



# **IMPROVED WATER INFRASTRUCTURE DELIVERY AND MANAGEMENT MODEL.**

by

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## **PREFACE**

The research contained in this dissertation was completed by the candidate while based in the Discipline of Construction Studies, School of Engineering of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Howard, South Africa.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.



Signed: T. C Haupt (Supervisor)

Date: 05/12/2020

## DECLARATION 1: PLAGIARISM

I, Onyeka Ifeanyi Nkwonta, declare that:

- (i) the research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;
- (ii) this dissertation has not been submitted in full or in part for any degree or examination to any other university;
- (iii) this dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;
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  - (d) this dissertation is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;
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Signed: Onyeka Nkwonta

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## **ABSTRACT**

Water plays a vital role in poverty reduction, economic growth, business competitiveness and enhancement of societal living in developing countries in particular. Provision of infrastructure involves a complex process and utilizes considerable amount of resources including construction materials, energy, finance and time. Infrastructures have long life span and they could create long-term impact on the environment and society. To achieve efficient and equitable economic growth of economy is an important way of managing water. Better access to sanitation services, clean water and water management creates tremendous strategy for economic growth of any country. There is a close link between water and economic growth of country. Water Management brings more efficiency and certainty in productivity across the health of nation and contributes to economic. Water is a critical part of most environmental services on which our ecosystems depend. Water requires optimal management to control competition for use due to population growth and scarcity, climate change, increasing demand and declining water supplies.

This research has attempted to develop a model for improving the delivery of water services in developing countries such as South Africa. The model lays a foundation for development of appropriate policies, regulations and procedures to improve water service delivery at EThekweni municipality. A triangulation approach was employed to develop the model using Delphi method and a structured questionnaire survey. The Delphi study involved three rounds with ten experts participating in all rounds until consensus was achieved. After the Delphi study, a conceptual model was developed and validated using data collected from experienced professionals that deals with water infrastructures at EThekweni metro. The data collection was based on convenience sampling where 306 questionnaire were distributed and 210 complete responses were received. Exploratory factor analysis (EFA) using Statistical Package for the Social Sciences (SPSS) and Maximum Likelihood with Promax rotation were used to determine the validity and reliability of the nine constructs of the conceptual model. Confirmatory factor analysis (CFA) was conducted using AMOS, software program to further test validity and reliability of constructs. The findings revealed that the structural model data was acceptable and eight out of eight hypotheses tested were significant.

The findings of this research indicates that stakeholders in Civil Engineering and construction industry have to improve their delivery practice in order to deliver good water services in the context of developing countries such as South Africa and also the work has contributed to the evolving current body of knowledge in the area of Water management and delivery.

## ISIQINISEKISO

Amanzi adlala indima ebalulekile ekwehliseni ubuphofu, ukukhula komnotho, ukuncintisana kwamabhizinisi kanye nokwenza ngcono impilo yomphakathi emazweni asathuthuka ikakhulukazi. Ukuhlinzekwa kwengqalasizinda kubandakanya inqubo eyinkimbinkimbi futhi kusebenzisa inani elikhulu lezinsizakusebenza kubandakanya izinto zokwakha, amandla, ezezimali kanye nesikhathi. Ingqalasizinda inesikhathi eside sokuphila futhi ingadala umthelela wesikhathi eside emvelweni nasemphakathini. Ukuphatha amanzi njengenzuzo yezomnotho kuyindlela ebalulekile yokuthola ukukhula komnotho okusebenzayo futhi okulinganayo. Ukutholakala okungcono kwamanzi ahlanzekile, izinsizakalo zokuthuthwa kwendle nokuphathwa kwamanzi kudala isu elikhulu lokukhula komnotho wezwe. Kukhona ukuxhumana okusondele phakathi kwamanzi nokukhula komnotho wezwe. Ukuphathwa kahle kwezinsizakusebenza zamanzi kuletha ukuqiniseka okuthe xaxa nokusebenza kahle komkhiqizo kuyo yonke imikhakha yezomnotho futhi kuneqhaza empilweni yesizwe. Amanzi ayingxenye ebalulekile yezinsizakalo eziningi zemvelo lapho imvelo yethu incike khona. Amanzi adinga ukuphathwa okuphelele ukulawula ukushoda nokuncintisana kokusetshenziswa ngenxa yokwanda kwabantu, ukwanda kwesidingo, ukuguquka kwesimo sezulu kanye nokwehla kokuphakelwa kwamanzi.

Lolu cwaningo luzame ukusungula imodeli yokwenza ngcono ukulethwa kwezinsizakalo zamanzi emazweni asathuthuka njengeNingizimu Afrika. Le modeli ibeka isisekelo sokwakhiwa kwezinqubomgomo, imithethonqubo kanye nezinqubo ezifanele zokuthuthukisa ukulethwa kwezidingo kumasipala weTheku. Kwasetshenziswa indlela yoonxantathu ukuthuthukisa imodeli kusetshenziswa indlela yeDelphi kanye nocwaningo lwemibuzo oluhleliwe. Ucwanningo lweDelphi lubandakanye imizuliswano emithathu nochwepheshe abayishumi ababambe iqhaza kuyo yonke imizuliswano kuze kutholakale ukuvumelana. Ngemuva kocwaningo lwaseDelphi, kwasungulwa imodeli yokuqagela yaqinisekiswa ngokusebenzisa imininingwane eqoqwe kochwepheshe abanolwazi ababhekene nengqalasizinda yamanzi kuMasipala weTheku. Ukuqoqwa kwedatha kwakususelwa kusampula elula kwakukhona imibuzo yemibuzo engama-306 nokusatshalaliswa izimpendulo eziphelele ezingama-210. Ukuhlaziywa kwesici sokuhlola (i-EFA) kusetshenziswa inguqulo ye-Statistical Package yeSayensi Yezenhlalakahle (SPSS) kusetshenziswa Ubukhulu obukhulu ngokushintshana kwePromax kusetshenziselwe ukuthola ubuqiniso nokwethemba kokwakhiwa okuyisishiyagalolunye kwemodeli yomqondo. Ukuhlaziywa kwesici sokuqinisekisa (i-CFA) kwenziwa ngokusebenzisa i-, uhlelo lwesoftware ukuqhubekisela phambili ukuvivinya ubuqiniso

nokwethembeka kokwakhiwa. Okutholakele kuveze ukuthi idatha yemodeli yokwakhiwa yamukelekile futhi yonke imicabango eyi-9 ehlolwe ibalulekile.

Okutholwe yilolu cwaningo okubandakanya ukunikela okusebenzayo, okwezemfundo kanye nokwenziwa kwemigwaqo kunomthelela omkhulu ekuthuthukisweni kolwazi lwamanje endaweni yokuthuthukisa ukulethwa kwezinsizakalo zamanzi emazweni asathuthuka njengeNingizimu Afrika.

## **DEDICATION**

This work is dedicated to God almighty for his protection and favour upon my life. I also dedicate it to my family for their support and unending love.

## **ACKNOWLEDGMENTS**

I would like to express my sincere gratitude and appreciation to my supervisor, Prof Theo Haupt, for his ever motivating attitude, sincere and constructive criticism and guidance and above all for his belief in my potential and also for introducing me to the challenges of infrastructure delivery in our society, for all his support and for the great enthusiasm he has always shown for my work. I cannot imagine having any other supervisor than Prof T Haupt. Furthermore, his careful reading of this thesis has improved its quality considerably.

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## PUBLICATIONS

### Journals

1. Onyeka Nkwonta, Karana Padayachee and Theodore Haupt (2019) A review on challenges facing infrastructure delivery and management in South Africa. Submitted at *Journal of Construction management*.
2. Onyeka Nkwonta, Karana Padayachee and Theodore Haupt (2020) A review on reservoir operating systems at eThekwini municipality South Africa. Submitted at *Journal of Construction management*

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- 1 Haupt T and Nkwonta O (2018). A review on improved infrastructure delivery in South Africa. In *Proceedings: 12th Built Environment Conference 6-7August 2018, Durban, South Africa*. Durban, 2018. Association of Schools of Construction of Southern Africa.
- 2 Onyeka Nkwonta and Theodore Haupt (2020) Aging water systems with growing demands, a study at eThekwini municipality South Africa. In *Proceedings: Water conference Bristol 3<sup>rd</sup> and 4<sup>th</sup> September 2020*
- 3 Onyeka Nkwonta and Theodore Haupt (2020) Importance of optimising reservoir operation at uMngeni system, eThekwini municipality South Africa. *Proceedings: Water conference Bristol 3<sup>rd</sup> and 4<sup>th</sup> September 2020*
- 4 Onyeka Nkwonta and Theodore Haupt (2020). The effect of aging infrastructure in water distribution systems in South Africa. Presented at *4<sup>th</sup> ICESW on 10<sup>th</sup>-13<sup>th</sup> August 2020 Ota Nigeria*

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## CHAPTER 1: INTRODUCTION

### 1.1 Background

Infrastructure plays a vital role in encouraging a more productive and competitive national economy (Hardwicke, 2015). While supporting economic growth, the development of infrastructure systems is critical for the social development of a nation by providing comfortable lives (Van der Mandele, 2006) and in many ways has made everyday life easier (Jonsson, 2015). Infrastructure is not only the glue that holds economic activity together, but it is an important economic activity on its own. However, building and operating infrastructure consume a large amount of resources (Van der Mandele, 2006). The provision and development of infrastructure assets typically requires long lead times, significant planning and the involvement of many stakeholders to ensure that the community that will benefit from its provision is appropriately consulted, and needs are prioritized within the funding constraints. Under these circumstances assets managers are faced with mounting challenges to manage and sustain these assets. In response to these challenges, an emerging theme that is being recognized in today's ever changing business environment is the driving need for municipalities to increase their efficiencies and effectiveness in order to improve their delivery of service to their customer base.

South Africa's investment in infrastructure gained momentum in the years leading up to the FIFA 2010 Soccer World Cup, and was set to expand as the foundation of a national growth and development strategy. Over the medium-term expenditure framework (MTEF) period, budgeted and approved public-sector projects total R844.5 billion (National Treasury, 2012). The South African government has made a huge construction spend commitment to provide much-needed infrastructure to support its economic growth and development plans. However, due to several systemic challenges there are considerable bottlenecks such as the need to accommodate continuing growth to support the economic and social development of nations (Stevens, 2006) and also significant parts of infrastructure are ageing and nearing the end of their economically useful lives (Hardwicke, 2015) that inhibit the effective delivery of infrastructural installations.

The National Treasury has identified the Infrastructure Delivery Management Systems (IDMS) as a strategic vehicle to enhance the effective rollout of infrastructural installations and manage those that already exist. The IDMS is a model that describes the processes that make up public sector delivery and procurement management as it applies to the construction industry. It outlines the core processes associated with the planning, delivery, procurement, operation and maintenance of infrastructure works.

However, the lack of capacity and expertise resident within the public sector is debilitating together with a lack of understanding and application of sound project management principles (IDMS, 2016).

South Africa's infrastructure challenges are not primarily the result of a lack of funding but are caused by institutional failures and a lack of appropriate capacity within departments responsible for design, delivery and maintenance of infrastructure. There is need to build the capacity of these entities to support improvement in the planning, procurement and management of infrastructure delivery at the national, provincial and local levels.

Institutional failures will control frameworks for the planning, design and execution of infrastructure projects and infrastructure procurement and also requirements for a number of matters as applied to the supply chain management system for infrastructure procurement and delivery management; and minimum requirements for infrastructure procurement. IDMS enables the separation of the supply chain management requirements for general goods and services from those for infrastructure. Underlying the separation of the supply chains is the notion that the effective and efficient functioning of the supply chain management system for infrastructure procurement and delivery management will realise value for money and good-quality service delivery. Value for money may be regarded as the optimal use of resources to achieve the intended outcomes. Underlying value for money is an explicit commitment to ensure that the best results possible are obtained from the money spent, or maximum benefit is derived from the resources available (IDMS, 2016).

In fact, over the past two decades, the performance of government owned infrastructure in South Africa suffered from low labour productivity, deteriorating fixed facilities and equipment, poor service quality and inadequate investment (Kessides, 2004). In light of the high cost and myriad problems with government owned infrastructure advances in economic thinking have caused many countries to reform the institutional options for the provision of infrastructure services. To achieve these goals and to significantly improve the infrastructure performance, the reform must entail a combination of competitive restricting privatisation and establishment of regulatory mechanism (Kessides, 2004).

The water resource infrastructure within South Africa is declining with assessments reflecting that some 83% of water resources having some form of implication for the fitness of use for one or other user groups (FSE, 2018). This deterioration of water infrastructure will be one of the major threats to the country's ability to provide sufficient water of suitable quality that can support development needs, whilst at the same time ensuring the environmental sustainability of the water use. The most significant issue in this regard is the ability to control

sources of pollution and to manage the available assets when it is necessary (FSE, 2018). Key drivers are the growing population, the need to develop the social economy to support ongoing development objectives, increasing urbanisation, and climate change.

The financial resources currently available for managing water infrastructure are insufficient for the task, and do not recognise the level of investment that is required to counteract the economic harm done by declining water services in our communities (FSE, 2018). Water services challenges have historically been viewed as “technical”, with the result that the funding required for Integrated Water Quality Management has often been insufficient. There are some challenges that affect the delivery of water services in communities and they are described below

1. Inadequate funding
2. Continued culture of non-payment;
3. Lack of political will to hold major polluters accountable;
4. The lack of sustainable financial models for local government, leading to inadequate funds to maintain Waste Water Treatment Works, such as ring fencing of funds to appropriate solution;
5. Inadequate implementation of environmental provisions related to community involvement:
6. Poor co-ordination and planning across the sector, and
7. Economic Policy uncertainties and anomalies as well as the generally uncertain political climate, which have resulted in inadequate investment by private sector companies (FSE, 2018).

Municipalities must be accountable to local communities. In doing so, with regards to water services and management which is the primary focus area of this study, municipalities must structure their administration, budgeting and planning in a manner that gives priority to the basic needs of the community, and promotes the social and economic development of its people. Municipalities are constitutionally mandated to provide basic services including the delivery of water and sanitation services.

According to Ehrhardt et al. (2007) regulation is about making decision and enforcing rules for the development, sanitation and management of urban water supplies in developing countries. However, the aim of regulation is to ensure that all role players comply with all the regulatory goals, objectives and measures in respect of the economic, political, social, technical and environmental deliverables as provided for in all relevant legislation and policy.

## **1.2 Problem Statement**

South Africa is experiencing serious challenges with regards to access to sustainable basic water services, facilitating economic growth and development, ensuring and maintaining service quality such as drinking water quality and wastewater management, as well as water use efficiency. All of these relate to ineffective infrastructure management (existing infrastructure), poor planning for new infrastructure, and very importantly, poor infrastructure management.

Besides, as large amounts of resources are required/or involved in infrastructure delivery, it is important to investigate whether the systems put in place and the processes adopted are effective in achieving the set objectives. In this regard, the South African construction industry is said to harbor many inefficiencies and ineffectiveness in its delivery system and processes (ERA, 2009). These inefficiencies result in a significant impact on the country's already constrained resources, as it means, among others, allocation of extra resources needed to implement the projects, a necessity to maintain infrastructure before their due period and not delivering the intended purpose the projects are incepted for.

One of the causes of the inefficiencies is the lack of a consistent system that identifies the major construction processes and presents 'better practice' on how they are effected (Wubishet, 2004). Many projects are not planned, executed and monitored according to the generally internationally accepted guidelines of such practices in modern construction management. There are various reasons for this including a lack of trained personnel, community involvement in the planning, non-appreciation of the importance of proper planning and monitoring schemes to improve performance- primarily driven by the impetus to dwell on actual physical works and the lack of appropriate guidelines in the management of the various processes. Nevertheless, improving the performance of the industry through effective and efficient systems and processes is important, not least because the industry has a bottom line effect on the country's economy and the society as a whole but also it is of importance for the industry's survival in the wake of the fierce international competition it is facing.

In line with this, this research work has embarked on modelling the construction management of water services processes systems as practiced within the South African construction industry such as

Ethekwini municipality. In its approach, the study takes ‘improved performance’ of projects on a consistent basis as its major target.

### **1.3 Research Aim**

This study aims primarily to understand the current situation, identify potential causes of the bottlenecks at EThekwini Municipality that affect water delivery and formulate evidence-based interventions to improve water delivery services

### **1.4 Research Questions**

1. What are the key elements that affect the delivery of water services?
2. What are the processes in the management of water infrastructure delivery services?
3. What are the challenges faced and approaches adopted in executing these processes?

### **1.5 Objectives**

1. To identify potential causes that affect water delivery and management at Ethekwini Municipality.
2. To develop a model by identifying the capabilities that are needed to execute the core processes for effective management of water services.
3. To assess the challenges faced and adopt an appropriate approach in improving water services delivery at Ethekwini Municipality.

### **1.6 Methodology**

The methodology will be divided into four phases

Phase 1. - Literature review and examining existing water services design, management and delivery policies and practices

This stage involves a thorough review of literature in the field of water services development and management. During the review, articulation gaps in existing research will be identified to form the basis for the development of research questions. The literature will also focus on the ability of infrastructure units within departments to perform tasks, produce outputs, define and solve problems and make informed decisions. These literature based research questions are then synthesised into an

integrative preliminary research framework to provide a conceptualisation factors of interest to explain how water services can improve and also to sustain their performance.

#### Phase 2- Conduct interview and conduct focus groups

After going through the literature review, and the establishment of the research, the second phase will focus on delphi study. It will help to contribute both theoretically and practically to the understanding of water organisations.

#### Phase 3- The conceptual model

Findings from phase one and two will pave the way for validation survey instrument which will be distributed to a large sample.. The sample will be asked to identify the main challenges faced in the management of water services as well as the approaches used to overcome them. The purpose of focussing on the challenges and difficulties is to draw out problems required in each water management process. Through this set of findings SEM model will be formulated.

#### Phase four- Validation survey

Findings from phase, one, two and three are compiled into a preliminary report to seek validation. The report and findings will be compared and analysed against literature and industry report, to check improvement in water delivery. The research design is shown in Figure 11.

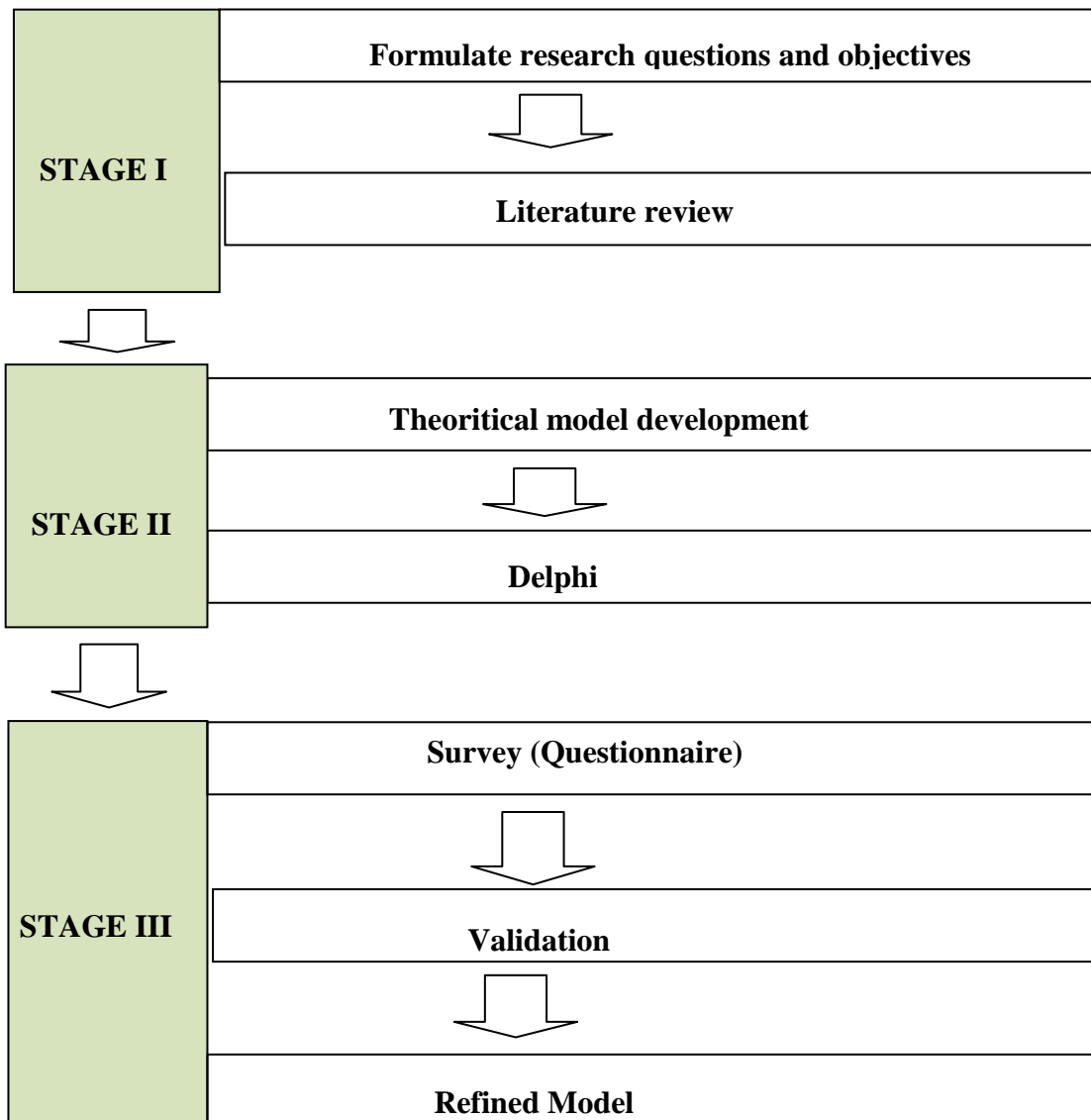


Figure 1.1: Research design

## 1.7 Assumptions

It is anticipated that this research can be used as initial benchmark information in prioritizing and designing improvement plan or action in water services to Ethekewini municipality. It is assumed that

by developing a model, infrastructure organizations or municipalities such as Ethekewini municipality can invest their resources to acquire the right capabilities. With the right capabilities and also knowledge of participants and the accuracy of their responses, infrastructure organization can achieve better performance and create value not only for asset owners but the larger society. It is also assumed that improved infrastructure management enhances the credibility and accountability of infrastructure asset owners by achieving better value for their investment. As such, this research is pursued with the aim of contributing to theory development and understanding of essential capabilities for infrastructure management.

### **1.8 Ethical considerations**

1. Ethical clearance will be obtained from UKZN prior to the study.
2. The protection of the privacy of research participants will be ensured.
3. Adequate level of confidentiality of the research data will be ensured.
4. Anonymity of individuals and municipalities, organisations participating in the research has to be ensured.
5. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests will be declared.
6. Any type of communication in relation to the research will be done with honesty and transparency.
7. Any type of misleading information, as well as representation of primary data findings in a biased way will be avoided.
8. Gate keepers letter will be obtained where required.

### **1.9 Knowledge dissemination of research findings**

The research findings were partly published in peer reviewed conference proceedings and were presented in international and local conferences. Two articles have been submitted for publication in a peer review journal.

### **1.10 Structure of study.**

In this chapter, the purpose has been to set the scene for the thesis by providing the background of the study. This is followed by the aim and purpose of the research. The chapter also justifies the significance of the work. The methodology adopted was briefly outlined.

Chapter two reviews the existing literature from IDMS on strategic management, to understand how resources and capabilities can enhance the performance of organization or municipalities. This provides the theoretical underpinning for developing a conceptual framework that addresses the research questions of this study.

Chapter three discusses the literature on water services delivery and models that were used in managing water services.

Chapter four focuses on Development of conceptual model with regards to challenges encountered in infrastructure water delivery systems. The model will lead to development of instrument on focus groups and Delphi study using a panel of national and international experts.

Chapter five discusses relevant methodology critical in resolving the research problem. In the chapter, Delphi methods research design was explained to be the relevant methodological design

Chapter six focuses on Delphi study which was used to achieve a reliable consensus among a selected panel of experts.

Chapter seven focuses on the findings of Delphi study with regards to challenges of infrastructure water delivery services and management in South Africa.

Chapter eight focuses on development of a validation survey. It also proposes the use of multiple case studies as the appropriate research strategy to explore qualitatively the infrastructure delivery of water services and management processes and capabilities needed for infrastructural organizations.

Chapter nine describes the development of a model (SEM) which will help to verify with extant literature to provide conceptual support to the themes identified.

Chapter ten focuses on discussion of findings on the challenges and approaches adopted for infrastructural delivery of water services..

Chapter eleven provides the summary of the key findings of and concludes the study. It outlines recommendations for further research.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Introduction

This chapter reviews the existing literature on IDMS from strategic management to understanding how resources and capabilities can enhance the performance of organization or municipalities. This provides the theoretical underpinning for developing a conceptual framework that addresses the research questions of this study.

### 2.2 What is Infrastructure?

Infrastructure services are at the very heart of economic and social development. They provide the foundations for virtually all modern-day economic activity, constitute a major economic sector in their own right, and contribute importantly to raising living standards and quality of life (Stevens et al., 2006). However, the term ‘infrastructure’ is often ambiguous as it is widely used in different context.

There are a variety of definitions for infrastructure from different perspectives. In every day usage, it tends to be used to refer to a wide range of things from military installations, information technology, buildings to physical networks such as transportation and water systems (Howes and Robison, 2005). The new Collins Dictionary and Thesaurus defined infrastructure as the ‘the basic structure of an organization, systems etc., or the stock of fixed capital equipment in a country including factories, roads, schools etc. considered as a determinant of economic growth’. Development economist often refer to infrastructure as ‘social overhead capital’ described as investments in networks such a transportation, water and sewerage, power communication and irrigation systems. From an economic standpoint, the production of such networked facilities are capital-intensive traditionally owned and managed by the public sector; hence they are sometimes called public infrastructure capital (Howes and Robison, 2005). These variations from different perspectives illustrate the considerable difficulties in trying to understand the concept of infrastructure. It also reflects the need for a systematic approach in defining the concept infrastructure.

The most elaborate attempt at a systematic definition was provided by Jochimsen (2013), cited in von Hirshhausen (2002), who defined infrastructure as ‘the sum of all basic material structures, institutional conditions and human resources available to the society, needed for the proper functioning of the economic sector. Jochimsen further distinguished between three components of the

infrastructure that are intended – institutional infrastructure, personal infrastructure and physical infrastructure.

Institutional infrastructure sometimes referred to as social or institutional capital relates to the system of informal and formal rules that govern an organization or a country. Personal infrastructure refers to ‘human capital’ – the stock of tacit and explicit knowledge and skills embodied in the workforce, nurtured through investments in education, training and supported by health and other social services. Physical infrastructure or physical capital comprises all physical elements of buildings, structures and networks – transportation, power supply, sewage and telecommunication systems, hospitals and industrial building etc.

Based on Jochimsen’s broad classification of infrastructure, Howes and Robinson (2005) further classified physical infrastructure according to function namely technical infrastructure, trade infrastructure and social infrastructure. Technical infrastructure, often referred to as economic infrastructure, comprises the long-lived networked, capital intensive and engineered structures indirectly supporting economic production. Trade infrastructure represents the facilities directly used for the production of goods and services such as factories, warehouses, shops and offices. Social infrastructure focuses on facilities directly related to human and social welfare such as schools, colleges, health centres, sports and recreational facilities, which are essential in raising living standards, quality of life and human development.

There is a need to speed up and improve water service delivery in the municipalities and the national government. Camay & Gordon (2005) did a research in 2004, and reported that nine million people had no access to clean water and by 2014, after 10 years, five million people had been provided with access which shows that a large number of municipalities still had service delivery problems (DWAF, 2013). This scenario indicates a geographical inequality /gross spatial that is found across the country, due partly to ineffective municipalities. The need for an alignment between legislation, policies, and strategies within the water services sector as well as alignment between the legislation, policies, and strategies of other sectors related to the water sector (such as, finance, water resources, housing, municipality and health) should be considered as fundamental important of any change in the manner in which service delivery is done. Therefore it can be concluded that policies should establish the vision, approach, overall goals and legislation then would create the enabling environment. Strategies set out will offer the detail of how the policies will be implemented in order to achieve the vision and goals (DWAF, 2013).

### **2.3 Infrastructure delivery management system (IDMS)**

The framework focussed on the ability of infrastructure units within departments to perform tasks, produce outputs, define and solve problems and make informed decisions. It addressed four dimensions: institutions, people, and organisational behaviour and human resources systems (Nkwonta and Haupt, 2018). Infrastructure Delivery Management System (IDMS) comprises three core systems, namely, a planning and budgeting, a supply chain management and an asset management system, all of which have forward and backward linkages. These core systems are located within portfolio, programme and project management, and operation and maintenance processes.

The National Treasury in South Africa has identified Infrastructure Delivery Management Systems (IDMS) as a strategic area to enhance the effective rollout of infrastructural installations and manage those that already exist. The IDMS is a model that describes the processes that make up public sector delivery and procurement management as it applies to the construction industry. It outlines the core processes associated with the planning, delivery, procurement, operation and maintenance of infrastructure works. However, the lack of capacity and expertise resident within the public sector is debilitating together with a lack of understanding and application of sound project management principles (IDMS, 2016).

South Africa's infrastructure challenges are not primarily the result of a lack of funding but are caused by institutional failures and a lack of appropriate capacity within departments. However there is need to develop a model that will help to build the capacity to support improvement in the planning, procurement and management of infrastructure delivery at the provincial level.

It will control frameworks for the planning, design and execution of infrastructure projects and infrastructure procurement and also requirements for a number of matters as applied to the supply chain management system for infrastructure procurement and delivery management; and minimum requirements for infrastructure procurement. IDMS enables the separation of the supply chain management requirements for general goods and services from those for infrastructure. Underlying the separation of the supply chains is the notion that the effective and efficient functioning of the supply chain management system for infrastructure procurement and delivery management will realise value for money and good-quality service delivery. Value for money may be regarded as the optimal use of resources to achieve the intended outcomes. Underlying value for money is an explicit commitment to

ensure that the best results possible are obtained from the money spent, or maximum benefit is derived from the resources available.

#### **2.4 The features of Infrastructure**

Many authors have sought to identify the features or characteristics of infrastructure such as water services (Firth et al., 1999 Grimsey and Lewis, 2004; van der Mandele, 2006). It is generally agreed that several features are central to the economic concept of infrastructure. These characteristics are best summarized by Firth et al., (1999) as follows:

- 1 Infrastructure network consist of nodes and links, which are complementary to one another and have to be combined to create a service. The understanding of the relationship between these components is crucial for the delivery of infrastructure services. For example, the context of transportation services, providing good roads, and railways are not sufficient. It is the service derived from the use of such facilities or physical infrastructure though integrating hard and soft facilities management that is crucial. There is therefore a need for a service-focused approach in the development of infrastructure projects. This interdependence results in a need for a central coordination. Governments often serve the role of controller or regulators of infrastructure networks.
- 2 Infrastructure networks often require large capital investment with a delay in returns, although the returns continue for a long time. There is a high degree of sunk costs, which means that if infrastructure is abandoned, it cannot be sold for other uses. Because of the high risks of returns and the lack of other uses, tendency exists for the market to under provide infrastructure in the absence of intervention.
- 3 The production of infrastructure services is subject to steeply increasing returns to scale. This implies a natural tendency toward monopoly, since large-scale firms can exploit cost advantages that are not available to smaller firms. Monopoly carries the risk of low services and high prices and thus has often stimulated policy makers to impose regulations.
- 4 Infrastructure generates public goods. This means the benefits are shared across the community in such a way that those who do not wish to buy the service cannot be excluded from the benefits created by those who do. Generally competitive markets will tend to under-produce these services. The use of infrastructure service is therefore subject to some degree of

non-rivalness and non-excludability. This outcome again usually leads to demand for government funding and regulation.

- 5 Almost invariably, infrastructure networks have many stakeholders, including their users, operators and service providers, investors and owners and ultimately, the general public. Many of infrastructure asset are of great strategic and military importance to the countries in which they function.

These characteristics explain why the public sector role is critical in infrastructure delivery to achieve development objectives such as national security and public service obligations, and to minimize the effect of market failure and externalities (Grimsey and Lewis, 2004; Howes and Robinson, 2005). The provision of infrastructure has always been imposed on the other facilitators of economic activity. For this reason, the ownership has, traditionally, often been in the hand of government organizations.

## **2.5 Difficulties in infrastructure delivery**

In recent years most of the industrialized world has faced many challenges in the development and management of infrastructure assets. On the other hand, infrastructure will provide a vital tool in resolving some of the major challenges faced by the societies such as supporting economic growth, meeting basic needs, lifting millions of people out of poverty, facilitating mobility and social interaction. On the other, environmental pressures in the form of changing climate conditions, congestion and so on are likely to increase, turning the spotlight firmly on the inherent tensions between the imperative for further infrastructure development and the quest for sustainability (Stevens et al., 2006). Some other challenges include:

1. The need to accommodate continuing growth to support the economic and social developments of the nation (Kessides, 2004; Stevens et al., 2006)
2. Significant parts of infrastructure are ageing and nearing the end of their economically useful lives (Hardwicke, 2005).
3. Current funding commitments are either inadequate or yet to be identified, to support the substantial cost of renewal and replacement (Hardwicke, 2005).

4. Current planning and political processes do not provide the necessary long term focus (Hardwicke, 2005).
5. Only limited infrastructure information is available in some key areas (Hardwicke, 2005).
6. The increasing sense of vulnerability of society and its economic structure because of perceived rise of terrorism (Stevens et al., 2006).
7. The continuing integration of economics and systems, for example through the increased globalization and trade in goods, services and information (Stevens, et al., 2006).
8. The need to satisfy multiple stakeholder demands (Nutt, 2004; van der Mandele et al., 2006)

These challenges have created a huge performance problem for state-owned infrastructures. For example, Kessides (2004) reported that high construction costs (caused by delays and changing environmental safety requirements) and expensive, politically driven programs have led to problems in the electricity sector. State-owned telecommunications entities were forced to adopt inefficient pricing structures and were used to generate revenue to governments and support excessive employment – delaying investment and modernization and undermining efficient operations. Railroads often failed to earn adequate revenue, had difficulties adjusting to changes in markets, experienced decline market shares for passenger and freight traffic, and exhibited poor productivity relative to technological opportunities,

In fact, over the past two decades, the performance of government-owned infrastructure suffered from low labour productivity, deteriorating fixed facilities and equipment, poor service quality, chronic revenue shortages and inadequate investment (Kessides, 2004). The pervasive government involvement in finance regulation, and the actual delivery of many infrastructure services had led to poor performance in many cases – by weakening managers’ operational and financial responsibility, imposing conflicting objectives, and politicizing decisions on investment, pricing, labour, and technological choice (Kessides, 1993).

This is similarly experienced in the context of South African infrastructure organizations such as Project Management of South Africa (PMSA). For example, in a recent audit report of the

performance management of the government sector entities involved in the management of transportation infrastructure in Eastern part of South Africa (EThekwini). There were several key areas of concern identified in the report in the management of infrastructures (PMSA 2016; Carroll and Buchholtz, 2012). These include:

1. The leadership of managing the transport network is not coordinated effectively. This makes it more difficult for the government agencies managing transport infrastructure to drive a strategic response in an integrated and coordinated manner.
2. There is a systematic weakness in integrated transport planning and land use across entities. The current activity to develop the transport systems, plans and initiatives were carried out in isolation and therefore lack integration.
3. Some long term transport plans were not reviewed, updated or renewed on a timely basis. Some documents contain out of data research and data to support their policy positions.
4. The systems supporting data collection and reporting for urban congestion management have significant deficiencies. The audit also found no framework or leadership to share data between entities to provide a complete picture about the transport need.

Given the high costs and myriad problems with government-owned infrastructure, advances in economic thinking have caused many countries to reform the institutional options for the provision of infrastructure services. The goals of these reforms are to increase the investment and service coverage, raise the productivity and cost effectiveness, improve service quality, align prices with underlying costs and make services more responsive to consumer and business needs. To achieve these goals to significantly improve the infrastructure performance, the reform must entail a combination of competitive restructuring, privatization, and establishment of regulatory mechanisms (Kessides, 2004).

With reference to participatory approaches in infrastructural service provision in upgrading interventions is being advocated for, informal settlements pose many challenges especially the problem of data limited environments in these areas that affect planners when planning. Within informal settlements are complex, economic, dynamic social-cultural and political systems that continually undergo changes (Magigi & Majani 2006). A major challenge facing local authorities lies

in devising methods that can address all these challenges while designing upgrading interventions (Otiso, 2003; Lemma, 2005).

## **2.6 Systems adopted for Infrastructure Improvement**

Recent years have seen a shift in government and public sector agencies towards a management culture that focuses on customer needs, accountability of results and competition between public and private bodies for contracts to deliver services that achieves cost recovery and value (Manning, 2002). In the search for new forms of governance in the provision of infrastructure, the government's role as direct service provider is transformed into one which government is an enabler; coordinating provision and takes action by and through others [stoker, 1998]. Concepts from the for-profit strategy literature have become increasingly more relevant in public sector management (Llewelly and Tapping, 2003). The focus has shifted to clients instead of citizens and communities, and by pursuing business-like outcomes instead of public policy-making (Charish and Roulliard, 1997). Research and managers of these public infrastructure organizations, struggling to find direction from competition-based strategy theories, turned to the "new public management" approach which was captured by Hood (1995, pp. 95-97) in various dimensions as follow:

1. A shift towards greater disaggregation of public organization into separately managed "corporatized" units for each public sector "product" [each identified as a separate cost centre, with its own organizational identity]
2. A shift towards greater competition both between public sector organizations and between public sector organization and the private sector.
3. A greater stress on discipline and parsimony in resource use and on active search for finding alternative, less costly ways to deliver public services, instead of laying the emphasis on institutional continuity, the maintenance of public services which are stable in "volume terms" and on policy development.
4. A move towards more "hands-on management" [that is, more active control of public organizations by visible top managers wielding discretionary power] as against the traditional "hands-off" style that is relatively anonymous bureaucrats at the top of public-sector organizations.

5. An increasing emphasis on more explicit and measurable [or at least checkable] standards performance for public sector organizations, in terms of the range, level and content of services to be provided, as against trust in professional standards expertise across the public sector.

A key argument for privatization is that owners and operators who face stiffer market competition, have strong incentives to control costs, respond to consumer needs, and adopt new technologies and management practices (Grimsey and Lewis, 2004). In addition to the above, the trend away from public to private provision of infrastructure has been underpinned by a market change in thinking and practice from “taxpayer pays” to “user pays” in the provision of infrastructure services such as water, power. This is ought to most likely achieve better economic use of services (Ibid). At the same time, technological changes and institutional innovations have been challenging traditional methods of operating infrastructure and allowing a wider application of commercially more appropriate pricing mechanism such as those used in the toll pricing for roads and bridges. Charging for the use of infrastructures ties the revenue stream directly to the use and should result in more effective and less political infrastructure financing problems.

In view of the movement towards “new public management” and in the quest to improve performance of infrastructure assets, many governments, including South Africa, have adopted some form of reform such as those proposed by Kessides (2004) that include a combination of competitive restructuring, privatizing, and establishment of regulatory mechanisms. In fact, the late 1990s were characterized by a significant shift from the public to private sector for the provision of infrastructure service.

There are three broad ways by which infrastructure can become more commercially orientated (Stern and Lankes, 1998). First, at the most basic level, the public sector operates in a manner that resembles more closely the ways the private sector works. This involves creating a subsidiary or separate management structure that provides clear goals, makes managers responsible for performances and allows them independence to carry out their tasks. This is also known as Government-Owned-Corporation (GOC).

Second, governments can seek the limited entry of new private providers through various forms of Public-Private-Partnership (PPP). This approach implies more active private sector participants, usually as provider of services, as well as a constructor and designer of assets.

Finally, the third alternative is for government to opt for full privatization of some public service. This is evident in the recent announcement by the Department of public works of its intention to sell off some its GOC to the private sector as a result of the recent global financial crisis.

## **2.7 Benefits of Infrastructure**

Infrastructure impact economic growth by lowering the cost in input factors in the production process, by improving the productivity of input factors and through initial construction period (Fourie, 2006). Infrastructure plays notable role in poverty reduction and in increasing equity (Sachs, 2004). Provision of infrastructure such as electricity in rural areas has positive impact in protecting the environment and reducing Green House Gas emission. Transport and communication infrastructure facilitates trade, investment, tourism and accessibility.

### ***2.7.1 Impact of Infrastructure Investment on Economic Growth***

Economic growth can be expressed in terms of the annual change in the rate of output which is commonly measured by Gross Domestic Product (GDP). An increase or decline in GDP is an indication of growth or recession of economy of a country. GDP represents the total money value of all the production that has taken place inside a specific territory during one year ( Myers,2004). However, to take into account countries population, GDP is expressed on a per capita basis where GDP is divided by the total population.

In newly developing countries, the construction sector can contribute as much as 20 per cent to GDP because it accounts for a significant amount of investment during a country's development. As industrialisation proceeds, factories, offices, infrastructure and houses are required and construction output as a percentage of GDP reaches a peak. Investment in construction is especially important during the development phases if an economy. In other words, construction is responsible for the output of buildings and infrastructure upon which most other economic activities depend (Ibid).

Once an economy has developed, the demand for construction products declines and construction output as a percentage of GDP tapers off. In an industrialised nation the building stock is well

developed, so the need to add to it is less. Much of the infrastructure and many of the buildings may be ageing, but the requirement for new build work is generally smaller—however, there is likely to be a far greater need for repair and maintenance work. Generally, therefore, the higher the GDP per capita, the higher the proportion of repair and maintenance work in the construction sector (Ibid).

Investment in infrastructure can also be measured using Gross Fixed Capital Formation (GFCF) which is a national income category representing spending on fixed assets including buildings, roads, railways, plants and machinery. This measure is normally expressed as percentage of GDP and doesn't include maintenance and repair expenditures (Ibid).

It has been observed that newly developing countries experience up to double the rate of expenditure on construction as their more developed counterparts (Ibid). Five stages of economic development shown in Figure 2.1 namely traditional society, preconditions to take-off, take-off, drive to maturity, and high mass consumption (Nuramo 2016). As indicated, adequate effort needs to be exerted in developing countries to reach the critical take-off stage. Lessons from the developing countries demonstrate that intensive investment in infrastructure is vital in enabling developing countries or societies reach higher level of economic development.

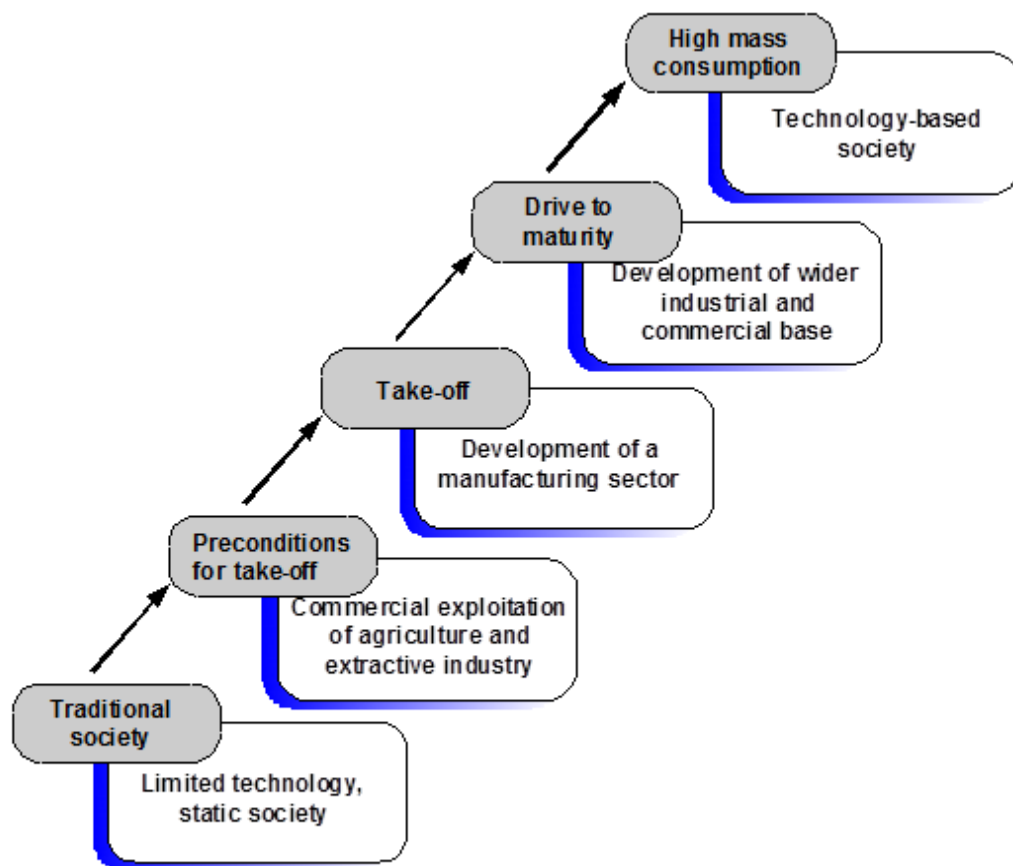


Figure 2.1: Rostow stages of economic growth (Nuramo, 2016).

The father of modern economics, Adam Smith, has noted that infrastructure enlarges goods markets by lowering transport costs and speeds up access for perishable merchandise (PID, 2005). Adequate infrastructure helps to determine the success of one country and the failure of another in economic, social and environmental terms. In development terms infrastructure serves as a catalyst for economic development, by improving access to resources and enhancing the impact of policy interventions (Aschauer, 1989; The World Bank, 1994).

Considerable efforts have been exerted in the last couple of decades to study the impact of infrastructure on economic growth and development in several countries. These studies, on the whole, implicated that under the right conditions, infrastructure has notable impact in promoting growth and equity (UN-HABITAT, 2011).

Apparently, there is an increasing consensus that infrastructure contributes to economic growth by raising labor productivity and lowering production and transaction costs (Dissou & Didic, 2013). Time series analysis and cross-sectional national studies have shown that infrastructure investment has high rate of return on economic growth and infrastructure variables are positively and significantly correlated with economic growth in developing countries (The World Bank, 1994).

Enimola conducted an empirical research to investigate the impact of infrastructure on the economic performance of the Nigerian economy and indicated that sustainable growth won't be embraced until governments generate enough funding towards eliminating infrastructure bottlenecks which impede productivity and economic growth. The study also found out that an increase in the share of expenditure in infrastructure is necessary and productive for Nigeria. Kumo conducted a study in South Africa for the period 1960 to 2009 and found a strong two-way causality between economic infrastructure investment and GDP growth.

Calderón and Servén (2004) used panel data from 1960 to 2000 encompassing over 100 countries and found out that quantity of infrastructure has a robust effect on growth where a one standard deviation increase in the stock of infrastructure results in a 3% increase in economic growth rate. Sahoo and Dash (2009) attempted to estimate impact of infrastructure quantity on economic growth in India using a data over 1970 - 2006. The results of the study indicated that long-term output elasticity of infrastructure is positive and statistically significant.

A study performed to investigate the role of infrastructure in promoting economic growth in China has shown that infrastructure development has significant positive contribution to growth and there is unidirectional causality from infrastructure development to output growth ( Sahoo, 2004). However, Miller (2013) claims that the current global investment in infrastructure projects represents a 'drop in the ocean' compared to the massive worldwide need particularly in developing countries.

## **2.8 The importance of infrastructure management**

Accountability is required for any organization, public or private. Those in charge of economic resources must give account of their stewardship, irrespective of whether the transactions and resources in question are those of a government or a private sector entity [Grimse and Lewis, 2002]. In the 21<sup>st</sup> century, the various stakeholders for infrastructure will continue to demand value for money

for their investment in infrastructure. Van der Mandele et al [2006] suggested that there are four main groups of stakeholders involved in the provision of infrastructure; users, service providers, government, and the general public. Each of these groups has conflicting demands from one another and are summarized as shown in Figure 2.2

1. Users, who are also the taxpayers, are constantly looking for better service level in terms of speed, capacity, security and reliability. Their main objective remains one of achieving the most effective and efficient “value for money” such as, for example, identifying the most cost effective way of securing a high quality service. They want the road to be free from congestion so that they can reach their destination faster. They also expect that the water and electricity supply to their homes are reliable and safe.
2. Service providers are constantly looking at how they can cater to the demand of these users efficiently so as to maximize the return to their shareholders. They always look at how operation cost can be minimized, and how to increase capacity and reliability of the infrastructure.
3. Government is concerned with the regulation of infrastructure to support economic development and ensure accessibility to the welfare effects of infrastructure moving beyond standard analysis of firm profitability and industry performance (Amos, 2004; Kessides, 2004). They are also concerned with accountability on the use of public fund to build, maintain and regulate the Infrastructure.
4. General public is generally concerned with the use of physical and environmental space for infrastructure. Issues of concern noise and air pollution together with a host of other environmental issues.

To satisfy the needs and conflicting demand of various stakeholders, infrastructure organizations have to explore ways to create value from their infrastructure and the way it will be managed. Infrastructure owners/providers need to focus on stewardship to meet the expectations for quality including safety, operational efficiency and accountability. This has placed pressure on these infrastructure organizations to better manage the performance of infrastructure assets to meet the rising expectations of stakeholders (IDMS, 2013).

The strive to improve effectiveness and overall operating performance requires clear understanding of how to manage an ageing asset portfolio in a way that allows their current performance to improve while also investing in new assets to meet future needs. Consequently, organizations that manage infrastructure are driven to adopt a more formal and holistic “infrastructure management models” an approach to the management of infrastructure in order to provide services in the most effective manner.

The rising importance of infrastructure management can be seen with growing number of reports and guidelines published by various organizations managing infrastructure assets (such as PMSA 2016 Caroll and Buchholtz 2012). In the addition, many councils and professional institutions are being formed to advance the concept of infrastructure management such as PICC (Presidential Infrastructure Coordinating Commission) CSIR (Centre for Scientific and Industrial Research) ASCOSA (Association of Schools of Construction of South Africa). Conferences, discussion meetings, symposia, courses have also sprung up prolifically, as have the inevitable battery of consultants seeking to persuade business of the huge rewards. The stages of services delivery cycle is shown in Figure 2.2. Infrastructure management has become more important than ever before because Infrastructure management has emerged as a tool that provides holistic approach to the management of infrastructure assets, PMSA provides a list of benefits for adopting a holistic approach to infrastructure management such as:

1. Better allocation of limited resources
2. Improved alignment of infrastructure with services
3. Reduced demand for new assets through better integration of services
4. More effective and maintenance of existing assets
5. Increased opportunity for partnering with private sectors
6. Wider consideration of the use of non-asset solution to meet service demand
7. Greater use of sustainable development solution to enhance cultural heritage and environmental outcomes
8. Realization of a return from surplus assets
9. Improved process and accountability for capital and recurrent works.

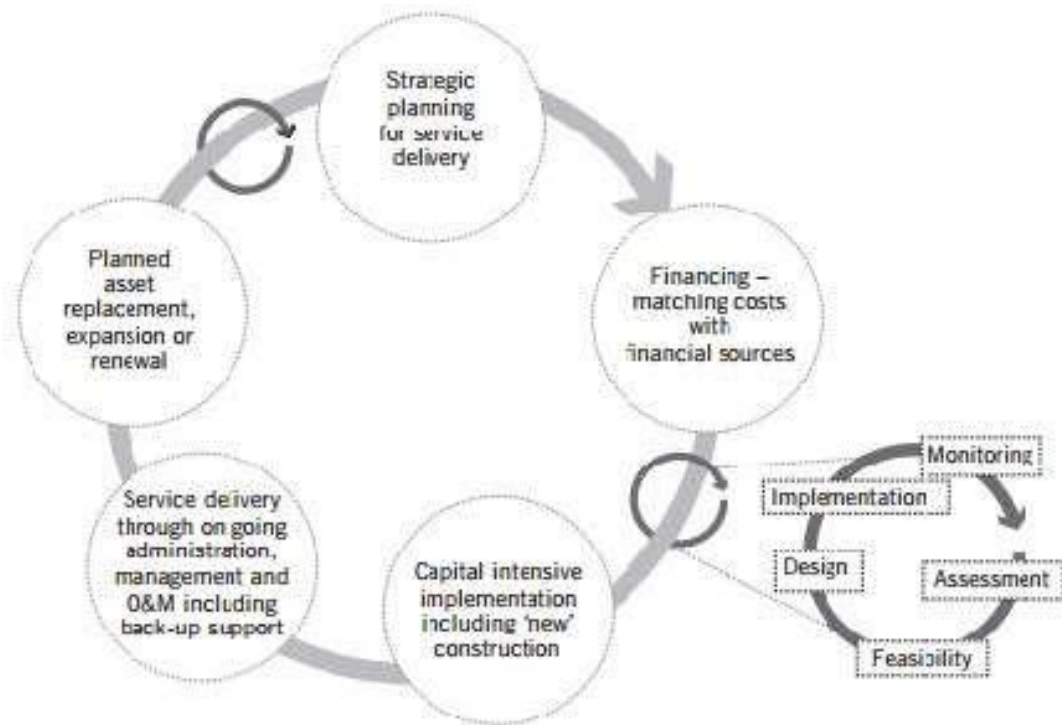


Figure 2.2: Stages in the service delivery cycle (Grimsey and Lewis, 2013)

## 2.9 Improved infrastructure management.

The concept of infrastructure management is not new but an evolving idea that has been attracting attention of many organisations operating and owning some kind of infrastructure assets. The term infrastructure management have been used widely with fundamental differences in interpretation and usage (Grimsey and Lewis, 2013).

Regardless of the context of the usage of the term, improved infrastructure management implies the process of optimising return by scrutinising performance and making key strategic decisions throughout all phases of an infrastructure lifecycle (Sarfi and Toa 2004). Improved infrastructure management is a philosophy and discipline through which organisations are enabled to more effectively deploy their resource to provide higher levels of customer service and reliability while balancing financial objectives. Several key unifying themes that form the heart of improved infrastructure management can be described as follows:

1. **Alignment of infrastructure and operations with corporate objectives:** The key goal of infrastructure management is the creation of value to the organisation, stakeholders from government. It is about understanding and managing the trade-offs between financial

performance, delivered operational and service performance and risk exposure. Hence, improved infrastructure management provides a structure for driving and integrating customer expectations, legislative requirements, operating requirements, and financial objectives throughout an organisation (Grimsey and Lewis, 2004; Howes and Robinson, 2005).

2. **Linking of decision-making and action with information:** improved infrastructure management is about obtaining the knowledge needed to optimise trade-offs among financial performance, operational performance and risk exposure. It is about decision making rather than the blind pursuit of technical performance (Humphrey, 2003). Decisions are driven by the actual condition and performance of infrastructures individually and collectively as well as by the risks to corporate objectives from infrastructural failure.
3. **Importance of life-cycle costing:** Costs are minimized, starting with the initial investment, continuing through operation and maintenance, and ending with disposal. The connections between the choice of infrastructure and the implications for the cost stream from maintaining those infrastructures are critical.
4. **Infrastructure management as a process:** To understand improved infrastructure management, the study need to identify and define the activities involved. Improved infrastructure management is about designing and implementing a new business process that can deliver higher returns to corporate stakeholders. One of the precepts of the discipline is that all business units should make decisions based on the same criteria. A sound infrastructure-management process ensures that business units do not sub-optimize by emphasizing parochial criteria at the expense of overarching corporate objectives (Humphrey, 2003).

Synthesising this discussion and themes, improved infrastructure management is strategic and systematic process of optimising decision-making in resources allocation with the goal of achieving planned alignment of an infrastructure asset with corporate goals throughout its life cycle. In fact, one of the first comprehensive adoptions of the term “Infrastructure management” was during the privatisation of water utilities in Great Britain in the 1980’s (Stapelbrg 2006).

In South Africa, infrastructure management made its way into the public works after apartheid regime. This development has indirectly forced organisations managing infrastructure to consider the useful life and cost effectiveness of infrastructure investments. South African government has to develop, refine and apply the concept of infrastructure management in the management of their respective infrastructures. There are several barriers preventing the advancement of improved infrastructure management.

### ***2.9.1 Lack of Recognition***

The first obstacle to the development of infrastructure and its management is found in the step child status that is often bestowed upon infrastructure management and maintenance groups within organisation. Recognition and prestige are more often accorded to infrastructure financing and investment activities. On the other hand infrastructure management is frequently associated with only maintenance, asset inventory, and its related services and therefore considered to be of less strategic importance (Grimsey and Lewis, 2004; Howes and Robinson, 2005).

The attitude is extended to the world of infrastructure management research. For example, there are many researches into infrastructure management systems that have inherent investment analysis capabilities. These infrastructure management systems focus on databases, asset inventories, technical models and other analytical tools. This perception extends also to infrastructure management as Jones (2007) who is compiling a Property Asset Management Guidelines for RICS found that infrastructure management is no different from property management as they both share similar principles, techniques, and organisational issue. Woodhouse (2004) argued that research has been disproportionately aimed at methods to get the jobs or functions done more efficiently resulting in doing the wrong work 10% quicker and cheaper that does not necessarily lead to a better long-term performance.

Consequently, infrastructure management research is currently more focused on an operational perspective rather than from a strategic and holistic management perspective. In view of the amount of emphasis in the analytical tools and technical models, there is a risk of approving that the implementation of infrastructure management should start through the development of more advanced technical modelling and other analytical tools that can talk to one another. This approach to improve infrastructure management also ignores a systematic focus that involves bringing a variety of infrastructures under one single entity. This view is also echoed by Stapelberg (2006) who noted that

most infrastructure management frameworks fail to have a system wide focus. The focus is more on individual infrastructures rather than the long-term infrastructural management needs of an organisation, however a compelling argument against the progression of the concept of infrastructure management is the general lack of conviction amongst senior management of the contribution of infrastructure management toward stakeholder values.

### ***2.9.2 Lack of definitions***

The second obstacle to the contentious state of what constitutes infrastructure management. Over the years many definitions of infrastructure management have been provided. From the various definitions given, it can be noted that while different perspectives have been taken by agencies and organisations, the importance of aligning infrastructure management goals with corporate goals is consistent. The definition of infrastructure management that is used by an organisation is an important one as this understanding plays a major role in how the organisation ultimately implements the associated asset management processes and models within their organisation (Grimsey and Lewis, 2004; Howes and Robinson, 2005).

Stapelberg (2006) conducted a comprehensive review of various infrastructure management models and frameworks of infrastructure and industrial assets owners both in the public and private sectors as well as those of asset management service providers. This review reveals that there are many infrastructure management frameworks and models that have been developed in practice. These frameworks rang in their level of complexity design and specific details. Although many models and frameworks have been developed, the diverse approaches to infrastructure management adopted by different organisations do not help in the development and advancement of infrastructure management but rather, creates more confusion to practitioners. Woodhouse (2006) noted that many such organisations realise that functional silos such as, for example traditional separation of engineering operations, maintenance and other functions) result in the missing some major opportunities.

### ***2.9.3 Increasing Complexity***

Globalisation is intensifying economic and other linkages among countries making it increasingly necessary to plan, develop and finance infrastructure across national borders. It has fundamentally changed how infrastructure business is visualized and conducted. The impact of globalisation on infrastructure provision and operations is both pervasive and extensive requiring therefore, a review of

existing business approach and the historic rules of thumb such as standard operating procedures used. For example, a globalized business means infrastructure planning at all levels will now require knowledge that is local and global. Understanding of local regulatory requirements is as needful as global consideration of economic activity when setting out the strategic corporate goals. In addition, cultural practices and local customs must be known ledged when setting in place business operations and procedures. Failure to modify the strategies of conducting business may result in significant impact on performance (Grimsey and Lewis, 2004; Howes and Robinson, 2005).

Globalisation coupled with deregulation and privatisation of infrastructure asset provision brings about an unprecedented level of complexity that is still evolving and needs refinement before it can transform the business of infrastructure organisation. Bartlett (2002) confirmed that infrastructure management is still evolving concept and that the roles and organisational arrangements varied widely requiring further development and on-going refinement.

Too and Tay (2008) suggest that under such competitive global climate, asset management must not only be regarded as an organisational function but also an important business resource. The incorporation of infrastructure asset as a business resource will ensure an integrated approach to developing optimal strategic options. This suggests that infrastructure management should no longer be constrained to a technical focus but should include a business management dimension.

## **2.10 Infrastructure and Economic Growth in Developing Countries**

Infrastructure access gap looms large in the developing world where an estimated 748 million people live without access to safe water, 1.2 billion without electricity, 2.8 billion still cook their food with solid fuel such as wood, 1 billion people live more than two kilometers away from an all-weather road, 2.5 billion without sanitation, and more than 1 billion without access to telephone services (Lin, 2008).

According to the World Bank (2011) despite the fact that ten percent increase in infrastructure investment contributes to one percent growth in GDP, there is a gap in infrastructure provision which is estimated at USD1 trillion in low- and middle-income countries, and the demand continues to grow as countries develop. While developing countries are engaged in massive construction undertakings to curb their infrastructure deficiencies, only limited progress has been made so far.

African countries, especially, sub Saharan Africa countries trail behind other regions in terms of infrastructure delivery and quality becoming an impediment to their economic development and a major constraint on poverty reduction (UN-HABITAT, 2011). To fill the infrastructure gap an estimated USD 93 billion, which is about 15% of GDP a year investment in infrastructure is needed in Africa (Ibid).

In the recent decades, the general approach to economic development has changed dramatically because of two issues that have emerged in the literature: human development and sustainable development (Todaro & Smith, 2012). The Human Development Index (HDI) has become a major instrument for measuring human welfare. Human development is concerned not only with personal income but also with other welfare variables that directly influence the quality of human life (Kusharjanto & Kim, 2011).

Studies by Leung and Meisen (2005) found that raising electricity consumption per capita can directly stimulate faster economic growth and indirectly achieve enhanced social development, especially in countries in which the United Nations Development Program (UNDP) rates the human development as medium or low. The same research indicated that electricity has the greatest influence on improvements in the HDI, where only 1% increase in the number of households with electricity, the HDI will increase by 0.2% over the long run. Meanwhile, a 1% increase in the water, road and education variables leads to corresponding increase in the HDI by 0.03%, 0.01% and 0.02%, respectively. They also found that the HDI responds to changes in infrastructure with a time lag.

The availability of sound infrastructure in a region can attract private and public investment, which in turn can lead to accelerated rates of economic and human development is shown in Figure 2.3 (Leung & Meisen, 2005).

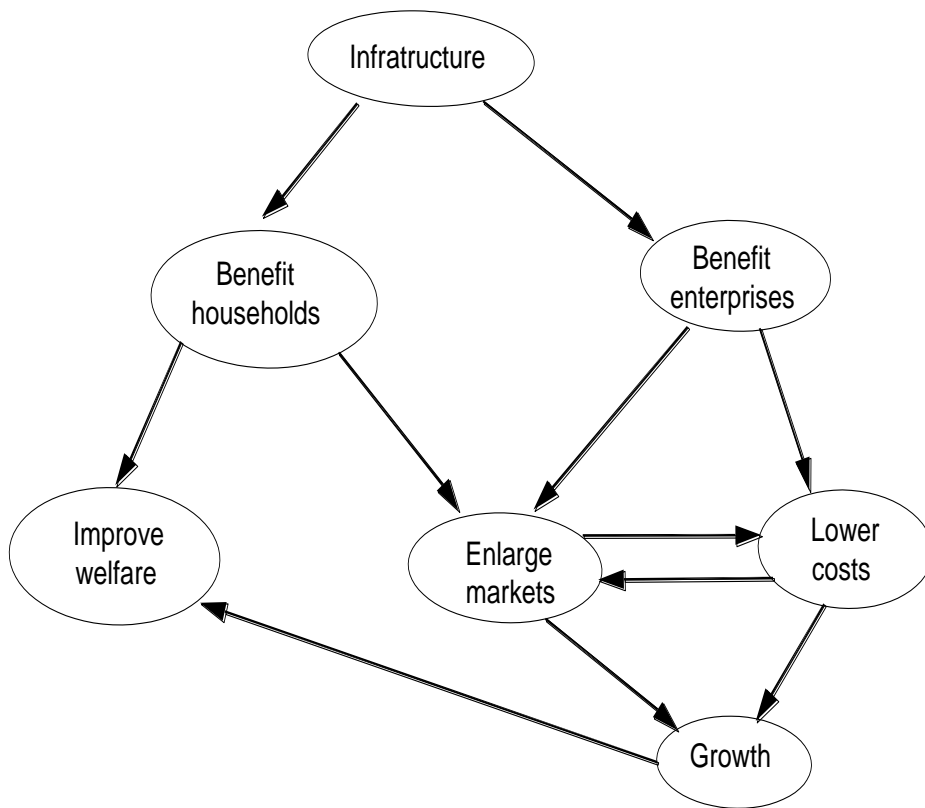


Figure 2.3: How infrastructure contributes to development (Nuramo, 2016)

## 2.11 Water Resources Management

Where the need for economic development is urgent, in developing countries such as South Africa, many people depend on sustaining their livelihoods through agriculture and natural resources. Therefore, it is necessary and important to assess all the implications of this natural resources, given the complexity of water resources systems (Wurbs 1993). Oliveira and Loucks (1997) stated that it will be a difficult decision, with regards to water services infrastructure serving multiple purpose objectives when defining a particular water supply's operating rules.

In river basin studies, all reservoir systems have their unique aspects and a variety of mechanisms are used in defining their operating rules. Most of the water resources optimization problems involve conflicting objectives (Chang 2001). Water infrastructures can increase the reliability of water supply thereby promoting livelihoods, raising agricultural productivity and reducing farmers' vulnerability to

droughts. The frequency and intensity of extreme hydrological events vary highly in South Africa (Ndiritu 2003), which obviously restricts the effective use of water and causes insufficient water supply.

To overcome the problem of insufficient water supply during periods of low flow and poor infrastructure, attention has been focused on improving water resources management, especially at EThekweni municipality (Chang 2001; Chen 2007). The majority of research in water resources has been devoted to developing ways to meet human water demands, while the explicit inclusion of environmental flow targets has received little attention. Lately, engineers often face criticism regarding water resources management due to the lack of careful assessment of environmental impacts caused by leadership operations. In an attempt to minimise these negative impacts, the related environmental aspects must be taken into account in the management of water storage facilities (Gibbins 2001; McCartney 2005; Bauer and Olsson 2008.).

### ***2.11.1 The Water Resources Planning Process***

The effective management of water resources is of great importance to ensure the supply of water resources to support changing water requirements over a selected planning horizon and in a sustainable and cost-effective way. Essentially, the purpose of the water resources planning process is to balance the available water resources in a system with the water requirements and losses to which the system is subjected. The process involves a number of aspects and it involves the assessment of the water resource capability of the system in question, the associated assurance of supply, strategies in managing water assets, culture of people in paying for water services, skills transfer, technology used and community involvement, current and projected water requirements, user priorities and acceptable risks of non-supply, as well as various water quality criteria (uMngeni, 2008).

### **2.12 Drivers of sustainable water service delivery**

From earlier reviews, it can be argued that for a community to keep water facilities operational over time requires a dynamic, inter-linked, interdependent and a complex mix of managerial, social, financial, institutional, environmental and technical issues. Similarly, Washalliance consider Financial,

Institutional, Environmental, Technological and Social (FIETS) as the main five sustainability drivers in concept called the (FIETS) sustainability model (Washalliance,2013) which advocate that users should be responsible for ensuring the sustainability of their water facilities without reliance on external support. It is a model that promotes user ownership and acceptance of responsibility for the post- construction operation without little or no reliance on external support.

This concept will require that communities are able to manage facilities without soliciting or continuing external support. However, the community-managed system has been established to be challenging. Therefore, exploring a household option that can engender absolute responsibility on the user would be pertinent. Therefore, this study will subsequently explore the five sustainability drivers as the core underlying concept of this research in relation to household managed approach.

#### 2.12.1 Water security and scarcity

Water security and scarcity, water pricing and charging and economic growth have influence on water consumption. Some countries such as South Africa use instruments that set the limits on water use and can influence fiscal policy on water use, both direct and indirect (Casey, Carter & Yoe, 2012). There are various ways that governments choose to collect and spend money to collect revenue through a raft of taxation, charging and pricing mechanisms. It gives a range of expenditure, grant, subsidy and payment mechanisms as the way of collecting administrative costs from households and business (Young, 2015).

South Africa is a water stressed country with between 500 m<sup>3</sup> and 1000 m<sup>3</sup> of water available per person per year (Ashton, 2002). Surface water is heavily committed for use, water is imported from neighboring countries, and the limited groundwater resources do not offer much reprieve (Scholes, 2001). As a result, water availability is predicted to be the single greatest and most urgent development constraint facing South Africa. The need for water is further highlighted by the fact that water scarcity in developing countries is closely linked to the prevalence of poverty, hunger and disease (Falkenmark, 1994; Ashton & Haasbroek, 2002).

#### 2.12.2 The use of quality water for domestic purposes

The use of water for domestic purposes cannot easily be distinguished from productive use at the household level, particularly among poor urban communities. Domestic quality water use to sustain livelihoods among the poor forms an integral part of household coping strategies. Generally society needs quality water, as it refers to the state of the water in terms of its purity or level of contamination. Water quality impacts water availability. Water of poor quality is less suited to support socio-

economic activities, which lead to scaling of pipes and infrastructure, interference with chemical processes and cause health risks (Ashton & Godfrey, 2007).

### **2.13 Chapter summary**

Infrastructure plays a vital role in economic development and normal functioning of economic systems. Due to their long lasting nature and their significant impact on the environment and the society, planning, design, procurement and construction of infrastructure systems should be done meticulously. Chapter 3 presents discussion on the importance of water delivery services.

## **CHAPTER 3: IMPORTANCE OF WATER SERVICE DELIVERY**

### **3.1 Introduction**

This chapter provides basic definitions and discusses the concept of improved strategy with particular emphasis on water delivery services. It attempts to justify the importance of water services considerations in delivery of sustainable infrastructure. Elements of water infrastructure sustainable management are briefly described and a theoretical framework for its considerations for developing countries is presented.

### **3.2 State of Water Globally**

Water is life. All living organisms are made predominantly of water. Water is necessary for all chemical reactions that occur in living cells, and is also the medium through which information is exchanged between cells. The sustainability of human development depends on the hydrological cycle, since water is essential for food production and all living ecosystems. Seventy percent of the earth's surface is covered by water. Ninety-seven percent of this water is contained in oceans, and is therefore salty and unsuitable for drinking or irrigation. Of the remaining 3% of freshwater, only 0,3% is found in rivers and lakes, the rest being frozen. Water is a renewable resource, made continuously available through solar energy, which enables it to evaporate from oceans and land and be thus redistributed around the world. This water runs off in rivers and refills our aquifers. On an annual basis, rainfall exceeds evaporation on continents by 44,000 km<sup>3</sup>. This amount of water returns to the oceans as river and groundwater runoff. This is known as the Water Cycle (Shiklomanov, 1999; Postel, 2001).

### **3.3 State of water in Africa**

The population of Africa in 2005 was estimated at about 905 million, and is expected to grow to 1,936 million by 2050. Currently, 39.7% of the population is urban, and this is expected to rise to 53% in the next 25 years. In 2003, the African economy grew by 3.7% and aid to African countries has been increasing in the last few years. Consequently, most African countries are slipping back or lagging behind in their attempts to achieve the MDGs (Postel, 2001; ADB, 2004). Africa's annual

renewable water resources are estimated at about 5,400 billion m<sup>3</sup> per year, of which roughly 15% is groundwater.

Africa has an average annual rainfall of 673.1 mm, which varies at the sub-regional level from 1,700 mm per year in the island countries to 71.4 mm in North African countries. The region also experiences rainfall fluctuations of varying frequencies and magnitudes, resulting in droughts and floods. The region has 24 major surface water basins and 38 major trans boundary groundwater aquifers. However, unlike rivers, little is known about these freshwater resources, which are distributed unevenly across Africa and are characterised by extreme temporal and spatial variations (UNDP, 2006). This calls for an enormous amount of investment in irrigated agriculture, water supply and sanitation, and the decentralisation of water supply and sanitation services to appropriate administrative levels. Transparent, open, accountable, gender-responsive, communicative and effective water governance at all levels of water management is also needed (UNDP, 2002). This can happen if appropriate policy changes are implemented at the regional and national levels to facilitate good governance, promote good water resource management practices, attract investment in agriculture and negotiate better access to markets. Many African countries face water stress (Gleick, 2000), but this is most pronounced in Northern and Southern Africa. The inter-basin transfer of water resources, improved infrastructural development and desalination are three possible solutions. Currently, about 300 million people in Africa do not have access to safe water, about 313 million have no access to sanitation, and over 88 million people are malnourished (UN, 2005). This takes a heavy toll on the social and economic progress of African countries.

### **3.4 Water problems in South Africa**

Access to sufficient, safe and affordable water is vital for human development. At present, globally, more than 1.2 billion people lack access to an adequate supply of water and more than 2.4 billion lack access to adequate sanitation. More than 2.4 million people die annually from water-related diseases due to the absence of a qualitatively safe water supply - most of these are children (World Bank, 2005). It is in recognition of the human rights approach to water that South Africa's constitutions specifically guaranteed access to water to all citizens, and the country was among the very first in the world with such a constitutional framework. South Africa is arid or semi-arid country. The country's rivers are relatively small in comparison with major rivers on the African continent, and are largely shared internationally - about 65 per cent of the land area of South Africa falls within internationally shared river basins (Schulze, 1997). Annual rainfall across the country averages around 450 mm per annum, which is barely half of the global average (Schulze, 1989; DWAF, 2013). The magnitude and

distribution of rainfall subject large parts of the country to extremes of periodic droughts and floods, emphasising the crucial need for efficient management of water resources as a national priority.

### ***3.4.1 Ensuring access to basic water services***

Water services authorities have the legislative responsibility of ensuring the provision of sustainable water services. In this case, this also implies free basic water services. This is probably the one important legislative clause which guarantees all South Africans a constitutional right to potable water. (DWAF, 2013). Linked to access to basic water services is the emphasis on the sustainability and viability of water services. Certainly, this is a critical area for water services authorities, because most of them are not yet ready to guarantee the right to access, let alone to ensure the sustainability of water services. The implication is that central government, while it is entitled to enforce rules and regulations, also has to commit resources to create viable and sustainable water services infrastructure. Some of the basic actions that water services authorities need to take in order to conduct their governance and/or provision functions are:

- a) Water conservation and demand management.
- b) The development and enforcement of regulations and by-laws.
- c) Billing and collect
- d) Improved infrastructure facilities

## **3.5 Infrastructural sustainability**

### ***3.5.1 Background***

The industrial revolution in Europe in 1770s brought a notable social, economic and environmental impact on the planet. While economic growth was sought by many countries and achieved by some, it was realized in mid 1960s that the economic growth achieved by some has compromised ecological limits of the planet. Several publications including the book entitled *Limits to Growth* (Meadows, 1972) tried to show limitations of economic growth. The book attempted to point out with quantitative terms that there is limit to economic growth and sustainability is not an option but a mandatory urgent

issue of the planet. This and several other related publications signified the need to consider issues of "sustainable development" in line with the strive for economic growth.

Realizing the pressing issues of the impacts of economic development on the environment especially the criticality of these concerns in developing countries, the United Nations General Assembly set up and mandated the World Commission on Environment and Development (WCED) in 1983 to examine these issues and formulate "A global agenda for change." In 1987, the commission released its report entitled "Our Common Future" stating that basic needs of significant portion of the world's population were not being met. The report alarmed that issues of poverty, inequality, and environmental degradation needed to be addressed urgently (Brundtland, 1987).

Another global milestone in relation to sustainable development after the work done by the WCED's was the Earth Summit, which was held in Rio de Janeiro, Brazil in 1992. The world leaders at the summit adopted an action plan for sustainable development for 21st century referred to as Agenda 21. The action plan clearly outlines an objective pertaining to the built environment aiming at improving the social, economic and environmental quality of human settlements and the living and working environment of all people (UNCED, 1992). Agenda 21 suggests participation and cooperation of the local authority as a determinant aspect in fulfilling objectives of the agenda and urges each local authority to adopt "a local Agenda 21". In response to Agenda 21, the International Council for Innovation in Building and Construction (CIB), produced an Agenda 21 on Sustainable Construction in 1999 through a collaborative research process (CIB, 1999). The fact that sustainability of the built environment consideration in developing countries needed a different approach prompted development of a discussion document for Agenda 21 for Sustainable Construction in Developing Countries in 2002 (CIB & UNEP-IETC, 2002).

### **3.6 Infrastructural development**

Todaro and Smith (Economic Development, 2012, p. 5) defined development as the process of improving the quality of all human lives and capabilities by raising people's levels of living, self-esteem, and freedom (Ibid, pp 2. 22) assert that development in all societies should have at least the following objectives:

1. To increase the availability and widen the distribution of basic life-sustaining goods such as food, shelter, health, and protection

2. To raise levels of living, including, in addition to higher incomes, the provision of more jobs, better education, and greater attention to cultural and human values, all of which will serve not only to enhance material wellbeing but also to generate greater individual and national self-esteem
3. To expand the range of economic and social choices available to individuals and nations by freeing them from servitude and dependence not only in relation to other people and nation-states but also to the forces of ignorance and human misery

Traditionally, development is defined as attaining persistent growth rates of per person income (Ibid). The per person income is expressed using Gross National Income (GNI) which is the total domestic and foreign output claimed by residents of a country.

The term 'infrastructural development' is in vogue. However, it does not yet have a universally accepted unambiguous definition. An assessment of the several definitions of term sheds light on the several challenges it attempts to address (Saha & Paterson, 2008). The most commonly used definition was first formulated in 1987 by the World Commission on Environment and Development (WCED). According to the commission publication (Brundtland, 1987) infrastructural development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future.

After the WCED report was published in 1987, several attempts were made by different authors to come up with globally accepted alternative definitions including the following, A pattern of social and structural economic transformations, which optimizes the economic and societal benefits available in the present without jeopardizing the likely potential of similar benefits in the future. (Goodland & Ledec, 1987). Agenda 21 (UNCED, 1992) highlighted that Human beings are at the centre of concern for infrastructural development. According to the report by CIB & UNEP-IETC (Agenda 21 for Sustainable Construction in Developing Countries: A discussion document, 2002, p. 6) infrastructural development is the kind of development we need to pursue in order to achieve the state of sustainability. It is a continuous process of maintaining a dynamic balance between the demands of people for equity, prosperity and quality of life, and what is ecologically possible. It is what we need to do.

Hanjalić (2008) defined infrastructural development as follows, a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development

and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.

According to Ed Barbier (1987) infrastructural development rests on three pillars namely economic, environmental and social. Despite the fact that some more pillars including technical, political and institutional are suggested by some thinkers the three pillars or also known as the triple bottom line are still widely accepted and used (Du Plessis, 2007). Figure 3.1 shows three intersecting circles representing the three pillars of sustainability with regards to infrastructure. Sustainability will be achieved when the three elements are met simultaneously.

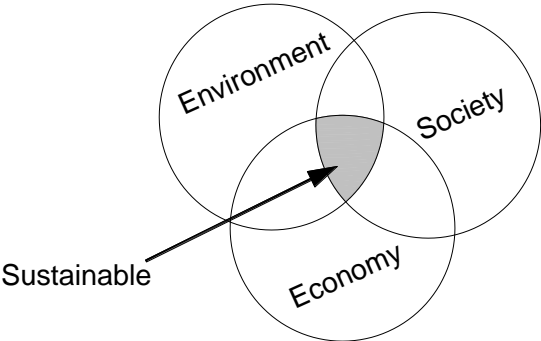


Figure 3.1: The three pillars of sustainability

(Adapted from Nuramo, 2016)

Literature portrays economic aspects of sustainable development in infrastructure as that "...require the development of an economic system that facilitates equitable access to resources and opportunities and the fair sharing of finite ecologically productive space, that enables sustainable livelihoods, and establishes viable businesses and industries based on sound ethical principles. " (CIB & UNEP-IETC, 2002, p. 6)

The social aspects of sustainable development in infrastructure is mainly involved with development of fair and just societies that foster positive human development and provide people with opportunities for self-actualisation and an acceptable quality of life. The third pillar, environmental aspects of sustainable development in infrastructure require that there will be a balance between protecting the physical environment and its resources, and using these resources in a way that will allow the earth to continue supporting an acceptable quality of life for human beings.

### **3.7 Stages of Economic Growth**

Several theories and models depicting stages of economic growth are in use. Major economic developments have been observed during the industrial revolution where European countries have undergone massive industrial undertakings. Economic growth historians indicate that before the industrial revolution begins in 1760s in Europe, all countries on the planet were in a more or less similar economic level. Beginning from 1760 economies of some countries transformed from agriculture to manufacturing. The industrial revolution brought about a major leap in economic development in these countries resulting in significant disparity in the level of economy in different countries. The industrial development owes to the technological advancement and major investment in the manufacturing sector.

The major global phenomenon after the industrial revolution was the birth of Socialism. Socialism became a reason for the ideological "cold war" between the Socialism and Capitalism. The two ideologies have their own approaches of growth and development in accordance with their fundamental teachings. This research focuses on after the end of World War II theories on stages of growth as they are believed to be closer to the reality and have attempted to express the ground situation far better than earlier theories.

#### **3.7.1 *Classical Economic Development Theories***

In general, the classical after World War II Economic Development theories are categorized as follows:

- (1) the linear-stages-of-growth model,
- (2) theories and patterns of structural change,
- (3) the international-dependence revolution, and the neoclassical, free-market counterrevolution (Todaro & Smith, 2012).

Recently, a heterogeneous approach that draws on the different classic theories has emerged .

#### **3.7.2 *Contemporary Models of Development and Underdevelopment***

Contemporary development models has broadened considerably the scope for modelling a market economy in the developing country context (Todaro & Smith, 2012). One of its major themes is incorporating problems of coordination among economic agents, such as among groups of firms, workers, or firms and workers together. Other key themes, include the formal exploration of situations

in which increasing returns to scale, a finer division of labour, the availability of new economic ideas or knowledge, learning by doing, information externalities, and monopolistic competition or other forms of industrial organization other than perfect competition predominate (Ibid).

The big push is a model of how the presence of market failures can lead to a need for a concerted economy wide and probably public-policy-led effort to get the long process of economic development under way or to accelerate it (Ibid).

### **3.8 Different ways of Measuring Development.**

Traditionally economic development or growth is considered as achieving persistent growth of income per capita where this growth is expressed in terms of per capita gross national income (GNI). GNI which is the most commonly used measure of level of the overall economic activity is calculated as the total domestic and foreign value added claimed by a country's residents without making deductions for depreciation of the domestic capital stock. On the other hand, Gross Domestic Product (GDP) measures the total value for final use of output produced by an economy, by both residents and non-residents (Todaro & Smith, 2012).

For the purpose of making a fair economic level comparison between developed and developing countries, their GNI and GDP values are adjusted using purchasing power parity (PPP). In simple terms, PPP is defined as the number of units of a foreign country's currency required to purchase the identical quantity of goods and services in the local developing country market as 1 USD would buy in the United States (Ibid)

In the 1960's the main focus was on micro-economic indicators including Gross National Product (GNP) (UN-HABITAT, 2011). However, during 1970s some countries were able to achieve their economic growth target as measured by the traditional economic indicators. However this "economic growth" didn't bring a notable improvement in the living standard of the majority of their population. This phenomenon indicated that the traditional definition of economic development needs to be revisited to address issues of poverty, inequitable income distribution and unemployment (Todaro & Smith, 2012).

According to Adams & Jeanrenaud (2008) it is not adequate to use GDP only as a measure of human development and stressed the need to add more criteria including social and environmental aspects in the existing set of matrixes. To this effect, United Nations Development Program (UNDP) presented a

holistic comparative measure of socioeconomic development of countries known as Human Development Index (HDI)(Ibid). The HDI attempts to rank all countries on a scale of 0 to 1 (lowest to highest human development) based on three goals namely, life expectancy at birth, knowledge and standard of living. Despite some criticisms, it apparent that HDI provides a better picture of development of countries and it also enables one to easily identify whether various significant groups within a country are participating in that development (Ibid).

### **3.9 Sustainable Construction in water sector**

The construction sector which in several aspects human beings attempt to use to establish secure conditions, is being seen as becoming a menace (Williamson, Radford, & Bennetts, 2003). Fairclough (2002) stresses that adopting a consistent and sustainable vision in the construction industry is a prerequisite to recover it from its underperformance. As the water sector is a major contributor to climate change and other related environmental threats it is essential that it makes a radical change in its practices to minimize if not preclude the impact of these threats (Du Plessis, 2007).

Du Plessis (2007) claimed that as much as half of total construction output may be in civil engineering projects including transport facilities, power projects, irrigation, drainage, and water supplies - namely infrastructure. As infrastructure is one of the major components of the construction industry, sustainable infrastructure is part and parcel of aspects of sustainable construction. According to a report by CIB (1999),sustainable construction entails sectorial contribution made by the construction industry in the areas of environmental, social, ecological and cultural aspects in the effort to achieve sustainable development. Sustainable construction is defined by Agenda 21 for Sustainable Construction in Developing Countries discussion document as follows (CIB & UNEP-IETC, 2002, p. 6) sustainable construction means that the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and built environments, an creates settlements that affirm human dignity and encourage economic equity.'

According to CIB sustainable construction is creating and operating a healthy built environment based on resource efficiency and ecological design. As depicted in

Table 3. 1, it articulated seven principles of sustainable construction that can be applied throughout the built environment life cycle.

Table 3. 1 Principles of Sustainable Construction

<b>Principles of Sustainable Construction</b>
1. Reduce resource consumption.
2. Reuse resources.
3. Use recyclable resources.
4. Protect nature
5. Eliminate toxics
6. Apply life-cycle costing
7. Focus on quality

Source: (Kibert, 2013)

In Table 3.2, Willetts (2010) summarizes widely used key themes associated with sustainable construction. The fact that infrastructure facilities last long signifies the need to design them to accommodate several requirements that would come in due course of their lifetime. These requirements include social, economic, financial, and environmental considerations.

Table 3. 2 Key sustainable construction themes

<b>Social</b>	<b>Economic</b>	<b>Environmental</b>
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Health and safety	Procurement	Resource consumption
Communities	Supply chain	Energy efficiency
Skills	Profitability	Waste
Stakeholder satisfaction	Competitiveness	Climate change
Inclusiveness	Growth	Water consumption
		Biodiversity and habitat
		Land use

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Willetts (2010)

Agenda 21 for Sustainable development (UNCED, 1992) outlined its human settlement objective as improving "... the social, economic and environmental quality of human settlements and the living and working environments of all people, in particular the urban and rural poor." The publication pointed out eight program areas to meet the human settlement programs as follows, namely

- a) Providing adequate shelter for all;
- b) Improving human settlement management;
- c) Promoting sustainable land-use planning and management;
- d) Promoting the integrated provision of environmental infrastructure: water, sanitation, drainage and solid-waste management;
- e) Promoting sustainable energy and transport systems in human settlements;
- f) Promoting human settlement planning and management in disaster-prone areas;
- g) Promoting sustainable construction industry activities;
- h) Promoting human resource development and capacity-building for human settlement development.

The eight program areas outlined by Agenda 21 directly and indirectly point at sustainable provision of infrastructure. According to Martland (2012) the drive to consider sustainability in infrastructure systems may originate from the following:

- Excessive reliance upon fossil fuels including coal, peat, petroleum, and natural gas
- The increase in the world's temperature and associated climate change
- Concerns in relation to equality and social justice
- Unrest in different societies due to economic crisis, internal conflicts, and absence of prospects
- Concerns of overcrowding and pollution within the largest cities

- Breakthrough in the automobile culture which resulted in devotion of huge amount of resource to vehicles and roads, excessive use of fossil fuel, escalated vehicle accidents, urban vehicle overcrowding which causes waste of time and resource.
- Intensified ecological imbalance including rapid extinction of species, grave threat to the habitat, contamination of water supply with toxic chemicals and erosion.

It is argued that social and environmental impacts of infrastructure systems likely become more apparent over their life-time for the following three reasons:

**a. Negative impacts may no longer be acceptable**

When infrastructure systems are first introduced to address needs of the society, their benefits might overweighs their negative impacts that the society might be willing to live with the negative impacts. However, after the needs are met, through time the society will start to question and inquire about the negative impact of the systems.

**b. Negative impacts were not initially apparent**

Some impacts of infrastructure systems will become apparent only years or decades after the systems have been put in place.

**c. Societal norms change**

As a result of change in lifestyle and mindset of the society in due course of time, systems that were acceptable when put up may not be acceptable anymore some years later.

While notable progress have been made with respect to development and assessment of 'green buildings', literature underscore that so far less attention has been paid to issues of improved infrastructure delivery (Huang & Yeh, 2008).

Lim and Yang (2006) identified a some processes which vividly portrays the spectrum of aspects connected with the process of infrastructure delivery.

***3.9.1 Social Aspect***

Employment and skill-transfer

The construction industry creates a considerable employment opportunity throughout the world. It is also argued that infrastructure construction may enhance skills of the employed (Fourie, 2006). It can therefore provide an opportunity to improve quality of the poor and enhance human development especially in developing countries (CIB & UNEP-IETC, 2002). According to a report by ILO (2001) while "employment intensity" of the construction activity in low-income countries is much higher than the high-income ones, the value of output per person is directly the opposite indicating the need to improve its productivity in those countries.

#### Health and Safety

The construction industry does not have a very good reputation in terms of health and safety records especially in developing countries (Ibid). Safety might refer to accidents or difficulties that could happen during normal functioning of systems (Martland, 2012). Health and safety concerns issues throughout lifetime of the built environment including construction, operation and demolition.

#### Poverty Alleviation

Sachs (2004) claimed that poverty alleviation has become an important drive for recent infrastructure project proposals especially in sub-Saharan African countries.

#### Inequality

While investment in infrastructure may increase equity, it could also have a negative impact on distribution of income (Fourie, 2006).

#### Security

Security might refer to prior measures taken to protect people and property from possible intentional attacks (Martland, 2012).

#### Risk

Risk is a general concept referring to possibilities of future accidents and undesirable occurrences (Ibid).

### **3.9.2 Economic Aspect**

Literature points out that economically efficient construction industry enhances environmental sustainability (CIB & UNEP-IETC, 2002). Flyvberg (2003) conducted a study in 258 major transport infrastructure projects constructed between the years 1927 and 1998 in different parts of the world and found an average 30% cost overrun and 40% failure in meeting client income targets.

Apparently, the construction industry leans towards putting more weight to initial capital cost of projects rather than operational cost of facilities. Resource wastage is very much pronounced in the construction industry. The construction industry should tailor its approach especially during the design stage to take into account operation stage aspects and end user requirements (Myers, 2004).

### **3.9.3 Environmental Aspect**

It is apparent that investment in infrastructure has notable positive impact on the economy. On the other hand the built environment including infrastructure has direct, complex, and long-lasting impact on the planet than any other human venture (Kibert, 2013). It is argued that particularly large-scale infrastructure projects such as power plants and dams have significant impact on the environment (Weiss, 1999).

As the construction industry is a highly resource consuming sector which is responsible for 40% of global CO<sub>2</sub> emission, any improvement made in this industry will have a notable impact in the global fight against excessive carbon emission. It is claimed that environmental impact of the construction industry in developing countries is anticipated to be larger due to their strive to industrialize their economy which requires massive construction activities (CIB & UNEP-IETC, 2002).

### **3.10 Chapter summary**

This chapter discussed the concept of water availability and briefly outlined aspects of water delivery development. Stages of economic development were explained. Infrastructure sustainability is described and the relationship between economic development and water delivery was explained. Particular discussion is made on water delivery and economic development in developing countries. Chapter four discusses the development of the conceptual model.

## **CHAPTER 4: WATER SERVICES DELIVERY DEVELOPMENT MODEL**

### **4.1 Water Services Provision and Delivery**

In South Africa, a public private partnership in Nelspruit and Harrismith both turned around service delivery in municipalities struggling with responsibility for townships and rural areas incorporated at the end of apartheid (Tucker et al. 2010). Both partnerships have brought in skilled staff and improved the quality and reliability of services, demonstrating the value of partnerships to municipalities which have low capacity and/or are overstretched. In both municipalities, cost recovery in low-income areas has been very challenging, although the PuP was quicker to engage flexibly and sympathetically with these communities (Tucker et al. 2010). The weakness of the concession in this area reflects in part a lack of monitoring capacity in the municipality. Both partnerships required a period of intensive negotiations with politicians and trade unions to build support. This process was shorter and more successful in the case of the PuP. Tucker et al. (2010) indicates the bottom line question in terms of sector performance is not so much whether a PPP or PuP is adopted, but rather whether appropriate institutional arrangements, financing mechanisms; subsidies and policies for pro-poor service provision are in place, and the capacity and willingness of government to take leadership in these areas. Involving a partner with the right expertise and capacity, which includes not just technical aspects but an understanding of customer care and the particular needs of low-income areas and households, may be most important (Tucker et al. 2010).

According to Tucker et al. (2010) this expertise may come from the public or private sector, and public sector providers and local private operators may offer a wealth of experience which has not yet been tapped. The important thing is to assess the local context and needs, explore partnership options and take the time to develop an appropriate arrangement for each situation. According to Tucker et al. (2010) it is important that governments are able to exercise choice in partnership development, and retain the flexibility to change arrangements which are not working. Providing effective water and sanitation services for urban areas in developing countries is challenging and there are no easy solutions, so room to experiment with new approaches is key. Support to new PPPs should consider working with the private sector in more flexible ways with lower risk to municipal governments (Tucker et al. 2010). Opportunities to partner with local private sector organizations and entrepreneurs should be explored, particularly for small towns. There is also a need for better monitoring of partnerships for lesson-learning and also accountability purposes. This is not to say, however, that it does not matter whether a partnership involves the private or public sector.

## 4.2 Other models

Despite international efforts, water and sanitation services are failing as much as a third of the world's population (Graham, 2005). Poor management, lack of financing, contentious politics, and other factors all contribute to a global crisis that saps not only human lives but economic and social development. However, recognizing these factors as problems has not yet resulted in solutions for much of the world's poor, and often poor governments are caught to some extent, their own fault in a dangerous cycle of poor infrastructure leading to weak revenue streams that cannot maintain or expand the infrastructure.

While many failures to provide basic services and to recover costs are most likely locational specific, there are also some trends that can be generalized, including political interference, poor assumptions about the market, and losses from undercapitalized infrastructure. This study will consider some of the models and demand-oriented issues in the world, Africa and South Africa with a specific focus on Ethekewini municipality. It will speak to specific costs that affect households, the spatial constraints that they face, as well as various value issues that are inherent in different water service delivery types and an assessment using different models

### *4.2.1 The system group model building (SGMB)*

The core concept of SGMB is used in US and it finds its roots in a popular application of system dynamics modeling known as Group Model Building (GMB). GMB is a method specifically targeted at engaging stakeholders in the process of building models to improve decision making in the face of complexity (Richardson 1995; Vennix 1996; Hovmand 2012). Vennix (1996) describes GMB as “a process in which team members [such as practitioners, stakeholders, experts, etc.] exchange their perceptions of a problem and explore such questions as: what exactly is the problem we face? How did the problematic situation originate? What might be underlying causes? and most importantly “How can the problem be effectively tackled?”

The overarching goal of GMB is to take participants' mental models that exist as individual implicit frameworks (Vennix 1996), and make these frameworks explicit through diagramming and quantitative simulation. Qualitative system dynamics modeling or diagramming is often most

appropriate when model variables cannot be accurately quantified, as is often the case for exploratory modeling, similar to what was done in this research. As such, the main benefits of group model building are the ways that the GMB process enables workshop participants to

- (i) formalize and align their mental models within a group to learn how certain factors cause a complex behavior (Vennix 1996; Andersen et al. 1997; Bérard et al. 2010; Wolstenholm 1982; Cavaleri and Sterman 1997), and
- (ii) provide a platform with which to discuss a complex problems using a unified method that better facilitates group consensus on possible strategies and future actions (Richardson 1995; Rouwette et al. 2011; Rouwette 2012; Vennix 1997; Visser 2007; Vennix 1993).

#### ***4.2.2 Empirical model building (EMB)***

When the findings from SGMB do not provide sufficient clarity for strategic action, the next step is to perform a case study within the process of empirical model building (EMB) to highlight some of the realities in the field needed to affirm and confirm the factor analyses that took place in the SGMB.

While this process will actively involve fewer stakeholders than SGMB, it is important that the whole group model building team remain in contact throughout the EMB process, and continue to hone in, reflect on, and amend their models build through SGMB in an iterative fashion. The output from these efforts is a similar factor diagram to what was build using SGMB, but instead is a diagram or network inferred using field data.

#### ***4.2.3 African context***

Within the Ugandan and Kenyan context, multi-stakeholder engagements are seen as a key for success (UNDP, 2013). The Water Partnership Program (WPP) of the African Development Bank (2010) corroborates this statement, identifying involving community management as an element for success. De Cecco (2012) conducted a study between Uganda and Tanzania and reported major differences in governance mechanisms. The study conducted by De Cecco (2012) suggests that Uganda has a successful water resource management system as a result of management's commitment in providing basic services to the poor. Largely, there are many concerns relating to governance in water resource

management in the Sub-Saharan Africa context. There are, however, success stories and plans that could lead to success. Looking at the aims and objectives of this study, it is necessary to gain perspective of governance in Sub-Saharan Africa countries to identify if certain challenges are a common feature or if the findings of this study are localised to South Africa. In the South African context certain parts of the country are faced with growing water demands and insufficient potable water sources (Pegram and Eaglin, 2011; Haigh et.al. 2010).

In addition to drought that leads to water shortages, provinces in South Africa such as Gauteng have incurred water contamination as a result of abandoned mines (Knuppe, 2011). Apart from water demand, industrial practices are applying enormous pressure on dwindling resources and South Africa has exceeded its natural availability of water (Mukheibir and Sparks, 2003; Pitman, 2011). Over-and-above this there are growing concerns that climate change presents further challenges in rainfall patterns (Mukheibir and Sparks, 2003; Galvin et.al. 2015). Water resource management is therefore a very critical area for many researchers. Water resource management in South Africa has a historical journey of importance. Initial reform initiatives supported a transformation of management structures from a centralised to a decentralised mode of operation (van Koppen and Schreiner, 2014). Since the decentralisation of governance in 1996, local government has been responsible for a wide range of services, including legislative compliance (Meissner, 2013). Despite the uncertainty of a decentralised system, it is widely accepted to ensure better governance and performance (Stanton, 2009).

Policy making power has subsequently been distributed to mandated institutions, where financial, political and administrative challenges are noted, even at local level (Stanton, 2009, Haigh et.al. 2010). Siebrits and winter (2013) reported that more effort must be applied toward policy aspects such as development, which include supporting evidence of policy creation, implementation and monitoring. Only when governance issues are understood in water resource management can South Africa progress to a sustainable water situation (Meissner, 2014; Siebrits et.al. 2014). Gumede and Dipholo (2014) identified major governance issues in a study that looked at New Public Management in South Africa. Sectoral boundaries, lack of coordination, fragmented responsibilities and inconsistencies between regulatory frameworks have been noted as complexities in water resource management (Haigh et.al. 2010; Meissner et.al. 2013). The challenges emphasised in water management have brought to surface a great need for water governance reform as poor governance is recognised as one of the causes of the current water crisis (Siebrits et al., 2014; Jankielsohn, 2012; Meissner, 2014).

This is underlined by Siebrits et al. (2014) whose research identified priority questions for key themes in South Africa. Using an integrated and Strategic Adaptive Management (SAM) approach Siebrits et al. (2014) presented > 10 topical questions for the key theme “governance”. Although these ideas

build a platform for further research, issues such as mismanagement highlight a hydro political agenda in water resource governance (Jankielsohn, 2012; Meissner, 2014). Manders et al. (2009) identified two problems within the policy framework, related to water quality in South Africa, that require attention. The first is that the delegation of powers at various levels within the government does not clearly identify roles and responsibilities and the second is that current frameworks treat the problem rather than identifying the root cause and preventing a recurrence (Manders et al. 2009). Meissner et al. (2013) suggests that despite the implementation of IWRM, institutional structures are still faced with disjointed management, alignment is therefore highly important to achieve a collaborated output and sustainable water management system. Alternatively, a study by Colvin et al. (2008) indicated that a progressive system of water laws and policies should be considered for effective water resource management.

#### **4.3 Development of framework and model**

In understanding institutional and policy frameworks, it is important to note that there are various tools that can be adopted for analysis. World Bank (2007) presents this variety in the form of Tools for Institutional, Political and Social Analysis (TIPS). There are three basic levels of analysis that are applied in TIPS. The first level is the macro-level which is designed for analysis within the context of the country as well as reform. The second level is the meso-level which is designed for analysis of policy implementation and operates within the realm of stakeholder.

The third level of analysis is the micro-level, which identifies the impact of policy reform by looking at analytical frameworks at implementation level and entails physical data collection. While this research does analyse elements of behaviour at national level, exploration of the how, why and what conditions are sought. For this reason, this study operates in the meso-level to provide greater understanding of the underlying features in policy implementation. In essence, this contributes toward detailing perspectives on governance frameworks in sustainable policy development. At meso-level, analysis is further subdivided into meso-stakeholder analysis and meso-institutional analysis. Both

levels are designed to test assumptions; however the mesostakeholder analysis tests interests of social actors while the mesoinstitutional level tests social rules governing implementation of policy.

To effectively analyse relationships at the meso-institutional level the institutional analysis and development framework has been applied. The framework was used to depict governance in water resource management using Delphi (Polski and Ostrom, 1999). This approach explains how actors interact with an array of factors from political, social, physical and environmental issues. Before adopting this framework as an analysis tool, the researcher first presents the framework depicting its origin and application. Due to the inherent difficulty of examining institutions and the invisible elements of policy making, The researcher developed a framework. It is used to provide an understanding of institutional arrangements by organising policy analysis activities and allows analysts to comprehend complex social situations and by providing foresight to issues that would lead to policy failures (Polski and Ostrom, 1999).

#### **4.4 General review of items used.**

Several researchers have developed checklists and lists of consideration aspects for sustainable infrastructure delivery and management. William MacDonough (1992) outlined the following nine principles of sustainable design known as *Hannover Principles*, namely

1. Insist on rights of humanity and nature to coexist in a healthy, supportive, diverse and sustainable condition.
2. Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale.
3. Consider all aspects of human settlement including community, dwelling, industry, and trade in terms of existing and evolving connections between spiritual and material consciousness.
4. Accept responsibility for consequences of design decisions upon human well-being, the viability of natural systems, and their rights to coexist.
5. Create safe objects of long-term value.
6. Eliminate the concept of waste. Evaluate and optimize the full life cycle of products and processes, to approach the state of natural systems, in which there is no waste.
7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.

8. Understand the limitation of design. Treat nature as a model and a mentor, not an inconvenience to be evaded or controlled.
9. Seek constant improvement by the sharing of knowledge.

Williams (2007) recommends the following three aspects to be taken in to account in the early stage of design development, namely

- a) **Connectivity:** Strengthening the link between the project, the project area, the neighbourhood and the ecology;
- b) **Indigenous:** Capitalizing on what is existing and sustainable for long in the project area; and
- c) **Long life, loose fit:** Design for the future while reflecting the past; in concise term flexibility.

#### ***4.4.1 Construction Materials***

Non-renewable mineral resources are consumed in large quantities in infrastructure with regards to water. Therefore, there is a need to shift from this trend. Construction activities should rather be able to consume renewable and recycled materials as much as possible. During the design phase selection of construction materials should be based on their environmental performance, service life and their detrimental effect on health (CIB, 1999).

#### ***4.4.2 Environmental Considerations***

##### Water Conservation

Reducing consumption of high quality drinking water, reducing urban runoff, significantly decreasing contamination of ground water, improving water distribution systems to reduce leakage, reducing sewerage water and improving reuse of water are some of the critical aspects in relation to water industry (CIB, 1999). Natural Hazards -Due to an increase of natural disasters over the last couple of decades, infrastructure systems need to operate under increasing pressure from their external environment (FIDIC, 2012). Land use. -Site selection and land use entail environmental, social and economic impacts. Efficient land use and conservation of open spaces and the structure of existing settlement are crucial (CIB, 1999).

#### ***4.4.3 Economic Considerations***

Historically, decisions regarding design and construction of infrastructure systems have been based largely on cost analysis and performance targets (Sahely, Kennedy, & Adams, 2005) which do not

depict the real picture of life cycle cost. Economic considerations need to include operation, maintenance and demolition cost analyses. (Shen, Wu, & Zhang, 2011) outlined the following indicators for assessment of infrastructure projects:

- Analysis of market supply and demand;
- Technical advantage;
- Project budget;
- Project financing channels;
- Project investment planning;
- Life-cycle cost;
- Life-cycle benefit/profit;
- Financial risk;
- Payback period; and
- Internal return ratio (IRR).

#### ***4.4.4 Social Considerations***

##### Early Stakeholder Involvement

Sustainability considerations require early stakeholders involvement to uncover possible undesirable effects of infrastructure development (FIDIC, 2012). Some of the indicators are client participation, provision of employment, beneficiaries participation, health and safety consideration for construction and operation stages and protection of cultural heritage.

#### ***4.4.5 Technological Considerations and Design Tools***

##### Information Technology

The design process in the water industry will increase in significance and intricacy requiring an integrated approach which necessitates the use of information technology to maintain a continuous flow of information throughout the project life (CIB, 1999). Life Cycle Assessment- Life cycle assessment (LCA) entails a detailed study of the impacts of a product from the very beginning to the very end (Myers, Construction economics: a new approach, 2004). LCA tool enables designers to quickly evaluate several design alternatives and identify the best option. It is claimed that LCA provides reasonable and comparable outcome concerning environmental impact, raw material use and energy consumption (CIB, 1999).

#### ***4.4.6 Design Professionals and the Design Process***

##### Integrated Design

It is argued that sustainable design needs an integrated design process where involvement of whole design team and iteration between design phases are required (Bragança, Vieira, & Andrade, 2014). Whole System Design- Blizzard & Klotz (2012) outline that sustainability challenges are intertwined and require a holistic design approach to enable designers holistically optimize solutions for social, environmental and economic considerations. The use of Sustainable Whole System Design approach is expected to offer more possibilities than the traditional design approaches.

#### ***4.4.7 Rating and Performance Evaluation Systems***

Design and evaluation of sustainable building and infrastructure is often aided by several rating systems, guidelines and design software. Green building and sustainable infrastructure rating systems are the two types of systems used in the built environment in general. Rating systems are found to be the most suitable tools for buildings and the two most popular tools are LEED (Leadership in Energy and Environment Design) and BREEAM (Building Research Establishment's Environmental Assessment Method) (Papadopoulos & Giama, 2009).

Sustainable infrastructure rating systems include Envision, Infrastructure Sustainable rating tool and Civil Engineering Environmental Quality (CEEQUAL) are in use in different parts of the world. Envision rating system is the leading especially in U.S. and it is found to be appropriate for project planning to inform goal setting and early design considerations for a range of infrastructure projects (Shealy, Klotz, Weber, Johnson, & Bell, 2016).

This rating system which was launched in 2012 was developed jointly by the Zofnass Program for Sustainable Infrastructure at the Harvard University and the Institute for Sustainable Infrastructure (ISI). Its aim is to promote advancement of in performance and resiliency of physical infrastructure in terms of economic, social and environmental aspects of sustainability. The system has five categories namely Quality of Life, Leadership, Resource Allocation, National World and Climate and Risk. A schematic of the framework model was developed in Figure 4.1.

#### **4.4.8 Communication**

The communication plan identifies how the stakeholder will be communicated with, the type, frequency, and medium. It establishes the content of the communication and what it intends to accomplish. Each stakeholder has their own unique needs and must be addressed individually. While it is true that stakeholders fall into groups with similar communication needs, one cannot stop at lumping stakeholders into groups. They must be communicated with on their own terms and given personal attention. This can be a tool for successful project management.

##### Stakeholder management

Throughout the project, each stakeholder is managed to ensure their communication needs are being met. The stakeholder is tracked using information systems to ensure they are adequately moving to their desired place of project buy-in. Not all stakeholders need to be in full approval, but often enough of an acceptance to avoid active opposition is enough.

Stakeholder management throughout the project execution phase consists of the following actions:

- Ensure that the Stakeholder Communications Plan is being followed. If not, take corrective action.
- Assess whether the Stakeholder Communications Plan is still meeting the needs of the project. If not, update it. A review of the actual communications can indicate whether the stakeholder communication needs have changed or new information is received that affects the plan. As shown in Figure 4.1, it shows the schematic of the framework.

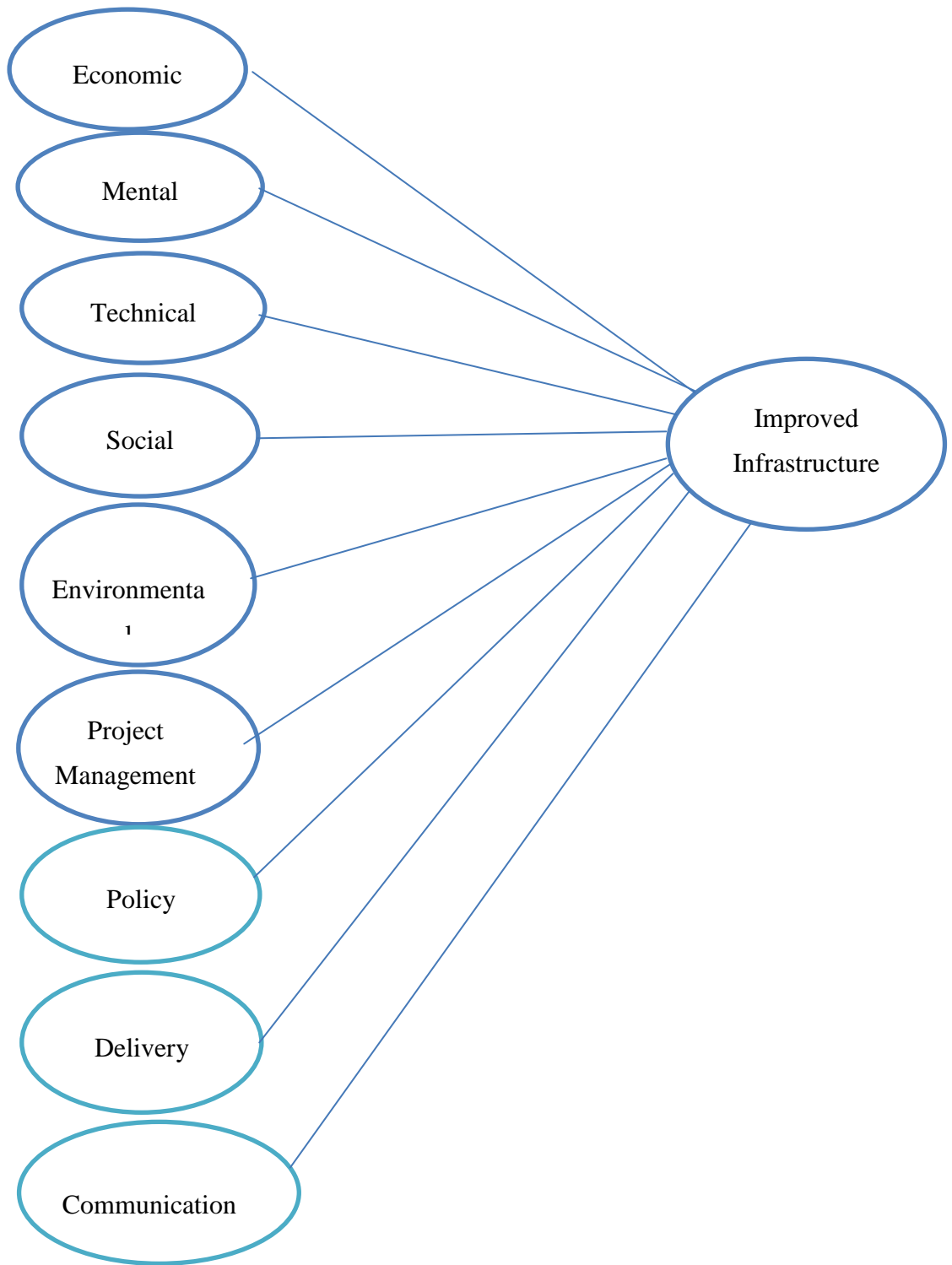


Figure 4.1: Schematic of the framework of the model

#### **4.5 Chapter summary**

This chapter described the framework of various approaches to water delivery to identify the items to be included in a model to improve water service delivery . Aspects of water sustainability were discussed and key water sustainable infrastructure design consideration elements and factors were presented. The next chapter presents and discusses research methodology of this research.

## **CHAPTER 5: RESEARCH METHODOLOGY**

### **5.1 Introduction**

This chapter highlights the research methodology in this research, and will describe the background, theories, processes and events that guided the research actions. The chapter will also explain the processes, from which the research data are generated. This includes an overall data gathering processes and fieldwork. Special attention was given to the sources of data, the rationale underpinning data selection and collection method. Overall, it explained how the process evolved based on consideration of various research approaches and fieldwork constraints.

### **5.2 Research approach**

Research approaches are generally categorised into either a mixed, qualitative (interpretive) or quantitative (verification) approach (Creswell, 2007; Neuman, 2006). Quantitative approaches seek to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of previous research or literature (Fellows & Liu, 1997). Scientific techniques and statistical methods are especially useful in quantitative research for looking at relationships and patterns and expressing these patterns with number (Rudestam and Newton, 2007). Quantitative data obtained from samples of observations are analysed using statistical methods to examine and compare sources of variance of phenomena, to help make decisions to accept or reject hypothesised relations between phenomena, and to aid in making reliable inferences from empirical observations (Kerlinger, 1977). Analyses of the data yield quantified results so that conclusions can be derived from the evaluation of results in the light of the theory and literature.

Qualitative approaches, on the other hand, means any type of research that produces findings not arrived at by statistical procedures or other means of quantification (Strauss & Corbin, 1998). It can refer to research about people's lives, experiences, behaviours, emotions and feelings, as well as about organisational functioning, social movements, cultural phenomena, and interactions between nations. Further, they suggest that some of the data may be quantified, as with census or background information, about the persons or objects studies, but the bulk of the analysis is interpretive. The data gathered may be unstructured but will tend to be detailed, and hence 'rich' in content and scope. Analyses of such data tend to be considerably more difficult than with quantitative data, it often

requiring a lot of filtering, sorting and other ‘manipulations’ to make them suitable for analytic techniques (Fellows & Liu, 1997) . In addition, a variety of external, environmental variables are likely to impact on the data and results and the researchers are likely to be intimately involved in all stages of the work in a more active way than usually is acceptable in quantitative studies. Due to these fundamental differences, qualitative researchers prefer the use of inductive, hypothesis generating research

### **5.3 Mixed Method Research and Triangulation**

Since the mid-1990s, researchers increasingly tended to use mixed methods, which combined qualitative and quantitative approaches within a study (Ridenour & Newman, 2008). Methodological pluralism entails use of multiple theoretical models and methodological approaches in order to question established models and understandings and accumulate knowledge (Knight & Ruddock, 2008). Abowitz & Toole (2010) claim that a mixed method approach which is the use of two or more methods to the problem is the best way to complement the innate limitations of using single methodological approach.

Employing more than one method of data collection together with mixed qualitative and quantitative approach is a broader form of triangulation and yields greater utility (Ibid). Arguably, combined use of qualitative and quantitative methodology in a research is called triangulation (Dawson, 2007). Triangulation is a valuable strategy in the research process, but more so when used when different methods with complementary strengths and weaknesses are mixed (Abowitz & Toole, 2010; Fellows & Liu, 2008). Abowitz & Toole (2010) further claim that using two or more research methods whose reliability and validity attributes compensate each other enables the triangulation of the “true” result.

There are two schools of thought about the use of mixed method research triangulation in social science research. One school of thought argues that qualitative and quantitative research approaches should not be mingled (Blaikie, 1991). The other school of thought advocates the use of hybrid approaches asserting that understanding of social phenomena requires the most efficient use of both paradigms (Creswell, 2014). Solving problems through construction management research requires holistic understanding of the problem and it should not restrict its approach to particular research paradigms (Love, Holt, & Li, 2002).

This study follows a mixed-method research approach where qualitative and quantitative research methods are employed and shown in Figure 5.1. Initially, a theoretical model is developed through a systematic literature review. The theoretical model was refined by a Delphi research method, which is a combination of both qualitative and quantitative methods. The refined model is validated using an empirical quantitative questionnaire survey.

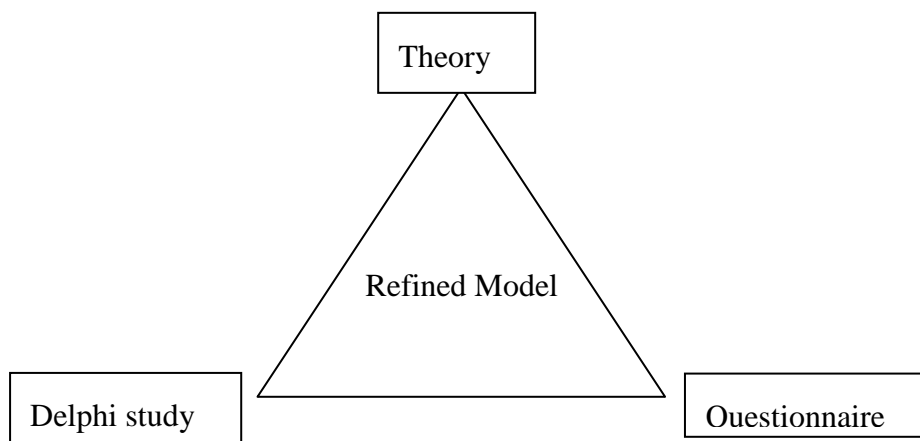


Figure 5. 1 Mixed research methods design

#### 5.4 Research Design

Research design can be described as the systematic approach to answer the research question through data collection and analysis and so presents a framework for conducting the research (Rugg & Petre, 2007; Bryman & Bell, 2007). Research design and research methodology are two distinct phases and concepts in a research.

Marczyk, et al (Essentials of Research Design and Methodology, 2005, p. 22) defines research methodology as "*the entire process of conducting research (i.e., planning and conducting the research study, drawing conclusions, and disseminating the findings)*" and research design as "*the many ways in*

*which research can be conducted to answer the question being asked".* Research design has different categories including experimental, quasi-experimental, and non-experimental (Ibid).

This research followed a three stage procedure. The first stage involved derivation of research questions and objectives from the research problem statement. Literature review was conducted to identify key elements for sustainable water delivery in developing countries. A theoretical model for water delivery tools in developing countries was developed using the key design elements.

In the second stage an iterative Delphi research technique was used to validate the key design elements identified in the first phase. The Delphi survey involved three iterations until consensus among panel members was reached. The third stage constituted administration of structured questionnaire survey among design professionals in the Engineering (Water sector) and Construction (EC) industry in South Africa. A pilot survey was conducted prior to administration of the actual survey to check viability of the research instrument. Results of the questionnaire survey were used to test the model refined in the second stage of the research.

## **5.5 Data collection method**

The Delphi technique is a research method used for acquiring the input of content and methodological experts also referred to as panellists, participants to responders (Colton & Covert, 2007; Hasson, Keeney, & McKenna, 2000). The Delphi technique is suitable for research in complex areas and when achieving consensus among experts in the research area is required. It is a preferred tool when the knowledge about a problem or phenomenon is incomplete (Giannarou & Zervas, 2014). A detailed discussion about the Delphi technique and how it is employed in this research is presented in the next chapter.

## **5.6 Review of the Literature**

The initial stage of the research involved reviewing the literature. The main intent of conducting a literature review was to become acquainted with the work that has already been done and to have an understanding of the present state of knowledge in the research topic area (Marczyk, DeMatteo, & Festinger, 2005). The literature review is the essential part of this research as it has provided the base

to develop the conceptual model. Rugg & Petre (2007) emphasise that literature review needs to be conducted in a comprehensive and systematic manner.

This research employed descriptive and analytical approaches during the literature review. The descriptive approach involves description of what previous authors have written and analytical approach involves critical analysis of the contribution of others (Naoum, 2007).

Three types of literature sources namely primary sources, secondary sources and reference guides were used in this research. Most accurate and reliable information is acquired from primary literature sources including refereed academic journals, refereed conference proceedings, technical reports and Government publications.

Secondary resources including textbooks, trade journals, magazines and newspaper were also used in the study. Reference guides provide basic information about a particular subject area quickly and in a concise manner. Dictionaries, glossaries, encyclopaedias and handbooks are typical examples of reference guides.

To avoid vagueness and misinterpretation, operational definitions of key concepts and terms in the context of this research are presented at the beginning of this thesis and in respective chapters.

## **5.7 Data analysis method**

In analysing quantitative data collected through the survey, raw data would first be reviewed first for consistency and completeness with the missing values verified against the source. The cleaning of raw data would be done to ensure that data is organised and synthesised. This process would be followed by analysing the data using the latest version of the SPSS (Salkind 2014),

The questionnaire as a measuring instrument was developed following thorough engagement of the literature. In terms of the structure, the questionnaire contains different forms of close ended questions, which give respondents a range of answers to choose from (Sunjka & Emwanu, 2015, Du Plooy 2009).

Closed ended questions also referred to standardised questions or fixed-alternative questions are highly structured questions and are mostly appropriate for survey studies. The simple close ended question in the instrument contains yes/no option. However, the researcher also added another type of close-ended question termed paired-comparison question (Du Plooy 2009). Paired-comparison questions are a type of close ended question where options given to respondents are more descriptive. The respondent is still expected to choose only one option however the yes/no option have been replaced by more descriptive options.

The questionnaire also includes inventory questions, another type of closed-ended question. Herein, respondents are not limited to choosing only one option but more than one. Inventory questions seek to obtain comprehensive overview of all possible options that could possibly apply to each respondent (Du Plooy 2009). The questionnaire also includes ranking questions. Ranked questions are another type of closed-ended questions and instead of selecting one option; the researcher provides more relevant options that the respondents will rank according to their own preference. There are also open-ended questions which allow respondents to briefly narrate their responses.

## **5.8 Validity and reliability of the survey instrument**

For quantitative data analysis, ensuring validity and reliability of the survey instrument and the corresponding results is important. Validity of a research can be described as soundness of the research design employed and it indicates the extent to which the data collection instrument precisely measures what is supposed to measure (Marczyk, DeMatteo, & Festinger, 2005; Hair, Black, Babin, & Anderson, 2010). Internal, external, construct, and statistical conclusion are the four main types of validity encountered in research design and methodology (Abowitz & Toole, 2010). While the prime purpose of validity is to produce valid conclusions, reliability is an estimate of measurement of error (Ridenour & Newman, 2008; Marczyk, DeMatteo, & Festinger, 2005).

Measurement validity determines if a given indicator precisely measures what it is supposed to measure (Abowitz & Toole, 2010). In a relative term more reliable measures show greater consistency than less reliable measured when the measure is used repeatedly (Hair, Black, Babin, & Anderson, 2010). Reliability focuses on the consistency or stability of results obtained from a measure and it can be ascertained through various methods including test-retest reliability, split-half reliability, alternate-from reliability and interrater reliability (Marczyk, DeMatteo, & Festinger, 2005). Careful operational

definition can lower concerns of issues related to measurement validity and reliability (Abowitz & Toole, 2010).

## **5.9 Structural Equation Modelling**

In some studies, factors cannot be measured straight from one influencing variable signifying the need for a method to measure the influence of multiple variable on the factor. Multivariate analysis techniques, which refer to statistical techniques that analyse more than two variables simultaneously, improve decision making through knowledge creation (Hair, Black, Babin, & Anderson, 2010).

Structural Equation Modelling is a relatively recent multivariate analysis method used to measure interrelated multiple indicators relationships simultaneously (Abowitz & Toole, 2010; Hair, Black, Babin, & Anderson, 2010). The term Structural Equation Modelling (SEM) does not refer to a specific statistical technique but it rather refers to a family of related techniques (Kline, 2011).

Quantitative research entails translation of qualitative factors into measureable quantitative values. When research involves large and complex concepts, those concepts need to be broken down into smaller and measurable components (Molenaar & Songer, 1998). While regression models can be used in translating concepts into numerical values, most standard regression models have limitation in representing the error in measurement (Molenaar, Washington, & Diekmann, 2000). The use of SEM produces more accurate representations by taking into account the measurement errors (Ibid).

Two components namely a structural model and a measurement model exist in structural equation models (SEMs). While the measurement model entails estimation of errors of measurement of exogenous variables and their intended latent variables, the structural model is concerned with modelling the relationship between latent variables (Molenaar, Washington, & Diekmann, 2000). In SEM, latent variables also referred to as constructor or factors, can be described as those variables that are not directly observable or measured (Schumacker & Lomax, 2004). Covariances or correlations between independent variables are referred to as exogenous variables (Kline, 2011).

While the SEM method was initially developed by sociologist and psychologists (Hair, Black, Babin, & Anderson, 2010), Doldi (2012) accentuate the suitability of SEM methodology for investigating relationships among multiple latent factors in the water sector. According to Molenaar (2010) structural equation models are well suited to deal with many of the research issues in the construction

and engineering management research; the authors further claim that construction engineering and management researches that involve measuring latent variables including decision support systems and predictive models often experience measurement errors and such research could benefit greatly from the use of SEM.

A research conducted to analyse relationships among key causes of delay in construction claimed that it has proven the capability of SEM to quantify the comprehensive relationships among investigated factors (Yang & Ou, 2008).

Due to program requirements and the multiple observed indicator variables used to define latent variables, large sample size is required in SEM (Schumacker & Lomax, 2004). Practically, high dimensional non-normal data with small to medium samples sizes are common (Bentler & Yuan, 1999), and statistics that work for such distribution and samples sizes needs to be identified.

Results of a research study indicated that practitioners can effectively model their data and accurately assess global data-model fit using SEM techniques with small to moderate samples sizes (Nevitt & Hancock, 2004). A study aimed at evaluation of models with small size sample showed that Monte Carlo results indicated that F-statistic performs satisfactory (Bentler & Yuan, 1999).

There are two prominent approaches in SEM namely covariance-based SEM and component-based SEM. While covariance based approach needs large sample sizes, component-based approach is mainly used for score computation and can be carried out on very small samples (Tenenhaus, 2008). A new component-based SEM method named Generalized Structured Component analysis has been proposed by Hwang & Takane (2001)The term large sample size is subjective and different authors have different definitions and approaches of arriving at the sample size. Despite the argument that large sample size is required, researches in construction management have used a relatively small to medium sample size to develop SEMs.

Islam & Fainran (2005) used 61 samples to develop a SEM to describe and quantify the influence of situational factors on project planning and effectiveness. Despite a relatively small sample, research with 87 responses satisfactorily proposed and tested a sequential model regarding clients' cooperative procurement procedures using SEM (Eriksson & Pesamaa, 2007)

## **5.10 Chapter summary**

This chapter presented a brief explanation of research methodology and explained the methods chosen for this research. Aspects of research design and research methods were discussed. Particulars of research in the field of water sector were outlined. Sampling techniques and data analysis procedures were presented validity and reliability of the industry survey instrument were discussed. Structural equation modelling technique was explained. Chapter 6 discusses about the Delphi techniques and presents results of the Delphi study

## CHAPTER SIX: DELPHI STUDY

### 6.1 Introduction

This chapter discusses the Delphi research technique and presents how it is applied in this research. Results of the Delphi study are deliberated and the resulting refined conceptual model is discussed.

### 6.2 The Delphi Research Instrument

#### *General background*

Since its development in 1950s, the Delphi technique has been used in various disciplines as a tool to aid forecasting and decision-making (Rowe & Wright, 1999; Landeta, 2005). It was first introduced by the US Air Force sponsored RAND Corporation in the early 1950s (Giannarou & Zervas, 2014). The technique acquired its name from the ancient Greek temple where the oracle could be found (Gupta & Clarke, 1996; Grisham, 2009). The original study conducted by RAND Corporation in the United States aimed at obtaining the most reliable consensus of a group of experts through a series of thorough questionnaires intercepted with controlled feedback (Dalkey, 1963; Linstone & Turoff, 1975). In the Delphi technique these series of data collection phases are commonly referred to as rounds or iterations.

Following this particular research, Delphi found its application in several fields including “classical” management science, operations research, environment, health, transportation, etc (Linstone & Turoff, 1975; Grisham, 2009). According to Landeta (2005) Delphi is possibly the best-known forecasting technique, which is based on opinions of experts in the areas under study. The Delphi technique has now become a mature and adaptable research method applied in several fields of researches across the globe (Skulmoski, Hartman, & Krahn, 2007).

According to Adler & Ziglio (1996) most Delphi applications aim at reliable and creative exploration of ideas or the production of appropriate information for the purpose of decision-making. Delphi is a widely accepted research technique in social sciences (Dalkey, 1963; Graham, Regehr, & Wright, 2003). The underlying assumption of the technique is that ‘group judgements’ are more reliable than

individuals and it is used with a general intention of getting the most reliable group opinion (Giannarou & Zervas, 2014).

Linstone & Turoff (1975) presented a general definition of Delphi technique as follows:

*“Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.”*

Delphi involves an anonymous process in which participants of the panel never meet or know each other. According to (Colton & Covert, 2007), due to the anonymous nature of the process, it is less likely that individual participants of the Delphi study are influenced by other group members.

Delphi is described by Gupta & Clarke (1996) as a *“long-range forecasting technique that elicits, refines, and draws upon collective opinion and expertise of a panel of experts”*. In the Delphi technique, questions or ideas in consideration are communicated to the participants so they give their opinion based on their knowledge and experience. Corresponding responses are collated and analysed to see how majority of the respondents responded to each items. The second round of requests is sent out with results of group responses of the first round so the panel members know what the group median responses are. This process continues until a predetermined level of consensus has been reached among the experts. Depending on the problem being researched, criteria to determine that a consensus among participants is reached are set at the outset of the Delphi study.

The Delphi technique is suitable for research in complex areas and when achieving consensus among experts in the research area is required. It is a preferred tool when the knowledge about a problem or phenomenon is incomplete (Giannarou & Zervas, 2014). According to Skulmoski (2007) Delphi works particularly well when it is used to improve understanding of problems, solutions or develop forecasts. Grisham (2009) stresses that Delphi should not be considered as a substitute to other scientific research techniques but rather as an alternative to approach complex and intertwined multi-disciplinary problems.

It is claimed that the Delphi technique is suitable to thoroughly collect qualitative data (Skulmoski, Hartman, & Krahn, 2007) Despite the argument that Delphi is a qualitative research technique, it has the potential to produce quantitative data (Sourani & Sohail, 2015). According to Skulmoski (2007) Delphi can be seen as a mixed research method where qualitative and quantitative data can be collected at the same time.

This research improved infrastructure delivery and management in developing countries such as South Africa with regards to water. The topic is complex and requires experts' input and consensus. In order to arrive at a refined list of techniques to assist in improving water services at Ethekewini Municipality, the Delphi method was employed in this research.

### **6.3 Attributes of Delphi**

The Delphi technique has four main attributes, namely:

- It is a repetitive process where participants must be consulted at least twice on the same issues or question (Landeta, 2005; Skulmoski, Hartman, & Krahn, 2007; Hasson, Keeney, & McKenna, 2000). This repetitive process gives the opportunity to participants to alter their opinion or judgement without fear and bias (Rowe & Wright, 1999; Hasson, Keeney, & McKenna, 2000).
- Anonymity of the participants is maintained and experts on the panel do not know who the other participants are throughout the process (Landeta, 2005; Colton & Covert, 2007; Grisham, 2009; Hasson, Keeney, & McKenna, 2000). Anonymity of the process gives the participants the opportunity to express their opinions freely and it avoids personal conflicts (Giannarou & Zervas, 2014; Skulmoski, Hartman, & Krahn, 2007).
- The exchange of information among the participants is channelled through the researcher, who is also named as the study group facilitator or coordinator, in order to maintain controlled feedback (Landeta, 2005; Skulmoski, Hartman, & Krahn, 2007). The group facilitator or coordinator processes the responses of the panel members in order to find out central tendencies, extreme outliers and their rationales (Grisham, 2009).
- The survey instrument for Delphi is designed in order that answers can be processed quantitatively and statistically (Landeta, 2005; Skulmoski, Hartman, & Krahn, 2007; Hasson, Keeney, & McKenna, 2000).

### **6.4 Limitations of Delphi research technique**

Despite its simplicity and flexibility, application of Delphi without proper design considerations might yield dubious results (Skulmoski, Hartman, & Krahn, 2007). The following are considered as limitations and common reasons for failure in the application of the Delphi technique:

- Overspecifying the structure of the Delphi and not allowing the contribution of other perspectives related to the problem (Linstone & Turoff, 1975);
- The difficulty of examination accuracy and reliability of the method (Landeta, 2005);

- Presuming Delphi as a substitute for all other human communications for the issue under consideration (Linstone & Turoff, 1975; Landeta, 2005);
- Limitation of the interaction involved during giving feedback (Landeta, 2005);
- Possible irresponsible action on the part of experts which may threaten the anonymity of the process (Landeta, 2005);
- Poor collation, presentation and interpretation of group responses (Linstone & Turoff, 1975);
- Manipulation of the study process by the facilitator (Landeta, 2005);
- Ignoring and not exploring disagreement in the group responses which could result in achieving artificial consensus (Linstone & Turoff, 1975);
- The enormous time required to administer the process (Landeta, 2005); and
- Underestimating the demanding nature of the process and not recognizing the time spent by the respondents (Linstone & Turoff, 1975).

Despite these limitations of Delphi, comparisons made with statistical groups and classical direct interaction groups have yielded positive results for the Delphi technique (Landeta, 2005; Sourani & Sohail, 2015). Landeta (2005) proposed the following six suggestions to improve application weaknesses and methodological limitations of Delphi, namely

- Setting up a team with understanding of the technique and with a very good knowledge of the study area;
- Selecting panel of experts based on their motivation to take part and make an effectible contribution to the study;
- Motivating experts to take part and to collaborate actively until the end of the process;
- Conducting pilot study prior to administering the actual Delphi study to improve the quality of the research instrument and calibrate possible challenges of motivating the panel of experts;
- Encouraging participants to provide qualitative feedback in order to improve the quality of the group opinion and to allow more interaction among panel of experts; and
- When the study is finalized, the participants should be informed that the study is finished and the results of the study should be communicated to them.

## **6.5 Application of Delphi in Water sector**

According to Gupta & Clarke (1996) Delphi is used in several fields including academia, business, management, health, housing, transportation and utilities. While the Delphi technique was widely used in different fields, its use in the construction management and engineering researches was limited due to lack of awareness and clear guidance in its application (Sourani & Sohail, 2015). Chong & Zin

(2010) argue that the low level of use of Delphi in construction research does not imply its inappropriateness for researches in the field of water management

A research aiming at developing guidelines for improving water services in Uganda, conducted a Delphi study to seek opinions from water engineers ( Ojijio, 2014). The Delphi method was used to produce recommendations for good communication between stakeholders in water sector at Uganda. Chong & Zin (2010) adopted the Delphi technique in a construction law research and claimed that Delphi method is well suited for the construction law research and that the method is reliable for construction law oriented research.

Harinarain & Haupt (2014) employed the Delphi technique to validate and to achieve consensus on proposed multiple drivers for effective management of HIV and AIDS management in the construction industry. A research aiming at identifying the risks that are critical for risk management of road construction projects and defining the shares of the parties involved in terms of handling the identified risks used the Delphi technique successfully (Perera, Rameezdeen, Chileshe, & Hosseini, 2014). In order to identify the key parameters that measure building projects complexity, a three round Delphi survey was conducted in China (Xia & Chan, 2012). The Delphi technique was used to develop a set of performance measures to evaluate health and safety performance at a project level in four rounds and with a panel of 16 members (Agumba & Haupt, 2012).

A research conducted to develop a multi-attribute model for procurement selection systems for construction projects demonstrated that the Delphi technique is a powerful and appropriate research tool for deriving objective opinions in a rather subjective area (Chan, Yung, Lam, Tam, & Cheung, 2001). Identification of potential drivers of change for sustainable construction, positioning of the identified drivers and prediction of expected progress in the coming decade was done using the Delphi technique (Manoliadis, Tsolas, & Nakou, 2006).

Research conducted in the areas of safety, risk management, procurement system selection, contractor selection and sustainability are considered suitable for application of the Delphi technique in the field of infrastructure (Sourani & Sohail, 2015; Hallowell & Gambatese, 2010; Chan, Yung, Lam, Tam, & Cheung, 2001).

One or more of the following factors signify the need to use Delphi as a research technique (Linstone & Turoff, 1975), namely:

- The problem benefits from subjective judgement of group of individuals;

- Potential participants of the research may represent diverse backgrounds with respect to experience;
- More group members than that can effectively participate in a face-to-face discussion are required for the study;
- Holding frequent face-to-face dialogue or discussion among group members is not feasible due to time and financial constraints;
- Anonymity of the research method is required due to several reasons including engaging participants with severe or unpalatable ideological differences; and
- Validity of the research output is ensured by preserving heterogeneity of the panel members.

In the field of management, Delphi has been used to draw group consensus for studies involving relative importance of issues (Delbecq, Ven, & Gustafson, 1975). Figure 6.1 shows the Delphi flow chart diagram

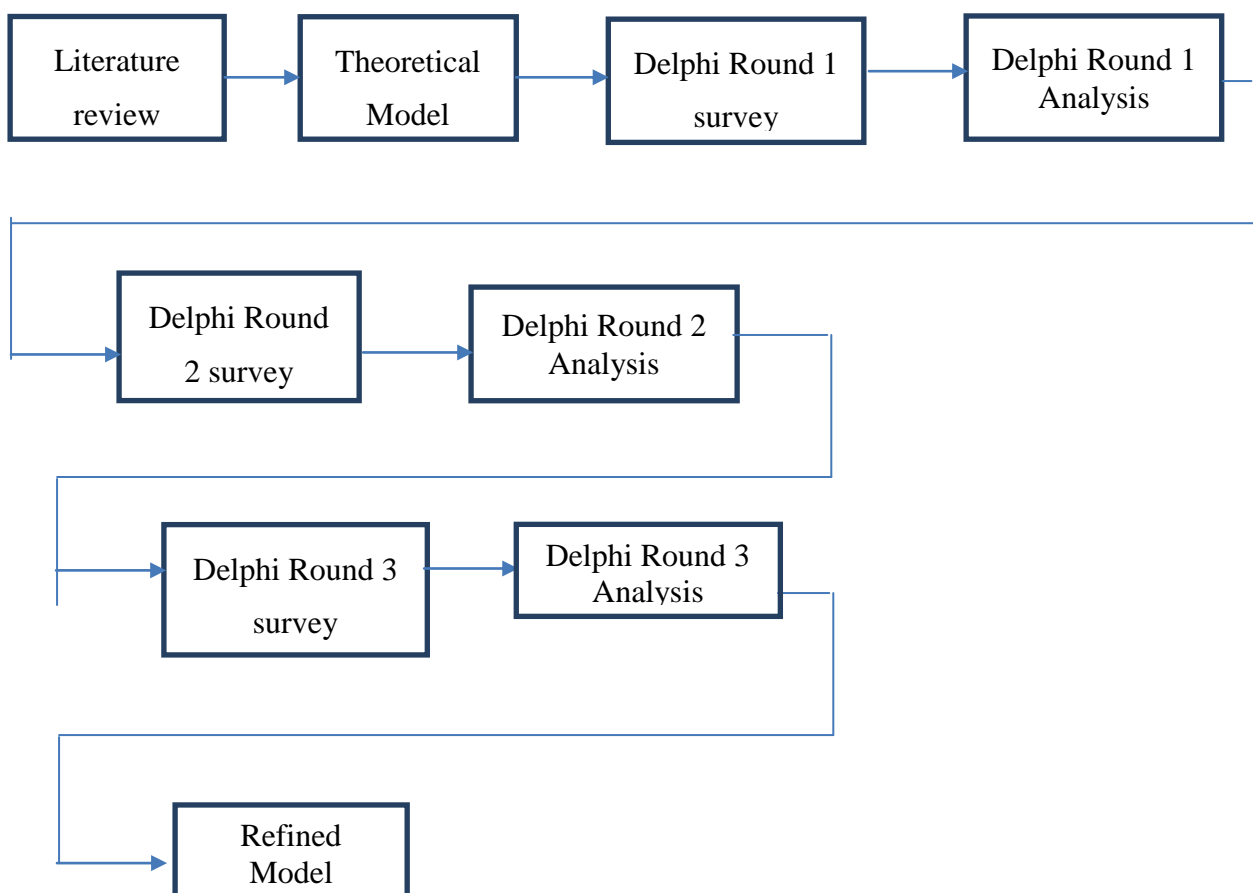


Figure 6. 1 Delphi study flow chart

Use of Delphi does not necessary depend on the field of study. Rather it should lend itself to the nature of the research being conducted (Sourani & Sohail, 2015). Linstone & Turoff (1975) outlined properties including the following to evaluate the appropriateness of employing Delphi technique, namely

- The problem does not lend itself to precise analytical methods but benefits from subjective judgements on a collective basis;
- When frequent group meetings are not feasible due to time and cost; and
- The fact that a supplemental group communication process increases the efficiency of face-to-face meetings.

The discussion made in this section justifies the appropriateness of using Delphi in this research.

## **6.6 Steps in the Delphi Study**

Delphi undergoes four distinct phases namely; exploration of the subject under discussion, process of reaching an understanding of how the group views the issue, bringing out the fundamental reasons for difference in individual responses and final evaluation which involves analysing responses and giving feedback for consideration (Linstone & Turoff, 1975). The following sections explain the key steps in the Delphi study.

### **6.6.1 Research problem identification**

Research project identification is one of the first steps in using Delphi technique in a research project. As the technique is only appropriate to investigate certain types of research problems, it is important to study the nature of the problem before deciding to use Delphi (Hasson, Keeney, & McKenna, 2000). The research question being attempted to be addressed using Delphi in this research was articulated and discussed in Chapter 1.

### **6.6.2 Role of researcher**

Hasson (2000) argues that the administrative skill of the researcher or facilitator plays notable role for successful completion of the Delphi study. The tasks of the researcher include systematically tracking respondents, sending reminders and meticulously analysing change of opinion. The researcher of this PhD project facilitated the Delphi study from the initial stage to the completion stage.

### **6.6.3 Selecting panel members**

The group of individual experts participating in the Delphi study are collectively called as “panel of experts”, “expert panels” or “panellists”. Selection of panel members is one of decisive steps in Delphi study. As the output of the study is dependent on the opinion of the members serving on the panel, it is critical to be cautious when selecting the experts (Skulmoski, Hartman, & Krahn, 2007).

Panel members should be knowledgeable, impartial, interested in the topic and should have the commitment to participate in all rounds of the study (Grisham, 2009; Hasson, Keeney, & McKenna, 2000). Identification of potential panel members involves consideration of the following factors:

- relevant knowledge and experience in the area being studied (Adler & Ziglio, 1996; Rowe & Wright, 1999);
- willingness and capacity to take part in the study (Hasson, Keeney, & McKenna, 2000);
- effective communication skill (Adler & Ziglio, 1996); and
- interest to allocate adequate time to participate in the study (Skulmoski, Hartman, & Krahn, 2007).

As the Delphi technique requires competence of participants rather than random sampling and representation of the population, purposive sampling technique is employed in selection of experts for the Delphi panel. According to Sourani & Sohail (2015) when researchers want to address the multiple sub-topics being researched they tend to recruit experts from a variety of backgrounds. Identification of potential experts could be done through literature search, recommendations from other experts, snowball sampling and searching the internet (Giannarou & Zervas, 2014; Bryman & Bell, 2007).

Arguably, identification and selection of experts is the most important consideration in formulating the Delphi panel of experts (Grisham, 2009). In this research, the following criteria were used in the identification and selection of potential experts to serve on the panel.

- A minimum of a BSc Honors in a relevant field of study including Civil Engineering, Construction, Developmental Economics specific to the Built Environment, Ecological and Environmental Planning, Hydrologist, Urban Planning, and Urban Design.
- A minimum of ten years of relevant professional and/or research experience.
- Specialization in the area of sustainable infrastructure, Water management, Water treatment, and sustainable built environment in the context of developing countries evaluated in terms of practical work experience, publication, participation of conferences and education background.

#### **6.6.4 Number of panel members**

One of the determining factors for successful implementation of Delphi is being able to retain all respondents till the completion of the study. Deciding on the panel size is another decision that has to be made at the outset of the study. The number and representativeness of panellists affect the quality and amount of data that will be collected (Hasson, Keeney, & McKenna, 2000). Literature has not prescribed size of Delphi panles, however they have recommended minimum sizes. Accordingly to Dalkey panel sizes could range from 7 to 30. Skulmoski (2007). claim that for homogenous groups a sample size of 10 to 15 can yield adequate results. According to Hallowell & Gambatese (2010) most studies recruited eight to sixteen panellists but suggested that eight should be the minimum.

While there are no hard and fast rules as to the size of Delphi study, literature suggest factors that have to be considered in determining the panel size including the following (Skulmoski, Hartman, & Krahn, 2007), namely:

- If the group is homogeneous, a smaller size of ten to fifteen people is suggested. However if heterogeneous group is involved the sample size might need to go as high as several hundred people.
- As the size of the group increases the group error decreases. However, as the result of the increase in the group size manageability of the Delphi process becomes cumbersome. There has to be a balance between quality of results and manageability of the process.
- When a small sample size is used, the result of the Delphi study has to be verified or validated by a follow-up study for instance interview or questionnaire survey.

Although large sample sizes in Delphi could help to reduce group errors, the dropout rate could be higher correspondingly. Since this research requires highly qualified and specialized experts, the researcher decided the panel size to be between 10 and 15. Non-probability purposive sampling technique was employed in selection of experts.

Once potential panellists have expressed their consent to participate in the study, it is imperative to inform them what exactly is required of them, how much of their time the research demands and what their responses will be used for (Hasson, Keeney, & McKenna, 2000; Grisham, 2009). In this research the questionnaire incorporated information including the iterative nature of the process, the estimated time it would take to complete survey and general instructions about the survey. Email correspondences were also made with all respondents about the extent of the study.

### ***6.6.5 Developing the Delphi survey instrument***

Once the potential panellists are identified the next step is developing the survey instrument. One of the major problems in Delphi design is obtaining quantitatively comparable estimates of respondents' individual opinion and judgement of possible causal relationships among drivers or key factors in the problem under investigation (Linstone & Turoff, 1975). Thus developing the survey instrument needs to take into account quantitative analysability of the responses obtained from the respondents. The research question has to be developed in a manner that is easily understood by the respondents.

A pilot study can be administered before the actual survey is launched. The pilot study serves to test and adjust the survey instrument for better understanding and to avoid misinterpretation (Skulmoski, Hartman, & Krahn, 2007; Christie & Barela, 2005). Since adequate literature review was conducted prior to the development of the questionnaire and as the survey instrument was commented and enriched by experienced professionals with different backgrounds a pilot study was not conducted for the Delphi study in this research. However, the initial survey instrument was adjusted during the first round survey following comments forwarded by two panellists.

While identifying true experts for the study is critical, those experts who have great insight are preoccupied and might not be able to fully participate in the process (Skulmoski, Hartman, & Krahn, 2007). To complement this challenge, it is advised to develop engaging, concise, and well-written survey instrument (Skulmoski, Hartman, & Krahn, 2007; Christie & Barela, 2005). Survey instrument development, specifically questionnaire survey instrument, involves determining content, length and response scale.

Taking into account the busy schedule of the panellists, it was attempted to make the questionnaire concise and clear. The instrument had two parts. While the first part was focusing on importance, the second one was focusing on impact of the design stage elements towards water services and management. The final survey instrument is incorporated in Appendix A.

The initial or first round Delphi survey instrument could be open-ended to widely cast the research net or it could be structured in order to direct the participants towards the goal of the study (Skulmoski, Hartman, & Krahn, 2007). In this research, due to the fact that an adequate literature review was conducted and as it was essential to enhance response rate of participants, only a structured questionnaire was developed and sent to the participants on the first round survey. The survey instrument was also reviewed by a highly experienced expert specifically in the area of water management in the context of developing countries.

### **6.6.6 *Criteria for attaining consensus***

In a Delphi study, though it depends on nature of the research, consensus is assumed to have been reached on a given item when a certain proportion of the respondents fall within a certain range of mean, median or standard deviation value of the group response (Giannarou & Zervas, 2014; Christie & Barela, 2005). Although attaining consensus is one of the underlying attributes of Delphi, there is no commonly practiced criterion of measuring consensus (Giannarou & Zervas, 2014).

Christie & Barela proposed that in order to achieve consensus, at least 75% of the respondents should rate the item two points above and below the group mean on a 10-point scale. It is recommended that each analysis need to include calculation of means and media as they depict central tendency of the group response (Giannarou & Zervas, 2014).

For unambiguous decision making, the researcher has to explicitly define what “consensus” means in the context of the research being undertaken (Hasson, Keeney, & McKenna, 2000). If there are outliers from the mean or median, the researcher should allow those panellists to give their explanation or argument for their outlying responses. The explanation or arguments given by those respondents should be kept confidential and the identity of the respondents must be withheld (Christie & Barela, 2005). After analysing 32 empirical Delphi studies Giannarou & Zervas (2014) concluded that there is a need to use more than one statistical measures to evaluate the consensus.

In this research the following two criteria were used to measure consensus in order to identify the key design stage elements that would be incorporated in the refined conceptual model.

- Importance scale: median 8, 9, 10 and at least 70% of the respondents rating the element from 8 to 10.
- Impact scale: median 8, 9, 10 and at least 70% of the respondents rating the element from 8 to 10.

The notion of infrastructural development, specifically water services and management is an emerging concept. Specifically, its application in the context of developing countries such as South Africa still need thorough research.

## **6.7 Chapter summary**

This chapter has discussed the Delphi research technique and explained how the technique is adopted in the research. Theoretical background including benefits, limitation and application areas of Delphi were presents. Application of Delphi in water management research is deliberated. The overall detailed application process of Delphi in this research was expounded and the result is discussed in chapter 7.

## 7 DELPHI RESULTS

### 7.1 Introduction

This chapter deliberates on the process and results of the Delphi study. Demographic information of the panellists is provided and descriptive statistics of results of each Delphi round is presented. Findings of the three round Delphi surveys were discussed.

### 7.2 Demographic Information of the Expert Panels

Using non-probabilistic purposive sampling, 38 potential experts were identified from water utility managers and professionals in water sector and invitation letters were sent to all. Out of 38, 11 expressed their consent to serve on the panel. Only 10 participated in the first round of the survey

Demographic information of the panellists who participated in round one was collated and presented in Table 7.1 and 7.2

Table 7.1 Gender composition and geographic location

<b>Demographic Variables</b>	<b>Number of participants</b>	<b>Percentage (%)</b>
<b>Gender</b>		
Male	8	80,0
Female	2	20,0
<b>Total</b>	<b>10</b>	<b>100,0</b>
<b>Country</b>		
South Africa	3	30,0
Nigeria	2	20,0
United States	2	20,0
Netherlands	2	20,0
France	1	10,0
<b>Total</b>	<b>10</b>	<b>100,0</b>

Table 7.2: Professional and academic background

<b>Demographic Variables</b>	<b>Number of participants</b>	<b>Percentage (%)</b>
<b>Experience</b>		
Academic	3	30,0
Industry	4	40,0
Both academic & industry	3	30,0
<b>Total</b>	<b>10</b>	<b>100,0</b>
<b>Highest level of education</b>		
BSc	2	20,0
MSc	3	30,0
PhD	5	50,0
<b>Total</b>	<b>10</b>	<b>100,0</b>
<b>Overall work experience as an academic or industry practitioner (years)</b>		
10 - 20	2	20,0
21 - 30	1	10,0
More than 30	7	70,0
<b>Total</b>	<b>10</b>	<b>100,0</b>
<b>Educational background</b>		
Civil Engineering	5	50,0
Environmental Engineering	1	10,0
Urban Planning	1	10,0
Economics specialising in Infrastructure	1	10,0
Hydrologist	1	10,0
Project Management	1	10,0
<b>Total</b>	<b>10</b>	<b>100,0</b>

Table 7.1 shows that participants were recruited from three continents namely Africa, Europe and America. The geographic diversity of the panels supports the notion that the process was indeed anonymous and that biasness in the finding or the results is alleviated. The experts fulfilled the requirements set out for participation in the Delphi panel. Each expert had experience of more than 10 years in the water management. The cumulative work experience of the panel was 302 years, where more than 90% of the panellists have worked in the field of study for more than 30 years.

Table 7.2 shows that the experts have adequate exposure to water management, infrastructure and built environment in the context of developing countries. The exposure was through education, practical experience and research. Up to 50% of the participants held doctorate degrees and the rest 50 % had either master's or honors degrees in relevant field of study.

### **7.3 Delphi Study Results**

The main question set out to be answered by the Delphi study is stated below:

This study aims primarily to understand the current situation, identify potential causes of the bottlenecks at EThekweni Municipality that affect water delivery and formulate evidence-based interventions to improve water delivery and management of infrastructure projects

While in the development of the survey instrument, the main research question was split into two aspects of importance and impact as follows:

*How important are various influences in delivery of water services in developing countries such as South Africa today?*

*Which of the various influences offer the greatest impact opportunities for improving delivery of water services in developing countries such as South Africa?*

The survey instruments used in the Delphi study are presented in Appendix A. The following sections present the Delphi study results.

#### **7.3.1 Round one**

The first round provided the panellists with two main questions each with 53 design stage elements to be rated using a 10-point Likert scale. Sample of the survey instrument used in the first round is presented in Appendix A. The 9 main drivers and the corresponding 53 indicators/elements were presented to the panellists to be rated according to their impact and importance. The first round survey instrument was set out to 11 panellists and 10 of them responded representing 90% response rate. Summary of first round responses is indicated in Table 7.3

First round responses were analysed and second round survey instrument was sent to the 10 respondents with summarized group response results of the first round. The responses of the first round were analysed to calculate statistical median and percentage of respondents who rated the elements with a value of 8 and above on 10-point Likert scale rating.

**Table 7.3: Round 1 results summary**

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>1. Economic consideration</b>				
Life cycle analysis	9	90,00	10	90,00
Cost efficiency	9	80,00	9.5	90,00
Cost benefit analysis	8	90,00	9	100,00
Bankability/profitable	7	70,00	9	90,00
Measurement of implementation	8,5	90,00	10	90,00
<b>2. Alternative materials</b>				
Use of materials with low health risk and pollution in water projects	9	90,00	9	90,00
Use of second-hand material	7	70,00	8	90,00
Prescribing low energy material	9	90,00	9	80,00
Utilizing potential of non-conventional materials in water projects	7.5	70,00	9	80,00
Use of locally available material in Water projects	8	80,00	8,5	90,00
<b>3. Social consideration</b>				
Client participation	9	90,00	9	80,00
Provision of employment opportunities	8	90,00	9,5	90,00
Beneficiaries participation	8	90,00	9	90,00
Accessibility of the infrastructure to the public including people with specific needs	7,5	70,00	8,5	90,00
Health and safety consideration for construction and operating stages	9	90,00	9	90,00
Satisfaction of the public	9	100,00	10	100,00
Protection of cultural heritage	7.5	70,00	9	80,00
Risk analysis and disaster mitigation	9	80,00	9	90,00
<b>4. Technical consideration</b>				
Technology	7.5	70,00	8,5	90,00
Experience	9,5	90,00	10	90,00
Using of diffusion theory	7	70,00	8	90,00
Production of operation and maintenance materials	9	90,00	9	80,00
Skills availability	9,5	90,00	9,5	100,00
Research, Development and innovation	9,5	90,00	10	90,00
<b>5. Environmental consideration</b>				

Climate resiliency (resistant to climate change)	9	80,00	10	80,00
Reduction effects on soil and the biodiversity	7	70,00	7.5	80,00
Reducing water pollution	9,5	100,00	10	90,00
Provision of green infrastructure	8	90,00	10	100,00
Uses of less energy during construction	9	80,00	10	80,00
Reducing carbon footprint	9	80,00	10	80,00
Optimizing site potential (Land use)	10	90,00	10	90,00
Ensuring efficient energy utilization both during construction and operation phases	7	60,00	9	90,00
<b>6. Design and project management</b>				
Early contractors involvement at design stage	10	90,00	10	100,00
Involvement of community	9	80,00	9,5	90,00
Selection of appropriate contract/Experience	9	90,00	9,5	100,00
Flexible design to accommodate on site changes	7,5	60,00	8,5	90,00
Proper construction quality control procedure	7	70,00	9	100,00
Implementation of strategies specific to the project	9	90,00	10	80,00
<b>7. Policy and regulations</b>				
Presence of water delivery regulatory requirements	10	90,00	10	90,00
Water rating systems	8	90,00	10	90,00
Inclusion of sustainability requirement in water briefs	9	90,00	9	80,00
<b>8. Professionals and the delivery processes</b>				
Awareness of client about water projects	8,5	80,00	9	80,00
Awareness of contractors on water projects	8,5	90,00	9	90,00
Knowledge and experiences of contractors/experts/designers	8,5	100,00	10	100,00
Skills of designers/contractors/experts	9	100,00	9	90,00
Appropriating adequate time for design	10	100,00	10	100,00
Willingness of designers/Engineers to implement sustainability design concept and practices in their design	10	90,00	10	90,00
<b>9. Communication</b>				
Education level of the managers	9	80,00	9	100,00
Stakeholder communication and consultation	9	80,00	9	100,00
Collaborative working ethos	9	80,00	9,5	90,00
Existing user cooperation	7.5	70,00	9	90,00
Collaboration and coordination among professionals	9	90,00	9,5	90,00
Targeted education to stakeholders	10	80,00	9	90,00

The following two criteria were used to measure consensus in order to identify the key elements that would be incorporated in the refined conceptual model.

- Importance scale: median 8, 9, 10 and at least 70% of the respondents rating the element from 8 to 10.
- Impact scale: median 8, 9, 10 and at least 70% of the respondents rating the element from 8 to 10.
- As indicated in Table 7.3, the blue highlighted 12 elements did not satisfy the consensus criteria. According to the pre-set criteria either group median of these elements were less than 8 or more than 70% of the respondents rated their importance and impact 7.5 and below on the 10-point Likert scale.

### 7.3.2 Round 2

On the second round, the group median of the first round responses and their individual responses of the first round survey were provided with the survey instrument so that the respondents would have an overview of central tendency of the group response. Sample of the second round Delphi instrument is included in Appendix B. Given the group median, the panellists were asked to review their first round ratings and revise them if deemed necessary. Each panellist was asked to provide a reason or open-ended explanation if his/her response deviated significantly from the group median. Summary of second round responses were presented in Table 7.4.

Of the 10 panellists who participated in the first round the same number responded to the second survey request. As the number of panellists participated in round 2 was still in the acceptable range, appropriate statistical analysis was conducted and summary of the second round results was sent out to the 10 members together with the third round survey instrument.

**Table 7.4: Round 2 results summary**

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>1. Economic consideration</b>				
Life cycle analysis	9	90,00	10	90,00
Cost efficiency	9	80,00	9,5	90,00
Cost benefit analysis	8	90,00	9	100,00
Bankability/profitable	6.5	70,00	9	90,00
Measurement of implementation	8,5	90,00	10	90,00

<b>2. Alternative materials</b>				
Use of materials with low health risk and pollution in water projects	9	100,00	9	90,00
Use of second-hand material	7	70,00	7	90,00
Prescribing low energy material	9	90,00	9	80,00
Utilizing potential of non-conventional materials in water projects	7	70,00	7	80,00
Use of locally available material in Water projects	8	80,00	8,5	90,00
<b>3. Social consideration</b>				
Client participation	9	90,00	9	80,00
Provision of employment opportunities	8	100,00	9,5	90,00
Beneficiaries participation	8	90,00	9	90,00
Accessibility of the infrastructure to the public including people with specific needs	7	70,00	7	90,00
Health and safety consideration for construction and operating stages	9	90,00	9	90,00
Satisfaction of the public	9	100,00	10	100,00
Protection of cultural heritage	7,5	70,00	8	80,00
Risk analysis and disaster mitigation	9	80,00	9	90,00
<b>4. Technical consideration</b>				
Technology	7,5	70,00	8,5	90,00
Experience	9,5	90,00	10	90,00
Using of diffusion theory	7	70,00	8	90,00
Production of operation and maintenance materials	9	90,00	9	80,00
Skills availability	9,5	90,00	9,5	100,00
Research, Development and innovation	9,5	90,00	10	90,00
<b>5. Environmental consideration</b>				
Climate resiliency (resistant to climate change)	9	80,00	10	80,00
Reduction effects on soil and the biodiversity	6,5	70,00	7,5	80,00
Reducing water pollution	9,5	100,00	10	90,00
Provision of green infrastructure	8	90,00	10	100,00
Uses of less energy during construction	9	80,00	10	80,00
Reducing carbon footprint	9	80,00	10	80,00
Optimizing site potential (Land use)	10	90,00	10	90,00
Ensuring efficient energy utilization both during construction and operation phases	7	60,00	8	90,00
<b>6. Design and project management</b>				
Early contractors involvement at design stage	10	90,00	10	100,00
Involvement of community	9	80,00	9,5	90,00
Selection of appropriate contract/Experience	9	90,00	9,5	100,00
Flexible design to accommodate on site changes	7,5	60,00	8,5	90,00
Proper construction quality control procedure	7,5	70,00	9	100,00
Implementation of strategies specific to the project	9	90,00	10	80,00
<b>7. Policy and regulations</b>				
Presence of water delivery regulatory requirements	10	90,00	10	90,00
Water rating systems	8	90,00	10	90,00
Inclusion of sustainability requirement in water briefs	9	90,00	9	80,00

<b>8. Professionals and the delivery processes</b>				
Awareness of client about water projects	8,5	80,00	9	80,00
Awareness of contractors on water projects	8,5	90,00	9	90,00
Knowledge and experiences of contractors/experts/designers	8,5	100,00	10	100,00
Skills of designers/contractors/experts	9	100,00	9	90,00
Appropriating adequate time for design	10	100,00	10	100,00
Willingness of designers/Engineers to implement sustainability design concept and practices in their design	10	90,00	10	90,00
<b>9 Communication</b>				
Education level of the managers	9	80,00	9	100,00
Stakeholder communication and consultation	9	80,00	9	100,00
Collaborative working ethos	9	80,00	9,5	90,00
Existing user cooperation	7	70,00	9	90,00
Collaboration and coordination among professionals	9	90,00	9,5	90,00
Targeted education to stakeholders	10	80,00	9	90,00

As indicated in Table 7.4, the 12 elements did not satisfy the consensus criteria. According to the pre-set criteria either group median of these elements were less than 8 or more than 70% of the respondents rated their importance and impact 7 and below on the 10-point Likert scale. Analysis of the second round indicated that there was still a slight difference from the first round result; therefore, it was necessary to conduct the third round survey to see if consensus is achieved.

### 7.3.3: Round 3

On the third round, group median of the second round responses and individual responses of the second round survey were provided to the panellists with the survey instrument so that they would have an overview of central tendency of the group response. Given the group median of the second round, each panellist was asked to provide a reason or open-ended explanation if his/her response deviated significantly from the group mean. Summary of third round responses were presented in Table 7.5.

Of the 10 panellists who participated in the first and second rounds, 9 of them responded to the third round survey in a reasonable time. As one of the experts didn't respond. Since consensus was achieved, this research completed the Delphi study on the third iteration.

**Table 7.5: Round 3 results summary**

	Importance	Impact
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	Median	% Response (8-10)	Median	% Response (8-10)
<b>1. Economic consideration</b>				
Life cycle analysis	9	90,00	10	90,00
Cost efficiency	9	80,00	9,5	90,00
Cost benefit analysis	8	90,00	9	100,00
Bankability/profitable	7	70,00	9	90,00
Measurement of implementation	8,5	90,00	10	90,00
<b>2. Alternative materials</b>				
Use of materials with low health risk and pollution in water projects	9	100,00	9	90,00
Use of second-hand material	7	70,00	8	90,00
Prescribing low energy material	9	90,00	9	80,00
Utilizing potential of non-conventional materials in water projects	7,5	70,00	9	80,00
Use of locally available material in Water projects	8	100,00	8,5	100,00
<b>3. Social consideration</b>				
Client participation	9	90,00	9	80,00
Provision of employment opportunities	8	100,00	9,5	90,00
Beneficiaries participation	8	90,00	9	90,00
Accessibility of the infrastructure to the public including people with specific needs	7,5	70,00	8,5	90,00
Health and safety consideration for construction and operating stages	9	90,00	9	90,00
Satisfaction of the public	9	100,00	10	100,00
Protection of cultural heritage	7,5	70,00	9	80,00
Risk analysis and disaster mitigation	9	80,00	9	90,00
<b>4. Technical consideration</b>				
Technology	7,5	70,00	8,5	90,00
Experience	9,5	90,00	10	90,00
Using of diffusion theory	7	70,00	8	90,00
Production of operation and maintenance materials	9	90,00	9	80,00
Skills availability	9,5	90,00	9,5	100,00
Research, Development and innovation	9,5	90,00	10	90,00
<b>5. Environmental consideration</b>				
Climate resiliency (resistant to climate change)	9	80,00	10	80,00
Reduction effects on soil and the biodiversity	7	70,00	7,5	80,00
Reducing water pollution	9,5	100,00	10	90,00
Provision of green infrastructure	8	90,00	10	100,00
Uses of less energy during construction	9	80,00	10	80,00
Reducing carbon footprint	9	80,00	10	80,00
Optimizing site potential (Land use)	10	90,00	10	90,00
Ensuring efficient energy utilization both during construction and operation phases	7	60,00	9	90,00
<b>6. Design and project management</b>				
Early contractors involvement at design stage	10	90,00	10	100,00

Involvement of community	9	80,00	9,5	90,00
Selection of appropriate contract/Experience	9	90,00	9,5	100,00
Flexible design to accommodate on site changes	7,5	60,00	8,5	90,00
Proper construction quality control procedure	7	70,00	9	100,00
Implementation of strategies specific to the project	9	90,00	10	80,00
<b>7. Policy and regulations</b>				
Presence of water delivery regulatory requirements	10	90,00	10	90,00
Water rating systems	8	90,00	10	90,00
Inclusion of sustainability requirement in water briefs	9	90,00	9	80,00
<b>8. Professionals and the delivery processes</b>				
Awareness of client about water projects	8,5	80,00	9	80,00
Awareness of contractors on water projects	8,5	90,00	9	90,00
Knowledge and experiences of contractors/experts/designers	8,5	100,00	10	100,00
Skills of designers/contractors/experts	9	100,00	9	90,00
Appropriating adequate time for design	10	100,00	10	100,00
Willingness of designers/Engineers to implement sustainability design concept and practices in their design	10	90,00	10	90,00
<b>9 Communication</b>				
Education level of the managers	9	80,00	9	100,00
Stakeholder communication and consultation	9	80,00	9	100,00
Collaborative working ethos	9	80,00	9,5	90,00
Existing user cooperation	7,5	70,00	9	90,00
Collaboration and coordination among professionals	9	90,00	9,5	90,00
Targeted education to stakeholders	10	80,00	9	90,00

As indicated in Table 7.5, the following 12 blue highlighted elements did not satisfy the consensus criteria. According to the pre-set criteria either group median of these elements were less than 8 or more than 70% of the respondents rated their importance and impact 7 and below on 10-point Likert scale.

The results of the third round showed convergence. Third round survey results shown insignificant difference from the second round. As consensus was achieved in the third round, listed 12 elements were eliminated from the list and the conceptual model was adjusted accordingly.

#### **Under economic consideration**

Bankability/profitable

#### **Under alternative materials**

Use of second-hand material

Utilizing potential of non-conventional materials in water projects

### **Under social consideration**

Accessibility of the infrastructure to the public including people with specific needs

Protection of cultural heritage

### **Under technical consideration**

Technology

Using of diffusion theory

### **Under environmental consideration**

Reduction effects on soil and the biodiversity

Ensuring efficient energy utilization both during construction and operation phases

### **Under design and project management**

Flexible design to accommodate on site changes

Proper construction quality control procedure

### **Under communication**

Existing user cooperation

## **7.4 Discussion of Delphi survey results**

The aim of the Delphi study in this research was identification and refinement of leading design stage elements that were perceived to be important and have major impact on water services and delivery in developing countries. After elimination of these 12 elements, 41 elements were considered for subsequent phase of the research. The following subsections discuss the results of the Delphi study under each leading indicator.

### **7.4.1 *Economic considerations***

Delivery of water services should promote utmost efficiency with reduction of cost and increasing cost effectiveness is a critical strategy for economic sustainability of infrastructure (Akadiri, Chinyio & Olomolaiye, 2012). Of all the five elements included in the Delphi survey under *Economic considerations* four of them were retained. Bankability do not have any influence or impact on the

current water services and delivery in South Africa. The results for economic considerations are shown in Table 7.6

Table 7.6: Economic consideration results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>1. Economic consideration</b>				
Life cycle analysis	9	90,00	10	90,00
Cost efficiency	9	80,00	9,5	90,00
Cost benefit analysis	8	90,00	9	100,00
Bankability/profitable	7	70,00	9	90,00
Measurement of implementation	8,5	90,00	10	90,00

#### 7.4.2 Alternative material

New environmentally friendly sustainable materials contribute to sustainability in the water sector and lead to minimization of worldwide infrastructure problems (Hossain, 2015; Bakhoun & Brown, 2012). John (2005) claimed that the easiest way for engineers to incorporate sustainability in water projects is thorough considerations in selection of environmentally sustainable building materials. The two eliminated elements deal either with utilizing of non conventional materials in water projects that is not appropriate to developing countries. The results of alternative material results are shown in table 7.7

Table 7.7: Alternative materials results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>2. Alternative materials</b>				
Use of materials with low health risk and pollution in water projects	9	100,00	9	90,00
Use of second-hand material	7	70,00	8	90,00
Prescribing low energy material	9	90,00	9	80,00
Utilizing potential of non-conventional materials in water projects	7.5	70,00	9	80,00
Use of locally available material in Water projects	8	100,00	8,5	100,00

### 7.4.3 Social considerations

Social component of water services can be integrated with the environmental and economic components by increasing awareness during planning and design phases (Valdes Vasques & Klotz, 2013). Of the eight elements included in the Delphi survey under *social considerations* leading factor, the eliminated elements, which are *Accessible of the infrastructure to the public and protection of cultural heritage*, did not satisfy the consensus. The result of social consideration is shown in Table 7.8.

Table 7.8: Social Consideration results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>3. Social consideration</b>				
Client participation	9	90,00	9	80,00
Provision of employment opportunities	8	100,00	9,5	90,00
Beneficiaries participation	8	90,00	9	90,00
Accessibility of the infrastructure to the public including people with specific needs	7,5	70,00	8,5	90,00
Health and safety consideration for construction and operating stages	9	90,00	9	90,00
Satisfaction of the public	9	100,00	10	100,00
Protection of cultural heritage	7.5	70,00	9	80,00
Risk analysis and disaster mitigation	9	80,00	9	90,00

### 7.4.4 Technical considerations

It is argued that, using of diffusion theory is focused mainly on the execution stage but not in the life cycle of the product that this needs to be reverted if sustainability of water project concepts have to be adopted (Azapagic & Collett, 2006). The results of the survey showed that the importance and impact of the eliminated elements do not have any influence in the current water services and delivery in South Africa. The result is shown below in Table 7.9.

Table 7.9: Technical consideration results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)

<b>4. Technical consideration</b>				
Technology	7.5	70,00	8,5	90,00
Experience	9,5	90,00	10	90,00
Using of diffusion theory	7	70,00	8	90,00
Production of operation and maintenance materials	9	90,00	9	80,00
Skills availability	9,5	90,00	9,5	100,00
Research, Development and innovation	9,5	90,00	10	90,00

#### 7.4.5 Environmental considerations

Establishing the actual impact of new structures in the environment is critical to reduce environmental impact (Brophy & Lewis, 2011). Improved water services and delivery plays a vital role in evaluating environmental impacts and formulating workable solution to reduce the impact. Eight elements were included in the Delphi survey under *environmental considerations* and six of them were retained. The eliminated elements proves not to influence the provision to improve water services and delivery in South Africa. The result is shown below in Table 7.10.

Table 7.10: Environmental consideration results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)

<b>5. Environmental consideration</b>				
Climate resiliency (resistant to climate change)	9	80,00	10	80,00
Reduction effects on soil and the biodiversity	7	70,00	7.5	80,00
Reducing water pollution	9,5	100,00	10	90,00
Provision of green infrastructure	8	90,00	10	100,00
Uses of less energy during construction	9	80,00	10	80,00
Reducing carbon footprint	9	80,00	10	80,00
Optimizing site potential (Land use)	10	90,00	10	90,00
Ensuring efficient energy utilization both during construction and operation phases	7	60,00	9	90,00

#### 7.4.6 Design and project management

As attributes or performance of infrastructures are basically defined through the process of delivery, it is imperative to tackle all relevant sustainability issues at the outset of the project (Gagnon, Leduc, & Savard, From a conventional to a sustainable engineering design process: different shades of sustainability, 2012). Of the six elements included in the Delphi survey under *Design and project management*, flexible design to accommodate on site changes and proper construction quality control procedure did not satisfy the consensus criterion and also they have no significant influence on the current or improving water services delivery. The result is shown in Table 7.11

Table 7.11: Design and project management

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>6. Design and project management</b>				
Early contractors involvement at design stage	10	90,00	10	100,00
Involvement of community	9	80,00	9,5	90,00
Selection of appropriate contract/Experience	9	90,00	9,5	100,00
Flexible design to accommodate on site changes	7,5	60,00	8,5	90,00
Proper construction quality control procedure	7	70,00	9	100,00
Implementation of strategies specific to the project	9	90,00	10	80,00

#### 7.4.7 Policy and regulations

Rating systems and related requirements are beneficial for establishing a system to evaluate performance of infrastructure and to enhance sustainable infrastructure delivery practices (Liu &

Nederveen, 2015; Ochieng, et al., 2014). The three elements included in the Delphi survey under *policy and regulations* were retained. The result of policy and regulations are shown in Table 7;12

Table 7.12: Policy and regulation results

	<b>Importance</b>		<b>Impact</b>	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>7. Policy and regulations</b>				
Presence of water delivery regulatory requirements	10	90,00	10	90,00
Water rating systems	8	90,00	10	90,00
Inclusion of sustainability requirement in water briefs	9	90,00	9	80,00

#### **7.4.8 Professionals and the delivery process**

John et al (2005) stress that successful application of sustainability in construction projects will be possible only if the various disciplines and professionals including owners, architects, engineers, contractors, material suppliers and operators have understood and involved in the process. According to (Bakhoun & Brown, 2012) good delivery is basic to bring about sustainable construction. Sarté (2010) claims that the traditional design procedure does not use sustainable frameworks. All elements

included in the Delphi survey under *professionals and the delivery process* were retained. The result are shown in Table 7:13

Table 7.13: Professionals and the delivery processes results

	Importance		Impact	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>8. Professionals and the delivery processes</b>				
Awareness of client about water projects	8,5	80,00	9	80,00
Awareness of contractors on water projects	8,5	90,00	9	90,00
Knowledge and experiences of contractors/experts/designers	8,5	100,00	10	100,00
Skills of designers/contractors/experts	9	100,00	9	90,00
Appropriating adequate time for design	10	100,00	10	100,00
Willingness of designers/Engineers to implement sustainability design concept and practices in their design	10	90,00	10	90,00

#### 7.4.9 Communication

The communication plan identifies how the stakeholder will be communicated with, the type, frequency, and medium. It establishes the content of the communication and what it intends to accomplish. Each stakeholder has their own unique needs and must be addressed individually. While it is true that stakeholders fall into groups with similar communication needs, one cannot stop at lumping stakeholders into groups. They must be communicated with on their own terms and given personal attention. Of the six elements included in the Delphi survey under *communication*, existing user cooperation do not satisfy the consensus criterial on the current or improved water service delivery. The results are shown in Table 7:14

Table 7:14: Communication results

	<b>Importance</b>		<b>Impact</b>	
	Median	% Response (8-10)	Median	% Response (8-10)
<b>9 Communication</b>				
Education level of the managers	9	80,00	9	100,00
Stakeholder communication and consultation	9	80,00	9	100,00
Collaborative working ethos	9	80,00	9,5	90,00
Existing user cooperation	7.5	70,00	9	90,00
Collaboration and coordination among professionals	9	90,00	9,5	90,00
Targeted education to stakeholders	10	80,00	9	90,00

## 7.5 Chapter summary

This chapter deliberated on the results of the three round Delphi study. Demographic information of the panellists was presented and findings of the survey were discussed. Chapter 8 presents the refined theoretical model and industry survey instrument.

## 8. WATER SERVICES AND DELIVERY CONCEPTUAL MODEL

### 8.1 Introduction

This chapter presents a conceptual model of water services and delivery in developing countries. The conceptual model is discussed and hypothesized relationships are outlined in the following sections.

### 8.2 Conceptual model for water service delivery.

A model in scientific interpretation can be viewed as one that endeavours to characterise reality (Fellows & Liu, 2008). Hair et al. (2010) stress that a conceptual model should show a simple representation of the relationship of set of variables being studied and it does not need to be complex and detailed. In construction management researches, models can be presented in graphical forms or mathematical expressions (Fellows & Liu, 2008). This research employed a path modelling approach to represent the model in a graphic and visually comprehensible form. Hypothesized relationships between the depended and independent variables of the study were shown in Figure 8.1

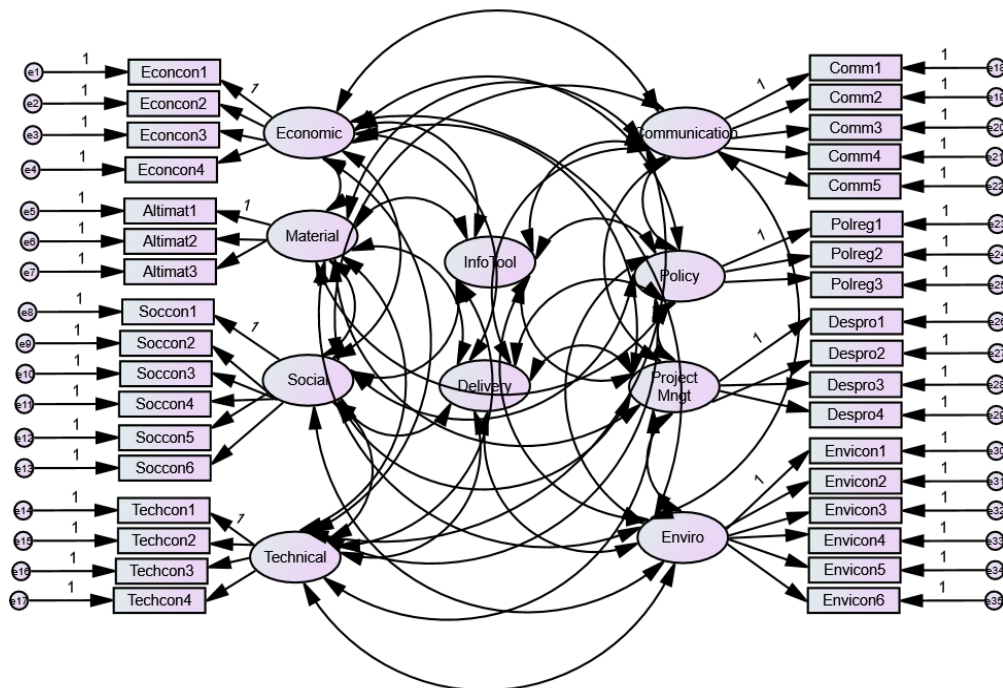


Figure 8.1: Model

### **8.2.1 Economic considerations**

Economics will play a notable role in the future of water services and delivery in our communities (Vallero & Brasier, 2008). This research can play a key role, during the planning stage, to incorporate increased efficiency and reduce cost capabilities to delivery and management of water infrastructure (Mihelcic & Zimmerman, 2010).

### **8.2.2 Alternative materials**

Principles of good delivery of water services entail optimization of the overall life cycle of products and processes with the aim of attaining to or reduced waste (McDonough & Braungart, 2002). Water infrastructure has to consider the main resource namely materials, in terms of their depletion and their social and environmental impacts (Sassi, 2006). According to Shealy et al. (2016) infrastructure outcomes are shaped by material choices. Selection of construction materials should be in light of their overall life cycle impact and possibilities of reuse or recycle should also be taken into account (McDonough & Braungart, 2003). The use of local materials with appropriate technology is encouraged and researchers should possibly address interaction of various construction materials with the local situation (Ibid)

### **8.2.3 Social considerations**

Shealy et al. (2016) emphasized that decision about water infrastructure widely dictate how the public will use water infrastructure services. Development of environment that considers effects of the community helps to create a community with a sense of identity and belongingness (Sassi, 2006). According to McDonough & Braungart (2003) Infrastructure should take into account the consequences of service decisions upon human well-being. Poorly planned environments result in increased health expenditure and lower worker productivity (Mihelcic & Zimmerman, 2010; Sassi, 2006).

### **8.2.4 Technical considerations**

If a water infrastructure does not satisfy its functional performance requirements, it has failed because it has not met the explicit minimum standards (Mihelcic & Zimmerman, 2010). While sustainable water infrastructure should incorporate aspects including environmental considerations toward

improving environmental quality, it should still strictly adhere to basic technical or functional requirements namely safety, health and wellbeing of the users (Vallero & Brasier, 2008). Functional requirements include users comfort and basic accessibility (Sassi, 2006).

The early stages of planning offer a great amount of flexibility to develop solutions that minimize risk (Mihelcic & Zimmerman, 2010). Planning of water infrastructure should be flexible to accommodate several functional requirements of users (McDonough & Braungart, 2003; Vallero & Brasier, 2008). Deliberation on the available options to choose the best alternative and considerations of future changes and adaptability need to be included in the process (Martland, 2012; McDonough & Braungart, 2003; Lechner, 2015).

### **8.2.5 *Environmental considerations***

Aspects of human health need to interrelate with and depend upon the natural world (McDonough & Braungart, 2003). Engineers ought to have good understanding of environmental risks (Mihelcic & Zimmerman, 2010). New construction has to be considered as an extension of existing infrastructure and the wide range of effects of construction materials in the local and global context need to be taken into account (McDonough & Braungart, 2003).

At the early stage of a water project, the researcher has the greatest opportunity to address the environmental impacts in connection with the final outcome (Mihelcic & Zimmerman, 2010).

### **8.2.6 *Design and project management***

Conventionally, the design process is characterized as purely direct, sequential and linear where incorporation of sustainability aspects implicates substantial costs (Vallero & Brasier, 2008). Design of water projects and its management requires more considerations when compared to conventional design (Azapagic & Collett, 2006). It should not be considered as an add-on criteria but it has to be seen as a well-integrated complement to the conventional design procedure (Gagnona, et al., 2012). Design principles and its management encourage direct and open communication between the different stakeholders involved in the process (McDonough & Braungart, 2003). Vallero & Brasier (2008) claimed that design strategies need an integrated approach.

Awareness of clients about sustainability plays a vital role to incorporate sustainable concepts in water infrastructure design (Vallero & Brasier, 2008). The overall design strategy should entail raising the

awareness of clients, the design team and users about sustainability (Sassi, 2006). Shealy et al. (2016) emphasised that more sustainable design needs additional time and technical consideration during the design process but often it is no more costly.

### **8.2.7 Policy and regulations**

Water infrastructure often uses planning aids including rating systems (Shealy, et al., 2016). Mihelcic & Zimmerman (Mihelcic & Zimmerman, 2010) argued that policy and regulations could play a meaningful role in assisting an engineering project for sustainability. Envision is one of the leading infrastructure rating systems where is found to be appropriate for several applications including delivery considerations (Shealy, et al., 2016).

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### **8.2.8 Professionals and delivery processes**

Vallero & Brasier (2008) argue that professional competence and character of professionals are essential elements for implementation of good delivery system. Good delivery processes are interrelated and the professionals are required to bring these requirements together in innovative ways (Akadiri, et al., 2012; Rekola, et al., 2012).

As greening engineering and delivery is a paradigm shift, professionals must be well informed of new developments (Vallero & Brasier, 2008). In order to practically apply good delivery strategies, adequate time and financial compensation should be in place (Hansen & Zenobia, 2011).

### **8.2.9 Communication**

The communication plan identifies how the stakeholder will be communicated with, the type, frequency, and medium. It establishes the content of the communication and what it intends to accomplish. Each stakeholder has their own unique needs and must be addressed individually. While it is true that stakeholders fall into groups with similar communication needs, one cannot stop at lumping stakeholders into groups. They must be communicated with on their own terms and given personal attention. This can be a tool for successful project management.

### 8.3 Hypothesis to be tested

When a research is based on theory and previous studies, it is proper to formulate a hypothesis that is to be tested (Fellows & Liu, 2008). The process of comparing results of collected data with what was theoretically expected to happen is termed as hypothesis testing (Saunders, et al., 2009).

Hypothesized relationships between the depended and independent variables of the study were shown in **Ошибка! Источник ссылки не найден.**Figure 8. 1. The following eight hypothesized relationships between the different variables in the conceptual model are:

**HA:** A positive relationship is predicted between *Alternative Materials* and *Improved water services Infrastructure*

**HB:** A positive relationship is predicted between *Design and Project management* and *Improved water services Infrastructure*

**HC:** A positive relationship is predicted between *Policy and regulations* and *Improved water services Infrastructure*

**HD:** A positive relationship is predicted between *Economic* and *Improved water services Infrastructure*

**HE:** A positive relationship is predicted between *Environmental* and *Improved water services Infrastructure*

**HF:** A positive relationship is predicted between *Technical Considerations* and *improved water services infrastructure*

**HG:** A positive relationship is predicted between *Communication* and *improved water services infrastructure*

**HH:** A positive relationship is predicted between *Social Considerations* and *improved water services infrastructure*

#### **8.4 Chapter summary**

This chapter presented and discussed the proposed water services and delivery conceptual model for water infrastructure in the context of developing countries. Elements included in the model were derived from literature review and established by the Delphi study. Hypothesized relationships between the different variables were presented. The next chapter presents results and analysis of the industry survey conducted at Ethekewini metro to validate the conceptual model.

## **9. RESULTS AND MODEL VALIDATION**

### **9.1 Introduction**

This chapter presents results of the industry survey that was conducted for the purpose of validating the theoretical model developed in the previous chapter. Descriptive statistical analysis and corresponding reliability, regression and validity tests were conducted. The Structural Equation Model (SEM) was developed using the industry survey result and the conceptual model was validated. The data analysis involved two stages, namely: descriptive statistical analysis and multivariate correlational data analysis including Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

### **9.2 Administration of the Industry Survey**

#### ***9.2.1 Questionnaire development***

This phase of the research employed a positivist approach where a structured questionnaire was used to collect data from experienced water professionals for the purpose of model validation. Questionnaires are one of the most popular methods of data collection (Lancaster, 2005). A structured questionnaire was used to minimize misinterpretations and misunderstandings in relation to the nature of data required and response obtained (Colton & Covert, 2007).

Prior to administering the final industry survey, a pilot survey questionnaire was developed and reviewed by five experienced academics, who had PhD's in Construction Management, Civil/Building Engineering and Engineering Management respectively. The review was conducted to assess clarity, length, completeness, readability and overall structure of the research instrument. The feedback obtained from the five academics was incorporated in the instrument before the final data collection was launched. A pilot study was also conducted to test clarity, completeness, language and over all layout of the research instrument and to assess problems of data collection methods and strategies.

The survey instrument was developed from the extensive literature review and the findings of the Delphi study. The instrument had two sections namely Section A and Section B. A sample of the invitation letter and pilot survey instrument are enclosed in Appendices A.1 and A.2 respectively. Section A requested respondents to provide background information including their profession, work experience, specialization and their willingness to include impacts and improvement of water infrastructure in the future.

### **9.2.2 Industry survey instrument**

The final industry survey instrument was developed. Questionnaire design including the structure, layout and arrangement of questions influences the extent of respondents' engagement in the data collection process (Root & Blismas, 2003). To enhance the response rate, extreme caution was applied in designing the layout of the industry survey (Lancaster, 2005). A sample of the final industry survey instrument and cover letter are enclosed in Appendices A.3 and A.4 respectively.

### **9.2.3 Sampling**

Once the data collection technique has been determined the subsequent step is determining characteristics and the minimum number of participants. The process of determining the number of participants is referred to as sampling and it involves ensuring that the population being studied is adequately represented by the sample (Fellows & Liu, 2008; Walker, 1997).

There are two types of sampling techniques namely probabilistic and non-probabilistic sampling (Zikmund, et al., 2009). In probabilistic or random sampling every member of the population being studied has an equal chance of taking part in the survey (Lancaster, 2005). Non-probabilistic or non-random sampling involves convenience sampling and 'snowball' sampling. In the case of convenience sampling, the population does not show a defined sample pattern and the researcher collects the data from the readily accessible sample (Fellows & Liu, 2008). Convenience sampling enables the researcher to obtain a large number of completed responses quickly and economically (Zikmund, et al., 2009). Snowball sampling is used to locate participants by chain-referral method where a respondent from the population will identify more potential respondents to be contacted by the researcher (Beins & McCarthy, 2012; Zikmund, et al., 2009).

This research targeted experienced water professionals in the Civil, Engineering and Construction (EC) Industry at Ethekwini municipality. The targeted population was specific both in terms of specialization and experience. To increase the response rate and minimise response time of the survey, non-probability convenient sampling technique was employed and both paper and email data collection techniques were used.

#### 9.2.4 Data collection

The industry survey was designed to be completed by experienced professionals who were involved in water infrastructure projects at Ethekewini municipality. The survey was conducted between July 2020 and October 2020

Ethekewini Municipality was approached to obtain a list of currently registered professionals in water projects within the municipality. While some information regarding registered contractors was obtained from the water services unit within the municipality,

Potential consulting firms and public organizations were identified and professionals working in them were contacted telephonically, physically and by email to confirm their willingness to participate in the survey. Snowballing was also employed to enhance the number of participants. Direct phone calls and personal contacts were made and participants were reminded at least once to further enhance the response rate.

As indicated in **Ошибка! Источник ссылки не найден.**Table 9. 1 a total of 301 questionnaires were sent out and 210 duly completed questionnaires were received representing a response rate of 72%. Percentage of completed questionnaires collected through paper survey was 58% and the remaining 42% of the responses were collected via email. Hair et al. (2010) recommended that for factor analysis the sample size should not be less than 100 and the minimum has to be 5 times the number of variables. Kline (2011) suggests 200 as a typical sample size for Structural Equation Modelling (SEM) and according to Schumacker & Lomax (2004) smaller models with well-behaved data require at least 100 to 150 cases. The responses received in this study are considered sufficient for the analysis.

**Table 9. 1 Questionnaire survey response rate**

Distribution Method	Number of questionnaires distributed	Number of questionnaires received	Received in Percentage (%)
Email	107	88	16
Paper	194	122	56
Total	301	210	72

### 9.3 Descriptive Data Analysis

Demographic information of the industry survey respondents is presented in this section. The analysis was done using IBM SPSS (Statistical Package for Social Science) Statistics. The software is referred to as SPSS in the thesis. The descriptive statistical analysis involved percentages, means and standard deviation of respondents profile including their gender, profession, level of education, specialization and professional experience.

#### 9.3.1 Respondents background information

Gender composition of the respondents is indicated in Table 9.2. The result shows that 78.1% of the respondents were male and rest of them were female.

**Table 9. 2 Gender composition**

		Frequency	Percent
Valid	Male	164	78.1
	Female	46	21.9
	Total	210	100.0

**Table 9.** outlines professional background of respondents. As indicated in the table, 58.1% of the respondents were Engineers and 12.9% of them were construction manager. Town planners constitute 5% of the respondents and 6% of the respondents had two professions namely Project manager and hydrologist. The results in **Table 9.** show that all respondents had bachelor's degrees, 26.7% had master's degrees and 5.7% had PhDs.

**Table 9. 3 Discipline**

	Frequency	Percent
Architecture	1	0.5
Town Planner	11	5.2
Water Engineer	53	25.2
Construction Manager	27	12.9
Civil Engineer	69	32.9
Quantity Surveyor	2	1.0
Hydrologist	13	6.2
Project Manager	14	6.7
Community Leader	3	1.4
Contractors	7	3.3

Water Board Managers	10	4.8
Total	210	100.0

**Table 9. 4 Highest Level of Education**

		Frequency	Percent
Valid	Bachelors	60	28.6
	Honours	82	39.0
	Masters	56	26.7
	Doctorate	12	5.7
	Total	210	100.0

As shown in 9.5 25% of the respondents had worked from 5 to 10 years in the construction industry and 21% of them had worked between 10 to 20 years. The result showed that more than 75% of the respondents had more than 10 years of experience in the water industry.

**Table 9. 5 Experience in the Water sector**

		Frequency	Percent
Valid	5 - 10 Years	53	25.2
	10 - 15 Years	45	21.4
	15 - 20 Years	82	39.0
	20 Years and Above	30	14.3
	Total	210	100.0

#### 9.4 Water management consideration factors

**Ошибка! Источник ссылки не найден.** Table 9.6 depicts that policy and professionals factors have the highest contribution with a mean value of 4.37 and 4.24 respectively. The statistic showed that Environmental considerations have the least contribution towards Improved water management.

Table 9.6: Measures of central tendency

N=210	Mean	Std. Deviation
	Statistic	Statistic
ECON1	3.93	.722
ECON2	3.96	.977

ECON3	3.58	1.105
ECON4	4.02	.855
MAT1	3.87	.851
MAT2	4.11	.810
MAT3	4.20	.773
SOC1	4.16	.869
SOC2	4.07	.889
SOC3	4.20	.821
SOC4	4.24	.904
SOC5	4.18	.882
SOC6	4.15	.592
TECH1	4.08	.852
TECH2	4.10	.902
TECH3	4.03	.855
TECH4	4.20	.833
ENVI1	3.98	.838
ENVI2	3.57	2.796
ENVI3	3.49	2.233
ENVI4	3.07	.839
ENVI5	3.97	.893
ENVI6	3.90	2.237
PROJECT1	4.04	.784
PROJECT2	4.20	.733
PROJECT3	4.14	.738
PROJECT4	4.24	.778
POLICY1	4.37	2.854
POLICY2	4.25	.775
POLICY3	4.16	.826
DEL1	4.14	.869
DEL2	4.26	.859
DEL3	4.05	.927
DEL4	4.00	.910
DEL5	4.35	.891
DEL6	4.05	.290
COMM1	4.27	.941
COMM2	4.14	.968
COMM3	4.11	.873
COMM4	4.10	.881
COMM5	4.24	.945
Valid N (listwise)		

**Legend:** **Econ** – Economic Considerations , **mat**- Alternative material, **SoC** – Social Considerations **TeCh** – Technical Considerations; **enc**– Environmental consideration; **Project** –Design and project management;; **policy**- Policy and regulation, **del**- Professionals and the delivery process, **comm**- Communication

## 9.5 Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was used to analyse the refined conceptual model elements using the latest version of Software Package for Social Sciences. The analysis included reliability, regression analysis, discriminant validity and convergent validity of the survey instrument. Unidimensionality of the elements was determined using factor extraction method namely Maximum likelihood with Promax Rotation.

Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were used to assess factor analysability of the data (Pallant, 2011; Tabachnick & Fidell, 2007). While KMO ranges from 0 to 1, for this research cut-off value of greater or equal to 0.7 ( $p < 0.06$ ) was used. Eigenvalue computation was also conducted where results of eigenvalue more than 1 were considered significant. The eigenvalue of a factor signifies the extent the total variance is explained by that factor (Pallant, 2011). Eigenvalues of less than 1 were considered insignificant and were eliminated.

Internal consistency reliability test was conducted using Cronbach's alpha coefficient to assess the consistency of the entire measurement scale (Hair, et al., 2010). In this research, Cronbach alpha coefficient value of 0.8 and above is considered to be acceptable (Pallant, 2011). Inter-item correlation values were calculated and values above 0.4 were considered acceptable (Hair, et al., 2010). Factor loadings or validity coefficients of elements were also calculated and factor loading value of 0.5 and above was considered acceptable (Ibid).

### 9.5.1 Exploratory Factor Analysis (EFA) of model constructs

The following sections presented and discussed reliability, convergent and discriminant validity measures of the nine water management factors.

#### 9.5.1.1 Economic considerations

Unidimensionality and reliability of *economic considerations* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.7. The results showed that

the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct. As indicated in Table 9.8, the calculated Cronbach's alpha coefficient was greater than the recommended 0.7 at 0.765 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.700 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicated consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results indicated that the data meets the factor analysability criteria.

Table 9. 7: Economic considerations factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A1.1	Life cycle analysis	.653	.624	.523	.565
A1.2	Cost efficiency	.743	.665	.580	.628
A1.3	Cost benefit analysis	.532	.515	.344	.374
A1.4	Measurement of implementation	.609	.580	.423	.460

Extraction Method: Maximum Likelihood

Table 9. 8: Economic considerations reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( $p$ )
4	0.765	0.700	485.180	10	.000

#### 9.5.1.2 Alternative Material

Unidimensionality and reliability of *Alternative material* construct were assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.9. The result showed that the corrected item-total correlation value was greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct. The calculated Cronbach's alpha was greater than the recommended 0.7 at 0.798 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.791 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicated consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results indicated that the data meets the factor analysability criteria.

Table 9. 9 Alternative material statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A2.1	Use of materials with low health risk and pollution in water projects	.463	.374	.436	.380
A2.2	Prescribing low energy material	.580	.432	.422	.478
A2.3	Use of locally available materials in Water projects	.456	.355	.365	.380

Extraction Method: Maximum Likelihood

Table 9. 10: Alternative Material reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( <i>p</i> )
3	0.798	0.791	360.523	30	.000

### 9.5.1.3 Social considerations

Unidimensionality and reliability of *social considerations* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.11. The results showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct. As indicated in Table 9.12 the calculated Cronbach's alpha was greater than the recommended 0.7 at 0.822 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.748 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicates consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results indicated the data meets the factor analysability criteria.

Table 9. 11: Social considerations factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A3.1	Client participation	.380	.415	.366	.243
A3.2	Provision of employment opportunities	.398	.454	.355	.295
A3.3	Beneficiaries participation	.480	.475	.372	.341
A3.4	Health and safety consideration for construction and operating stages	.630	.611	.541	.617
A3.5	Satisfaction of the public	.712	.688	.543	.602
A3.6	Risk analysis and disaster mitigation	.555	.501	.432	.511

Extraction Method: Maximum Likelihood

Table 9. 12: Social considerations reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( <i>p</i> )
6	0.822	0.748	936.425	24	.000

#### 9.5.1.4 Technical Considerations

Unidimensionality and reliability of *technical considerations* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.13. The result showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measures of the construct. As indicated in Table 9.14 the calculated Cronbach's alpha was greater than the recommended 0.7 at 0.785 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.762 with Bartlett's test of Sphericity of

$p < 0.000$  was obtained. This indicated consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . These results indicated that the data meets the factor analysability criteria.

Table 9. 2 Technical considerations factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A4.1	Experience	.465	.415	.210	.208
A4.2	Production of operation and maintenance materials	.577	.512	.292	.350
A4.3	Skill availability	.660	.565	.378	.412
A4.4	Research, Development and innovation	.654	.542	.391	.465

Extraction Method: Maximum Likelihood

Table 9. 3 Technical considerations reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( $p$ )
4	0.785	0.762	350.575	12	.000

#### 4.5.8.1 Environmental considerations

Unidimensionality and reliability of *environmental considerations* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.15. The results showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measures of the construct. The calculated Cronbach's alpha coefficient was greater than the recommended 0.7 at 0.826 showing acceptable internal reliability. As Indicated in Table 9.16 the Kaiser-Meyer-Olkin (KMO) of 0.755 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicated consistency with the KMO suggested cut-off value of 0.70 and

Bartlett’s Test of Sphericity of  $p < 0.005$ . The results indicated that the data meets the factor analysability criteria.

Table 9.15 Environmental considerations factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A5.1	Climate resiliency ( resistant to climate change)	.513	.532	.395	.265
A5.2	Reducing water pollution	.580	.572	.430	.332
A5.3	Provision of green infrastructure	.761	.723	.511	.654
A5.4	Uses of less energy during construction	.764	.743	.622	.697
A5.5	Reducing carbon footprint	.765	.698	.567	.671
A5.6	Optimizing site potential ( Land use)	.765	.676	.571	.654

Extraction Method: Maximum Likelihood

Table 9. 16: Environmental considerations reliability statistic

Items	Cronbach’s Alpha	KMO	Bartlett’s test of Sphericity		
			Appr. Chi-square	df	sig. (p)
6	0.826	0.755	866.652	18	.000

4.5.8.2 Design and Project Management

Unidimensionality and reliability of the *design and project management* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.17 and Table 9.18. The result showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct. The calculated

Cronbach's alpha coefficient was greater than the recommended 0.7 at 0.814 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.765 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicates consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results indicated that the data meets the factorability criteria.

Table 9. 17: The design and Project management factor statistic

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A6.1	Early contractors involvement at design stage	.376	.498	.566	.564
A6.2	Involvement of community	.376	.532	.570	.870
A6.3	Selection of appropriate contract	.256	.426	.218	.222
A6.4	Implementation of strategies specific to the project	.276	.576	.565	.567

Extraction Method: Maximum Likelihood

Table 9. 18 The design and Project Mangement approach reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( <i>p</i> )
4	0.814	0.765	987.524	26	.000

#### 4.5.8.3 Policy and Regulation

Unidimensionality and reliability of *policy and regulation* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.19. The result showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct.

Table 9. 4 Policy and Regulation factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A7.1	Presence of water delivery regulatory requirements	.578	.486	.288	.328
A7.2	Water rating systems	.543	.501	.388	.466
A7.3	Inclusion of sustainability requirement in water briefs	.613	.505	.287	.376

Extraction Method: Maximum Likelihood

As indicated in Table 9.20, the calculated Cronbach's alpha coefficient was greater than the recommended 0.7 at 0.752 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.798 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicated consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results suggested that factor analysis could be conducted with the data.

Table 9. 5 Policy and Regulation reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( <i>p</i> )
3	0.798	0.752	305.432	12	.000

#### 9.5.1.8 Communication

Unidimensionality and reliability of the *communication* construct was assessed using Exploratory Factor Analysis (EFA) and the results are presented in Table 9.21 and Table 9.22. The result showed that the corrected item-total correlation values were greater than the recommended cut-off value of 0.3 indicating that the elements were good measure of the construct. The calculated Cronbach's alpha coefficient was greater than the recommended 0.7 at 0.843 showing acceptable internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.755 with Bartlett's test of Sphericity of  $p < 0.000$  was obtained. This indicates consistency with the KMO suggested cut-off value of 0.70 and Bartlett's Test of Sphericity of  $p < 0.005$ . The results indicated that the data meets the factorability criteria.

Table 9. 21 Communication factor statistics

Item	Element	Factor loading	Corrected item-total correlation	Communalities	
				Initial	Extraction
A8.1	Education level of the managers	.788	.644	.420	.532
A8.2	Stakeholder communication and consultation	.820	.645	.445	.520
A8.3	Collaborative working ethos	.537	.531	.356	.383
A8.4	Collaboration and coordination among professionals	.694	.645	.422	.467
A8.5	Targeted education to stakeholders	.680	.665	.432	.426

Extraction Method: Maximum Likelihood

Table 9. 6 Communication reliability statistic

Items	Cronbach's Alpha	KMO	Bartlett's test of Sphericity		
			Appr. Chi-square	df	sig. ( <i>p</i> )
5	0.843	0.755	460.420	16	.000

## 9.6 Regression Analysis

In this research multivariate regression analysis was conducted and model selection criteria supports multivariate regression analysis modelling and is shown in Table 9.23, with the post-estimation tests confirming the validity of the model results were shown in Table 9.24. For both impact and improvement, the regression coefficients lie between the lower and upper limits of the credible intervals indicating that the predictor variables influences the endogenous variables

Table 9.23 : Improving factors MV regression analysis

	Model1	Model2	Model3	Model4	Model5
VARIABLES	goal	econgoal	envgoal	socgoal	othergoal
econ	0.132*** (0.049)	0.0265 (0.069)	0.299*** (0.096)	-0.0424 (0.050)	0.245* (0.135)
alm	0.00986 -0.0376	0.0503 -0.0529	-0.074 -0.0735	-0.036 -0.038	0.0991 -0.103
soc	0.0624 (0.059)	-0.0033 (0.083)	0.0101 (0.116)	0.115* (0.060)	0.128 (0.162)
tec	0.150*** (0.054)	0.171** (0.076)	0.177* (0.106)	0.0212 (0.055)	0.229 (0.149)
enc	0.0808 (0.051)	0.168** (0.071)	-0.0854 (0.099)	0.03 (0.051)	0.211 (0.139)
dpm	-0.0485 (0.046)	0.0613 (0.065)	-0.200** (0.090)	0.0966** (0.047)	-0.152 (0.127)
pnr	0.0227 (0.045)	0.0222 (0.064)	0.13 (0.089)	-0.0169 (0.046)	-0.0444 (0.125)
pdp	0.176*** (0.067)	0.138 (0.094)	0.189 (0.130)	0.136** (0.067)	0.242 (0.183)
com	-0.112** (0.051)	-0.264*** (0.072)	-0.202** (0.100)	-0.144*** (0.052)	0.161 (0.141)
Constant	2.902*** (0.598)	3.447*** (0.841)	3.842*** (1.169)	4.256*** (0.604)	0.0643 (1.642)
Observations	210	210	210	210	210
R-squared	0.168	0.126	0.116	0.085	0.111
Prob > F	0.0000	0.0012	0.0029	0.0344	0.0046
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1					

**Legend:** **Econ** – Economic Considerations , **alm-** Alternative material, **SoC** – Social Considerations  
**TeC** – Technical Considerations; **enc**– Environmental consideration; **Pdm** –Design and project management;; **pnr**-Policy and regulation, **pdp**- Professionals and the delivery process, **com**- Communication

Table 9.24: Model Selection criteria

	goal	econgoal	envgoal	socgoal	othergoal
econ	-88.952	55.413	183.7607	-93.2037	324.411
alm	-80.014	53.272	191.9384	-92.9123	329.7315
soc	-79.167	56.345	192.132	-93.8503	330.4449
tec	-84.261	53.851	188.9527	-92.1841	329.2
enc	-86.056	48.854	192.1352	-92.6804	325.7803
dpm	-80.017	56.343	186.2709	-96.035	330.5349

pnr	-77.749	55.040	189.9037	-92.4684	333.4496
pdp	-85.318	52.931	189.8954	-94.3938	330.3422
com	-77.903	46.909	189.6081	-96.576	330.267
full	-98.597	42.415	180.5156	-97.4682	323.4306

**Legend:** **Econ** – Economic Considerations , **alm**- Alternative material, **SoC** – Social Considerations **TeC** – Technical Considerations; **enc**– Environmental consideration; **Pdm** –Design and project management;; **pnr**- Policy and regulation, **pdp**- Professionals and the delivery process, **com**- Communication

## 9.7 The Structural Equation Modelling

Structural Equation Modelling (SEM) provides a quantitative test of a hypothesized theoretical model (Schumacker & Lomax, 2004). It has two basic components namely measurement model and structural model (Hair, et al., 2010). While the measurement model specifies how latent variables are measured in terms of observed variables, the structural model expresses relationships among latent variables (Yang & Ou, 2008; Islam & Fainran, 2005). The subsequent section present how SEM was used for validation of the theoretical model developed in this research.

### 9.7.1 Confirmatory Factor Analysis

In the preceding sections of this chapter unidimensionality and reliability of the constructs were assessed using Exploratory Factor Analysis and sufficient evidence was demonstrated. EFA analysis was followed by confirmatory factor analysis using *AMOS* (Analysis of Moment Structures version 24). The analysis employed maximum likelihood robust estimator to analyse the construct validity of the measurement models. Since there were missing data in the data set full information maximum likelihood estimator was used to estimate the missing data.

CFA provides information on the individual variables and fit indices in order to assess how well the survey data fits the proposed conceptual model. The following fit indices were considered in this research: Satorra Bentler chi-square, Root-Mean-Square-Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI) and the Standardized Root Mean Square Residual (SRMR) and shown in Table 9.25

Table 9. 25 Cut-off criteria for model fit indices

Model criterion	Fit	Symbol/ Acronym	Acceptable threshold levels and interpretation	Source / References
Chi-square test		$\chi^2$	Low $\chi^2$ relative <i>df</i> with an insignificant <i>p</i> - value ( $p > 0.05$ )	(Schumacker & Lomax, 2004)

Normed chi-square	$\chi^2/df$ ratio	Ratio of ( $\chi^2$ ) to $df \leq 2$ or 3 <i>good fit</i> Ratio of ( $\chi^2$ ) to $df \leq 5$ <i>acceptable</i>	(Schumacker & Lomax, 2004)
Root-Mean-Squared-Error of Approximation	RMSEA	< 0.05 with confidence interval (CI) 0.00-0.05 “good fit” > 0.06 to 0.08 with confidence interval 0.00-0.05 “acceptable fit” > 0.08 to 1.00 with confidence interval 0.00-0.05 “mediocre fit” > 1.00 with confidence interval 0.00-0.05 “poor fit”	(Schumacker & Lomax, 2004; Hair, et al., 2010)
Comparative Fit Index	CFI	$\geq 0.95$ “good fit” $\geq 0.90$ “acceptable fit”	(Hair, et al., 2010)
Tucker-Lewis Index	TLI	$\geq 0.95$ “good fit” or $\geq 0.90$ “acceptable fit”	(Schumacker & Lomax, 2004)
Standardized Root Mean Square Residual	SRMR	$\leq 0.05$ “good fit” $\leq 0.08$ “acceptable fit”	(Schumacker & Lomax, 2004; Hair, et al., 2010)

### 9.7.2 Improvement measurement model

In this section, confirmatory factor analysis for *improved water services* latent variable is presented. Standardized factor loadings of the observed variables for the latent variable are shown in Figure 9.1. The standard factor loadings of the variables, were found to be statistically significant, and the result indicated convergent validity. The standard factor loadings of the variables were all statistically significant and the result indicated convergent validity. The model did not include any cross loadings, therefore, the standardized factor loadings were interpreted as the correlation between the observed variable and the construct were presented in Table 9.26

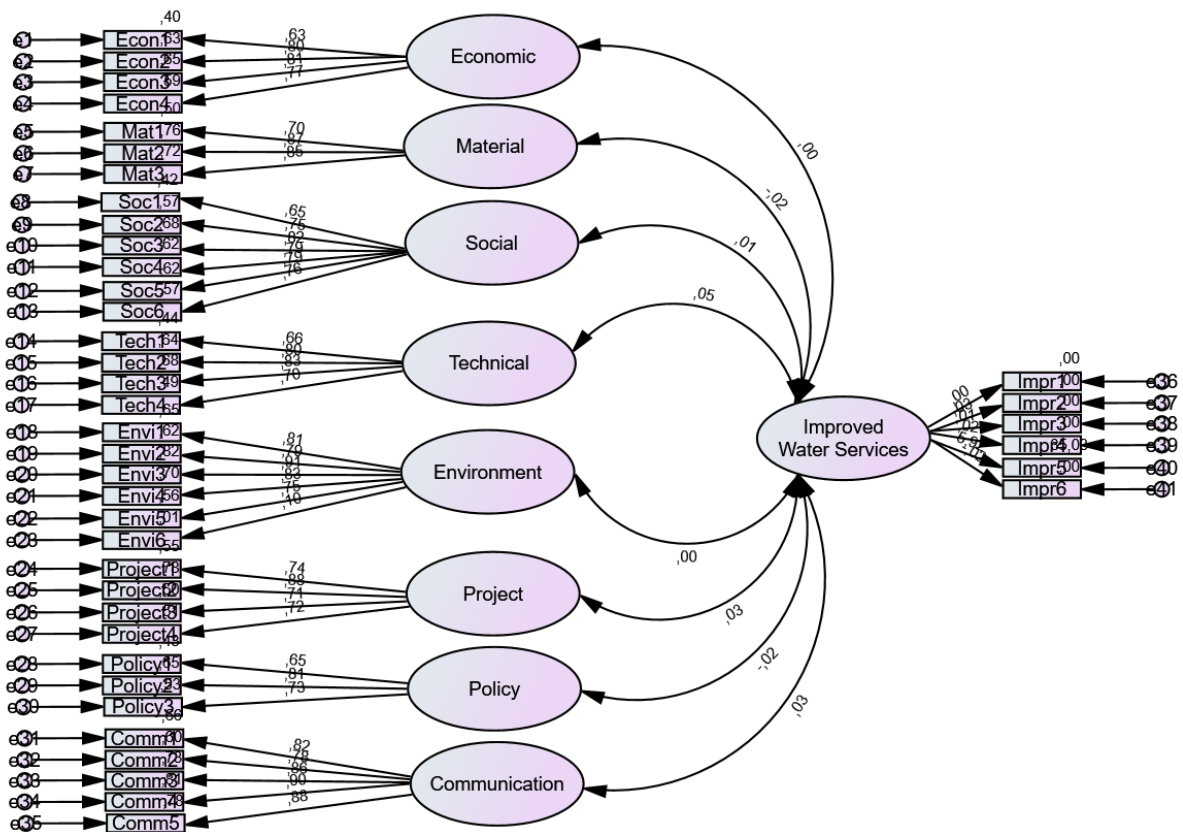


Figure 9.1: Measurement model for improved water services

Table 9.26: Validity Analysis on improved water services

	CR	AVE	MSV	MaxR(H)	Economic	Material	Social	Technical	Environment	Project	Communication	ImprServ	Policy
<b>Economic</b>	0,840	0,569	0,000	0,851	<b>0,755</b>								
<b>Material</b>	0,851	0,658	0,001	0,870	**	<b>0,811</b>							
<b>Social</b>	0,892	0,581	0,000	0,898	**	**	<b>0,762</b>						
<b>Technical</b>	0,837	0,564	0,002	0,851	**	**	**	<b>0,751</b>					
<b>Environment</b>	0,869	0,559	0,000	0,921	**	**	**	**	<b>0,748</b>				
<b>Project</b>	0,848	0,584	0,001	0,871	**	**	**	**	**	<b>0,764</b>			
<b>Communication</b>	0,927	0,718	0,001	0,934	**	**	**	**	**	**	<b>0,848</b>		
<b>ImprServ</b>	<b>5,465</b>	5,839	0,002	36,945	-0,004	-0,022	0,014	0,048	-0,003	0,028	0,025	<b>2,416</b>	
<b>Policy</b>	0,775	0,537	0,000	0,789	**	**	**	**	**	**	**	-0,022	<b>0,733</b>

## 9.8 The Conceptual Model: Testing Hypothesis

The conceptual model for this study is built around eight hypothesized relationships between different variables. The relationships were hypothesized as follows:

**HA:** A positive relationship is predicted between *Alternative Materials* and *Improved water services Infrastructure*

**HB:** A positive relationship is predicted between *Design and Project management* and *Improved water services Infrastructure*

**HC:** A positive relationship is predicted between *Policy and regulations* and *Improved water services Infrastructure*

**HD:** A positive relationship is predicted between *Economic* and *Improved water services Infrastructure*

**HE:** A positive relationship is predicted between *Environmental* and *Improved water services Infrastructure*

**HF:** A positive relationship is predicted between *Technical Considerations* and *improved water services infrastructure*

**HG:** A positive relationship is predicted between *Communication* and *improved water services infrastructure*

**HH:** A positive relationship is predicted between *Social Considerations* and *improved water services infrastructure*

### 9.8.1 Hypothesis Results

The hypothesized results are indicated in Table 9.27:

Table 9.27: Standard factor loading and p-value analysis

			<b>Significance</b>	<b>Regression Estimate</b>	<b>P-Value</b>	<b>Accepted/Rejected</b>
ImprServ	<-->	Material	Positive	0,054	0,049	Accepted
ImprServ	<-->	Project	Positive	0,022	0,050	Accepted
ImprServ	<-->	Policy	Positive	0,018	0,048	Accepted
ImprServ	<-->	Economic	Positive	0,059	0,046	Accepted
ImprServ	<-->	Environment	Positive	0,041	0,049	Accepted
ImprServ	<-->	Technical	Positive	0,047	0,041	Accepted
ImprServ	<-->	Communication	Positive	0,027	0,041	Accepted
ImprServ	<-->	Social	Positive	0,016	0,041	Accepted

The eight factors were hypothesized to have a positive relationship with Improved infrastructure delivery process and could not be rejected.

## 9.9 Chapter summary

Results of the industry questionnaire survey were discussed in this chapter. Descriptive statistics and corresponding reliability, regression and validity test were carried out. Exploratory and confirmatory factor analyses were conducted. Structural model was developed and tested to measure how the data collected using questionnaire survey fits into the hypothesized conceptual model. The next chapter discusses the results presented in this chapter.

## 10 DISCUSSION

### 10.1 Introduction

This chapter briefly discusses the demographic data of the respondents who participated in the industry survey. It also discusses results of the improved water infrastructure services using structural equation model that was validated in the previous chapter. The discussion of the results was based on evidence from the literature.

### 10.2 Discussion of the descriptive data analysis

The industry survey gathered demographic data of the water experts who participated in the study. The data collection employed both paper and email techniques with response rates of 72%. The paper data collection approach yielded a better response rate than the email-based data collection method. The overall response rate was found to be acceptable at 72% when compared with the industry norm. The majority of the respondents were male (78.1%). In terms of profession, more than 58.1% of the respondents were engineers.

### 10.3 Discussion of validated Structural Equation Model results

The model analysis that was conducted previously showed that all the nine hypothesized relationships were found to be significant except one. There were seven relationships between the independent variable and the three intervening variables. The following sections discuss these ten relationships.

#### *10.3.1 Relationship between Improved water services Infrastructure and Materials*

The relationship between *Alternative materials and Improved water services infrastructure* was found to be significant. This finding shows that Water service delivery have influence on alternative material considerations. It is argued that the easiest way to have good delivery of water or its infrastructure is to incorporate careful selection of appropriate materials (John, et al., 2005)

#### *10.3.2 Relationship between Design and Project Mangement and Improved water services delivery*

The relationship between *design/project management and improved water services* was found to be significant. This finding shows that Water services delivery have influence on the design approach/management. The design approach or methods/ management can be explained as any

procedures, techniques and aids for designing (Cross, 2005) and also management of the water infrastructure and its application is influenced by experts judgement (Gagnon, et al., 2012). The responsibility of creating the methodologies and practical tools to synergize the diverse stakeholders for good delivery of projects lies in the hands of water experts and poses a challenge to them (Kibert, 2013).

### ***10.3.3 Relationship between policy and regulation and Improved water services delivery***

The relationship between *policy and regulation and improved water service delivery* was found to be significant. This finding shows that good water delivery process have influence on policy and regulation processes in a water project. It is argued that the easiest way to incorporate policies in a water project could be through careful selection of appropriate water rating systems (John, et al., 2005)

### ***10.3.4 Relationship between Economic consideration and Improved water service delivery***

The relationship between *economic considerations and improved water service delivery* was found to be significant. This finding shows that good water service delivery have influence on economic considerations. Money play a critical role in the life cycle of a project (Smith, 2008) and in order to meet the delivery criteria and in addition to the basic functional requirements should be concerned about the long-term costs of the water infrastructure (John, et al., 2005).

### ***10.3.5 Relationship between environmental considerations and Improved water services delivery***

The relationship between *environmental considerations Improved water service delivery* was found to be significant. This finding shows that good water delivery services have an influence on environmental considerations. Environmental considerations of a water project including Life Cycle Assessment, provision of green infrastructure and sometimes climate resiliency which enhance delivery in a water project (Basbagill, et al., 2012).

### ***10.3.6 Relationship between Technical consideration and improved water services***

The relationship between *technical consideration and improved water services* was found to be significant. This finding shows that technical consideration have influence on improved water services. Rwelamila et al. (2000) argue that in order to successfully deliver sustainable built infrastructure, particular attention should be given to technical considerations such as experience,

skills of experts. As all stakeholders in water sector process including hydrologist, have impact and influence on improving services at the municipality (Smith, et al., 2006), it is argued that a water expert should have experience and skills that can provide adequate supply of water services within the municipality.

#### ***10.3.7 Relationship between communication and improved water services delivery***

The relationship between *communication* and *improved water services* was found to be significant. This finding shows that communication fall into groups with similar communication needs, one cannot stop at lumping stakeholders into groups. Water experts and the community must be communicated with, their own terms and given personal attention. These was a tool for successful project management.

#### ***10.3.8 Relationship between social considerations and improved water services delivery***

The relationship between *social considerations* and *improved water services* was found to be significant. This finding shows that social considerations imply implementation of and delivery of water projects. Inclusion of social aspects at the beginning of a water project assists to ensure workers safety during construction and improve the envisaged use of the project by the final users (Valdes-Vasquez & Klotz, 2013). Taking into account social issues at an early stage could assist to ensure good delivery performance of final products (Azapagic & Collett, 2006).

### **10.4 Chapter summary**

This chapter briefly discussed the demographic data of the industry survey participants. The findings of the structural equation model that was developed and validated previously were also discussed. The discussion was done based on evidence from the literature. The next chapter summarizes findings of the research and provided recommendations for future research.



## 11 CONCLUSION AND RECOMMENDATION

### 11.1 Introduction

This chapter outlined on outcomes of the research and presents conclusions drawn from the findings. Limitations of the study are presented and contributions of the research are outlined. Areas for further research are suggested and concluding remarks are made.

### 11.2 Research objectives

Arguably, water infrastructure plays a vital role in poverty reduction, economic growth, business competitiveness and enhancement of societal living. Provision of infrastructure involves a complex process and utilizes considerable amount of resources including construction materials, energy, finance and time. Infrastructures have long life span and they could create long-term impact on the environment and society. The key research question of this study was: “What are the key elements that affect the delivery of water services?, What are the processes in the management of water infrastructure delivery services?, What are the challenges faced and approaches adopted in executing these processes? with corresponding three research objectives. Findings of this research in light of the three specific research objectives are discussed in the subsequent sections.

#### 11.2.1 Research objective 1

The first objective of this research is to identify potential causes that affect water delivery and management at Ethekekwini Municipality.

Extensive literature review and Delphi technique were employed to meet this objective of the research.

Using the literature review 9 leading factors and 55 elements were identified and presented to the panel of experts in the Delphi study. The panel of experts rated the importance and impact of the elements in three rounds until consensus was achieved. Results of the Delphi study indicated that 43 elements were perceived to have significant importance and impact on improving the delivery of water services.

The 9 leading factors under which the identified 43 elements were categorized were

- economic considerations,

- alternative material
- social considerations,
- technical consideration
- environmental considerations,
- Design and project management
- policy and regulations,
- professionals and the delivery process,
- Communication.

All elements categorized under policy and regulation, and professions and the delivery process achieved the consensus criteria and were retained. Only one element was excluded from each of the two leading factors, namely economic considerations and communication. Each environmental considerations and technical considerations leading factors had 6 and four elements retained. The other two leading factors namely alternative material and design and project management had three and four elements retained each. Following refinement of the leading factors and their corresponding measuring elements, a conceptual model was developed.

While 43 elements were retained after the three round Delphi study, following the deliberation on the industry practice, the elements and their corresponding leading factors were revisited. The model had ten leading factors and forty three corresponding measuring elements. The revised leading factors were professionals and the delivery process, technical considerations, Alternative material, policy and regulation, design and project management communication, social considerations, economic considerations, environmental considerations, the improved water delivery system. The leading factors represented three types of variables in the model namely independent, intervening and dependent variables. The model had one independent, one dependent and eight intervening variables. The objective was achieved and the corresponding specific research question was answered.

### ***11.2.2 Research objective 2***

The second objective of the research was to develop a model by identifying the capabilities that are needed to execute the core processes for effective management of water services. To achieve this objective quantitative data was collected from experienced water experts in the Civil Engineering and Construction industry around Ethekewini municipality using a structured questionnaire. Structural equation modelling was conducted to validate the conceptual model using the data collected from the

industry. Results of the study confirmed that there were eight direct relationships between the eight variables in the model.

The dependent leading factor improved water delivery process was found to have significant direct relationship with all eight intervening leading factors. The objective of the research was achieved

### ***11.2.3 Research objective 3***

The third objective of the research was to assess the challenges faced and adopt an appropriate approach in improving water services delivery at Ethekewini Municipality. Structured questionnaire survey instrument was used to collect data and results showed that more than 72% of the participants consider the nine elements as a prime concern in improving the delivery of water services. The survey further indicated that almost all respondents who did not consider the nine elements as their prime concern were willing to make it their prime concern in their improvement of water delivery within the municipality in the near future. The objective was also achieved.

## **11.3 Contributions of the study**

The findings of this research significantly contribute to the evolving current body of knowledge in the area of water infrastructure specifically in the context of developing countries such as South Africa. As discussed in the subsequent sub-sections, the contributions of this study have practical, academic and methodological significance.

### ***11.3.1 Practical contributions***

The findings of the research provide guidance to professionals and other stakeholders in the Civil Engineering and Construction industry to improve their delivery practice in order to deliver good water services in the context of developing countries such as South Africa using the nine elements used in this study.

Clients can cooperate with water professionals and make use of the model validated in this research to tune their project requirements or objectives to ensure good delivery of water project. The validated model provides a clear direction to policy makers, councils, directors, community leaders, professional associations and relevant statutory organs to develop appropriate guidelines, regulation and policies to ensure good delivery of water services.

### ***11.3.2 Academic contributions***

This research provides a better understanding of key factors and their relationships with provision of good water services especially in the context of developing countries such as South Africa. The results also broaden the knowledge of the nine elements of water delivery services. This research lays a foundation for further research in the areas of water infrastructure, water conservation and management and construction.

### ***11.3.3 Methodological contributions***

This study followed a two-step research methodology to validate the research instrument used in the research. The first phase involved content validation where Delphi technique was employed to validate the instrument content. The second step involved construct validity where exploratory factor analysis and confirmatory factor analysis were conducted. The factor analysis was conducted using structural equation modelling where the relationships between the different variables in the proposed model were determined. This overall methodology is not frequently used in construction-related research.

## **11.4 Limitations of the study**

Limitations of a research state the difficulties faced in carrying out the research (Naoum, 2007). Limitations encountered in relation to this research are outlined as follows:

- The industry survey conducted in this study targeted mostly water professionals. More Inclusion of the perceptions of other stakeholders including clients, contractors, statutory organs, community leaders and end users could provide a more complete picture;
- The data collection was based on non-probabilistic convenience sampling technique. As responses came only from those who were available and willing to participate in the study due to outbreak of covid 19 and no claims of generalizability could be made beyond the cases considered in the study;
- This study employed a structured questionnaire to collect opinions of respondents using subjective measured variables. Response could be exposed to bias when subjected measures are used specially in cases where self-reporting survey instruments are used;
- Different water infrastructure types have their own peculiarities including functional requirement and construction technique. This research included all water infrastructure types

and no differentiation was made to take into account the disparity among different infrastructure systems;

- Analysis of Impact of demographic information of respondents on their response was not conducted;
- The conceptual model developed in this model was validated using the data collected from water professionals in Ethekwini municipality. No attempt was made to make comparisons with other municipalities.

### **11.5 Recommendations for further study**

This research has contributed to the body of knowledge in the area of water management and services. The results emerged from this research implied that there are several areas to be studied in the future. The suggestions for further studies are made based on the limitations of the research.

- The model presented in this research provided a basis for further development. Follow up studies could be conducted to develop a framework for practical implementation of the model developed in this research.
- Further studies should use probabilistic random sampling in order to ensure generalizability of the study.
- Researches specific to different types of water infrastructure systems need to be done in the future.
- Further study is suggested to validate significance of the relationship between measured variables.

### **11.6 Conclusion**

This research has attempted to provide a well-defined and basic model for implementation of good water delivery services in developing countries with a particular emphasis at Ethekwini. The model lays a foundation for development of appropriate policies, regulations, procedures and delivery of good water services within the municipality. Several recommendations were drawn from the findings of the research and were forwarded to assist the Civil Engineering and Construction industry to ensure provision of good water services delivery. The research has outlined its limitations and forwarded recommendations for further studies.

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## APPENDIX A: LETTER TO PARTICIPATE IN DELPHI STUDY



University of KwaZulu-Natal  
School of Engineering  
Department of Construction Studies  
Howard College Campus  
Durban 4041  
South Africa

February 2019

Dear Sir/Madam,

**Re: Expert/s to participate in Delphi study**

I am currently doing a Doctor of philosophy in Construction Management in the school of Engineering at University of KwaZulu-Natal South Africa, under the supervision of Prof Theo Haupt on the topic Improved infrastructure delivery and management with regards to water services. The first stage of the research uses Delphi technique which utilises a consensus building approach among individuals such as yourself with recognised experience and advanced knowledge in water services.

I invite you to participate in this study by serving on my panel of experts, while I look forward to your invaluable contribution to the study. You could recommend another expert by providing me with their contacts information if you are unable to participate

Your participation is totally voluntary and you are assured of complete confidentiality, should you wish to know the finding of the research, I will be glad to send a summary of the result

Thank you for your consideration of the initiative and I am looking forward to hearing from you. Your participation will contribute to improvement of water services and delivery in South Africa

Thanking you in advance,

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## APPENDIX B: SURVEY QUESTIONNAIRE

### Delphi Round 1 Survey Questionnaire

Research Title: Improving Infrastructure Delivery and Management model in South Africa – with regards to water management

Dear Participant

Thank you for agreeing to serve on my panel of experts. Your participation is valued and I look forward to working with you in the iterative rounds of the survey until a level of consensus is achieved on the issue covered in the instrument.

Please return the completed Questionnaire via email to [nkwonta@mut.ac.za](mailto:nkwonta@mut.ac.za). Completing the questionnaire is intended to take approximately 30 minutes. The Questionnaire has two sections. Section A deals with the current design and other influences on current water services delivery and management in South Africa. Section B is concerned with key designs and other influences on improving water services delivery and management in South Africa

SECTION A DEALS WITH THE CURRENT DESIGN AND OTHER INFLUENCES ON CURRENT WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA

#### Instructions

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**How important are the following influences in delivery of water services in developing countries such as South Africa today?**

1.								
	1	2	3	4	5	6	7	8
Life cycle analysis								
Cost efficiency								

Cost benefit analysis								
Bankability/profitable								
Measurement of implementation								
<b>2. Alternative Materials</b>								
Use of materials with low health risk and pollution in water projects								
Use of secondhand material								
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects								
Use of locally available materials in Water projects								
<b>3. Social Consideration</b>								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage								
Risk analysis and disaster mitigation								
<b>4. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								

Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								
<b>5. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity								
Reducing water pollution								
Provision of green infrastructure								
Uses of less energy during construction								
Reducing carbon footprint								
Optimizing site potential ( Land use)								
Ensuring efficient energy utilization both during construction and operation phases								
<b>6. Design and Project Management</b>								
Early contractors involvement at design stage								
Involvement of community								
Selection of appropriate contract/Experience								
Flexible design to accommodate on site changes								
Proper construction quality control procedure								
Implementation of strategies specific to the project								
<b>7. Policy and Regulations</b>								
Presence of water delivery regulatory requirements								

Water rating systems								
Inclusion of sustainability requirement in water briefs								
<b>8. Professionals and the delivery processes</b>								
Awareness of client about water projects								
Awareness of contractors on water projects								
Knowledge and experiences of contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

SECTION B: CONCERNED WITH KEY DESIGNS AND OTHER INFLUENCES ON IMPROVING WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA

**Which of the following influences offer the greatest impact opportunities for improving delivery of water services in developing countries such as South Africa if adapted generally?**

**Instructions**

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

Aspect								
1. Economic Consideration	1	2	3	4	5	6	7	8
Life cycle analysis								
Cost efficiency								
Cost benefit analysis								
Bankability/Profitable								
Measurement of implementation								
2. Alternative Materials								
Use of materials with low health risk and pollution in water projects								
Use of secondhand material								
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects								
Use of locally available materials in Water projects								
3. Social Consideration								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage								
Risk analysis and disaster								

mitigation								
<b>4. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								
Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								
<b>5. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity								
Reducing water pollution								
Provision of green infrastructure								
Uses of less energy during construction								
Reducing carbon footprint								
Optimizing site potential ( Land use)								
Ensuring efficient energy utilization both during construction and operation phases								
<b>6. Design and Project Management</b>								
Early contractors involvement at design stage								
Involvement of community								
Selection of appropriate contract/Experience								
Flexible design to accommodate on site changes								
Proper construction quality control procedure								
Implementation of strategies specific to the project								

<b>7. Policy and Regulations</b>								
Presence of water delivery regulatory requirements								
Water rating systems								
Inclusion of sustainability requirement in water briefs								
<b>8. Professionals and the delivery processes</b>								
Awareness of client about water projects								
Awareness of contractors on water projects								
Knowledge and experiences of contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

Thank you for participating in this study. In case of any queries, regarding this survey and the research, you may contact either my supervisor or me at

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## APPENDIX C: DELPHI ANALYSIS

### Delphi Round 1 Survey Questionnaire

Research Title: Improving Infrastructure Delivery and Management model in South Africa – with regards to water management

Dear Participant

Thank you for agreeing to serve on my panel of experts. Your participation is valued and I look forward to working with you in the iterative rounds of the survey until a level of consensus is achieved on the issue covered in the instrument.

Please return the completed Questionnaire via email to [nkwonta@mut.ac.za](mailto:nkwonta@mut.ac.za). Completing the questionnaire is intended to take approximately 30 minutes. The Questionnaire has two sections. Section A deals with the current design and other influences on current water services delivery and management in South Africa. Section B is concerned with key designs and other influences on improving water services delivery and management in South Africa

SECTION A DEALS WITH THE CURRENT DESIGN AND OTHER INFLUENCES ON CURRENT WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA

#### Instructions

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**How important are the following influences in delivery of water services in developing countries such as South Africa today?**

#### IMPORTANCE SCALE

	1	2	3	4	5	6	7	8
Life cycle analysis								
Cost efficiency								
Cost benefit analysis								
Bankability/profitable								
Measurement of implementation								
<b>10. Alternative Materials</b>								
Use of materials with low health risk and pollution in water projects								
Use of secondhand material								
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects								

Use of locally available materials in Water projects								
<b>11. Social Consideration</b>								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage								
Risk analysis and disaster mitigation								
<b>12. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								
Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								
<b>13. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity								
Reducing water pollution								
Provision of green infrastructure								
Uses of less energy during construction								
Reducing carbon footprint								

Optimizing site potential (Land use)								
Ensuring efficient energy utilization both during construction and operation phases								
<b>14. Design and Project Management</b>								
Early contractors involvement at design stage								
Involvement of community								
Selection of appropriate contract/Experience								
Flexible design to accommodate on site changes								
Proper construction quality control procedure								
Implementation of strategies specific to the project								
<b>15. Policy and Regulations</b>								
Presence of water delivery regulatory requirements								
Water rating systems								
Inclusion of sustainability requirement in water briefs								
<b>16. Professionals and the delivery processes</b>								
Awareness of client about water projects								
Awareness of contractors on water projects								
Knowledge and experiences of contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								

<b>17. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

**SECTION B: CONCERNED WITH KEY DESIGNS AND OTHER INFLUENCES ON IMPROVING WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA**

**Which of the following influences offer the greatest impact opportunities for improving delivery of water services in developing countries such as South Africa if adapted generally?**

**Instructions**

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**IMPACT SCALE**

<b>Aspect</b>								
<b>10. Economic Consideration</b>								
	1	2	3	4	5	6	7	8
Life cycle analysis								
Cost efficiency								
Cost benefit analysis								
Bankability/Profitable								
Measurement of implementation								
<b>11. Alternative Materials</b>								
Use of materials with low health risk and pollution in water projects								
Use of secondhand material								
Prescribing low energy material								
Utilizing potential of non-conventional materials in								

water projects								
Use of locally available materials in Water projects								
<b>12. Social Consideration</b>								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage								
Risk analysis and disaster mitigation								
<b>13. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								
Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								
<b>14. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity								
Reducing water pollution								
Provision of green infrastructure								
Uses of less energy during construction								

Reducing carbon footprint								
Optimizing site potential (Land use)								
Ensuring efficient energy utilization both during construction and operation phases								
<b>15. Design and Project Management</b>								
Early contractors involvement at design stage								
Involvement of community								
Selection of appropriate contract/Experience								
Flexible design to accommodate on site changes								
Proper construction quality control procedure								
Implementation of strategies specific to the project								
<b>16. Policy and Regulations</b>								
Presence of water delivery regulatory requirements								
Water rating systems								
Inclusion of sustainability requirement in water briefs								
<b>17. Professionals and the delivery processes</b>								
Awareness of client about water projects								
Awareness of contractors on water projects								
Knowledge and experiences of contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and								

practices in their design								
<b>18. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

Thank you for participating in this study. In case of any queries, regarding this survey and the research, you may contact either my supervisor or me at

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## Delphi Round 2 Survey Questionnaire

Research Topic: IMPROVED INFRASTRUCTURE DELIVERY AND MANAGEMENT IN SOUTH AFRICA.  
 Thank you for participating in round 1 of the Delphi survey. I acknowledge your busy schedule and significant time you have invested in this survey. The purpose of round 2 is to provide you with a chance to change your response, if desired, given the median Delphi panel member's response of each statement. Completing the survey is intended to take approximately 15 -20 mins. Please return the completed questionnaire via email to [nkwonta@mut.ac.za](mailto:nkwonta@mut.ac.za)

**Direction and Instruction:** Next to each statement. You will find two values. Group median from round 1 survey indicated in the column to the far right of each table and your round 1 survey response

1. Accept the group median response by learning the statement rating completely unchanged.
2. Maintain your original round 1 response in the column box or
3. Indicate a new response by placing an x in the appropriate box

Note- if your response in action 2 or 3 above is more than two units above or below the group median of each statement. You may provide reason (s) for the difference at the end of the table eg. Group median 7 and your response is 4 or 10, this response is two units below or above the group median respectively.

The Questionnaire has two sections. Section A deals with the current design and other influences on current water services delivery and management in South Africa. Section B is concerned with key designs and other influences on improving water services delivery and management in South Africa

### SECTION A DEALS WITH THE CURRENT DESIGN AND OTHER INFLUENCES ON CURRENT WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA

#### Instructions

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**How important are the following influences in delivery of water services in developing countries such as South Africa today?**

#### IMPORTANCE SCALE

Aspect	IMPORTANCE SCALE							
	1	2	3	4	5	6	7	8
<b>1. Economic Consideration</b>								
Life cycle analysis								
Cost efficiency								X
Cost benefit analysis								X
Bankability/profitable							X	
Measurement of implementation								X
<b>2. Alternative Materials</b>								
Use of materials with low health risk and pollution in water projects								X

Use of secondhand material							X	
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects							X	
Use of locally available materials in Water projects								
<b>3. Social Consideration</b>								
Client participation								
Provision of employment opportunities								X
Beneficiaries participation								X
Accessibility of the infrastructure to the public including people with specific needs							X	
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage								X
Risk analysis and disaster mitigation								X
<b>4. Technical Consideration</b>								
Technology							X	
Experience								
Using of diffusion theory							X	
Production of operation and maintenance materials								X
Skills availability								
Research, Development and innovation								
<b>5. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity							X	

Reducing water pollution									X
Provision of green infrastructure									X
Uses of less energy during construction									
Reducing carbon footprint									
Optimizing site potential ( Land use)									X
Ensuring efficient energy utilization both during construction and operation phases							X		
<b>6. Design and Project Management</b>									
Early contractors involvement at design stage									X
Involvement of community									X
Selection of appropriate contract/Experience									X
Flexible design to accommodate on site changes							X		
Proper construction quality control procedure							X		
Implementation of strategies specific to the project									
<b>7. Policy and Regulations</b>									
Presence of water delivery regulatory requirements									X
Water rating systems									
Inclusion of sustainability requirement in water briefs									
<b>8. Professionals and the delivery processes</b>									
Awareness of client about water projects									X
Awareness of contractors on water projects									
Knowledge and experiences of contractors/expert/designers									
Skills of designers/contractors/experts									

Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								<b>x</b>
Existing user cooperation.							<b>x</b>	
Collaboration and coordination among professionals								
Targeted education to stakeholders								

**SECTION B: CONCERNED WITH KEY DESIGNS AND OTHER INFLUENCES ON IMPROVING WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA**

**Which of the following influences offer the greatest impact opportunities for improving delivery of water services in developing countries such as South Africa if adapted generally?**

**Instructions**

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**IMPACT SCALE**

Aspect	IMPACT SCALE							
	1	2	3	4	5	6	7	8
<b>1. Economic Consideration</b>								
Life cycle analysis								
Cost efficiency								
Cost benefit analysis								
Bankability/Profitable								<b>x</b>
Measurement of implementation								
<b>2. Alternative Materials</b>								

Use of materials with low health risk and pollution in water projects								
Use of secondhand material							x	
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects								x
Use of locally available materials in Water projects								x
<b>3. Social Consideration</b>								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage							x	
Risk analysis and disaster mitigation								
<b>4. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								x
Production of operation and maintenance materials								x
Skills availability								
Research, Development and innovation								
<b>5. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								

Reducing effects on soil and the biodiversity								x	
Reducing water pollution									
Provision of green infrastructure									x
Uses of less energy during construction									x
Reducing carbon footprint									x
Optimizing site potential ( Land use)									x
Ensuring efficient energy utilization both during construction and operation phases								x	
<b>6. Design and Project Management</b>									
Early contractors involvement at design stage									
Involvement of community									
Selection of appropriate contract/Experience									
Flexible design to accommodate on site changes									
Proper construction quality control procedure									
Implementation of strategies specific to the project									
<b>7. Policy and Regulations</b>									
Presence of water delivery regulatory requirements									
Water rating systems									
Inclusion of sustainability requirement in water briefs									
<b>8. Professionals and the delivery processes</b>									
Awareness of client about water projects									
Awareness of contractors on water projects									
Knowledge and experiences of contractors/expert/designers									

Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								<b>x</b>
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos							<b>x</b>	
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

Thank you for participating in this study. In case of any queries, regarding this survey and the research, you may contact either my supervisor or me at

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### Delphi Round 3 Survey Questionnaire

Research Topic: IMPROVED INFRASTRUCTURE DELIVERY AND MANAGEMENT IN SOUTH AFRICA.  
 Thank you for participating in round 1 of the Delphi survey. I acknowledge your busy schedule and significant time you have invested in this survey. The purpose of round 2 is to provide you with a chance to change your response, if desired, given the median Delphi panel member's response of each statement. Completing the survey is intended to take approximately 15 -20 mins. Please return the completed questionnaire via email to [nkwonta@mut.ac.za](mailto:nkwonta@mut.ac.za)

Direction and Instruction: Next to each statement. You will find two values. Group median from round 1 survey indicated in the column to the far right of each table and your round 1 survey response

1. Accept the group median response by learning the statement rating completely unchanged.
2. Maintain your original round 1 response in the column box or
3. Indicate a new response by placing an x in the appropriate box

Note- if your response in action 2 or 3 above is more than two units above or below the group median of each statement. You may provide reason (s) for the difference at the end of the table eg. Group median 7 and your response is 4 or 10, this response is two units below or above the group median respectively.

The Questionnaire has two sections. Section A deals with the current design and other influences on current water services delivery and management in South Africa. Section B is concerned with key designs and other influences on improving water services delivery and management in South Africa

The Questionnaire has two sections. Section A deals with the current design and other influences on current water services delivery and management in South Africa. Section B is concerned with key designs and other influences on improving water services delivery and management in South Africa

#### SECTION A DEALS WITH THE CURRENT DESIGN AND OTHER INFLUENCES ON CURRENT WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA

#### Instructions

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**How important are the following influences in delivery of water services in developing countries such as South Africa today?**

#### IMPORTANCE SCALE

Aspect	IMPORTANCE SCALE							
	1	2	3	4	5	6	7	8
<b>1. Economic Consideration</b>								
Life cycle analysis								X
Cost efficiency							X	
Cost benefit analysis							X	
Bankability/profitable							X	
Measurement of implementation								X
<b>2. Alternative</b>								

<b>Materials</b>								
Use of materials with low health risk and pollution in water projects							X	X
Use of secondhand material							X	
Prescribing low energy material								
Utilizing potential of non-conventional materials in water projects								
Use of locally available materials in Water projects								
<b>3. Social Consideration</b>								
Client participation								
Provision of employment opportunities								
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage							X	
Risk analysis and disaster mitigation								
<b>4. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory								
Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								
<b>5. Environmental Consideration</b>								

Climate resiliency ( resistant to climate change)									
Reducing effects on soil and the biodiversity								X	
Reducing water pollution									X
Provision of green infrastructure									
Uses of less energy during construction									
Reducing carbon footprint									
Optimizing site potential ( Land use)									
Ensuring efficient energy utilization both during construction and operation phases									
<b>6. Design and Project Management</b>									
Early contractors involvement at design stage									
Involvement of community									
Selection of appropriate contract/Experience									
Flexible design to accommodate on site changes									
Proper construction quality control procedure									X
Implementation of strategies specific to the project									
<b>7. Policy and Regulations</b>									
Presence of water delivery regulatory requirements									
Water rating systems									
Inclusion of sustainability requirement in water briefs									
<b>8. Professionals and the delivery processes</b>									
Awareness of client about water projects									
Awareness of contractors on water projects									
Knowledge and experiences of									

contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								
Collaboration and coordination among professionals								
Targeted education to stakeholders								

**Summary of reason given by the panel of experts in round 2 survey**

Bankability can't influence delivery of water services delivery and materials have small contribution in delivery of water services to developing countries

**SECTION B: CONCERNED WITH KEY DESIGNS AND OTHER INFLUENCES ON IMPROVING WATER SERVICES DELIVERY AND MANAGEMENT IN SOUTH AFRICA**

**Which of the following influences offer the greatest impact opportunities for improving delivery of water services in developing countries such as South Africa if adapted generally?**

**Instructions**

Indicate your rate of agreement with the following statements based on your experience and judgement on a scale of 1-10 using a 10 point scale as shown below.

**IMPACT SCALE**

Aspect	IMPACT SCALE							
	1	2	3	4	5	6	7	8
<b>1. Economic Consideration</b>								
Life cycle analysis								X
Cost efficiency								
Cost benefit analysis								
Bankability/Profitable								X

Measurement of implementation								
<b>2. Alternative Materials</b>								
Use of materials with low health risk and pollution in water projects								X
Use of secondhand material							X	
Prescribing low energy material							X	
Utilizing potential of non-conventional materials in water projects								X
Use of locally available materials in Water projects							X	
<b>3. Social Consideration</b>								
Client participation								
Provision of employment opportunities								X
Beneficiaries participation								
Accessibility of the infrastructure to the public including people with specific needs								
Health and safety consideration for construction and operating stages								
Satisfaction of the public								
Protection of cultural heritage							X	
Risk analysis and disaster mitigation								
<b>4. Technical Consideration</b>								
Technology								
Experience								
Using of diffusion theory							X	
Production of operation and maintenance materials								
Skills availability								
Research, Development and innovation								

<b>5. Environmental Consideration</b>								
Climate resiliency ( resistant to climate change)								
Reducing effects on soil and the biodiversity								X
Reducing water pollution								
Provision of green infrastructure								
Uses of less energy during construction								X
Reducing carbon footprint								X
Optimizing site potential ( Land use)								X
Ensuring efficient energy utilization both during construction and operation phases								X
<b>6. Design and Project Management</b>								
Early contractors involvement at design stage								
Involvement of community								
Selection of appropriate contract/Experience								
Flexible design to accommodate on site changes								
Proper construction quality control procedure								
Implementation of strategies specific to the project								
<b>7. Policy and Regulations</b>								
Presence of water delivery regulatory requirements								
Water rating systems								
Inclusion of sustainability requirement in water briefs								
<b>8. Professionals and the delivery processes</b>								
Awareness of client about water projects								

Awareness of contractors on water projects								
Knowledge and experiences of contractors/expert/designers								
Skills of designers/contractors/experts								
Appropriating adequate time for design								
Willingness of designers/Engineers to implement sustainability design concept and practices in their design								
<b>9. Communication</b>								
Education level of the managers								
Stakeholder communication and consultation								
Collaborative working ethos								
Existing user cooperation.								X
Collaboration and coordination among professionals								
Targeted education to stakeholders								

**Summary of reason given by the panel of experts in round 2 survey**

Use of second hand materials does not have any connection with water services delivery. Bankability has no connection in water services delivery as a development economist. It is banks becoming largely convinced to stable cash flow loans to be repaid.

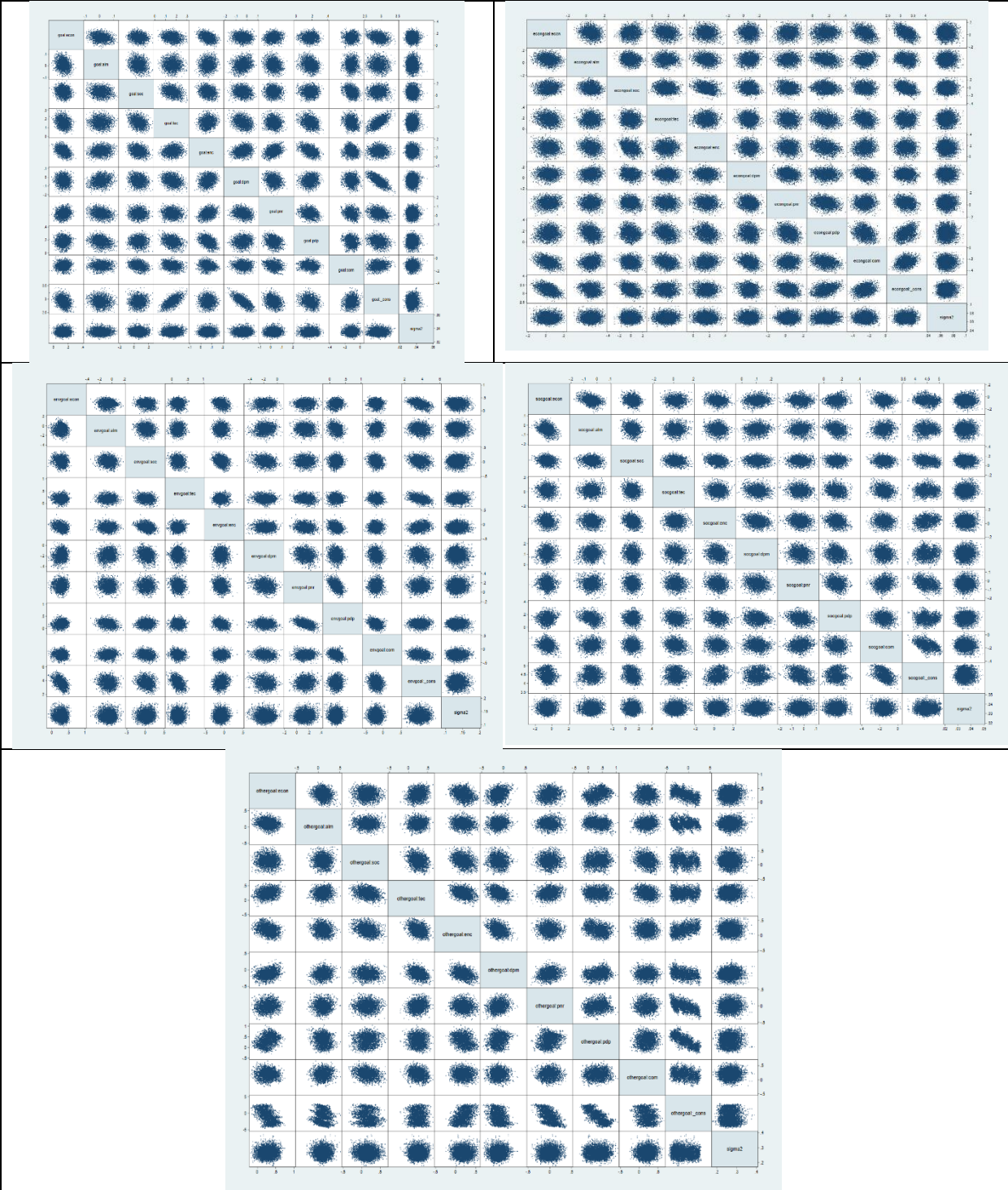
Provision of employment to stakeholders has allowed local people to take ownership of projects designed with local employment in the mind to forge backward and forward linkages with the rest of the economy. This is reflected in skill management and training and development. Item 8 and 9 (Professionals and communication). They are key as a requirement on improving delivery in the area of water services.

Thank you for participating in this study. In case of any queries, regarding this survey and the research, you may contact either my supervisor or me at

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**APPENDIX D: REGRESSION ANALYSIS**

Scatter plots matrix



Post-estimation test by parameters

