use of GIS and the challenges of using GIS.

5.3 Discussions

The discussions were guided by the study objectives as follows:

5.3.1 Extent of GIS Use

For objective one, respondents were required to indicate the extent to which the NCWSC used GIS in its operations based on specific areas. The key areas of operation ranged from improved mapping of customer accounts with the land parcel; effective detection of pipe bursts in transmission lines; efficient asset management; improved mapping customer meters with corresponding account number; accurate capturing of water meter readings; prioritizing repair and replacement of water pipes works; improved new customer connections, better determining location of existing water lines and improved efficiency and enhanced planning of water facilities.

Respondents were categorical that Improved mapping of customer meters with corresponding account numbers, efficient asset management and improved new customer connections were identified as key areas where the use of GIS was used to a great extent. It is clear from the research findings that the use of GIS at the NCWSC was to a moderate extent.

Oloufa and Ikeda (1995) argue that GIS technology is being widely used in many disciplines primarily because conventional database systems do not have any information related to the geographic location of the data in relation to data taken at different locations, GIS is applied in four sections of the water infrastructure sector: asset management, distribution management, customer and outage management. The study findings revealed that the extent of GIS use at the NCWSC would be categorized in the four broad sections in line with existing literature.

5.3.2 The Benefits Realized With the Use of GIS

For objective two, respondents rated thirteen benefits realized as a result of using GIS in operations at the NCWSC. The thirteen benefits included: quick response in determination of water pressure, reduced errors in readings of water meters, quick response in identification of leaks, reduced manpower to track the condition and maintenance history of assets, standard procedure in contracting new customers, cost effective to on-line drawings and maps, reduced paper work in capturing customers queries, easy access to information, reduced data entry, standardized interface for searches by location and data type, reduced legal cases from false information to customers, improved asset management planning on repairs undertaken and enhanced computing capabilities to wide range of user. However, respondents were categorical that reduced errors in readings of water meters, quick response in determination of water pressure and quick response in identification of leaks were the major benefits as a result of using GIS at the NCWSC.

Prisley (1987), contend that benefits due to increased efficiency are considered the easiest to quantify. Increased efficiency in managing and evaluating data and information increases in efficiency results in reduced labour costs and associated with data activities. Parcel mapping with a GIS instead of hand drafting is a typical example of increased efficiency of GIS in water utilities. It can be achieved by enhancement of productivity.

The use of GIS leads to operational benefits (Antenucci 1991), strategic benefits (Longley et al. 2005; Pick 2008) and external benefits (Gramlich 1981, cit. by Wilcox 1990).The study findings revealed that they were similar with those found elsewhere in the literature review.

5.3.3 The Challenges of Using GIS

For objective three, eighteen challenges were identified as key challenges experienced during the use of GIS at the NCWSC. They ranged from: lack of suitable infrastructure for capturing geo-based data, lack of top management support in decision making, inadequate IT training on use of GIS application, lack of capturing proper workflows across contributed by buyers, lack of systems integration with existing systems, high software costs in data loggers, lack of technical support from the GIS partners, unexpected technical problems due to incomplete implementation, negative staff attitude towards the use of GIS projects, high costs of field equipment, lack of data integration with technical tools, lack of copyright law on in data handling, inadequate experienced experts in GIS and strong resistance to change in introducing technology. Respondents unanimously agreed that inadequate IT training on use of GIS application, lack of capturing proper workflows across contributed by users and lack of proper network connection to transfer large amount data were identified as the major challenges. Kanter, 1983; Somers, 1989; Anderson, 1991; Campbell, 1992; and Medyckyj-Scott and Hearnshaw (1993) argue that there are various types of barriers to GIS success and which are classified into technical and non-technical. The no-technical issues have been labeled: organizational and human dimensions, institutional barriers, political climate, interpersonal and resistance to change.

Elsewhere, (Anderson and Preecs 1989; Levinsohn 1989) argues that avoidance of the Organizational and human dimension (Campbell, 1994) of technology transfer and innovation/adoption creates critical barriers to successful implementation. Various authors have identified institutional or organizational issues as critical dimensions of GIS technology-transfer effort. The findings of this research are in agreement with the existing literature findings as revealed.

5.4 Conclusion

It is safe to conclude that GIS use at the NCWSC was applied to a moderate extent as revealed by the study findings. Further, the research revealed that use of GIS led to improved mapping customer meters with corresponding account numbers, efficient asset management and improved new customer connections were identified as key areas where the use of GIS was used to a great extent. However, respondents were categorical that reduced errors in readings of water meters, quick response in determination of water pressure and quick response in identification of leaks as the major benefits as a result of using GIS at the NCWSC. Respondents unanimously agreed that inadequate IT training on use of GIS application, lack of capturing proper workflows across contributed by users and lack of proper network connection to transfer large amount data were identified as the major challenges.

5.5 Recommendations

With due regard to the ever increasing desire to have better organizational performance, there is need to invest in GIS application. This is because the use of ICT applications and in particular GIS at the NCWSC greatly supports the technical operations. This therefore calls upon the management of NCWSC to come up with a GIS policy which outlines the strategies and guidelines of applying the same effectively in the organization. This should be done in a manner in which all the stakeholders are happy. This ensures that they are incorporative, acceptable, accessible, ethically sound, have a positive perceived impact, relevant, appropriate, innovative, efficient, sustainable and replicable.

Further, the management needs to invest in employee training on GIS and sensitization to GIS technology which could enhance their competence and less resistance to change in introducing new technology.

5.6 Limitations of the study

The researcher encountered various limitations that were likely hinder access to information sought by the study. This included:

The respondents approached were reluctant in giving information fearing that the information they give would be used to intimidate them or print a negative image about their company. The researcher handled the problem by carrying an introduction letter from the University and assured the respondents that the information would be used purely for academic purpose.

The researcher also encountered problems in eliciting information from the respondents as the information required was subject to areas of transparency, and confidentiality which could not be accurately quantified and/or verified objectively. The researcher encouraged the respondents to participate without holding back the information they have as the research instruments would not bear their names.

5.7 Suggestions for Future Research

The research aimed at establishing the extent, benefits and challenges of using GIS NCWSC. From the researchers finding application of GIS has a number of benefits despite the challenges. There is need to undertake more research on the implementation of GIS in water utilities and impact of GIS in water companies. It is recommended that this aspect could be further researched or pursued in a future research endeavor.

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APPENDICES

Research Questionnaire

Dear Respondent,

My name is Francis, a postgraduate student pursuing my Master degree in Business Administration, University of Nairobi. Currently, doing a research titled **Application of Geographical Information System in Nairobi City Water and Sewerage Company.**

In this regard, you have been selected to take part in this study as a respondent. Kindly respond to all items to reflect your opinion and experience. Please answer all the questions freely. You will not be identified from the information you provide and no information about individuals will be given to any organization. The data collected will be used for this academic research only.

Note that **ALL** information will be treated **CONFIDENTIAL.**

Kindly therefore, fill the questionnaire submitted within five days after receipt to enable me complete my research.

Yours Sincerely,

Francis Maina.

PART A: GENERAL QUESTIONS

1. Please provide responses to the questions below.

a.	Department	
b.	For how long have you worked in the specific department?	Less than 1 year [ ] 1-2 years [ ] 3-5years [ ] Above 5 years [ ]

PART B: EXTENT OF GIS USE

2. To what extent of GIS use has the Nairobi City Water and Sewerage Company applied the following in areas of operation? *(Check all that apply in a to j)*

		Very great extent	**Great extent**	**Moderate extent**	**Small extent**	**No extent**
a.	Improved mapping of customer accounts with the land parcel					
b.	Effective Detection of pipe burst in transmission lines					
c.	Efficient Assets Management					
d.	Improved mapping customer meters with corresponding account number					
e.	Accurately capturing of water meter readings					
f.	Enhanced prioritization of repairs and replacement of water pipes works					
g.	Improved new customer connections					
h.	Better determining location of the existing water lines					
i.	Improved efficiency and enhance planning of water facilities					
j.	Other. (Specify)					

PART C: Benefits of GIS

3. To what extent has Nairobi City Water and Sewerage Company experienced the following benefits relating to use of GIS? Tick appropriately using a likert scale of 5 where 5= Very great extent, 4= Great extent 3= Moderate extent and 2= Less extent and 1= No extent at all.

		Very great extent	**Great extent**	**Moderate extent**	**Small extent**	**No extent**
a.	Quick response in determination of water pressure					
b.	Reduced errors in readings of water meters					
c.	Quick response in identification of leaks					
d.	Reduced manpower to track the condition and maintenance history of assets such as water mains, valves, hydrants, meters, storage facilities, sewer mains, and manhole.					
e.	Standard procedures in contracting new customers					
f.	Cost effective to on-line drawings and maps					
g.	Reduced paper work in capturing customers queries					
h.	Easy access to information					
i.	Reduced data entry					
j.	Standardized interface for searches by location and data type					
k.	Reduced legal cases from false information to customers					
l.	Improved asset management planning on repairs undertaken					
m.	Enhanced computing capabilities to wide range of users					
	Other. (Specify)					

PART D: Challenges of using GIS

4. To what extent has the Nairobi City Water and Sewerage Company experienced the following challenges relating to use of GIS? Tick appropriately using a likert scale of 5 where 5= Very great extent, 4= Great extent 3= Moderate extent and 2= Less extent and 1= No extent at all.

		Very great extent	Great extent	Moderate extent	Small extent	No extent
a.	Lack of suitable infrastructure for capturing geo-based data					
b.	Lack of top management support in decision making					
c.	Inadequate IT training on use of GIS application					
d.	Lack of capturing proper workflows across contributed by users					
e.	Lack of systems integration with existing systems					
f.	High software costs in data loggers					
g.	Lack of technical support from the GIS partners					
h.	Unexpected technical problems due to incomplete implementation					
i.	Negative staff attitude towards the use of GIS application					
j.	Inadequate funds and high cost of producing spatial data					
k.	Lack of proper network connection to transfer large amount of data					
l.	Lack of defined standard and procedures to determine the cost of GIS projects					
m.	High costs of field equipment					
n.	Lack of data integration with technical tools					
o.	Lack of copyright law in data handling					
p.	Inadequate experienced experts in GIS					
q.	Strong resistance to change in introducing technology					
r.	Other. (Specify)					