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GIS and Water Utilities: the case of Johannesburg Water

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A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg in fulfilment of the requirements for degree of Masters of Science by Course Work and Research report in the School of Geography, Archaeology and Environmental Studies.

Johannesburg 2005

Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Note: Tragically, Lawrence Woghiren died while in the final stages of completing this research report. He was thus unable to sign this declaration. As supervisor I have signed this declaration on Lawrence's behalf (Charles Mather). I know this to be his own, unaided work.

_____(Signature of supervisor) _____ day of

_____2005.

Abstract

This research report focuses on the implementation of Geographical Information Systems (GIS) in Johannesburg Water, the water utility of the City of Johannesburg Metropolitan Council. The research contributes to a broader debate on the implementation of GIS technology in private and public institutions. While this research field has a long and reasonably strong tradition in the developed world, research on GIS and organisations in the developing world is in its infancy. Based on interviews with a range of personnel in Johannesburg Water the research provides an assessment of the history of GIS implementation in this institution. The history, which begins in the 1980s, examines the development of the technology in Johannesburg Water focusing on the experiences of staff and various software and hardware choices. The research also examines current implementation issues and the impact of GIS in decision-making in this organisation. Finally, the research assesses the implementation of GIS in Johannesburg Water in relation to various theories of, and approaches to, GIS implementation.

Acknowledgements

It is with deep appreciation to God, biological and Christian family, friends and colleagues, that this report is completed. The events of the past eighteen months will not be forgotten in the minds of those who walked with me. I am now in my inheritance, enjoying the graciousness of a father who loved me through it all.

I give honour to my mother and siblings who were always there for me; the Woghiren family who loved and supported me; my Christian family and friends who walked with me along the paths of life; my colleagues who sharpened my skills and have enabled me to walk this far as a professional; and my supervisor, Prof Charles Mather, who coached me during this work. Thank you all. I am eternally grateful.

I acknowledge those who would use this work for their development and pray that they find growth in it as I did.

Lawrence Woghiren
1971-2004
Written by Adesola Ilemobade (in representation)

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Chapter 1: Introduction

Introduction

Geographical Information Systems (GIS) are spreading quickly in both the private and public spheres of the world. These systems can be applied to land use planning, highways and route management, emergency services planning, electricity, water and sanitation services management, (Arnoff, 1991; Masser and Campbell, 1993). GIS has been especially used in every facet of water resources, and is particularly important in managing water utilities and wastewater facilities for flood control and response and for watershed management (Dangermond, 2003).

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. The use of GIS in the water/wastewater industry may also be efficiently linked with hydraulic models (Dangermond, 2003). Finally, GIS is being used for infrastructure management, operations and maintenance, planning and engineering, finance and administration, among other uses in water utilities.

The use of GIS as a tool for decision–making in organizations in the public and private spheres has become widespread (Maguire, 1991; Campbell and Masser, 1995; Dangermond, 2003). Promoters of the technology argue that it contributes to organizational effectiveness and efficiency, through its ability to simulate complex analysis and may enhance decision-making capabilities at various levels, from operational and managerial, to strategic levels in private and public sector organizations (Campbell and Masser, 1995). However, GIS has the negative attributes of increasing dependency on sophisticated technology, requiring foreign expertise and high level of skills (Yapa, 1991).

Though literature on the issues of GIS implementation in organizations is on the increase, issues of GIS implementation in water utilities remain scanty. Moreover existing literature does not distinguish issues of implementation between organizations or utilities. There is

an implicit assumption that these issues involve the same components, such as the technological and human components of GIS implementation. Moreover, the literature assumes that these issues are basically the same, irrespective of the implementing organization. However, where differences do exist would be in the area of GIS application. This study investigates the implementation of GIS in a water utility with the assumption that issues regarding GIS implementation are not too different from what obtains in other organizations.

Introducing and implementing GIS technology in organizations involves the complex process of managing change within environments that are typified by uncertainty, entrenched institutional procedures, and individual staff members with conflicting personal motivation (Masser and Campbell, 1993). Personal, organizational and institutional factors are likely to have profound influence on the extent to which the opportunities offered by GIS will be realized in practice (Masser and Campbell, 1993). Water utilities, like any other organization, are faced with the above issues. Burrough (1986) advocates for a GIS implementation strategy that would include the retraining of personnel and managers to use the technology in the proper organizational context, together with the necessary investment in hardware and software.

GIS being a relatively new technology needs continuous research into its different aspects. It was observed by Goodchild (1995) that the issues of the adoption and impact of GIS technology, and the organizational structures for the efficient exploitation of GIS remain on the research agenda for the future. An offshoot of this observation and the seemingly lack of literature on the implementation and impact of GIS in water utilities in South Africa, when compared to the volumes that have been published on this aspect of GIS application in other parts of the world (Bromley and Coulson, 1991; Gibbons, 1998; ESRI, 2001; Pierce, 2001; Patkar and Kumar, 2002), has led to this research. A better understanding of GIS technology by users, managers, and decision makers is crucial to the appropriate use of the technology (Arnoff, 1991). The key to understanding this multi-faceted technology is seeing how the technology is being employed, and to evaluate its implementation (Dangermond, 2003). The purpose of this research is to investigate how GIS is being implemented, and what its impacts are in a water utility.

GIS has the potential if well implemented by planners in South Africa water utilities, to realize to an extent, the guarantee of access to water as a basic human right. This right is guaranteed by the South African constitution. Also, the constitution conferred on local governments the authority to provide water and sanitation services to people within their jurisdiction (Constitution of the Republic of South Africa, 1996). Local government being one of the most important users of GIS (Masser and Campbell, 1993) is better equipped to effect this constitutional provision.

According to Hill and Mc Connachie (2001) the public 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 public sector should take advantage of new techniques, toolkits and technologies. GIS is one such technology that undoubtedly has great potential. Local government authorities 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)

Most of the existing literature on GIS in South Africa has focused on issues around GIS and social debates (Da Cruz, 1999); society and resource redistribution (Mather and Paterson, 1995; Lupton and Mather 1996; Fincham 1999; Harris *et al* 1995; Wiener and Harris, 1999); application in natural resource management (Cinderby, 1995); in policing (Lochner and Zietsman, 1998); in development planning (Hill and Mc Connachie, 2001); while an example of the available literature in water utilities focuses more on the development of GIS software, such as Sinske and Zietsman (2002).

This research set out to examine the implementation and impact of GIS in Johannesburg Water (JW), the water utility of the City of Johannesburg Metropolitan Council. It is hoped that the findings of this research will contribute to the growing knowledge on the applications of GIS in organizations, particularly in the water and sanitation service industry of South Africa and the wider GIS community.

JW provides water and sanitation services to over 3 million people in Johannesburg and its environs on behalf of the City of Johannesburg Metropolitan Council (JW, 2002). This service should not only be provided to guarantee peoples' constitutional right to clean

potable water, it should be done efficiently and effectively. GIS has the potential to effectively and efficiently change the way these services are planned and delivered, if well implemented.

Prior to the establishment of the City of Johannesburg Executive Mayoral Council, a number of the previous town councils in the Johannesburg area such as Randburg, Sandton, Central Johannesburg, Roodepoort, Soweto, Deep South, had separate GISs. These GISs were combined into a single unified system and database when Johannesburg Water was created combined into a single unified system and database when Johannesburg Water was created (Manager, Johannesburg Water, Pers comm.).

The research was conducted in Johannesburg Water (Pty) Limited (JW) for the reason that it functions primarily as a utility that provides water and sanitation services and also an organization where GIS is used substantially. Johannesburg Water is a public water utility, wholly owned by the City of Johannesburg Metropolitan Council. The company is charged with the responsibility of providing water and sanitation services to the City of Johannesburg, an area stretching from Midrand in the north, Alexandra in the east, Orange farm in the south and Roodepoort in the west (JW, 2003).

The key findings of this research may be summarised as follows: first, the implementation of GIS in Johannesburg Water must be seen in the context of changes in the structure of the organisation, which facilitated the implementation process. Second, the implementation of the technology has led to some improvements in service delivery and in terms of spatial decision-making. In the longer term it is expected that there will be further improvements in service delivery in line with the full implementation of GIS in JW. The third set of findings relate to the relationship between implementation theory and the experience of Johannesburg Water's implementation of GIS. The results suggest an uneven fit between implementation theory and the case study.

Study Area

The City of Johannesburg as it is known today has come from a long history of transition. The six administrative Councils, Randburgee, Sandton, Old Johannesburg, Roodepoort, Soweto, Deep South that were existing at the end of the apartheid era in 1994, were

transformed into a four municipal local councils (MLC) structure: Northern MLC, Eastern MLC, Western MLC and Southern MLC. These were collectively known as the greater Johannesburg Transitional Metropolitan Council (GJTMC).

Greater Johannesburg Metropolitan Council (GJMC) was established to ease the transformation of the MLCs to the City of Johannesburg a megacity. At the initial creation of GJMC it existed side by side with the MLCs until the MLCs were completely integrated into GJMC (GJMC, 1999).

After the elections of December 2000, GJMC and the four municipal local councils went through a process of corporatisation and unification to become a Unicity, known as the City of Johannesburg in the Guateng province of South Africa (Figure 1.1). The City is currently divided into eleven administrative regions (Figure 1.2) with the responsibility of providing all municipal services that were provided by the former metropolitan local councils.

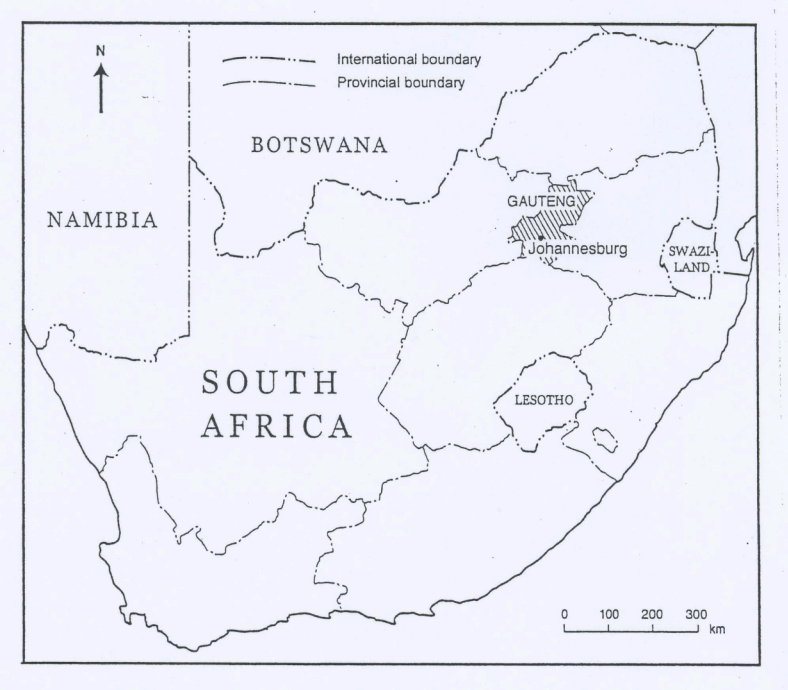


Figure 1.1: Gauteng Province

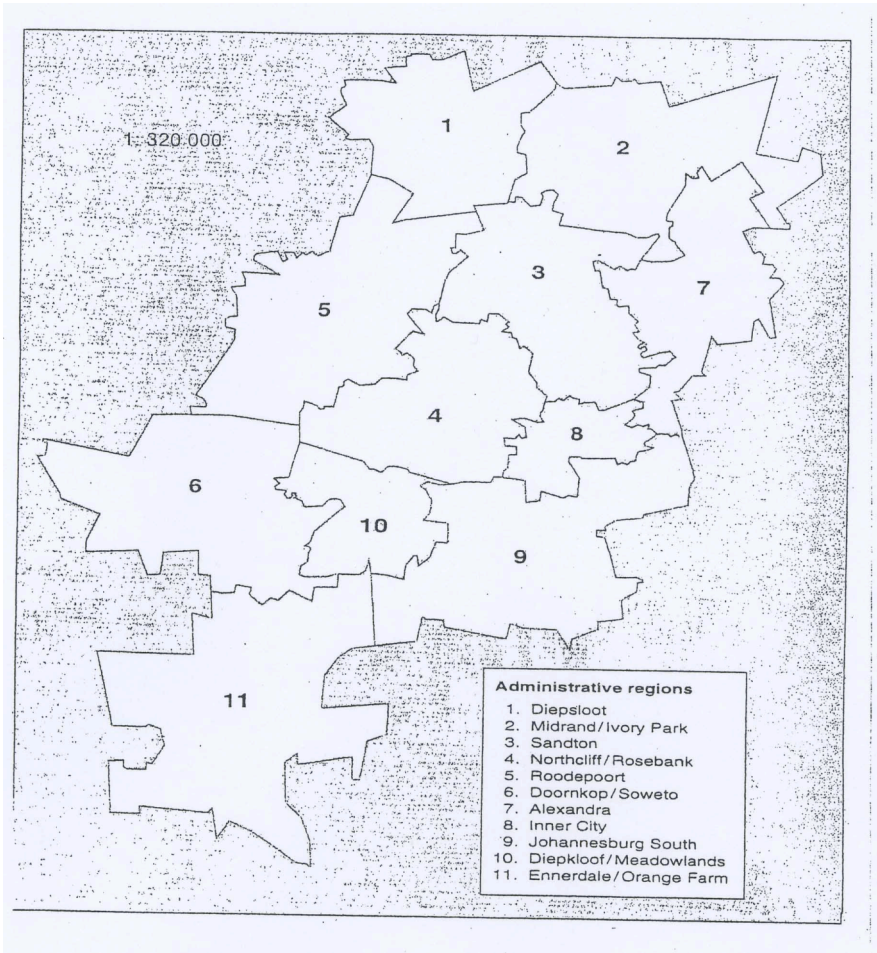


Figure 1.2: Administrative regions of Johannesburg Metro Council

A wholly owned company known as Johannesburg Water (Pty) Limited (JW) was created by the City to manage water and sanitation services, in line with the policy of corporatisation and privatization under the iGoli 2002 transformation plan. Municipal services rendered by the City council's departments were to be provided and operated under a corporate structure (Figure 1.3).

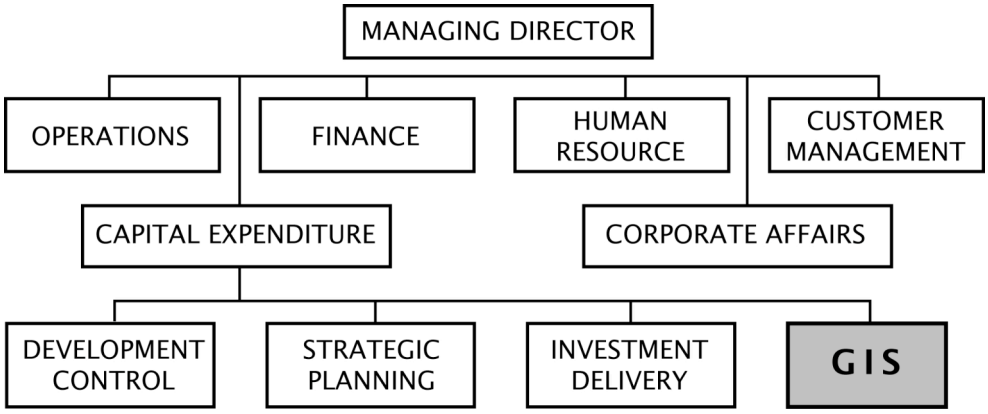


Figure 1.3: The organizational structure of Johannesburg Water

Structure of the Report

The remainder of the report is organized into four chapters.

Chapter two focuses on a review of literature relevant to the study, highlighting historical perspectives and development of GIS in the First and Third World. This chapter also considers theoretical debates surrounding GIS and issues on implementation and applications in water utilities.

Chapter three discusses the methodology adopted for the study.

Chapter four presents findings on the implementation and impact of GIS in Johannesburg Water. Included in this chapter is a comparative analysis of the findings presented.

Chapter five summarizes the research and draws conclusions from the research findings. Included in this chapter are recommendations for an effective and successful implementation of GIS in water utilities. These recommendations are based on the research findings and existing literature on GIS implementation in organizations. Finally, areas for future research are suggested.

Chapter 2: Literature Review

Introduction

There is a wealth of research on Geographic Information Systems (GIS). The research may be divided into 3 broad strands. First, there is a focus on the use of GIS as a research tool. Not surprisingly, research in this first strand includes case studies by geographers, but also by a range of experts including biologists, geologists and social scientists. The second strand of research is more recent and focuses on the history and development of GIS since the 1960s. This research focuses on the individuals and companies involved in the promotion of GIS technology mostly in Canada, the United States and the United Kingdom. The third strand focuses on issues of *implementation*. Geographers have been at the forefront of this research strand, which has explored the use of GIS in various public and private institutions and the expansion of GIS beyond the first world. The focus of this research report is on the issue of implementation.

This chapter provides an overview of the literature on GIS; the chapter also highlights themes that are pertinent to this particular study. The chapter begins by focusing on the history of GIS, debates on GIS implementation, the implementation of GIS in the first and third worlds. The chapter ends by examining the use and relevance of GIS in water utilities.

History of Geographical Information Systems

There are several stages of evolution in the development of GIS, which overlapped in time and occurred at different moments in different parts of the world. However, most of the early development originated in North America, notably United States and Canada (Coppock and Rhind, 1991). It is a widely believed that the first GIS was the Canada Geographic Information System (CGIS) developed for and by the government of Canada in 1964 (Taylor, 1991; Goodchild, 1995; Rhind, 1998).

Development of GIS

There are four stages or phases in the evolution of GIS as identified by Coppock and Rhind (1991). These phases started with the pioneering age and ended in the current phase. The pioneering age, which is the first phase, extended from the late 1950s to about 1975. In this phase the development of GIS was in both the United States and the United Kingdom and it was characterised by individual developments, limited international contacts, little data in machine-readable form, and ambitions that were way ahead of the computing resources of the day.

The second phase was approximately from 1973 to the early 1980s. This saw a regularisation of experiments and practices within GIS and was fostered by national agencies. There was still the continuation of local experiments, and the duplication of efforts was prevalent (Coppock and Rhind, 1991). The dominance of GIS by commerce characterised the third phase; this was from about 1982 until the late 1980s. The fourth and current phase, which started from the late 1980s, saw the domination of the user. This was facilitated by the competition among vendors, embryonic standardisation on open systems and an increase in the perception by the user on what a GIS should do and look like (Coppock and Rhind, 1991).

In South Africa not much by way of documented literature exists on when the development of GIS actually began, except that it was probably in use within government agencies during the later part of the apartheid era corresponding to the forth phase of the development of GIS world wide. The transition to democracy in the middle 1990s has witnessed a rapid development of GIS (Weiner and Harris, 1999).

A necessary part of the evolution of ever more complex information systems has been the introduction of these systems into organizations to assist in their day-to-day operations (Obermeyer and Pinto, 1994). Introduction of GIS into organisations has heightened the concern for its implementation among vendors and users, thus gaining prominence as a topic for research and debate. The difficulties associated with GIS implementation has resulted in a large number of significant case studies and best practice manuals (Wentworth, 1989; Bromley and Coulson, 1991; Campbell and Masser, 1993; Campbell,

1994; Obermeyer and Pinto, 1994; Campbell and Masser, 1995; Sahay and Walsham, 1996).

Implementation of GIS

In its basic sense, GIS implementation can be defined as the introduction of a new information system, program, or model that has been accepted by organisational personnel. Successful implementation is defined by dramatic changes and improvements in the decision making process of the personnel. The concept of implementation in the context of organisations may be viewed as a change phenomenon or process for creating organisational change (Obermeyer and Pinto, 1994). Literature in the area of implementation remains largely unfocused, even though it has increased in volume over the years. Early work on implementation tended to focus on the important participants in the implementation process rather than on the type of implementation being considered (Obermeyer and Pinto, 1994).

The introduction and implementation of computer-based systems into organisations has shown that marginal gains, unforeseen problems or even complete failure is far more common than success (Campbell, 1991). For an implementation effort to be seen as successful, according to Obermeyer and Pinto (1994), it should be measured against three criteria, (i) technical validity: the belief that the system to be implemented works, (ii) organisational validity: a measure of the congruence between the organisation and the system to be implemented or the appropriateness of the system to the organisation, and (iii) organisational effectiveness: an improvement in decision making.

Cambell and Masser (1993) have suggested that there are three necessary and generally sufficient conditions for the effective implementation of computer-based systems. These are:

1. Information management strategies that identify the needs of users and takes into account the resources at the disposal of the organisation.
2. Commitment to and participation in the implementation of any form of information technology by individuals at all levels of the organisation.
3. A high degree of organisational and environmental stability.

Clearly defined goals, sufficient resource allocation, top-management support, implementation schedules, competent technical support and adequate communication channels, have generally been found to be crucial to new system implementation successes (Obermeyer and Pinto, 1994).

GIS implementation is the entire technology transfer process, from when an organisation becomes aware of the technology through to when it adopts it. Adoption means that an organisation has incorporated a GIS into its operations and regularly uses it where appropriate, in its day-to-day activities (Aronoff, 1991). Accordingly GIS implementation can be seen as a six-phase process:

1. **Awareness**: People within the organisation become aware of GIS technology and the potential benefits to their organisation. Potential uses and users are postulated.
2. **Development of system requirements**: The idea that a GIS could benefit the organisation is formally acknowledge and a more systematic and formal process is instituted to collect information about the technology and to identify potential users and their needs. A formal needs analysis is often done at this stage.
3. **System evaluation**: Alternative systems are proposed and evaluated. The evaluation process takes into account the need analysis of the previous phase. At the end of this phase, a formal decision must be made whether or not to proceed with acquisition of a GIS.
4. **Development of an implementation plan**: Having made the decision to proceed with acquisition of a system, a plan is developed to acquire the necessary equipment and staff, make organisational changes, and fund the process. The plan may be a formally accepted document or a more or less informal series of actions.
5. **System Acquisition and Start-Up**: The system is purchased, installed, staff is trained, creation of the database is begun, and operating procedures begin to be established. Creation of the database is usually the most expensive part of the implementation process. Considerable attention is needed to establish appropriate data quality controls to ensure that the data entered meet the required standards

and that suitable updating procedures are implemented to maintain the currency and integrity of the data base.

6. **Operational Phase**: By this stage the initial automation of the database is complete and operating procedures have been developed to maintain the database and provide the information services that the organisation requires. In this phase procedures are developed to maintain the GIS facility and upgrade services so that the GIS continues to support the changing information needs of the organisation. Operational issues concerning the responsibilities of the GIS facility to provide needed services and to guarantee performance standards become more prominent.

In almost every GIS implementation, GIS system vendors or contractors assist in the set-up of a GIS and they also provide technical support. GIS vendors are developers of commercial GIS hardware and software; they are crucial in any implementation effort (Aronoff, 1991; Campbell, 1991; Campbell and Masser, 1995). Aside from being valuable in GIS implementation, they have a powerful economic interest in the successful implementation of their GIS (Obermeyer and Pinto, 1994)

The design and implementation of a GIS is a major, long-term undertaking. From the initial contact with the technology by an organisation, through to when a system is finally operational commonly takes anything from one to several years (Aronoff, 1991). According to Obermeyer and Pinto (1994) the primary problems that underlie most implementation efforts are usually organisational rather than technical. Organisational problems as used here, refer to the human aspects that can inhibit or limit the potential acceptance and use of the technology: 'The issues responsible for implementation failures are almost always people problems' (Aronoff, 1991, pg.249).

When implementing a GIS there are four factors that enhance the chances of success (Campbell and Masser, 1993). These are:

1. Simple applications producing information that is fundamental to the work of potential users.
2. User directed implementation, which involves the participation and commitment of all the stakeholders in the project.

3. Awareness of the limitations of the organisation in terms of the range of available resources.
4. A large measure of stability with respect to the general organisational context and personnel, or, alternatively an ability to cope with change.

For an effective implementation of GIS among most classes of potential users, a combination of both centralized and decentralized process models is required (Obermeyer and Pinto, 1994). The classical implementation conceptual model presumes a centralized structure with a technological innovation originating from an expert source. And at the adaptation level, decentralized implementation processes are often required in order to meet the differing database development needs of groups and individuals within the organisation.

The implementation of GIS hardware and software generally follows the classical model while the decentralized model provides an understanding of the implementation of data characteristics and data handling methods appropriate to the organization (Obermeyer and Pinto, 1994). In a study of the implementation of GIS in British local governments, Campbell and Masser (1995) found a threefold typology of system implementation. These are:

1. *Classically corporate*, which involves the whole authority participating in the project with the central computer services or planning department taking the lead. The results of this approach are reflected in a workstation or mainframe-based system, using software that is designed to provide limited automated mapping or facilities management capabilities. However, with this approach it is not expected that GIS will enhance the information processing facilities available within the organisation (Campbell and Masser, 1995).

2. *Theoretically/pragmatically corporate* is the second system of implementation that is typified by a 'bottom-up' demand for GIS facilities from service delivery departments. This approach is characterized by the involvement of three or four departments with the lead taken by the computing, a technical service department or in some cases joint responsibility for the project. Its main benefit is

enhancement of the information processing facilities (Campbell and Masser, 1995).

3. The third approach is the *fiercely independent* approach which is typified by the introduction and development of a GIS by a single department, most likely one involved in a technical service and has experience in information handling with in house technical expertise (Campbell and Masser, 1995).

Interestingly, the third approach was found to be the most widely adopted approach in the implementation of GIS among the organisations that Campbell and Masser studied. Geographic data and processing operations are fundamentally different from those used in a Management Information System (MIS). Their evidence suggested that GIS should be developed and implemented independently of an MIS. In addition, it indicated the need for a separate organisational unit different from MIS. This group would then be able to focus all its efforts on GIS implementation and operation (Aronoff, 1991). In Johannesburg Water, a separate division handles the implementation of the GIS, which is independent of the Management Information System.

In another study, successful users of the top-down approach for implementing GIS in the UK have been public utilities whose task are clearly defined (Bromley and Coulson, 1991). The top-down approach to GIS implementation is one where technological considerations are given prominence over the user's work patterns and their detailed information needs. Such a top-down approach can be said not to be beneficial to GIS where handling geographical information may make radical changes to the user's work practices (Medyckyj-Scott, 1989; Bromley and Coulson, 1991).

Sahay and Walsham (1996) found that in developing countries there are inhibiting and enabling factors associated with GIS implementation. The inhibiting factors include data, human resources, structure and financial factors. Data factors include the availability of data in appropriate scales, usability problems due to the dependency on remotely sensed data, quality of the data, and non-standardized formats of data that are not supported by standard software. Human resource factors are in the form of an acute shortage of trained people, a general lack of awareness about GIS among planners and the dominance of GIS

technocrats that contribute to organizational issues being made subservient to technical concerns during implementation.

Structure factors relate to the style of decision-making and the forms of developing country organizations. Decision-making is often confined to a central official, which despite having inadequate knowledge about GIS technology, is responsible for taking critical decisions relating to the implementation of the GIS. The sectoral form of organization, together with an almost total absence of policies that bring about coordination, often leads to duplication of efforts. Finance as an inhibiting factor relates to the absence of long term funding for the implementation of GIS, which is more often a long time process (Sahay and Walsham, 1996).

According to Sahay and Walsham's (1996) research, enabling factors for the implementation of GIS involve the development of approaches that will provide continuity in the implementation effort, the development of practices that will smooth the transition of people from their existing ways of doing work to using GIS and the institutional mechanisms that relate to policy level initiatives around GIS. How these factors play out in Johannesburg Water will be considered later in the report.

Since GIS encompass data as well as hardware, software and organisational components, the complexity of these systems as well as the volume of data used in its operation constrain its performance (Gittings *et al*, 1994). Given the complexity of the technology, users have to be well trained in its use. Procedures should be defined to coordinate among users, how data types will be defined and the types of output products required. Written procedures are needed for source data collection, interpretation, accuracy verification, and the preparation of data for input (Aronoff, 1991).

Training staff to handle GIS may be very expensive for organisations and may therefore be a limiting factor in its adoption. Aangeenbrug (1991) notes that the advent of GIS in organisations is fraught with many problems ranging from technical to institutional and that "few, if any, independent analysis of the cost benefit of GIS have been documented outside the GIS vendor/consultant community" (Aangeenbrug, 1991, pg.106) and goes

further to urge that "vendors and researchers must also avoid the use of jargon and hype if GIS are to be taken up and applied successfully" (Aangeenbrug, 1991, pg.106).

The ultimate success of a GIS will depend on the people who implement the GIS. The implementation plan should define the group or groups within the organisation who will be responsible for the implementation and operation of the GIS. It is their enthusiasm and commitment that will see the project through the inevitable stumbles and set-backs. They make GIS implementation happen and keep it sustainable (Aronoff, 1991; Cavric *et al*, 2003). According to Aronoff (1991) staff functions to be provided for in a GIS implementation, are a project coordinator, a GIS system manager, a data base manager, system analysts/programmers, and data entry personnel.

Managing the implementation process is very critical. The GIS user groups must be well coordinated, a detailed data base design must be completed, equipment that will be purchased, the training of people to handle the GIS, and the contractor or vendor services must be well managed (Aronoff, 1991).

Obermeyer and Pinto (1994) noted that literature on implementing and managing GIS theory has been elusive, reflecting the relatively recent widespread implementation of GIS when compared to the existence of the technology. The debates around the implementation of GIS are not isolated from the general debates surrounding GIS among professionals and theorist within the parent discipline. The literature review now shifts to consider these broader debates within GIS with a view to situating the research on implementation.

The quantitative revolution and post-positivist debates

The advent of GIS has provoked debates within the discipline of Geography (Mather, 2002). Taylor and Johnson (1995) and Shaw (1993) suggest that the development of GIS marks the resurgence of a new quantitative revolution in geography. According to Taylor and Johnson (1995) the quantitative revolution provided a benchmark for the consideration of contemporary geography, and this is particularly the case for GIS. To them, proponents of GIS combined the early technical concerns of quantifiers with the

later social, economic and political concerns of those who advocate applied geography. According to Kenzer (1992) GIS is the technique side of geography and can be referred to as an offshoot of applied geography.

According to those critical of GIS, GIS practitioners constitute a new approach to research and planning. They are said to be strictly applied quantitative geographers with a strong emphasis on positivism and the positivist approach and assumption to problem solving (Haywood, 1990; Lake, 1993; Taylor, 1990, 1991; Taylor and Overton, 1991). According to da Cruz "the development of GIS within a theoretical context dominated by a positivist – oriented epistemology has had important social and ethical implications" (da Cruz, 1999, pg.120). However, it has been largely separated from the post-positive and post-structuralist revolution that transformed human geography.

In the 1980s and 1990s context of human geography, GIS represents an anachronism, out of place with its positivist theoretical underpinnings that is still firmly entrenched in the 1960s (da Cruz, 1999). Accordingly: "The GIS research agenda which has concentrated on the technical problems arising out of the technology and its potential applications has been unaffected by the developments and critiques within human geography since the 1980s. Accordingly there has been no critical analysis of the role played by GIS in geography or of the social implications of the technology on the part of the GIS establishment" (da Cruz, 1999, pg.199).

Shaw (1993) contributes to the debate by stating that, with the use of tools such as GIS autocorrelation, geographers have developed theories, models and applications based on geographic concepts, citing as an example GIS's powerful ability to represent geographic space in geographic enquiries as a great value to geography. Dobson (1993, pg.437) believes "GIS will help geographers generate sound theory and challenge faulty theory in a broad spectrum of science".

Goodchild (1988) equates the importance of GIS to geography to be the same as what high technology is to society: "GIS does not automate an existing manual process, but instead it offers to change the way geographers work in fundamental ways" (Goodchild, 1988, pg. 561). He goes further to state that GIS is important to geographical analysis,

being a technology that can remove many of the impediments, that prevents the wider application of methods and models developed by quantitative geographers.

Goodchild has also suggested that GIS is important as it provides a formal model of spatial information and of the relationships among objects in space. As a consequence, "GIS has become an integral part of geography and there is a strong perception within the ranks of geographers that GIS is a critical factor in the future growth and survival of the discipline" (da Cruz, 1999, pg.119).

Goodchild (1995) notes the importance of visualization in geography and the significance of the map as a tool for spatial analysis. According to him, many forms of spatial analysis are complex, having the need to harness the intense computing power of current systems to solve spatial problems.

Openshaw (1991) sums up the debate by declaring that all that really changed, was the manner by which geographers could perform some of their more explicit geographical works and the appearance of an information framework within which all geographers should be able to work.

Monmonier (1993) postulates that geography is no longer in control of the powerful technology that uses and exploits its name. His views indicate a 'usurping' of computational Geography under the rubric of 'GIS' by a variety of disciplines, including computer science, regional planning, forestry and survey engineering. His argument is for GIS to be controlled by Geography with GIS researchers involving more aspects of traditional Geography in their research agendas.

These debates within Geography are not unrelated to issues around implementation. If GIS does usher in positivist approaches, then this has implications for how receptive the systems might be in different organisations. As the next section suggests, it may also lead to technocratic planning practices.

GIS and technocracy

Many scholars and researchers have tended to define Geographical Information Systems (GIS) in various ways, ranging from the technologically based to those highlighting the organisational aspects (Maguire, 1991). Most of these definitions bring to the fore the inherent technocracy of GIS. Like all technologies GIS is a technocratic tool and can be found within the positivist-technocratic (rational planning) model (Atken and Michael, 1995; Lake, 1993; Obermeryer, 1995).

Even though GIS has become wide spread in its use and it is also user-friendly Obermeyer (1995) notes that it is 'naïve' to assume that it is devoid of technocracy. Technocracy, as used here, can be equated with the use of technology by technicians, scientist and engineers to provide rational decision about the allocation of resources to the development of physical and social infrastructure.

According to Lake (1993) the ascendance of GIS to a position near or at the core of both planning and geography has actively 'resurrected and rehabilitated' the rational model and has reaffirmed the importance of the positivist-technocratic approach to problem solving. Aitken and Michael (1995) concur that researchers portray GIS as an integral part of planning discourse and favour the rational instrumentalist perspective. This perspective is based on a modernist discourse, which adheres to the premise that through the application of rational-scientific methods and technology it is possible to build better communities (Aitken and Michael, 1995).

However, Aitken and Michael (1995) are confident that GIS will not drive organisational and institutional change along the lines of the rational strategic and instrumental planning model like other technological innovations. They believe that since GIS is socially constructed, communicative rationality, which recognises the importance of dialogue and the daily process by which understandings are reached, and collective identities constructed, should be of greater consideration in GIS.

Not only was GIS technology and its relevance to the discipline of geography and society debated, professionalism and ethics in the GIS community and among GIS practitioners were issues that were found to be contentious.

Ethics and the GIS community

Developing theory, methods and applications around GIS without considering the context within which these geographical information systems are produced and implemented, introduces the danger of creating or reinforcing dominating discourses (Aitken and Michel, 1995). The GIS community is so new that codes of conduct have not yet been developed for, or offered expressly to, its practitioners, and this raises a wide range of social and ethical questions (Onsrud, 1995).

The ethical issues alone are complex, because the systems tend to be used in a variety of contexts (Curry, 1995). Ethical conduct can be defined as that behaviour desired by society that is above and beyond the minimum standards of behaviour established by law (Onsrud, 1995).

According to (Openshaw, 1993) an established GIS profession does not exist, neither is there any certification of GIS skills, and seemingly few standards or guidelines related to its use with little or no interest in GIS abuse questions. Currently, there is questionable conduct in the development and use of GIS (Onsrud, 1995). However (Obermeyer, 1994) states that there is a GIS profession that it is devoid of professional ethics, even though the rudiments of an ethical culture do exist.

Lake (1993) supports the view that the GIS community lacks a formal professional code of ethics and Obermeyer (1994) goes further to state that competency within the field, issues related to data quality, policy for pricing data and information made available by GIS are of critical ethical concerns. These shared concerns and others form the foundation for the need of a code of ethics to be developed within the GIS community (Obermeyer, 1994).

A problem that is common with professional codes of ethics is that most often they are developed by consulting the members of the group or discipline without consulting the consuming public or the public at large (Onsrud, 1995). As a result, there is typically embedded in such codes an emphasis on fair dealings among members of the group and a bias towards members of the discipline over members of the public. Therefore, codes of ethical conduct should be prepared by gauging opinions of both the discipline and that sector of the public likely to be dealing with or consuming the relevant products and services (Onsrud, 1995).

Ethical conduct in GIS should also take cognisance of the different environment in which GIS is practiced and used in its formulation. This means that when formulating ethical conduct within the GIS community, it should have an international appeal with inputs from both the First World and the Third World. Considering the fact that the process and style of implementation may be different, especially with regard to acquisition and development of the required data needed for a successful implementation effort.

First World versus Third World

The disparity in the levels of application and implementation of GIS between the First and Third World is great. This stems from the fact that the level of financial resources needed to sustain a technology such as GIS is astronomical. Though the cost of acquiring GIS is decreasing, it is still out of the reach for many Third World countries that are struggling to provide the basic necessities of life for their populations (Taylor, 1991).

According to Taylor (1991) GIS is a First World technology and its utilization in the Third World would depend largely on the way technology transfer takes place. Given the resources available to the First World, the form of implementation of GIS could go the whole way, investing in everything available in hardware and software (Campbell, 1991). However, taking into consideration the resource base of most Third World countries, this may not be the situation. GIS implementation in the Third World should be selective of the most appropriate application and need that would take into consideration the level of technological growth (Taylor, 1991; Yapa, 1991; Yeh, 1991).

In-spite of the above scenario, applications of GIS in Third World countries has often resulted from initiatives funded or supported by international aid agencies for pilot or research projects as opposed to operational systems (Taylor, 1991; Yeh, 1991).

Geographical Information Systems in the First World

The use of GIS in First World countries has become wide spread to such an extent that it is being used in nearly every facet of life (ESRI, 1998). Considering that GIS was developed by these nations it is not surprising then, that the most recent advances made in GIS technology can be found in them. However not all the developed countries adopted GIS at the same time. United States (including Canada) and United Kingdom pioneered the technology in its early stages of development (Coppock and Rhind, 1991; Taylor, 1991; Goodchild, 1995; Rhind, 1998)

North America has played the leading role in the development and applications of geographical information systems, applying it in such fields as forestry, property and land parcel data, utilities, civil engineering, transport, facility and distribution planning, agriculture and environment amongst others (Tomlinson, 1987). The development of GIS in Europe was highly localised, and with great variations. Initially Swedish and British research groups led the way and later, significant contributions came from the Netherlands and other countries (Coppock and Rhind, 1991; Rhind, 1998).

Sweden initiated GIS development in the early 1970s with its Land Data Bank Systems (SLDS), which culminated in its functioning for Uppsala in 1975 (Coppock and Rhind, 1991; Rhind, 1998). In Britain the earliest machine-readable geographical database was probable a mechanical machine that had spatial information stored on punch cards. The earliest substantive GIS-based research in the United Kingdom was by Coppock in the 1950s (Rhind, 1998).

Australia's GIS programme commenced in the late 1970s with a continental-scale GIS, the Australia Resources Information System (ARIS) (Coppock and Rhind, 1991). The development of GIS in the Netherlands started in the early 1970s resulting from it's long standing planning tradition and the need for careful management of the natural, built and

social environment of the country (Otten, 1991). Interest in GIS only began to gain prominence in Japan and former Soviet Union in the 1980s (Coppock and Rhind, 1991). Recently, there has been a substantive upsurge in the interest and development of GIS in Italy and Portugal (Rhind, 1998).

The early 1980s saw an increase in the installation and implementation of GIS in different levels and departments of urban and regional governments in the developed countries in North America, Europe and Australia (Yeh, 1991). However, the wider use of GIS in North America has been constrained by a number of factors, such as the lack of an overall program of large-scale digital base mapping. GIS is also being constrained by the lack of available data (Tomlinson, 1987). Tomlinson (1987) noticed very little support from users for the establishment of a large, general-purpose bank of digital data. However this problem has been overcome, as Openshaw and Goddard (1987) seem to suggest.

Geographical Information Systems in the Third World

The role GIS is playing in everyday life in the Third World is expanding very rapidly. Even though it is not as developed to levels that exists in the developed nations. GIS is a First World technology and its utilization in the Third World will depend to an extent on the way technology transfer takes place (Taylor, 1991). Eighty percent of the cost of implementing GIS in developing nations is attributable to database development, as yet, GIS cannot effectively handle very large databases and the cost of data collection is astronomical (Taylor, 1991). In many Third World countries there are problems associated with database development such as the quality of data and data collection. The problems of data collection are further compounded by the rapid rate of change due to urbanisation (Taylor, 1991).

Given that GIS is a techno-representation readily controlled by the powerful, how then can GIS technology initiated in industrialised countries be valuable where fewer resources are available? This question by Dunn *et al* (1997) gives a lot to ponder on and if GIS can be an effective tool for locally desirable change, how then should it be introduced and managed to this end? Dunn *et al*, (1997) and Taylor (1991) make a case for indigenous scientist, having an important role to play in adoption and implementation of GIS. They

have an appreciation of both GIS technology and the development problems faced by their home countries (Dunn *et al*, 1997).

GIS has inherent limitations (such as being an expensiveness technology) and cannot in itself solve problems. Trying to introduce GIS where it does not yet belong will create situations where it has little to offer except the latest technology (Taylor, 1991). The need to be cautious in adopting GIS by developing nations where resources are scarce and poverty, disease and environmental degradation are reaching crises proportions (Taylor, 1991) cannot be over emphasized.

Most of the early developments and applications of GIS in the Third World can be traced from early to mid 1980s, partly through the initiatives of aid groups establishing a number of systems by foreign experts, for example in Jamaica and Thailand by USAID and the World Bank respectively (Coppock and Rhind, 1991). The late 1980s saw an expansion of the application of the technology in Third World countries (Taylor, 1991).

According to (Hastings and Clark, 1991) the development of GIS activities in Africa began around 1976, mostly from the desires to apply computer technology to cartography, remote sensing, data management and environmental assessments. The United Nations Environment Programme (UNEP) with its headquarters in Kenya was one of the early initiators of GIS in Africa. As part of its programmes under the Global Environmental Monitoring Systems (GEMS) a GIS was designed for the production and application of spatial database for global environmental study.

Other than UNEP, the Food and Agricultural Organization and the United Nations Institute for Training and Research, are among other UN agencies active in GIS in Africa. In 1991 few GIS installations were very active, however, the activity rate is increasing very rapidly (Hastings and Clark, 1991). Despite the increasing rate of GIS activities, Africa still has the lowest rate of GIS usage among the continents with only 1.3 percent of over 450,000 licensed users of GIS and image processing software worldwide (Cavric *et al*, 2003)

Apart from the agencies of the United Nations that are active in the use of GIS in Africa, the Desert Research Institute (DRI); an organization participating in the Minerals, Petroleum and Groundwater Assessment Program (MPGAP) conducted by the Egyptian Government with assistance from United States Agency for International Development (USAID) have integrated GIS in its operations (Hastings and Clark, 1991).

Implementation of GIS in South Africa

The adoption and use of GIS in South Africa can be traced back to the late 1970s, when a mining company called 'Billiton' incorporated it in its operations (Personal communication[1]). Prior to the 1994 demise of apartheid in South Africa, the application of GIS was geared towards the implementation and maintenance of apartheid.

The hegemonic power relations embedded within GIS were eminent: apartheid was in essence a geographical project, which was implemented and maintained by the agencies of the state. They viewed GIS as a way to maintain or increase their power within a government bureaucracy, but since the advent of democracy in 1994 the development of GIS has been very rapid (Weiner and Harris, 1999). And "it is clear that GIS as a spatial technology is extremely useful in research, planning and business in post apartheid South Africa" (da Cruz, 1999, pg.119)

According to Weiner and Harris (1999, pg.7) "the current scramble for data and GIS in post-apartheid South Africa demonstrates, that the technology and data is deeply embedded within the country's historical politics and power relations". Researchers and planners are using GIS technology in an attempt to undo the injustices of the past or to improve access to resources previously denied to the oppressed communities, in the transition from apartheid to development (Mather and Paterson, 1995; Weiner and Harris, 1999). The types of GIS applications emerging tend to reinforce traditional planning applications (Weiner and Harris, 1999).

The plans for a National Spatial Information Framework (NSIF) had reached an advanced stage (Weiner and Harris, 1999). There is a notable absence of critical debates

[1] Personal communication with the GIS Manager in Johannesburg Water, September 2003.

surrounding the use of GIS, even though its diffusion into the private and public sectors of South Africa had been very rapid (Lupton and Mather, 1996). Though GIS technology is in the hands of the technocrats in South Africa, any planning that ignores the political and social features of the landscape will face strong resistance at the local level (Fincham, 1999).

The adoption and implementation of GIS in South African local governments goes back to the early 1980s, when the local authorities of the former Johannesburg local councils implemented a GIS developed by Siemens of Germany (Personal communication). The Johannesburg city council had an operational GIS in its planning department (Lupton and Mather, 1996). Cape Town metropolitan council is said to have the biggest GIS system in Africa (Weiner and Harris, 1999).

Though there is a great chasm in the adoption, application and implementation of GIS between the First and Third Worlds, GIS is being applied and implemented in the water utilities in countries belonging to both Worlds. The level of implementation may differ depending to what extent GIS technology has been developed in any particular country.

Geographical Information Systems in water utilities

The use of GIS technology is rapidly expanding in the water/wastewater industry, moving from project-specific implementation to full enterprise-wide installations. The growing trend in GIS implementation in the industry is toward system operations (ESRI, 2001). Increasingly, GIS is being integrated into overall maintenance operations while moving away from exclusive use by an organization's planning department (ESRI, 2001). Over the past decade, GIS implementation has grown from being an expensive process to being the development of a necessary tool for utilities. Most medium to large utilities have aggressive implementation projects under way or have gone through the implementation process and have established GIS programs (Pierce, 2001).

These programs are used for analysis and simulation on the water network prior to adding any new components to it such as a change in the diameter of a pipe, the installation of a water storage facility, or the alteration of pressure on a particular valve (Dangermond,

2003). GIS is being used more and more for network expansion in determining the location of existing lines and planning where new ones should be added. The data management and display capabilities of a GIS can be used to create, manage and analyse 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). It is also being used for inventory management and project tracking (Aronoff, 1991; Dangermond, 2003). A majority of water and wastewater utilities use GIS technology to integrate all kinds of information and applications with a geographic component into one, manageable system (ESRI, 1998).

In today's competitive world, a successful utility must take maximum advantage of its resources, from people to equipment to information. Using GIS to integrate geographic with other corporate data has become absolutely vital to this task (ESRI, 1998). GIS provides much more than a map; it uses geography to provide the framework for all the major activities and components of a utility's business (ESRI, 1998).

In 1987 about 200 utilities in North America had potential interest in GIS applications because of its capabilities for the handling and display of spatial data (Assat, 1987). Every division within Public Utilities in Salt Lake City is now tied to the GIS section in one way or another, from billing to maintenance, to distribution, to engineering and to upper management, GIS is embedded in the Department's every day operations (Salt Lake City, 1999). And in the United Kingdom public utilities are the major users of GIS (Martin, 1991).

The town of Dumbivali in Mumbia Metropolitan Region in India uses GIS to mange its water utilities (Patkar and Kumar, 2002) and also the entire municipal infrastructure in Mizapur was analysed and is being managed using GIS (Gibbons, 1998). In Jamaica’s National Water Commission, GIS was installed to improve efficiency and also enhance planning of the water and sewerage facilities. Trinidad and Tobago’s Water and Sewerage

Authority has incorporated GIS in its management of the underground pipe network (ESRI, 2001).

Like all new innovations introduced into an organisation, the overall objective for acquiring and successfully implementing a GIS is to improve the way the organisation does its work; most especially its planning and decision making as it affects the way services are delivered (Obermeyer and Pinto 1991).

GIS in planning and decision making

According to Kemp *et al* (1992) most definitions of Geographical Information System (GIS) emphasize the importance of analysis and support for decision-making as the primary objective of the technology. Armstrong *et al* (1986) described the concept of a spatial decision support system as a GIS-based computer, designed to support a user in making spatial decisions in a complex environment. A useful GIS should be able to assist in management decisions by giving a spatially referenced insight into a wide range of processes and activities (Cinderby, 1995). And would provide the basis for making more effective and informed decisions (Bromley and Coulson, 1991).

According to (Openshaw, 1993) supporters of GIS claim that due to its explicitness, there is an improvement of the overall quality of decision-making, in that there is now, an explicit and visible basis for a decision. Since measuring utility in decision-making is a difficult task, it has been argued that user satisfaction may serve as an appropriate substitute for utility in decision-making (Ives, Olson and Baroudi, 1983; Obermeyer and Pinto, 1994).

GIS has potential for planning and offers an opportunity to transform and empower planning practices (Levine and Landis, 1989; Innes and Simpson, 1993). Cinderby (1995) identifies how GIS can help at many levels in management and planning. These are: strategic planning (identification and trend analysis), tactical planning (assessing the alternatives and targeting the issue), operational planning (managing resources to meet set objectives) and project planning (the design and physical placement of resources).

The formulation of planning policy requires the comprehensive analysis of environmental, social, demographic and economic information against the physical geography of an area (Bromley and Coulson, 1991). Thus creating a major role for GIS to play in the development of policy and in the monitoring and evaluation of those policies based on the cross-examination of data generated by several departments. A GIS provides the planner with the capacity to map or locate land parcels and to follow events in the development process (Harris, 1989). The existence of a GIS could encourage the involvement of all planners who want information; thereby changing planning attitudes and allowing for the rapid generation of alternatives in the planning process (Hill and McConnachie, 2001).

A true GIS will connect a mapped representation of the environment or other spatial phenomena with a database, consisting of individual and aggregate observations about the land and the events and uses located on it (Harris, 1989). The potential for GIS to provide readable, analytical maps quickly and cheaply gives planners the opportunity to implement innovative strategies for interactive citizen involvement in ongoing policy discussion. GIS gives planners the capabilities to forecast different growth scenarios that would result from alternative regulatory policies (Innes and Simpson, 1993).

These capabilities permit planners to be actively involved in the development of regulatory policies that would enhance and improve service delivery (Innes and Simpson, 1993). A GIS could assist in streamlining the planning process, cutting down on bureaucracy, reducing duplication and increasing the vertical and horizontal flow of information in local authorities (Hill and McConnachie, 2001).
The most significant planning tasks require comprehensive, multipurpose and multi-user geographic information systems (Innes and Simpson, 1993). Many planners are visually oriented, and the information most useful in planning and administration involves spatial distributions. Their interrelationships as defined in part by the coincidence, contiguity and propinquity of different activities, events, and conditions, as provided by the mapping and display characteristics of a GIS, are of enormous psychological and operational importance (Harris, 1989).

There are limitations to what a GIS can support beyond administrative and reactive planning, such as the structure of a GIS assuming implicitly that what is most important in

the regulatory system of planning, is a snapshot of the present conditions in as much details as may be available, supplemented with parts of the recent history of the area (Harris, 1989).

An important impediment to the use of GIS in planning come from the planners themselves; because planners are not funded, their influence on these systems (GIS) may be very limited. Again planners' limited vision of the potential of GIS is an even more basic problem (Innes and Simpson, 1993). The main benefits of GIS to planning accrue as higher quality service to the public and more informed decisions (Innes and Simpson, 1993).

The role GIS has played in decision-making and planning has been shown in different case studies (Al-Ankary, 1991; Curtis and Taket, 1989; Hansen, 1996; Lochner and Zietsman, 1998). For instance, in London, GIS aided the planning of health care needs for localities in the Tower Hamlets District Health Authority (Curtis and Taket, 1989). It was used as a tool that aided in the making of informed and guided decisions with spatial significance, on the design and maintenance of facilities by Washington Water Power in the USA (Hansen, 1996). And in Netherlands GIS is either under consideration for future use or have already been acquired, installed and implemented for use in the daily practice of planning, management and decision-making (Ottens, 1991).

Decision-making relating to the funding and planning of municipal services in Saudi Arabia, were greatly improved with the implementation of a municipal geographical information system that provided graphic representation of such services (Al-Ankary, 1991). In other case studies in Mirzapur (Gibbons, 1998) and Mumbia (Patkar and Kumar, 2002) both in India, GIS was proven to be a very useful tool in aiding decision making and planning for the cities' water utilities and monitoring land use and development projects.

Couclelis (1991) warns that, the current emphasis in GIS data on the absolute positions of objects, and the inability of GIS to represent information about interaction constitutes a serious impediment to GIS application in planning, and has led to an inevitable emphasis on the physical rather than the social or economic aspects of human activity. Openshaw

(1993) warns of dangers associated with some GIS-inspired decisions, such as ruining businesses and wasting of public resources. In the same breath he also says that not using GIS may actually lead to poorer decision-making.

The concern is that with so many GISs being applied to a plethora of problems, at many different scales and scattered across many disciplines, there is a real and rapidly increasing prospect of GIS-based spatial decision-support systems being blamed for causing damage and harm owing to virtually any 'permutation' of data errors, misapplications, GIS user abuse and even deliberate use as a weapon of war or terrorism (Openshaw, 1993). Such as the 1991 Gulf war and the recent invasion of Iraq.

If GIS is ultimately to take a place at the strategic planning level, then it will need to develop an effective interface with various decision-support services. Such as those currently embedded within an executive information and intelligence systems, with functions ranging from economic evaluation methods, performance indicator analysis, and various project evaluation methods (Macgill, 1990). These in turn will be related to other organisational activities- their management information systems, financial planning, capital expenditure programs, and the institutional and organisational arrangements and hierarchies within which these are managed on a day-to-day basis.

A crucial precondition for the development and extension of geographical information systems to become a strategic planning tool at the executive level would be knowledge of the organisational context for decision-making in particular cases, and awareness of the institutional set-up supporting executives. This should be taken very seriously when implementing a GIS. Research into such dimension is radically lacking at the present time (Macgill, 1990).).

"It's apparent that GIS will continue to play a larger role into the future," These are the words of Mr. Nick Kryger, Public Utilities GIS manager of Salt Lake City (Salt Lake City, 1999). To make more effective progress in the future of GIS and planning, researchers must first codify existing practices, and then document and explain successes and failures. Ultimately building a framework for practitioners to apply in the overall innovation effort (Innes and Simpson, 1993).

GIS in planning and decision making in South Africa

In South Africa, GIS is aiding the planning processes and decision-making in organisations, especially those dealing with geospatial data; such as the Metropolitan Demarcation Board and the Independent Electoral Commission. Many environmental consulting firms such as SRK consulting in Johannesburg have adopted the use of GIS in their activities; this includes providing site-specific decision that are environmentally significant to their clients (Personal communication[2]). GIS was used in the boundary demarcation of Johannesburg local councils (Lupton and Mather 1996). Informed decision on effective policing and crime management in Paarl, were made with the aid of a GIS (Lochner and Zietsman, 1998).

However it is frequently being used only for digital map production (Weiner and Harris, 1999). Fincham (1999), Weiner *et al* (1995) advocate for the involvement of local communities in a participatory GIS, where local communities are involved in planning and are also keen to contribute information and ideas about services. This participatory GIS has the potential to transform local planning (Fincham, 1999) and the way services such as water is delivered.

Critics of GIS technology in South Africa have accused it of being a top-down approach to planning, which reinforces the planning practices of the apartheid government during the apartheid era. Thus casting aspersions on the appropriateness of GIS technology in the South African context. It is the opinion of Hill and McConnachie (2001) that by implementing a GIS the scope of the planning process could be strengthened in South Africa. Accordingly, the sooner GIS is regarded and seen as an integral part of local government operational planning and management, the more rapidly genuine advancement will be made in local planning in South Africa (Hill and McConnachie, 2001).

[2] Communication with a Senior Scientist at SRK Consulting, Johannesburg, May 2002.

There is little, by way of documented research on the application of GIS in water utilities, as most researchers focus more on the debates surrounding the social issues of GIS and its place and relevance in society (Hill and McConnachie, 2001; Mather, 2000; da Cruz, 1999; Weiner *et al*, 1995).

Conclusion

The implementation of a GIS involves much more than the hardware, software and the organisational environment in which it is implemented. A good understanding of the technology is of equal importance. GIS technology by its very nature is an interesting subject for research; this has led to the abundance of literature on almost every area of the technology. This chapter has tried to highlight some of that literature by starting with its development in the early part of the 1960s through the work of Richard Tomlinson to the level and development of GIS in the First and Third Worlds.

The literature review also identified various approaches to implementation. These approaches included those focusing on the issue of success; here the focus was on assessing the success or otherwise of implementation (Obermeyer and Pinto, 1994), the conditions for the effective implementation of GIS, and finally the factors that are likely to enhance the chances of successful implementation (Cambell and Masser, 1995). A second theme within 'approaches to implementation' examines phases or typologies of implementation. Cambell and Masser's (1995) three typologies and Aronoff's six-phase implementation process were reviewed. The literature on GIS implementation in the developing world tends not to be based on typologies or success strategies, but is instead concerned with the various reasons for the failure of GIS implementation relating to factors of data quality, human resources and poor training techniques. These issues will be explored in the context of the research findings.

Chapter Three: Methodology

Introduction

Research involves collecting primary and secondary information. On the one hand primary research procedure involves the researcher generating data from laboratory experimentation or field exercise. And on the other hand the researcher collects data from existing sources in secondary research procedure. This chapter highlights the primary and secondary research procedures and methods adopted for this research, such as in-depth interviews, participant observation and search for relevant literature. Problems encountered during the field exercise are also discussed.

Primary Research

Primary research is carried out by collecting data "in the field" from real people and analysing that data for patterns and themes. Conducting interviews and formulating recommendations from the findings is an example of primary, or field, research. In conducting primary research investigation or studies, quantitative or qualitative research methodologies are used and in some situations they are combined, depending on the subject of investigation.

Research Methods

Research methods can be classified in various ways, however one of the most common distinctions is between qualitative and quantitative research methods. Quantitative research methods were initially developed in the natural sciences to study natural phenomena. While qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena (Myers, 1997).

Examples of quantitative methods include survey methods, laboratory experiments, formal methods (e.g. econometrics) and numerical methods such as mathematical modelling. Examples of qualitative methods are action research, case study research and

ethnography. Qualitative data sources include observation, participant observation, interviews, questionnaires, documents and texts, and the researcher's impressions and reactions. In Information Systems, there has been a general shift in research away from technological to managerial and organizational issues, hence an increasing interest in the application of qualitative research methods (Myers, 1997).

The motivation for doing qualitative research, as opposed to quantitative research is that qualitative research methods are designed to help researchers understand people and the social and cultural contexts within which they live and work (Myers, 1997). According to Kaplan and Maxwell (1994) the objective of understanding a phenomenon from the point of view of the participants and its particular social and institutional context is largely lost, when written data are quantified. An advantage of a qualitative approach is that a wealth of detailed information about a specific event is produced. This increases understanding of the cases and situations studied on the one hand, and on the other hand it reduces the capacity to generalise (Myers, 1997).

A large number of Geographical Information System (GIS) implementation research consists of single case studies, in which practitioners and academic researchers report on the success or failure of their particular implementation effort within a local government, planning agency, or some other user site such as organisations (Wentworth, 1989; Obermeyer and Pinto, 1994).

Case study approach

This research set out to examine the implementation of GIS technology in Johannesburg Water (JW) and how it impacts on planning and decision-making. In order to achieve this goal, the case study research method of the qualitative research methodology was adopted for the research, rather than a quantitative research methodology. Existing literature have shown that the case study approach is most popular and probably most suited for researching the implementation of GIS in an organisation.

The term "case study" has multiple meanings. It can be used to describe a unit of analysis or to describe a research method (Myers, 1997). The discussion here concerns a case study as a research method.

According to Yin (1994) the scope of a case study can be said to be an empirical inquiry that investigates an existing phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not evidently obvious. The case study research method is particularly well suited to information systems research, since the object of the research is the study of information systems in organizations, and interest has shifted to organizational rather than technical issues (Myers, 1997).

Campbell (1995) noted that much of the debates on the most appropriate research methods to investigate the implementation of computer-based systems including GIS, focused on the merits of the different approaches to case studies. In case studies, retrospective reporting of the successes and failures of the implementation efforts is often prone to considerable information loss and bias, particularly when there has been an elapse of considerable time since the implementation effort occurred (Obermeyer and Pinto, 1994). It is important for case studies to be structured in such a manner that the researcher gets behind the formal appearance of the activities of the organization and the individuals that operate in them (Campbell, 1995).

The two forms of case study methodology approaches used in researching information systems including GIS are discrete-entity and web model approaches. According to Campbell (1995) the discrete-entity approach concentrates on interviewing the people most directly involved with the technology and formal statements of intent are obtained, and the web model attempts to examine the social and political network within which computer based systems are located.

In a web model type approach Campbell (1995) suggests that it is important to define the broad boundary of the case study and interview a wide range of individuals including those not directly involved with the project (GIS). It was the intention of the researcher to

adopt both approaches in this research but due to the limitations[3] experienced at the site of the research, the web model was not fully adopted.

In case study research methods, there is always the use of techniques to collect data. These techniques are most often qualitative in nature, such as interviews and participant observation.

Interviews

The technique for data collection associated with qualitative research methods adopted for this research included the use of interviews. A case study researcher uses interviews and documentary materials first and foremost to gather information; afterwards participant observation is used to collect additional information (Myers, 1997).

The purpose of interviewing is to find out what is in and on someone else's mind. The interviewer should not have any predetermined categories for organizing what is said, but be quite open to the viewpoint of the person being interviewed. It is the responsibility of the interviewer to provide a framework within which people can respond comfortably, accurately and honestly (Myers, 1997). In qualitative research the choice of interviewees are made on their relevance to the research topic rather than their representativeness (Neuman, 1999).

There are three approaches to data collection when using interviews (McMillan and Schumacher, 2001). These approaches are Informal Conversational Interview approach, Standardized open-ended Interview approach and General Interview Guide approach. These interview approaches are defined by (McMillan and Schumacher, 2001), as:

• **The Informal Conversational approach/interview**: this relies on the spontaneous generation of questions in the natural flow of interacting with subjects. And is typical of interviews conducted in participant-observer fieldwork. This approach is useful when the researcher can spend an extended period of time in the setting. Since the data gathered

[3] Refers to the problems experienced in Johannesburg Water (Pty) South Africa.

will be different for each person interviewed, considerable time must be spent throughout reviewing the content of conversations to plan future interviews to help gather responses to similar questions across subjects. Each new interview will build on those completed. Without this 'round' approach to the interviews, patterns and themes may never emerge.

The advantages of the Informal Conversational approach are its flexibility, its responsiveness and it is context sensitive. While its disadvantages are it is very time consuming, depends heavily on the interviewer's conversational skills, it is hard to guard against asking questions that impose interpretations on the situation and it is difficult and difficult to pull together and analyse the data.

• **Standardized open-ended Interview approach**: This involves developing all the questions in complete form prior to the interview and used as specified. Its use is ideal when data is to be collected by more than one interviewer and when time with subjects is limited. Having questions prepared insures that you collect the data you need from each subject without the need for a follow-up.

Advantages of this approach are; the exact instrument used in the interview is available for inspection by decision makers and others interpreting the work, making data analysis easier; variation in the results among interviewers can be minimized, since it des not depend heavily on the interpersonal or communication skills of the researcher; since the interviews are highly focused time is used efficiently. There is a reduced need for interviewer judgements; an assurance that the same amount of information will be gathered from each subject and credibility of the interview is enhanced.

Problems associated with this approach are, it does not permit the interviewer to pursue topics not anticipated when the interview was written, constraints are placed on the use of different lines of questioning with different people based on their unique experiences and it is heavily dependent on adequate planning.

• **General Interview Guide approach**: an interview guide is a list of questions or issues that are to be explored through interviews. This approach is particularly useful in conducting group interviews. It keeps interactions focused but allows individual

perspectives and experiences to emerge. The advantages are that it is responsive (particularly when follow-up/probing questions employed), is flexible, basically the same information is obtained from subjects, the structure helps the interviewer remain focused and the responses are systematic and comprehensive.

The disadvantages associated with this approach include its vulnerability to interviewer effects (the researcher must be responsive, spontaneous, and insightful to direct relevant follow-up questions), it depends heavily on adequate planning to insure that all relevant issues included in the guide are covered, the structure of questions are potentially weak, biased, leading and judgmental. By laying down a road map flexibility may be lost.

Interviews with a small pool of people characterised the nature of the interviews that were conducted in JW. A combination of the Standardized open-ended and Informal Conversational interview approaches was used because of their advantages as out lined above and also to allow the interviewees express their opinions and experiences on the issues that were raised.

The interviews were focused and structured and designed to encourage dialogue with the interviewee. Responses from the interviewee were written down. The interviews were not recorded with a tape recorder, so as to reduce the inhibition of the respondent and increase the chance for a successful interview. Sahay and Walsham (1996) did not use a tape recorder for some of the interviews conducted in their research; it was their thinking that this might reduce respondent inhibition.

Observation

Observation often works in conjunction with interviewing but can sometimes be carried out without an interview component. Observational techniques serve to fill the gap between what people say and what they actually do Observational techniques also help us gain understanding of social interaction patterns, such as, a work team's knowledge sharing activities. Observation-based research helps get at aspects of experience that people aren't aware of, because what they do remains largely implicit to the individual. That is, people are often not aware of how they do things and therefore can't articulate this

knowledge in an interview, but through observation their behaviour is revealed (McMillan and Schumacher, 2001).

Like interviews, observational research can be very open or more structured. Unstructured observation could involve hanging around a work group for several hours to get a picture of a typical workday. Unstructured observation focuses on aspects such as,
Artefacts are physical objects in use (technologies, pens, whiteboards, documents, toys, etc.). Symbols refer to noticeable markers of the organizational culture, such as patterns of interaction, dress code, and the physical site. More structured observation techniques would be used to understand how a person completes a particular task or interacts with a specific product or technology (McMillan and Schumacher, 2001).

The purpose of collecting observational data is to be able to describe the setting, activities, and people observed and follow through with information on the meanings of what was observed from the participants' perspective. Some limitations of observations are that, the observer may affect the situation being observed in unknown ways, only external behaviours are focused on and typically only a limited sample of activities are observed (McMillan and Schumacher, 2001).

Observations were used in this research on the occasions that visits were made to Johannesburg Water. The purpose of the observations was to see how staff interacted with each other and performed their duties and how effectively they utilized the GIS software. On one occasion while waiting to interview the GIS Manager, it was observed that there was a feeling of cordiality in the GIS unit. Personnel in the unit tended to assist each other in solving job related problems.

Preliminary visit to Johannesburg Water

A preliminary visit was undertaken to familiarize with the company, this was with the view of identifying officials that would be interviewed. It was found out from this visit that third level management personnel occupied a very important niche in the decision-making process, which usually, was a section head. These managers worked directly with

the line staff and apart from using GIS or its products themselves, they had first hand experience with the staff that used the GIS or the products of the GIS.

During the preliminary visit, some of the officials were interviewed without scheduling appointments with them, due to their busy schedule. Scheduling appointments with them within the time frame set for the research may have proved to be virtually impossible, so they were willing to be interviewed immediately for between five minutes to one hour thirty minutes.

Prior to embarking on the field exercise, three officials were contacted and intimated with the topic of the research over a period of six months. This was to get a general feel of what might be the likely obstacles to conducting the research in the company. Two of the officials responded positively and one of them; the Project Manager in the Operations department proved to be very valuable in providing an in-road into the company and also facilitated some of the interviews.

Officials interviewed

The identification and subsequent interview of officials were carried out in three categories. Officials mostly involved with the implementation of the GIS made up the first category of officials to be interviewed. And they happen to be those in the GIS unit, who work directly with the GIS on a day-to-day basis. The second category of officials that were interviewed are third level management personnel and they use the GIS and its products; they are not directly involved with the GIS implementation effort. The third category of officials that were to be interviewed, were those not directly involved with the implementation effort nor did they use the GIS or its products.

First category officials

Two officials in this category were interviewed. They are the GIS Manager; a third level management personnel, and the GIS Coordinator. The GIS manager, who happens to be the head of the GIS Division, was interviewed for about an hour on one visit and for about one and half hours on another. She was very helpful and provided very useful

information. Initially, the GIS Coordinator was very sceptical and wary of the researcher, he specifically wanted " approval from the top" before any information could be divulged. Not until after an assurance from the Projects Manager that it was all right to talk to the researcher and that approval would be obtained from the Executive Director, did the interview proceed. The interview lasted for about one and a half hours.

Second category officials

The officials interviewed in this category are the Investment Manager in the Capital Expenditure Department, The Manager-Revenue in Customer Services-Revenue Department and the Networks Managers in Operations Department.

The Investment Manager responded very well to the interview, which lasted for about twenty minutes, providing useful information. The Manager-Revenue also responded very well to the interview and was interviewed for about fifteen minutes. The Networks Manager was not very keen to be interviewed, this was probably due to the atmosphere pervading in the organisation towards the research and more-so by an outsider researcher. The interview with the Networks Manager lasted for about twenty minutes.

Third category officials

Two officials in this category were interviewed. They are the Projects manager; a third level management personnel and a staff in the Operations Department. The Projects Manager was very helpful during the interview, which lasted for about ten minutes. A lot of time, aside from the interview, was spent with the Projects manager as was noted above, through the initial contact with the researcher. The staff member that was interviewed was also very helpful; the interview lasted for about forty minutes.

Secondary research

Secondary research describes information gathered through literature, publications, broadcast media, and other non-human sources. This information or data is generally easier to gather than primary information or data. Secondary literature summarizes the

research and data of many different sources and presents an overview of a topic. It is not original research, but an excellent source of background information on a topic (Zikmund, 2003).

Secondary research methodologies involve the collection and analysis of data and information from already existing sources such as research reports and other publications. Various studies have been conducted on the impact, effectiveness and implementation of GIS in organisations. The advantages of secondary research include data not being expensive to collect, obtained rapidly, while the disadvantages include uncertain accuracy of data, data not consistent with needs. The time period may be inappropriate; that is, the data maybe outdated (Zikmund, 2003).

A comprehensive survey of relevant literature from journal articles, textbooks, and Internet resources was done to gain an understanding of the research and methodology that would. Publications and press releases obtained from Johannesburg Water were consulted extensively.

Data analysis

A descriptive narration has been used to present the data obtained in the field in two sections. Section one describes the findings on the characteristics of the GIS implementation and impact in Johannesburg Water and how it has affected planning, decision-making and service delivery. In section two, the findings will be analysed by comparing the implementation effort in Johannesburg Water with that established in the literature reviewed.

Conclusion

In conducting research or study it is very important for the researcher to adopt methods that would help in achieving the aim of the research. Methodologies provide a researcher with the necessary tools with which to conduct a research or an investigation. These tools can either be qualitative or quantitative by their nature. This chapter highlighted the methods and tools that were used in conducting the research. The tools employed in this

research were interviews and a form of participant observation. The interviews were based on some structured questions. As the field investigation progressed, these tools were modified to meet the challenges that were constantly being faced. The problems encountered during the research were also highlighted as well as the technique used in presenting and analysing the data.

Chapter Four: Research Findings

Introduction

The purpose of this chapter is to present the information obtained on the GIS implementation effort and impact of GIS on planning, decision-making, and service deliver practices. The discussion in this chapter will be in two sections. Section one presents the findings on the implementation of GIS: the hardware and software components, development of the GIS database and the GIS implementation strategy, as well as its role in planning and decision-making and impact on the operations and maintenance of the water and sewer infrastructure in Johannesburg Water (JW). Section two presents an analysis of the findings by comparing the implementation of GIS in Johannesburg Water with that established in the literature reviewed.

Geographical Information Systems implementation

Johannesburg City Council adopted GIS in 1982, when it implemented a system developed by Siemens of Germany. In the Johannesburg City Council two people were sent to Germany for training on how to operate the system, since it was configured in German. One of the two people sent for the training is the current GIS Manager in Johannesburg Water, who at the time of the training was an employee of the Johannesburg City Council.

According to the GIS Manager, "the Planning department spearheaded the implementation of the GIS, leaving the other departments in the city council to follow. The Siemens system operated on a Unix operating system, using Genemap software. The system was used to process water and hydraulic data, working very well for about 10 years" (Interview). At this time water and wastewater existed as a single department in Johannesburg City Council.

The 1994 restructuring of local councils in the Johannesburg area saw the creation of seven municipal local council structures. The department of water and wastewater in Johannesburg City Council was split into two separate departments. Department of Bulk water was more responsible for bulk water from Rand Water, while the Department of

Wastewater was responsible for the collection and treatment of wastewater in the city's operational area. The restructuring also resulted in a name change from Johannesburg city council to Greater Johannesburg Metropolitan Council.

Implementation of the GIS changed from the Siemens based GIS to ESRI's Arc Info. Again, the planning department took the lead in spearheading this change, after an evaluation of GIS software of the time, leaving the other departments to follow suit. The other departments had to change because of the compatibility and exchange of data, between them and the planning department. The departments of Bulk Water and wastewater continued to implement ESRI's Arc Info, until the departments' services were taken over at the creation of Johannesburg water.

The GIS that existed in some of the seven municipalities were rudimentary. For example four of the municipalities (Randburg, Midrand, Soweto, Eastrand) had some form of an Information System operating in the spreadsheet format, but no GIS. The information contained in the spreadsheet was mainly Customer information data. Two municipalities: Rooderport and Johannesburg city council had an information system that comprised a GIS complete with attribute data. Only Mooderfontein had no system at all (Neither GIS nor Information System).

When Johannesburg Water was incorporated all the different municipal information systems and GIS were amalgamated into one single system and format that culminated into a GIS with a database. Amalgamating the municipal systems kick-started the GIS implementation effort. Implementation effort as used here refers to the planning and execution of the set-up of the actual hardware and software needed, as well as developing and sustaining the required database to run the GIS**.**

A GIS vendor with the right type of software for the GIS data needs of JW, was found in Munsys Technologies (Pty) Limited. They develop software for the creation of intranet GIS websites that resides on a central server. This vendor was not shopped for, unlike the case of the British local governments that had to actively shop for a vendor that would fulfil their hardware and software needs (Campbell, 1991; Campbell and Masser, 1993). This vendor was probably chosen for its experience in developing GIS for municipal

structures. Municipalities in South Africa have used the company's GIS products since 1997[4]. Apart from providing the software needed for the GIS, they also assisted in the initial development and set-up of the GIS and by providing technical assistance when needed.

Geographical information Systems implementation in Johannesburg Water is based on a dedicated GIS unit, with some departments, such as Capital Investment and Customer Services-Revenue having online access to the intranet GIS. The Capital Investment Department uses the Alchemy software to gain access to the intranet GIS. However, the Operations Department, which is responsible for the water and sewer network, does not currently have online access to the intranet GIS, but there are plans to install software to provide a link to the GIS.

According to the manager of the GIS there was no policy that guided the GIS implementation effort at the early stages of implementation. However, she further stated that a policy was only formulated after the implementation effort. This policy provides the operational objectives for GIS in the organisation.

Hardware and Software components

The hardware components on which the GIS system is built comprises of a single server and 7 workstations. Software being used is Munsys (for the intranet GIS), Oracle (for the database), AutoCAD (for map design) and AutoDesk's MapGuide, within the MapGuide is the use of Cold Fusion and Dreamweaver. The Cold Fusion and Dreamweaver software is used to customise MapGuide to suit the data needs of the organisation. There is an organisation wide local area network of about 300 PCs and 150 GIS user licenses. Capital Investment Department uses the Alcamey software to gain access to the Intranet GIS. Presently the system configuration serves the GIS needs of the organisation.

[4] http://.www.munsys.com/products/intranet.aspx

Personnel in the GIS Unit

The GIS Division is in the department of Capital Expenditure. There are seven permanent and three temporary staff members, with varying experience in GIS. There is the GIS Manager that heads the division, a GIS Developer and an Assistant GIS Developer, a Supervisor, three Data Capturers and three Temporary staff. At the time of employment the staff in the unit had varying degrees of experience. From the GIS manager with over twenty-two years of experience working with GIS, to one of the data capturers who had just about a year's experience of working with GIS. Only one of the Data Capturers had no experience in GIS, at the time of employment.

In addition to experience in GIS, the Supervisor also had experience with using AutoCAD software (AutoCAD is used for map design), as she has an engineering background. She supervises the 3 data capturers. The staff member with out any GIS experience was trained in-house. From observation there seems to be a cordial atmosphere in the GIS work environment, with the staff helping each other to solve job related difficulties. Training programs are held in-house to enable the personnel to meet the challenges and demands of the job.

Data Development and Application

The largest expenditure in implementing a GIS is in the creation of the database. It involves organizing and converting existing data into a suitable digital format and entering the data into the GIS. Data base development requires experienced personnel. A new GIS site will either have to hire or contract for this expertise (Aronoff, 1991).

The development of the required data needed for the GIS was based on the need to cater for all water and sewer reticulation in Johannesburg Water's operational area. Other database layers are provided by the City of Johannesburg, such as Cadastral, Roads, Electricity, Parks, etc. "We only concentrate on two main layers. Other layers such as, Depot boundaries, Water Zones, Sewer Service connections, etc., are considered to be insignificant" (comments by the GIS Developer).

The GIS unit provides data to the departments, sections and units (users) that make a request. The data provided is specific to the request made by the user, which is then published by the GIS division. Access to this data by the user, is by online intranet Mapguide software. A coordinated and good working relationship exists between the GIS division and the users of the GIS products. This relationship is further strengthened by regular user group meetings held between the GIS division and the different user groups such as the other departments and sections and deports. Also, meetings are held between the GIS section and the city's corporate GIS and other UAC's, and between the GIS division and the GIS system vendor. This interaction allows for system performance evaluation and feedback with all stakeholders.

GIS implementation strategy in JW

Johannesburg Water has adopted a two-phase implementation strategy for implementing and developing its GIS implementation effort. Phase one involves the development and set-up of the server, workstations and required database. Accessing the GIS by the users in the other departments and sections is via intranet access. The GIS unit publishes data via the server over the intranet, where the requesting user can access. This data is specific to the requesting user and though it is published over the intranet the data is accessible only through authorisation. However all data update is done by the GIS unit, since they are responsible for managing the server.

The second phase of the implementation strategy involves the creation of a GIS/Information system application (called HANSEN), being developed by Worwick Africa (Pty) Ltd, to totally integrate all users in JW, in a uniform database cum warehouse. However, some data to be used in the system would be sourced from the City of Johannesburg's administration, and other agencies and structures of the city.

With this system in place, according to JW's coordinator, "we will be able to access all kinds of information in other companies - we will be able to look at building plans, electricity supply, road data, etc. and they will be able to see our data as well, of which the GIS will play a major role" (Interview).

The integration of databases from the City of Johannesburg and its other agencies with those of JW forms the core of the second phase of JW's GIS implementation. JW has a five-year implementation schedule for its GIS/IT programme, costing over R50 million. The thinking in JW is that when the HANSEN software project is finally complete, service delivery would be enhanced. For instance water and sewer depots and pump stations would be able to access spatial data and information much more quickly than how it is at present. Presently, spatial data is obtained via printed maps, which have to be obtained from the head office of JW.

Problems of GIS implementation in JW

As in every situation that involves the interaction of humans and technology, the GIS in Johannesburg Water has its share of problems, such as the inadequacy and completeness of data and that the information provided is not up-to-date and on time. These are some of the problems being experienced by the Manager Revenue and the Investment Manager respectively.

According to the GIS Manager, the major problem that is experienced by the GIS section is the inaccuracy of the information supplied by other departments and sections. (Being the custodian of the database of the organisation only the GIS unit can modify the data contained in the GIS). This human generated problem affects the overall performance of the unit, in that, if incorrect data is inputted into the GIS, the resultant product will be incorrect. And this has a major implication for all activities relying on the output from the GIS. According to researches into the use of GIS in organisation, problems associated with GIS are more often human induced and not from the technology itself.

GIS contribution to planning and decision-making in JW

GIS is used in planning and the processes involved in decision-making in Johannesburg Water. The Investment Manager said that with the ALCHEMY system, which he defined as software, through which the department connects to the intranet GIS. He added that users could view drawings and other relevant information required for proper planning and design of projects, over the intranet. According to the Investment Manager the on-

time information provided by the GIS improves planning and decision-making in the department.

In the past, planning for the maintenance of the water and sanitation infrastructure, which is carried out by the Operations Department, was done with the aid of maps and plan books. These were drawn manually, which was an arduous and rigorous task that took many man-hours. But since the GIS implementation in Johannesburg Water, the maps and plan books are now prepared for the Operations department by the GIS division.

According to the GIS Manager, the management of Johannesburg Water took a decision to de-commissioning the Mooderfontein sewer plant. But before this could happen, sewer from Mooderfontein had be routed to the Northernworks, since the Northernworks sewer plant had a bigger capacity to handle and treat sewer than the Mooderfontein sewer plant and it was more cost effective to route all sewer from Mooderfontein to the Northernworks, than keeping Mooderfontein treatment plant in operation. The GIS was able to spatially represent the best route for a pipe that would link Mooderfontein sewer plant to the Northernworks sewer plant. This function of the GIS also played an important part in the de-commissioning of the Vorna valley sewer plant in the Midrand area of Johannesburg.

According to the GIS Developer, the GIS is being developed to such a level that it would be used to enhance the supportive role for decision-making and/or day-to-day operations. For instance the generation of "life cycle" statistics for every single asset, making it possible to work out probability of failure vis-à-vis company cash flow & fix/replace policies, etc. To the GIS Coordinator, "this is an example of what the final picture of the GIS capability in Johannesburg Water would look like when implementation is complete".

An important aspect of the GIS implementation, according to the GIS manager is that the 'call centre' where customers call-in to lodge complaints, would be linked to the GIS to enable operators pinpoint the exact location of complaints. This information will be fed to the maintenance team working close to, or in that location. With this in place, service delivery would be given a boost, as the time taken to effect repairs would further be

reduced. At present the call centre receives 350,000 calls a month, out of this figure only about 19,000 – 20,000 jobs are processed. This figure on the number of calls processed is expected to increase considerably with the full implementation of the GIS.

Impact of GIS in Johannesburg Water

Users of the GIS and its products in the other departments and units in the organisation do not have direct access to the server. This reinforces the notion of power play surrounding the ownership and control of data. The GIS unit does not internally generate all the data fed into the GIS. The division is charged with the sole responsibility of maintaining and operating the server used for the GIS. In this way, the unit is able to wield some form of superiority and control over the other units and departments, when it comes to accessing the GIS. Since the GIS users can only access the data that is published by the GIS unit and nothing more.

Since the implementation and use of GIS in Johannesburg Water, there has been a very positive impact of GIS in the organisation. These impacts are felt mostly in the departments that require spatial information such as Operations, Customer-Revenue Services and Capital Expenditure. For instance, the Networks Manager in the Operations department, said that before the GIS was implemented, work done in the department was very tedious and time consuming.

For example plan books and maps needed for the design and maintenance of water reticulation and sewer networks, were prepared manually but now the GIS does it. And also, the GIS acts as a support database in the operation and maintenance of these water reticulation and sewer network systems. The Manager-Revenue said that GIS benefits the department in achieving set targets, and by plotting service installation and work scheduling, work could be spread around equal cycles.

When asked to rate the performance of the GIS since installation, these Managers all rated the performance of the GIS to be above average. Moreover, the GIS that is being operated in Johannesburg Water seems to have made a good impression with them. According to the GIS manager “there has been an increase in the usage of the GIS by users, up from 20

percent at the early stages of implementation to 40 percent presently"; this figure is expected to increase when the second phase of the GIS implementation is complete.

Role of GIS in JW's Service delivery

The increase in the use of the GIS has indirectly led to efficient and effective delivery of services. This is in line with part of Johannesburg Water's mission statement, that the organisation would be customer focussed, responsive and efficient in all their operations. Work performance by the individual users of the GIS has become more efficient and in turn, has translated to service delivery becoming more efficient and effective. For instance, in the rehabilitation of Soweto water reticulation network (Operation Gcin'amanzi), planners were able to visualize the mapped old reticulation system with the aid of the GIS. The incorporation of aerial photographs in the GIS provided planners with actual land use and land cover overlying the old reticulation system. Thus helping planners to identify the best places to route the new water reticulation network and site water fixtures efficiently, effectively and conveniently for the benefit of their clients.

Comparative Analysis of GIS implementation in JW

Data analysis can be conceptualised as an inductive process involving the description and understanding of field data (Sahay and Walsham, 1996). In analysing the data collected from Johannesburg Water, transcripts were prepared from the interview notes to identify the relevant themes in the data. These themes made it possible to compare the implementation effort in Johannesburg Water with what an implementation effort comprises as identified in the literature reviewed. The assumption underlying this research is that basic issues regarding the implementation of GIS in organisations can be generalised, irrespective of the implementing organisation.

Such issues are, style or model of implementation approach, technical aspects of hardware and software, requiring a vendor, organisational and institutional factors. However, modifications of these basic issues to system implementation would exist, depending on the circumstances and experience of the implementing organisation. This in itself would make GIS implementation somewhat different form organisation to organisation.

Implementing GIS in Johannesburg Water

Aronoff's (1991) six-phase GIS implementation processes do not seem to be directly evident in Johannesburg Water; this is not to say that elements of some of the phases cannot be identified (see chapter two). For instance, phase one of Aronoff's GIS implementation processes refers to the initial awareness of GIS technology by an organisation and this cannot be said to have happened in the case of JW. The peculiar circumstances that surrounded the implementation of GIS in JW account for this: implementation of the GIS commenced with the amalgamation of existing GISs and information systems. However, given the context of awareness, it is safe to assume that the founders of JW were aware of GIS and its potential.

Aspects of phase five and phase six of the implementation processes can be identified, except that, unlike where staff are trained to operate the system in Aronoff's processes, in the case of JW, people who already had GIS experience were employed to implement the GIS.

In relation to Campbell and Masser's (1995) typology of implementation, the fiercely independent approach, which is typified by the introduction and development of a GIS by a single department has been the route taken by Johannesburg Water in implementing its GIS program. Yet elements of the classic model can be recognised. This refers to the limited access to the GIS by some departments, as highlighted above.

In developing the required data for the GIS system, the decentralized model of implementation is evident. This model as highlighted by Obermeyer and Pinto (1994), could be used to explain the implementation of data characteristics and data handling methods appropriate to the organization. The GIS unit does not generate all the data used in the system, for instance water and sewer meter readings are obtained from the Operations Department, while information relating to the categorisation of customers into the different demand classes is obtained from the Customer Services-Revenue Department.

Johannesburg Water seems to have met two of the three necessary conditions for an effective implementation of GIS. According to (Campbell and Masser, 1993), they are:

1. **Information management strategies that identify the needs of users and takes into account the resources at the disposal of the organisation.** This condition can be said to have been met, since this is part of the goals of the Capital Investment Department; the parent department of the GIS unit.

2. **A high degree of organisational and environmental stability**. The goal for the creation of Johannesburg Water, amongst others, is for a commercially viable venture with a high degree of stability that would encourage investor confidence.

There was not enough data available from the research findings, to be able to conclude whether or not the third condition was met. This condition is the **Commitment to and participation in the implementation of any form of information technology by individuals at all levels of the organisation**.

An implementation effort can be said to be successful, when measured against the three criteria for a successful implementation. These are, **technical validity; the belief that the system to be implemented works, organisational validity; a measure of the congruence between the organisation and the system to be implemented or the appropriateness of the system to the organisation, and organisational effectiveness; an improvement in decision making**, because these criteria for success seem to play out in Johannesburg Water.

In terms of the implementation of GIS in Johannesburg Water it is possible to reach the following conclusions: firstly, there is a technical validity, given the robustness of GIS to diverse applications. Secondly, the organisational validity comes from the fact that GIS is well suited to the activities of Johannesburg Water, which is mainly the provision of water and sanitation services. Finally, since the implementation of GIS in Johannesburg Water, there has been a considerable improvement in decision-making.

Recapping from the literature reviewed, the four factors that enhance the chance of success of a GIS implementation, according (Campbell and Masser, 1993), are:

1. **Simple applications producing information that is fundamental to the work of potential users.**
2. **User directed implementation, which involves the participation and commitment of all the stakeholders in the project.**
3. **Awareness of the limitations of the organisation in terms of the range of available resources.**
4. **A large measure of stability with respect to the general organisational context and personnel, or, alternatively an ability to cope with change.**

From the research findings, the factors listed above have played a part in the GIS implementation in Johannesburg Water (JW). The first factor refers to the use of simple applications producing information fundamental to the work of the user. This factor is evident in the case of JW. The applications being used in the GIS in JW are simple and easy to use such as the munsys intranet package, which allows users to access directly the information they require for their work. This is evident in the increase of usage of the GIS from 20 percent to 40 percent.

The second factor is that implementation is directed at the user and it involves the participation and commitment of all the stakeholders in the project. This also is evident in JW, a coordinated and good working relationship exist between the GIS section and the users of the GIS products. This relationship is further strengthened by user group meetings, held between the GIS unit and the different user groups such as the other departments, sections and the deports. Also meetings are held between the GIS section and the city's corporate GIS and other UAC's, and between the GIS unit and the GIS vendor (Munsys). This interaction allows for system performance evaluation and feedback with all stakeholders.

The third factor refers to the awareness of the limitations of the organisation, in terms of the range of available resources. The GIS unit is aware of the limitation of the available resources at the disposal of the organisation for the unit, this awareness comes in the form

of the development of the GIS, in planned phases. Resulting in the most basic equipments needed for the implementation effort, being accommodated in the phase one of the implementation.

The fourth and final factor that will enhance the chance of success of a GIS implementation is a large measure of stability with respect to the general organisational context and personnel, or alternatively, an ability to cope with change (Campbell and Masser, 1993). In Johannesburg Water this factor is seen in the way work practices are changing, especially in the departments of Operations and Capital Expenditure, with respect to the implementation and use of GIS.

Not all of the inhibiting factors for GIS implementation in developing countries, highlighted by Sahay and Walsham (1996) regarding financial, structure, humanpower and data are evident in the GIS implementation in JW. For instance, finance does not seem to be a problem, as JW is committing over R50 million in a five-year period for the complete implementation of its GIS/IT programme.

Structure relates to the style of decision-making and the forms of developing country organizations; decision-making is often confined to a central official who, despite having inadequate knowledge about the GIS technology, is responsible for taking critical decisions relating to the implementation of the GIS (Sahay and Walsham, 1996). Within the GIS unit in Johannesburg Water, decision-making is by the GIS Manger, who is also consulted when major decisions are to be made regarding the GIS in the organisation.

Trained humanpower does not seem to constitute a problem for the GIS division in Johannesburg Water, as very experienced staff run the division. For instance, the GIS Manager has over twenty-two years experience in the use of GIS, and has been with Johannesburg city council structures for over twenty years. The inhibiting factor experienced by JW's GIS, as highlighted by Sahay and Walsham (1996) is that of data quality. According to the GIS Manager, the inaccuracy of the information that is supplied by other departments and sections constitutes a major problem for the GIS.

The enabling factors that involves the development of approaches that will provide continuity in the implementation effort, the development of practices that will smooth the transition of people from their existing ways of doing work to using GIS are seemingly in place in Johannesburg Water. However, the institutional mechanisms that relate to policy level initiatives around GIS could not be conclusively defined.

Role of GIS in planning and decision making

The implementation of GIS has created a very important niche for GIS in planning and the processes involved in decision-making in Johannesburg Water. GIS gives planners the capabilities to forecast different growth scenarios that would result from alternative regulatory policies (Innes and Simpson, 1993). These capabilities permit planners to be actively involved in the development of regulatory policies that would enhance and improve service delivery (Innes and Simpson, 1993). Using GIS to forecast different growth scenarios that would play a major part in the formulation of policies is what the GIS Coordinator hopes the GIS would achieve in Johannesburg Water. According to the Investment Manager, GIS is being used to view drawings and other relevant information required for the proper planning and designs of projects.

It was used as a tool that aided in the making of informed and guided decisions with spatial significance, on the design and maintenance of facilities by Washington Water Power in the USA (Hansen, 1996). As was in the case of Washington Water and Power in USA, the GIS is helping the Operations department in Johannesburg Water to establish repair points in the field when carrying out maintenance of the water and sewer pipeline network. Also the GIS aided in the design of new water reticulation and sewer pipelines by spatially representing the optimum routing for these pipelines. The visual representation of the optimum route for the pipes, proved to be very helpful.

Conclusion

The research findings from Johannesburg Water show that the organisation's GIS implementation were characterised by the experiences associated with the creation of the company. JW's GIS implementation cannot be said to conform fully to what has been

established in the literature reviewed. Though the fundamental issues regarding the implementation of GIS remain the same, there is the existence of some minor but important differences. From the findings, GIS has had a significant impact in Johannesburg Water, these impacts are most noticeable in the way it has really improved work practices and service delivery. There is no doubt that the prevailing organisational and institutional dynamics would have an impact on the GIS in Johannesburg Water. However, what impacts these dynamics have on the GIS and its implementation, are not conclusively determined in this research.

Chapter Five: Conclusion and Recommendation

Introduction

This chapter will present the summary of the research; conclusions from the research findings focus more on the differences and similarities that characterised the implementation of GIS in Johannesburg Water in comparison to existing literature. Recommendations will be made from the findings of this research, which might act as a guide to organizations wishing to implement a GIS. Suggested areas for future research are also highlighted.

Summary

This research has been carried out due to a need to fill a gap in the existing literature on the implementation and impact of GIS in water utilities in South Africa. Chapter one presented an introduction and outline of the research. In chapter two, an indebth literature survey was carried out to understand the history and development of GIS, the country context and organizational complexities in which GIS are implemented. Existing literature have shown that since the advent of GIS in Canada, it has been embroiled in debates both within the academic and professional circles. The technology has diffused from the country of origin to countries in the First and Third Worlds.

Also, GIS has been applied in nearly every industry and endeavour that humans have engaged in and also it has been used in a variety of ways and in different organisation, from land use planning to water and sanitation services management. GIS has been found to contribute significantly to planning and decision-making processes, which is the main incentive for implementing a GIS in any organization.

A conclusion drawn from the literature indicates that, the basic issues regarding GIS implementation can be generalized, irrespective of the implementing organization. Such issues as technological, human, organizational and institutional factors are issues that will come into play in any implementation effort. And also, there is wide spread agreement on

what constitutes GIS implementation successes and failures, and steps that should be taken to achieve success and minimize failures in any implementation effort.

Chapter three presented the method adopted in researching the implementation and impact of GIS in Johannesburg Water. This method was the case study approach and was adopted, because many researches into GIS and other information systems used this approach. The techniques that were employed to collect information in the field were in-depth interviews with structured open-ended questions and a form of participant observation. These techniques best suited the research due to the nature of the organization that was studied.

The research findings and analysis were discussed in chapter four. These involved the use of descriptive narration to present the data findings, while data analysis was done by comparing the GIS implementation effort and its impact on the implementing organisation, with that established in the literature reviewed.

Conclusions

This research aimed at investigating the implementation and impact of GIS in Johannesburg Water. Findings from the organization revealed that the GIS implementation effort followed the general trend of GIS implementation as established from the literature reviewed. However it is unique, owing its uniqueness to how the organisation was created. At the creation of Johannesburg Water, the different water and sanitation departments that existed in the former municipal local structures were merged to form an organisation.

Two major themes characterised the GIS implementation effort in Johannesburg Water. Firstly, the implementation effort commenced with the amalgamation of the existing GIS/Information Systems that were in the former local councils of Johannesburg. The organisation did not go through with some parts of the initial process of a new system implementation effort. This is in regard to shopping for an identified systems vendor. The GIS vendor that helped in configuring the GIS system was picked because of its long-standing experience in the area of municipal GIS systems.

Secondly, the implementation of GIS hardware, software and data requirements in Johannesburg Water could be said to be a combination of the centralised and decentralised models, centralised in the sense that the GIS unit was responsible for implementing the GIS, while the decentralized model provides an understanding of the implementation of data characteristics and data handling methods appropriate to the organization. Other departments such as Customer Services, Operations and Capital Expenditure, contribute data used in the GIS.

The implementation effort in Johannesburg Water is not completely without headaches. These headaches, which are human in nature impact on the efficiency of the GIS and they refer to the problems of inaccurate data bedevilling the GIS implementation effort. Just like Aronoff's prediction, 'The issues responsible for implementation failures are almost always people problems' (Aronoff, 1991, 249). However, there were complaints of the data provide not being of real time. This could be a defect in the technology and not necessarily a human problem.

It is the finding of this research that the implementation of GIS in Johannesburg water has had an overall positive impact on the organisation. From its role as a decision support tool, through its contribution to planning, to an overall improvement on the way services are delivered. The implementation of GIS in Johannesburg Water is not too different from that published in the literature on GIS implementation in organisations. However, the process of the GIS implementation effort re-emphasises the circumstances surrounding the creation of Johannesburg Water.

Aspects of the implementation of GIS in Johannesburg water can be said to conform to the generalisation of GIS implementation processes and approaches in organisations, as established in the literature reviewed. However, distinguishing characteristics do exist in Johannesburg Water's GIS implementation that cannot be explained by existing literature. This is what differentiates GIS implementation between organisations.

Recommendations

Since there is no perfect style or approach to GIS implementation, it is recommended that in any new GIS implementation, the implementation effort should commence with the drafting of plans and or policies that would spelt out comprehensive strategies, that would guide the development and adaptation of the system to the implementing organisation. These strategies should take into consideration any organisational or institutional factors that maybe unique to it. The implementation plan should define the group or groups of people within the organisation that will be responsible for the implementation and operation of the GIS.

Judging from the problems of inaccuracy of data used in the GIS of Johannesburg Water it is recommended that all data and information should be thoroughly scrutinized for anomalies, before being fed into the system. This would go a long way in prevent aspersions being cast on the integrity of GIS. The output of the GIS will not be trusted if the data are unreliable, and early impressions tend to be long remembered. Also, data that are inaccurate or incorrectly entered can be difficult and very costly to correct.

There is a real and rapidly increasing prospect of GIS-based spatial decision-support systems being blamed for causing damage and harm, owing to virtually any 'permutation' of data errors or misapplications (Openshaw, 1993).

This research did not investigate the organizational/institutional factors and human issues in respect of the political or power play that may have been involved in the implementation effort. It is recommended that this aspect could be further researched or pursued in a future research endeavor.

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