DEFECTS ON MUNICIPAL ROADS IN NORTH WEST PROVINCE OF SOUTH AFRICA: INTERNAL STAKEHOLDERS' VIEW ON THE COMMON TYPES, CAUSES AND PREVENTIVE MEASURES

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A RESEARCH REPORT SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE M.SC. IN BUILDING DEGREE AT THE SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT, UNIVERSITY OF THE WITWATERSRAND.

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FEBRUARY 2019

DECLARATION

I declare that this research project is my own unaided work. It is being submitted for the degree of Master of Science in Building at the School of Construction Economics and Management, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any university.

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(*Signature of Candidate*)

February, 2019.

ACKNOWLEDGEMENT

I wish to acknowledge the support of the following people whom have made the execution of this research project possible: my supervisor - Dr. Oluwayomi Babatunde for his guidance, my family members for their patience and understanding throughout the course of my study and this research in particular, and the respondents who took time to participate in this study. I could not have done this research project without all of you. Lastly, I would like to thank the two external examiners whose valuable feedback have provided additional insights to improve on this final version of the dissertation report.

ABSTRACT

Purpose: Premised on the overall condition of road pavements in South Africa and its resultant fatality rate and impacts on economic activities, the purpose of this study is to establish the nature of the defects on municipal roads in the North West province of South Africa. The nature is being explicated in terms of the common types, causative factors, and preventive measures for the defects. This information is necessary for the development and implementation of strategies to improve safe connectivity for national and regional activities.

Design/methodology/approach: A cross-sectional survey design was adopted. A structured questionnaire was administered to a sample using face-to-face approach. A stratified sample was drawn from a target population of internal stakeholders of road/ highway construction projects in the North West province of South Africa. This was complemented with a purposive sample of participants who have completed the defects liability period of a municipal road project within the five years prior to 2018. The 49 respondents include 11 implementation officers, 20 consulting civil and structural engineers and 18 contractors. The resultant data were analyzed using repeat measures ANOVA.

Findings: Related to the Northwest province of South Africa, the most common types of road defect on municipal roads are *potholes* and *crocodile cracking* with *bleeding/flushing* being the least common ($p>.05$). The main cause of the defects was *planning and coordination of on-site activities* while, paradoxically, *design changes during road construction* was found to be the least cause ($p<.05$). This paradox can be attributed to the contractor group's significant disagreement on *planning and coordination of on-site activities* as a main cause. Lastly, the top three important preventive measures were *contractors to ensure adherence to standards*, *defining acceptable quality from inception*, and *training for all on road construction standards*.

Research limitations/implications: The results cannot be readily generalized for South Africa because they have been derived from the North West Province. However, they have implications for the necessary intervention for good quality and safe road infrastructure.

Originality/value- Being based on the views of the three main groups of highway construction project internal stakeholders, this report presents a valuable holistic view as South Africa is committed to delivering its transport sectors' Millennium Development Goals.

Keywords

ANOVA, highway construction, patent defects, quality management, standards.

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ANSI	American National Standards Institute
ASQ	American Society for Quality
CIDB	Construction Industry Development Board
DTI	Department of Trade and Industry
ECSA	Engineering Council of South Africa
GDP	Gross Domestic Product
ISO	International Organization for Standardization
JBCC	Joint Building Contracts Committee
KPI	Key Performance Indicator
OCI	Overall condition index
SABS	South African Bureau Standards
SANRAL	South African National Roads Agency Ltd
SANS	South African National Standards
TQM	Total Quality Management

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CHAPTER 1 - INTRODUCTION

1.1 BACKGROUND

It is worth reiterating the reasons for developing and maintaining infrastructure; particularly, road infrastructure. Investments in infrastructure development yield significant economic development (Giang and Low, 2013). Infrastructure development has, historically, accounted for the different levels of gross domestic product (GDP) per capita between developed and developing countries (Madisson, 1983). BRICS countries (Brazil, Russia, India, China, South Africa) are fast closing this gap through sustainable infrastructure development (Santana *et al*., 2014). Road infrastructure development project is unique because it facilitates spatial/ physical connectivity and mobility (Gramaglia, 2016) and its cost-benefit evaluation is an important stage in the development process (Van Damme *et al*., 2016).

Conversely, road accidents have, historically, caused losses to the national economy in terms of GDP (Elvik, 2000). The social costs are 2.7% of GDP on average in high income countries and 2.2% of GDP in low and middle income countries, with 50% of the costs relating to injuries and 23% - 30% relating to fatalities (Wijnen and Stipdonk, 2016). The four causes of road accidents include failure types, psychological precursors, unsafe acts, and breakdown of defences, where the failure types represent the more permanent weaknesses within a system and the most important to be eliminated because it relates to defects in its design and construction (Wagenaar and Reason, 1990).

Defects during the design and construction stages lead to a rework, meaning that appropriate pro-active strategies need to be developed to reduce it in the first instance (Love and Edwards, 2004). Most defects in the highway construction industry have their roots in the design stage, where an unrealistic budget is established based on assumed existing conditions (Creedy *et al*., 2010). In order to prevent obvious design defects making it through to the construction stage, highway construction project design defects are classified as patent defects (discoverable upon a reasonable investigation of the plans) or latent defects (not reasonably discoverable) (Hanna *et al*., 2015).

The high probability of defects occurring on highway construction projects has led to a multi-level quality management practice being used, involving different tests and inspections to identify any non-conformance and/or its recurrence (Battikha, 2003). Post-completion, road networks undergo safety inspections (see Cafiso *et al*., 2011) to identify defects, including those that are likely to create a danger or serious inconvenience to road users or the wider community for immediate or urgent action to improve on road safety (see Hughes *et al*.,

2015). This remedial action or intervention is premised on understanding of the defects in terms of frequency, causes, and preventive measures (Lopez *et al*., 2010).

Central to this study, most of the municipal road projects in South Africa are marred by defects such that they constitute hazards (e.g., see Al-Masaeid, 1997) and do not reach their design life period. Mohammed and Labuschagne's (2008) study flagged South Africa as having the highest road accident fatality among the 22 countries considered, based on the International Road Safety Comparisons Report. Figure 1.1 illustrates the extent of the conditions of the road networks in South Africa between 2009 and 2013. Most of the road networks falls under the condition of fair and good. Similarly, Kannemeyer's (2016) report rated most road pavement condition in South Africa on overall condition index (OCI) values of fair and good. OCI values span from 0 to 100, where zero indicates that a road is impassable and 100 indicates that a road is in an excellent condition.

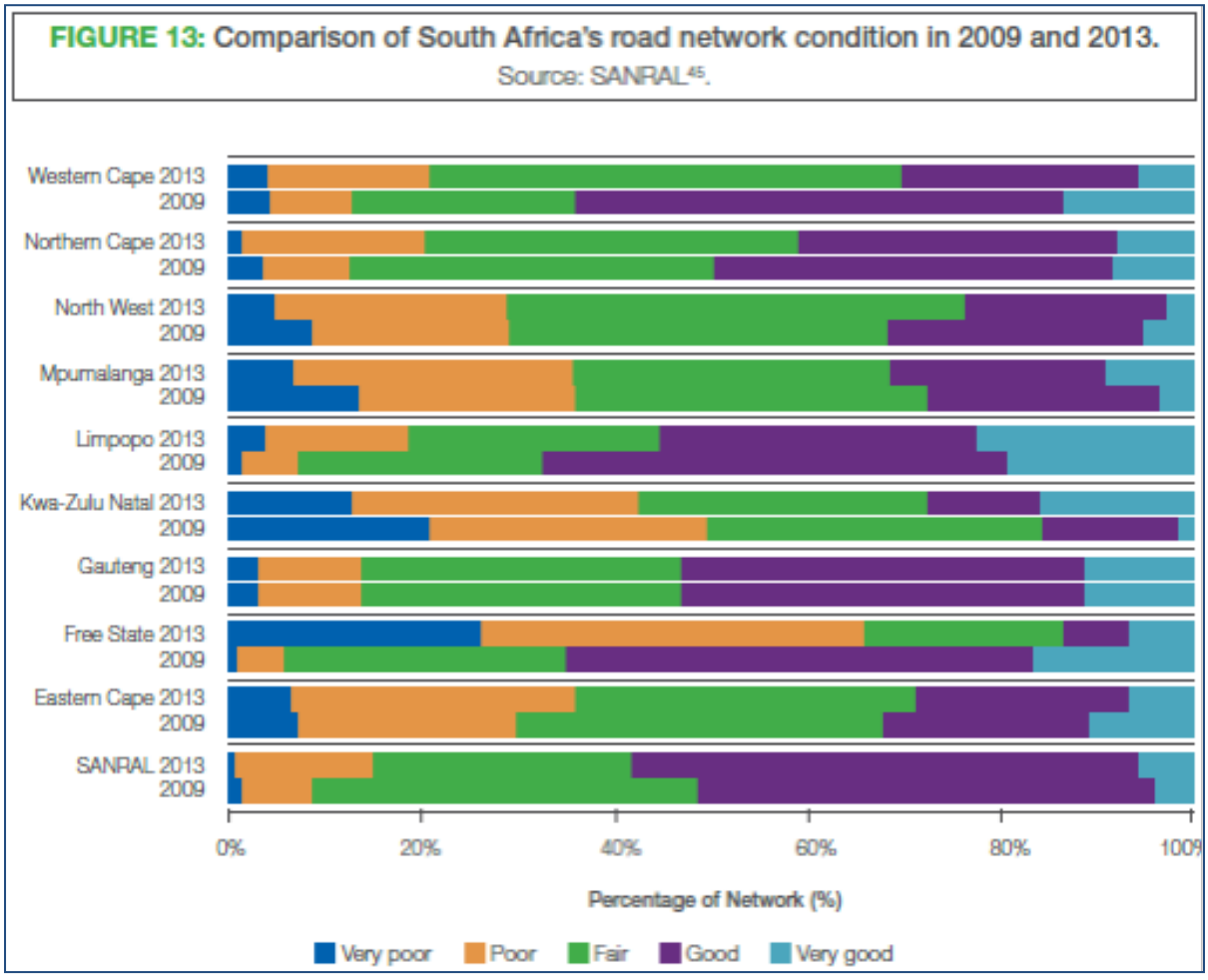

Figure 1.1: Comparison of South Africa's road network conditions between 2009 and 2013 (Source: 10th Annual State of Logistics Survey for South Africa, 2013)

Kannemeyer (2016) also indicated that about 40% of the overall paved roads across the nine provinces in South Africa are in poor condition as depicted in Figure 1.2. This is worrying considering that, according to Kannemeyer (2016), South Africa has the 10th longest total and 18th longest paved road in the world, with a replacement cost above two trillion rands (1 rand = 0.072 USD as of date). The replacement cost is to put most of South Africa's roads in very good condition.

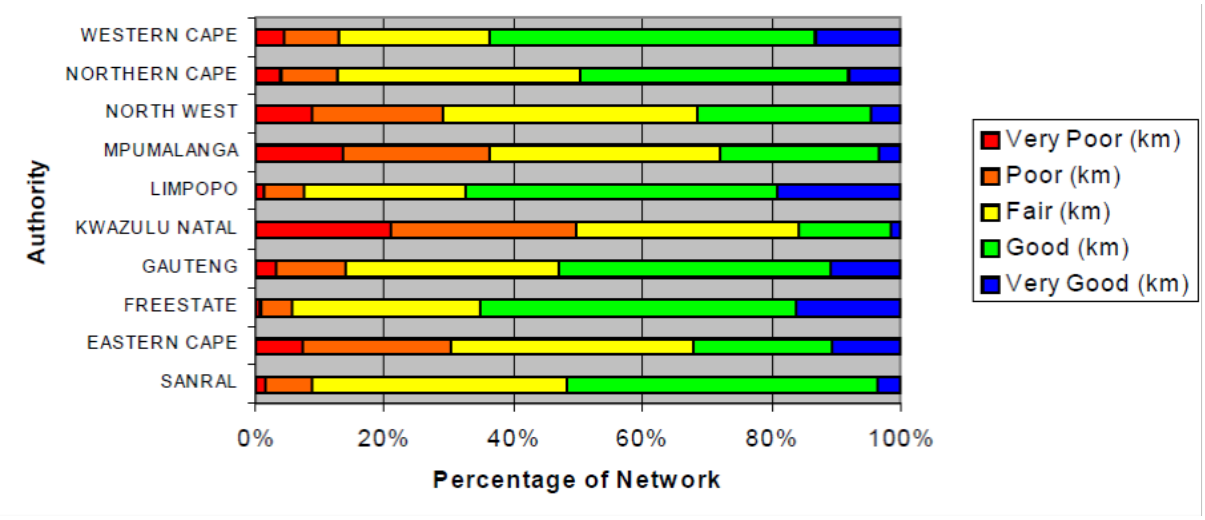

Figure 1.2: Status of provincial road conditions

(Source: Kannemeyer, 2016)

Granted that road networks need to be maintained, the fatality rate and high replacement costs raise the question on the underlying problem with regard to the defects experienced on road projects in South Africa. The completion of any road construction project has been based on some design and construction standards including specifications which have been approved by the relevant stakeholders (e.g., designers, constructors, and supervisors) appointed by the relevant government to do so. Some of the external stakeholders in South Africa include the South African National Standards (SANS), which was formerly known as South African Bureau Standards (SABS); the Construction Industry Development Board (CIDB) which is a national body established by an Act of Parliament (Act 38 of 2000), and the Engineering Council of South Africa (ECSA). In addition, South Africa also adopts international standards by the International Organization for Standardization (ISO). These external stakeholders regulate the roles and responsibilities of the internal stakeholders like the client's representatives, consultants, and contractors. This being the case, the common types, causes, and preventive measures for the road pavement defects need to be unearthed towards achieving a near zero defect in both the design and construction stages (Brewer and Bagranoff, 2004; Got and Xie, 1994; Wang, 2013). This information is

necessary for the development and implementation of strategies to improve safe connectivity for national and regional activities.

1.2 PROBLEM STATEMENT

The high number of defects on municipal roads in South Africa constitute safety threats and opportunity costs to replace and, as a result, affect intra- and inter-economic activities (Kannemeyer, 2016; Mohammed and Labuschagne, 2008). This is compounded by the different stakeholder groups involved in construction projects (Davis, 2014; Olander and Landin, 2008) and, particularly, mega projects like road (Mok *et al*., 2015). Consequently, it is important to investigate the road project internal stakeholders' views on the nature/type of the defects, causes of the defects and, in doing so, the their preventive measures. This is analogous to the systems approach to managing a problem (Lyneis and Ford, 2007).

1.3 RESEARCH AIM

The aim of the research is to establish the nature of the defects occurring on municipal pavement roads in the North West province of South Africa from the perspective of the internal stakeholders.

1.4 RESEARCH QUESTION

Tied to the research aim is the main research question of what is the nature of the defects on municipal pavement roads in the North West province of South Africa from the perspective of the internal stakeholders?

1.5 RESEARCH OBJECTIVES

The following three objectives were established to achieve the aim:

- ➢ To identify the common types of road defect;
- ➢ To examine the design- and construction- related factors causing road defects; and
- ➢ To recommend possible preventive measures.

1.6 RESEARCH HYPOTHESES

The following three hypotheses were established to achieve the preceding three objectives:

- ➢ There is no significant difference in the internal stakeholder group view on the common types of road defect;
- ➢ There is no significant difference in the internal stakeholder group view on the impact of the factors; and

- ➢ There is no significant difference in the internal stakeholder group view on the possible preventive measures.

1.7 RESEARCH METHODOLOGY

A cross-sectional survey design was used because the study was carried out once and over a relatively short period of time (Levin, 2006; Retting *et al*., 2003). A face-to-face structured questionnaire was used as the research method because of the advantage of its response rate over the telephonic interview (Holbrook *et al*., 2003) and e-mail questionnaire (Newman *et al*., 2002). Stratified random sampling technique (Teddlie and Yu, 2007) was used on a target population of public client representatives, civil and structural consulting engineers as well as contracting firms in South Africa's North West province. A purposive sampling technique was then used to obtain a homogenous sample of participants who have completed the defects liability period of a municipal road project within the five years prior to 2018; hence, a stratified purposeful sampling technique (Onwuegbuzie and Collins, 2007). The repeated measure analysis of variance (ANOVA) statistical tests (Bakeman, 2005; Games, 1990) were performed on the data to conclude on the hypotheses.

1.8 STRUCTURE OF THE REPORT

Chapter 1 provides the background for this research project leading to the research problem identified and its justifications. It discusses the research aim, question, objectives, hypotheses, and methodology to orientate towards and serve as the basis of the discussions presented in the subsequent chapters.

Chapter 2 focuses on the review of the literature with respect to the objectives and hypotheses of this study. The descriptive literature review (Pautasso, 2013) adopted and followed systematically for the objectives of this study. The chapter concludes with a summary of the relevant findings from the existing studies as a basis for the fieldwork.

Chapter 3 discusses the research design and method used in this study with respect to the objectives. It follows Saunders *et al*.'s (2016) research onion to discuss and justify the philosophy, approach to theory development, methodological choice, strategy, time horizon, and techniques and procedures used in this study.

Chapter 4 begins with a summary of the demographic profile of the respondents to gauge how well it reflects that of the survey population for external validity (Kelley *et al*., 2003). The descriptive statistics was then followed by statistical analysis for each hypothesis leading to the significant findings for each objective.

Chapter 5 concludes based on the empirical findings on the types, causes, and preventive measures for the defects on municipal roads in the North West province of South Africa. It discusses the practical/managerial and theoretical implications of the findings, including the limitations and recommendations for future study.

CHAPTER 2 - LITERATURE REVIEW

2.1 OVERVIEW

This chapter provides an overview of the literature review method and types with steps. It then reviews the existing literature on standards and quality management in general and for highway construction in particular. Related to the objectives of this study, it reviews the literature on the types of road defect, the causes of road defects, and existing preventive measures. It concludes by synthesizing the findings as a basis for the design of the research instrument to be adopted during the subsequent fieldwork.

2.2 IMPORTANCE OF LITERATURE REVIEW

Literature review deals with or involves a search and study of current writings on the problem under investigation because the research needs to be informed by existing knowledge in a subject area (Cronin *et al*., 2008). The literature review identifies and organizes the concepts in relevant literature because concepts transcend disciplinary boundaries and literature can be found in a wide range of different kinds of sources (Walker, 2000). In addition to integrating the essential knowledge on a concept under investigation, the literature review can also develop into a conceptual framework (Rowe, 2014) as exemplified by Seuring and Müller (2008).

Premised on the literature review, the conceptual framework grounds the study in the relevant knowledge bases that lay the foundation for the importance of the problem statement and research question(s); thus, made up of the relevant theoretical and empirical work (Rocco and Plakhotnik, 2009). The conceptual framework can be viewed as providing a theoretical overview of intended research and order within that process (Leshem and Trafford, 2007). The theoretical framework, on the flip side, synthesizes existing theories and related concepts and empirical research to develop a foundation for new theory development (Grant and Osanloo, 2014; Lederman and Lederman, 2015). Accordingly, Randolph (2009) indicated that literature reviews are important in:

- Supporting the identification of a research topic, question or hypothesis;
- Identifying the literature to which the research will make contribution;
- Building an understanding of theoretical concepts and terminology;
- Facilitating the building of a list of the sources that have been consulted;
- Suggesting research methods that might be useful; and
- Analyzing and interpreting results.

2.3 METHODS AND TYPES OF LITERATURE REVIEW

Yang and Tate (2012) identified the following four methods of conducting a literature review, relating to a study's focus progressively moving from being qualitative to quantitative: (1) *Narrative review* is the traditional and unsystematic way of reviewing the literature and is skewed towards a qualitative interpretation of the literature, which makes it vulnerable to subjectivity; (2) *Descriptive review* focuses on systematically revealing an interpretable pattern and trend, which is representative of the current state of a research domain/an investigated area; (3) *Vote counting* is used to draw inferences about focal relationships by combining individual research findings to see how they support a particular proposition; and (4) *Meta analysis* aims at statistically providing support for a research topic by synthesizing and analyzing the quantitative results on many empirical studies, including the relationships between certain independent variables and dependent variables. Meta analysis provides for a much less subjective literature review in a specific research context.

These methods of literature review serve as the basis for categorizing literature review into the following four types (see Cronin *et al*., 2008; Green *et al*., 2006): (1) *Traditional or narrative literature review*; (2) *Systematic literature review*; (3) *Meta analysis*; and (4) *Meta synthesis*, which is a non-statistical technique. The aim of this study is to investigate the nature of the defects occurring on municipal pavement roads in the North West province of South Africa from the perspective of the internal stakeholders. Consequently, its three objectives lend to adopting a combination of narrative and descriptive literature review methods. The conceptual framework of the crucial role of internal stakeholders in highway construction projects to establish the nature of pavement defects is adopted.

This adoption is because the project team plays a crucial role in the determination of defective construction work (Barrett, 2009). The project team can be categorised as dominant stakeholders because they have legitimate power (Mitchell, 1997). The project team are internal stakeholders of a construction project because they are directly involved in the decision-making process (Atkin and Skitmore, 2008). As the internal stakeholders, they are responsible for contract structuring for effective risk allocation, including dealing with the patent and latent defects (Hanna *et al*., 2015). Lastly and from Erlsten's (1967) study, the *American Jurisprudence Proof of Facts* asserts for defectively designed highways that:

> *"There are two basic design requirements in automobile safety: design to prevent traffic accidents and design to prevent injuries when a crash occurs…"*

The subsequent narrative and descriptive review of the literature was conducted based on library catalogues, search engines, and on-line databases using the keywords (please see the abstract) central to this study, as supported by Rowley and Slack (2004).

2.4 QUALITY AND QUALITY MANAGEMENT

It is important to understand quality and quality management as defined among practitioners and scholars. The American National Standards Institute (ANSI) and the American Society for Quality (ASQ) define quality as: “The totality of features and characteristics of a product or service that bears on its ability to satisfy given needs.” According to the International Organization for Standardization (ISO), quality management can be defined as: “All activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system.” ASQ defines total quality management (TQM) as “… a management approach to long-term success through customer satisfaction [in an effort in which] all members of an organization participate in improving processes, products, services, and the culture in which they work.”

In academia, quality has been defined as meeting the legal, aesthetic and functional requirements of a project, leading to quality being defined for the construction industry as meeting the requirements of the designer, constructor and regulatory agencies as well as the owner (Asim *et al*., 2013). The authors further indicated that quality in construction can be characterized by meeting the:

- requirements of the design as to provision of well-defined scope of work;
- meeting the requirements of the contractor with regard to provision of contract plans;
- trained staff and adequate building materials;
- meeting the requirements of the owner with regard to operation and maintenance;
- meeting the requirements of regulatory agencies with regard to public safety and health;
- environmental considerations;
- protection of public property including utilities; and
- conformance with applicable laws, regulations, codes and policies.

TQM in the construction industry according to the existing relevant studies (e.g., Harrington *et al*., 2012; Tan and Abdul-Rahman, 2011) is, as a result, a philosophy involving the following three words:

a) Total: Everyone in the organization is involved in creating and maintaining the quality of the services and products offered by the organization. It is a comprehensive way of dealing with complex sets of interacting issues involving everyone at all levels and addressing all major issues.

b) Quality: The organization through individual and collective actions focuses on meeting customer's needs, at lowest cost, first time and every time and hence recognizing that it is the customer's perception that identifies quality. Total quality therefore refers to achieving quality according to some requirements or laid down standards.

c) Management: While managing the system, the emphasis should be towards continuous improvement and not on quick fixes so that quality can be achieved. This requires everyone in the organization to be responsible for managing their own job. TQM portrays a whole systems view for quality management. TQM builds on the idea that an organization is an interactive network of communication and control.

The concept of quality and quality management in construction industry and, particularly, highway construction (e.g., Battikha, 2003; Erickson, 1989; Mungle *et al*., 2013) is to ensure efforts to achieve the required level of quality for the product are well planned and organized. The high costs of road accidents call for distributed, mobile, and social systems for road surface defect detection (Aksamit and Szmechta, 2011). The realization augurs well and supports the conceptual framework of internal stakeholder management (Atkin and Skitmore, 2008; Nyandika and Ngugi, 2014) adopted in this study.

2.5 STANDARDS

A standard provides generally acceptable best practices against which the extent of non-compliances or defects can be measured (Crawford, 2007). ISO 8402 standard defines quality as the degree of excellence in a competitive sense, such as reliability, serviceability, maintainability or even individual characteristics. It is therefore critical and important to look into the relevant standards for requirements and procedures (e.g., Fayek *et al*., 2004), the violation or omission of which could contribute to defects that occur within the municipal roads in South Africa.

2.5.1 CIDB STANDARDS

The construction industry development board (CIDB) prescribes best practices and sets national standards. CIDB promotes common and ethical standards for delivery of construction projects and contracts. To implement these objectives, South Africa's CIDB is mandated to establish:

- ➢ Code of conduct for all role players in the construction process;
- ➢ Standard for uniformity in Construction Procurement
- ➢ National register of projects; and
- ➢ National register of contractors.

Furthermore CIDB's standard for uniformity in construction procurement requires that employers enter into a contract for construction works using one of the following standard forms of contract:

- ➢ General Conditions of Contract for Construction Works;
- ➢ Conditions of Contract for Construction;
- ➢ Conditions of Contract for Plant and Design-Build;
- ➢ Conditions of Contract for FIDIC EPC/Turnkey Projects or Short Form of Contract;
- ➢ JBCC series 2000 Principal Building Agreement or Minor Works Agreement; or
- ➢ NEC3 Engineering and Construction Short Contract or NEC3 Engineering and Construction Contract.

In order to avoid poor management on the site, CIDB's guide carefully articulates how the work should be carried out from site handover to completion period. During this phase, the contractor does the work in accordance with the requirements of the Scope of Work, specifications and standards; hence, the Employer pays the Contractor for work which is properly done and certified by employer's representatives. The Engineer provides all the information which is necessary for the Contractor to do the work.

2.5.2 SABS/SANS

Each municipality is required develop their special conditions of contract based on the South African National Standards (SANS) and general conditions of contract. SANS is an independent body reporting to the Department of Trade and Industry (DTI). SANS develops

and distributes specifications and accredits the South African Bureau of Standards (SABS) as a testing and certification body in South Africa (Engineering News, 2016). According to SANS, the following standards need to be part of any contract between the contractor and the municipality government for road construction projects:

- General

This section covers the principles, responsibilities and requirements applicable to the contract as a whole, to certain tender conditions, as well as to all work and costs involved in the establishment of the contractor's organization, camps and construction equipment on the site, and their removal after completion of the work.

- Ancillary works

This section covers the clearing of the site and the necessary construction of the works covered by the contract

- Earth works

This section covers provisions of a general nature relating to all earthworks and trenching operations.

- Drainage and erosion protection

This section covers all the work in connection with the construction of subsurface drains and drainage blankets at the locations and to the sizes, shapes, grades and dimensions as shown on the drawings or as directed by the engineer.

- Roads and parking areas

This section covers the construction of sub grade and sub base layers using un-stabilized or stabilized selected gravel material and the construction of base layers using only un-stabilized material. This section does not, however, include the construction of shoulders and gravel wearing courses, which are dealt with under section 603.

- Structures

This section covers the foundation work for all structures except prefabricated culverts and pipes, and it also covers excavations to accommodate structures and for the founding of structures, as well as dewatering, cofferdams, backfilling, foundation fill, grouting.

- Specific works

This section covers various requirements and items of work associated with the construction of concrete reservoirs and which are not covered by other sections of these specifications.

Some of the items in this section, however, apply to other water-retaining structures such as pumping stations, sedimentation tanks.

- ➢ Quality control

This section covers the general responsibilities of the contractor for ensuring that the quality of workmanship and materials provided under the contract comply with the requirements of the contract. It also describes the engineer's responsibilities and authority regarding acceptance control and lays down general principles in dealing with substandard work and remedial measures.

2.5.3 ISO STANDARDS

ISO develops voluntary, consensus-based, market relevant international standards that support innovation and provide solutions to global challenges (ISO, 2018). These standards provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. International standards are the backbone of our society, ensuring the safety and quality of products and services, facilitating international trade and improving the environment in which we live in. A SANS standard may be either locally written or created by adopting an international (usually, ISO) standard (Infrastructure News, 2016). Conformity to international standards helps reassure consumers that product, systems and organizations are safe, reliable and good for the environment (ISO, 2018).

Accordingly, an ISO standard has been created to meet five objectives:

- ➢ Achieve, maintain, and seek to continuously improve product quality in relation to the requirements;
- ➢ Improve the quality of operations to continually meet customers' and stakeholders' needs;
- ➢ Provide confidence to internal management that quality requirements are being met;
- ➢ Provide confidence to the customers that quality requirements are being met; and
- ➢ Provide confidence that quality system requirements are fulfilled.

Under road construction, the standards will cover general earthworks, excavations, foundations construction, bridge construction and road engineering. The standards will also prescribe the key performance indicators (KPIs). Horak *et al*. (2001) articulated that road project KPIs are designed to be objective measures of performance for a road authority such as the the following three aspects that need to be addressed in asset management KPIs for roads:

- ➢ Performance – which are functionally related such as measuring skid resistance, rutting, texture, and roughness;
- ➢ Visual appearance – including number, degree and extent of defects; and
- ➢ Structural –which include determination and calculation of remaining life.

These KPIs coupled with optimal maintenance and rehabilitation policies are the basis for the performance-based road maintenance contracts (Abu Samra *et al*., 2016). Performance-based road maintenance contracting is a challenge for public sector projects (Richmond *et al*., 2016), especially in developing countries (Sultana *et al*., 2012).

2.6 DEFECTS

Defects are associated with factors such as quality deviations (Burati *et al*., 1992), non-conformance (Abdul-Rahman, 1995), and quality failures (Love and Li, 2000). Defects can arise because the work was not carried out in correctly and in accordance with good practice or a particular design, or because the wrong materials have been used (Adlinge and Gupta, 2013). Alternatively, the designer could be at fault because a defect means that a particular design is not working in the manner that it should. In the frequently used design and build scenario, the contractor would normally have the primary the liability for design and build failures. An an overarching principle, the Joint Building Contracts Committee (JBCC) defines a defect as “any aspect of material and workmanship forming part of the works that, in the opinion of the principal agent, is due to the failure of the contractor to comply with his obligations in terms of the agreement” (MDA Consulting, 2015).

The precise description of pavement surface defects is of primary importance when defining road surface conditions in order to establish a diagnosis of the problems encountered and selecting the most appropriate maintenance treatment. This description must be understandable to all; hence, the aim of this study is to investigate the nature of the defects occurring on municipal pavement roads in the North West province of South Africa from the perspective of the internal stakeholders. It is, in particular, essential that engineers concerned with road maintenance have a common language for describing what they observe on road surfaces (Highways Department, 2013). Road defects are “the visible evidence of an undesirable condition in the pavement affecting serviceability structural condition or appearance” (Highways Department, 2013; Oxfordshire County Council, 2013). However, in considering defects as a matter of principle, work may be defective even if it has been carried out with all due skill and care but it fails to meet a particular specification. (Highway Department, 2013).

A patent defect is one that is detectable either at or before apparent practical completion or during the defects liability period, and a latent defect is one which has been concealed in the works and may not become apparent for many years (Hanna *et al*., 2015). Latent defects are caused by various deficiencies in the design, poor quality of construction, and inefficient maintenance management (Chong and Low, 2006). Defects within new infrastructures are a result of non-compliance with the Building Code or Construction Code and published acceptable tolerances and standards. Defective building construction not only contributes to the final cost of the product but also to the cost of maintenance, which can be substantial, since defective construction may lead to the complete failure of a structure (Ganesh *et al*., 2016). This is a reason that many countries have established road surface deficiency catalogues, including South Africa (see SANRAL, 2013).
However, it is not enough to draw up a descriptive list, the various types of defects must also be classified, their most likely cause(s) assessed and appropriate remedies agreed. Hence, the three objectives of this study as discussed in the preceding chapter. This is a system view taken to understand the nature of the pavement road defects in South Africa.

2.6.1 Common types of defect on road projects

Pavement failure is defined in terms of decreasing serviceability caused by the development of cracks and ruts (Adlinge and Gupta, 2013). From the existing relevant studies (see Highway Department, 2013; Oxfordshire County Council,; SANRAL, 2013), the six common types of pavement road defects are: (1) rutting; (2) crocodile cracking; (3) longitudinal cracking; (4) bleeding/flushing; (5) pumping; and (6) and potholes.

- Rutting – This typically occurs over long sections where the axle loads cause consolidation or shear failure of one or more pavement layers. The narrower the rutting, the higher in the pavement the deformation has normally occurred;
- Crocodile cracking – This is the typical cracking that occurs in the wheel path when axle loads cause excessive flexure and cracking of the surfacing. They are normally barely visible to the naked eye until more water ingresses through the cracks;
- Longitudinal cracking – This is normally due to deep-seated movement under the pavement such as slip failure or shrinkage of clayey sub grades. It is also regarded as an unconnected crack running longitudinally along the pavement;
- Bleeding/flushing – This is caused by the binder migrating to the surface of the pavement, and occurs when a mix has a high binder content, known as a “rich” or “fatty” mix. It is a partial or complete aggregate immersion into the binder;

- ➢ Pumping – This occurs when the fine material from the underlying layer is pumped through surface cracks by traffic loads. It is often the first indicator of pavement failure, detectable by lines looking like white powder at the edges of the crack; and
- ➢ Potholes – This occurs when the cracked area of surface lifts off the base and the traffic causes the base to erode. They are bowl-shaped depressions in the pavement developing from another defect and allowing water entry.

These common types of defect lead to the first hypothesis of this study as "*there is no significant difference in the internal stakeholder group view on the common types of road defect*".

2.6.2 Design and construction factors leading to road defects

Design and construction are the two important phases of project life cycle which affect the quality outcome of construction projects significantly (Lopez *et al*., 2010; Love and Li, 2000). Design and poor workmanship in the construction process combined to form more than 90% of the total failure events (Ali and Wen, 2011). From the existing relevant studies (see Callistus *et al*., 2014; Ganesh, 2016; Park *et al*., 2013; Love and Edwards, 2004; Shittu *et al*., 2013), the ten design- and construction-related factors causing pavement road defects are: (1) deformation or aging of pavement; (2) non-adherence to road construction standards; (3) design changes during road construction; (4) absence of on-the-job training programs; (5) inexperience and incompetence of the laborers; (6) poor supervision and inspection for quality assurance; (7) control over the nominated subcontractors; (8) planning and coordination of on-site resources; (9) motivation and commitment of the site management; and (10) the impact of the contractual arrangement.

- ➢ Deformation or ageing of pavement – the permanent deformation of asphalt mixture is a major distress that could result in unsafe driving conditions such as accelerating moisture damage, and in some cases steering problems;
- ➢ Non-adherence to road construction standards – adherence to road standards through development, certification, accreditation, and implementation augurs well for preventative maintenance of roads rather than dealing with defective roads;
- ➢ Design changes during road construction – design change increases cost and time production and redesign substantially. In many instances, the redesign costs are so substantial that the change is not implemented, leading to defects;
- ➢ Absence of on-the-job training programs – these involve intentional learning in terms of the duration, objectives, resources, and evaluation to gauge training effectiveness measured along trainees' reactions, results, job behavior, and returns;

- ➢ Inexperience and incompetence of the laborers – the, generally, skilled labour shortage and, particularly, perceptions of the construction industry as being dirty, demeaning, and demanding have affected the experience and competence thereof;
- ➢ Poor supervision and inspection for quality assurance – supervision and inspection have a major influence on the overall performance and efficiency of construction projects; otherwise, the resultant situation of defects and reworks prevails;
- ➢ Control over the nominated subcontractors – this is client's quest to retain some control over the selection of specialist contractor without necessarily becoming directly involved in detailed contractual arrangements with the specialist;
- ➢ Planning and coordination of on-site resources – This deals with the contractual arrangements, on-site management (site assessment and layout, site mobilization and on-site administration and control), and resource planning/programming;
- ➢ Motivation and commitment of the site management – this is vital to the future success of the construction project because, if recognized correctly, managers can avoid the high costs of turnover, including from the intrinsic factors; and
- ➢ The impact of the contractual arrangement – poor governance in public construction is a major issue. Governance failures can lead to the construction of the wrong infrastructure, poor quality construction and excessively high prices for work.

These design- and construction-related factors leading to road defects are the basis of the second hypothesis of this study as "*there is no significant difference in the internal stakeholder group view on the impact of the factors*".

2.6.3 Measures to prevent/minimise road defects

The concept of total quality management (TQM) is generally understood, and often also described, as some form of "management philosophy" based on a number of core values, such as customer focus, continuous improvement, process orientation, everybody's commitment, fast response, result orientation and learn from others (Hellsten and Klefsjö, 2000). Through the lens of TQM from the existing relevant studies (see Andy and Price, 2010; Bhamber and Kerridge, 2010; Fapohunda, 2014; Harrington *et al*., 2012; Haupt and Whiteman, 2004; Hoonakker *et al*., 2010; Jha and Iyer, 2006; Ling and Tan, 2015; McCollough and Benson, 1993), the ten preventive measures for pavement road defects are: (1) defining acceptable quality from inception; (2) training for all parties on road construction standards; (3) adhering to all road construction standards; (4) attention to design and construction strategies; (5) standards-compliant material and equipment; (6) employers to ensure adherence to their standards; (7) consultants to ensure adherence to standards; (8) contractors to ensure adherence to standards; (9) contract-based risk assessment for changes; and (10) qualified construction manager to lead.

- ➢ Defining acceptable quality from inception – unlike the idealistic zero defects, the acceptable quality level is what customers set as the maximum number of acceptable quality limits based on business, financial and safety levels;
- ➢ Training for all parties on road construction standards – road design and construction standards play a key role in ensuring defects-free products because they ensure technical soundness, operability; and, eventual, maintainability;
- ➢ Adhering to all road construction standards – standards go through the three major steps of invention, formalization, and proliferation. Adherence to road construction standards is important for the review process for continuous improvement;
- ➢ Attention to design and construction strategies – Besides standards, there are design and construction strategies that can be used to mitigate defective design and methods of construction as well as the safety risk associated the final product;
- ➢ Standards-compliant material and equipment – the, generally, skilled labour shortage and, particularly, perceptions of the construction industry as being dirty, demeaning, and demanding have affected the experience and competence thereof;
- ➢ Employers to ensure adherence to their standards – supervision and inspection have a major influence on the overall performance and efficiency of construction projects; otherwise, the resultant situation of defects and reworks prevails;
- ➢ Consultants to ensure adherence to standards – the engineering consultants involved should ensure adherence to the clients standards and, in addition, be able to meet and match the changing demands of the construction sector;
- ➢ Contractors to ensure adherence to standards – the need for contractors' strict adherence to standards is not to stifle their creativity. Standards exist for quality assurance so much so that substantial compliance will have the same effect;
- ➢ Contract-based risk assessment for changes – like any large-scale engineering project, road construction face an increasingly turbulent environment, governability can be improved through strategic contract packaging for robustness; and
- ➢ Qualified construction manager to lead – the turbulent environment of engineering projects necessitate construction managers who are adaptable to the changing demands both in management and general manpower development policies.

These measures to prevent or minimise road defects are the basis of the third and last hypothesis of this study as "*there is no significant difference in the internal stakeholder group view on the possible preventive measures*".

2.7 SUMMARY

A combination of narrative and descriptive literature review methods were used to review the existing standards for quality management in highway construction projects. In addition, the conceptual framework of the crucial role of internal stakeholders in highway construction projects was adopted. The literature review and conceptual framework culminated in six common types of road defects, ten design- and construction-related factors that could potential lead to these road defects, and ten possible mitigation/preventive measures. These findings from the literature review will serve as the basis for the field investigation in the North West province of South Africa as discussed in the next chapter.

CHAPTER 3 - RESEARCH DESIGN AND METHOD

3.1 OVERVIEW

This chapter discusses the research design and method used to achieve the aim and objectives of this study. The research design and research method are discussed within Saunders *et al*.'s (2016) research onion in a bid to also justify the philosophy, approach to theory development, methodological choice, strategy, time horizon, and techniques and procedures used in this study. It elaborates on the ethical procedures followed as well as the population, sampling technique and sampling frame.

3.2 RESEARCH ONION

As presented in Figure 3.1, the research onion illustrates the stages that must be covered when developing a research strategy. When viewed from the outside, each layer of the onion describes a more detailed stage of the research process (Saunders *et al*., 2016)

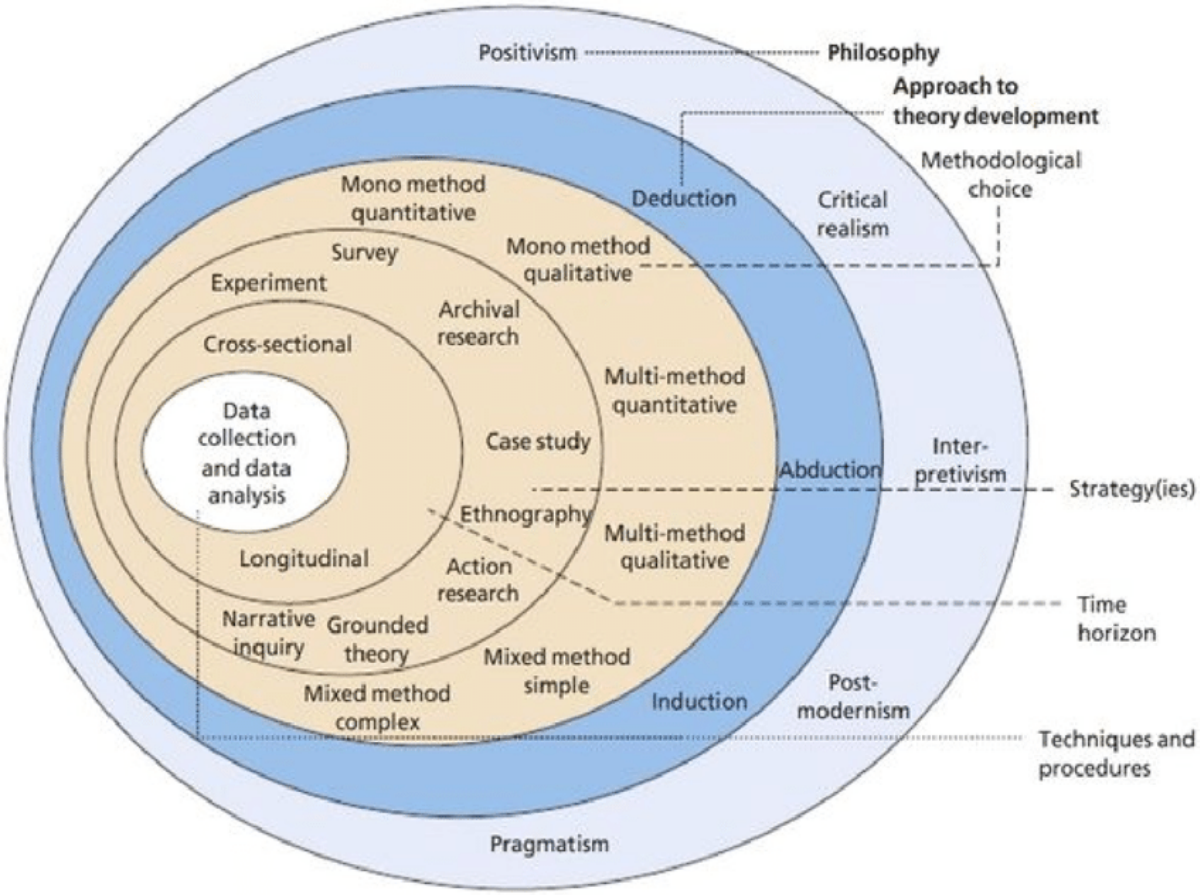

Figure 3.1: The research 'onion'

Source: Saunders *et al*. (2016)

The research onion provides an effective progression through which a research methodology can be designed. The usefulness of this tool lies in its adaptability for almost any type of research methodology and can be used in a variety of contexts (Bryman, 2016). A researcher's understanding and associated decision with regard to outer layers of the onion provide the context and boundaries within which data collection techniques, processing of data and analysis procedures take place (Sahay, 2016).

3.2.1 Research philosophy

From the first layer of the onion model, the research philosophy used in this study is positivism. Saunders *et al*. (2016) conceived positivism as relating to the philosophical stance of the natural scientist and entailing working with an observable social reality to produce law-like generalizations. On the contrary, qualitative purists (also called *constructivists* and *interpretivists*) reject positivism on the ground that multiple constructed realities abound such that time- and context-free generalizations are neither desirable nor possible because research is value-bound (Johnson and Onwuegbuzie, 2004). It should, nonetheless, be stressed that misconceptions abound with regard to positivism, attributable to its basic assumption that real causes exist (Hunt, 1991). The strengths of the positivist research lie in the use of existing theories to develop hypotheses to be confirmed or refuted, the conscious efforts to remain neutral and detached from the research and the overarching emphasis on the scientific method, statistical analysis, and generalizable findings (Mark, 2010). It is because of the preceding ontological, epistemological, axiological, and methodical stances that this study's research philosophy is positivism.

3.2.2 Research approach

From the second layer of the onion model, the research approach used in this study is deductive. Saunders *et al*. (2016) conceived the deductive approach as being typified by theory building and research design strategy for theory testing. Deductive reasoning is a theory testing process which commences with an established theory or generalization, and seeks to see if the theory applies to specific instances (Hyde, 2000). Deduction begins with an expected pattern that is tested against observations, whereas induction begins with observations and seeks to find a pattern within them (Babbie, 2016). A deductive approach makes interpretation much easier and it answers the main question of whether what a researcher has conceptualized is valid (Jahn, 2011). The deductive approach has the advantages of the possibility to: explain causal relationships; measure concepts quantitatively; and generalize research findings to a certain extent (Arifin, 2016). Deduction owes much to what can be thought of as a scientific research (Saunders *et al*., 2016); hence, appropriate for this study which seeks to test hypotheses.

3.2.3 Research methodological choice

From the third layer of the onion model, the research methodological choice used in this study is quantitative. Saunders *et al*. (2016) distilled the quantitative research as being characterized by numeric (i.e., numbers) data collection technique (such as a questionnaire) or data analysis procedure (such as graphs or statistics). The quantitative approach has grown out of a strong academic tradition that places considerable trust in numbers represent ing opinions or concepts (Amaratunga *et al*., 2002). In a quantitative study any number of strategies can be adopted when collecting data and these can include interviews, questionnaires, attitude scales or observational tools (Corner, 2002; Coughlan *et al*., 2007). For this study, the mono method quantitative method is used because a single data collection technique involving the questionnaire and corresponding quantitative analytical procedure was used as supported by Saunders *et al*. (2016). The main assumption underpinning the quantitative research is that human behaviour can be explained by what may be termed ``social facts'' which can be investigated by methodologies that utilize ``the deductive logic of the natural sciences'' (Amaratunga *et al*., 2002).

3.2.4 Research strategy

From the fourth layer of the onion model, the research strategy used in this study is the survey. Saunders *et al*. (2016) saw the survey strategy as usually associated with a deductive research approach, allowing to collect quantitative data for quantitative analysis using descriptive and inferential statistics. Consequently, the purpose of the survey is to produce statistics that is quantitative or numerical descriptions about some aspects of the study population (Fowler, 2013). From Kelley *et al*. (2003), the advantages of the survey research strategy include: (1) producing data based on real-world observations (empirical data); (2) data collection from a more representative sample; and (3) large amount of data in a short time for a fairly low cost. The disadvantages include: (1) trade-off between data coverage and data relevance for relevant issues, problems, or theories; and (2) the difficulty to control for a high response rate be it by post, face-to-face or over the telephone. A survey can be exploratory (for preliminary insights), confirmatory/explanatory (for theory testing) and descriptive (for deeper understanding) (Forza, 2002). This study used a face-to-face confirmatory survey to establish the nature of municipal road defects.

3.2.5 Research time horizon

From the fifth layer of the onion model, the research time horizon used in this study is the cross-sectional survey. Saunders *et al*. (2016) described the cross-sectional survey as

being carried out to study a particular phenomenon at a particular time as against over a period of time to identify trend in the form of either a change or a development. In other words, it is used to determine prevalence (Mann, 2003). Its main drawback is its potentially higher degree of bias since it is completed by a group of respondents or a single respondent at a single point in time (Maxwell and Cole, 2007; Rindfleisch *et al*., 2008). By and large, a cross-sectional survey is used when the purpose of the study is: (1) descriptive, often in the form of a survey; and (2) to find the prevalence of the outcome of interest, for the population or sub-groups within the population at a given timepoint (Levin, 2006). The following advantages make the cross-sectional survey design the most potent for this study: (1) relatively inexpensive and little time to conduct; (2) can estimate prevalence of outcome of interest because sample is usually taken from the whole population; and (3) there is no loss to follow-up because participants are interviewed only once (Sedgwick, 2014).

3.2.6 Research techniques and procedures

The techniques and procedures cover the myriad of considerations, including ethics, involved in the systematic approach of collecting the required information or data from the participants. The data are either existing but reused for another research goal; that is, secondary data or purpose-generated for a specific research goal; that is, primary data (Hox and Boeije, 2005). Systematic data collection is important because it is only possible to obtain sample data from a sub-group of the population (i.e., target or accessible population) to investigate the phenomenon under consideration (Barreiro and Albandoz, 2001). This, on the one hand, ensures a study's credibility and integrity as well as its methodology's validity and reliability on the other hand (Coughlan *et al*., 2007). Reliability refers to replication and consistency of an earlier research design to achieve the same findings while validity refers to the appropriateness of the measures used, accuracy of the analysis of the results and generalizability of the findings (Saunders *et al*., 2016). This it to ensure population generalizability, both in qualitative research (Leung, 2015) and quantitative research (Polit and Beck, 2010). These considerations are discussed in detail in the subsequent sub-sections as applicable to this present study.

3.3 RESEARCH INSTRUMENT

Before collecting any data, the researcher will need to design a research instrument. Research instruments are simply devices for collecting relevant information for addressing the objectives of a research project, and there are many alternatives from which to choose (Wilkinson and Birmingham, 2003). The research instruments are, in other words, the research methods (Davis, 1992) and they exist in diverse forms; for example, see Charyton

et al.'s (2008) study on creative engineering design assessment and Lloria and Moreno-Luzon's (2014) on the design of a research instrument for measuring organizational learning. The common research instruments in the descending order of researcher control, from being researcher-led to participant-led, include questionnaires, interviews, content analysis, focus groups, observations, and video analysis (Wilkinson and Birmingham, 2003).

For this study, a closed-ended or structured questionnaire was used as presented under Annexure 1. The questionnaire has two main sections (A and B). Section A sought four sets of primary data on the participants background including their positions in their respective client, consultant or contractor organizations; their highest post-Grade 12 educational qualification; years of post-Grade 12 working experience, and, lastly, gender. Section B sought three sets of primary data on the levels of occurrence of the common road defects (Section B1), how the design- and construction-related factors account for the defects (Section B2), and the importance of the identified preventive measures (Section B3).

The structured questionnaire was administered face-to-face. Closed-ended questionnaires provide the inquirer with quantitative or numerical data (Zohrabi, 2013). The face-to-face mode has the advantage of response rate over both the online/e-mail questionnaire (Newman *et al*., 2002) and telephonic interview (Holbrook *et al*., 2003). The other advantages and disadvantages of the paper-based face-to-face and online questionnaires are summarized in Table 3.1. Likert scale items developed from the findings through the literature review on the common types of road defects (Section 2.6.1), factors leading to road defects (Section 2.6.2), and measures to prevent/minimize road defects (Section 2.6.3) were used as shown in Sections B1, B2, and B3 of **Annexure 1**.

3.4 RESEARCH ETHICS

Ethics in a research project refer to the standards of behavior that guide a researcher's conduct in relation to the rights of those who either become the subjects of the research projects or are affected by the outcome of the research projects (Saunders *et al*., 2016). Premised on the different social norms and philosophical approaches, ethical considerations do exist along the dimensions of the specific discipline of the study and the particular case under study (Horton, 2008). Consequently, ethical judgements in research demand that an individual make a personal evaluation of the degree to which some behavior or course of action is ethical or unethical (Sparks and Pan, 2010).

Table 3.1: Face-to-face versus online surveys

Type	Advantages	Disadvantages
Paper surveys	People may be more likely to fill in paper surveys than online surveys.	Have to print, hand out and collect the questionnaires.
	If posting out surveys, need to bear in mind the postage costs for sending and receiving.	
	Collating and analysing the data takes time.	
Online surveys	People may find it more flexible to respond and easier to understand, if designed carefully.	Have to get used to the software and set up the survey online.
	No postage or printing costs.	Access people's email addresses for the link to the online survey.
	Collates the data for you, which saves time and makes analysis easier.	Only people who have internet access will be able to fill in the survey.

The potential ethical dilemmas arising from different social norms and conflicting philosophical approaches saw this study abiding by the codes of ethics prescribed by the School of Construction Economics and Management's ethics committee in line with the codes, rules, and policies of the University's research ethics committee (e.g., see Resnik, 2011). This study involved humans as its main subjects and objects; hence, the need to obtain a formal permission in the form of clearance to do the research following the formal submission of the procedural ethical practices as supported by Lundin (2011). A copy of the ethics clearance certificate for this study can be found under **Annexure 2**.

Realizing that all people recognize some common ethical norms but different individuals interpret, apply, and balance these norms in different ways in light of their own values and life experiences, some specific ethical considerations taken in this study and supported by Lundin (2011) include: (1) not falsifying data; (2) not disclosing company/individual secrets; (3) respecting the desire of actors to keep personal matters away from the public; and (4) being constantly aware of the dangers inherent in balancing real case data with fictional data. These are rooted in the following ethical principles garnered from Resnik (2011): (1) honesty; (2) objectivity; (3) integrity; (4) carefulness; (5) openness; (6) respect for

intellectual property; (7) confidentiality; (8) responsible reporting/publication (9) social responsibility; (10) non-discrimination; and (11) human subject protection.

3.5 POPULATION

A population is an entire group about which some information is required to be ascertained (Banerjee and Chaudhury, 2010). The population for this study was the internal stakeholders of highway construction projects in the nine provinces in South Africa. The nine provinces are presented in Figure 3.2.

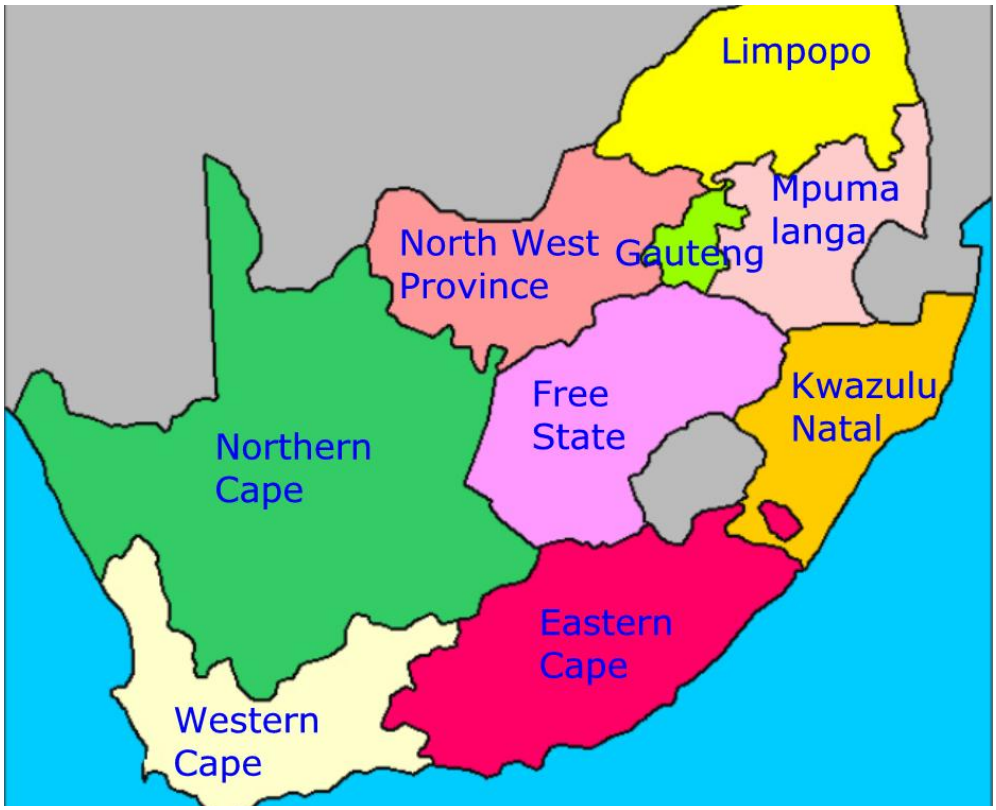

Figure 3.2: Provinces in South Africa

This population being large lends to this study's target population, or subset of the population, according to Acharya *et al*. (2013), to be the internal stakeholders working on municipal road projects in South Africa's North West province as presented in Figure 3.3.

Figure 3.3: North West Province, South Africa

These internal stakeholders represent the study elements and they include senior managers and mid-level line managers at the different client, consultant, and contractor organizations. Employees of the North West Provincial Government's Department of Public Works and Roads (www.nwpg.gov.za) were the target population for the client organization; employees of civil engineering consulting organizations in the North West province were the target population for the consultants, and employees of CIDB-registered Grades 6 to 9 contracting organizations under the class of civil engineering works (https://registers.cidb.org.za) were the target population for the contractors.

3.6 SAMPLING TECHNIQUE

The sample being a subset of a population (Acharya *et al*., 2013) means that any inferences from a sample refer only to the defined population from which the sample has been properly selected (Banerjee and Chaudhury, 2010). This lends to sampling, which is defined as a valid alternative to collecting data from the entire population (Saunders *et al*., 2016). This is even more important because the sampling design affects the validity and reliability of a

research project (Lameck, 2013). From Acharya *et al*. (2013), sample representativeness depends on the three factors: (1) sampling methodology/technique; (2) sample size; and (3) response rate. The two main sampling techniques include: (1) probability or representative sampling; and (2) non-probability sampling, with further classifications under these two (see Acharya *et al*., 2013; Banerjee and Chaudhury, 2010; Saunders *et al*., 2016).

For this study, probabilistic stratified random sampling technique was used on the target population of public client representatives, civil and structural consulting engineers as well as contracting firms in South Africa's North West province. The stratified random sampling technique was explicated by approaching the North West province as a stratum and taking random samples of the study elements (Acharya et al., 2013; Teddie and Yu, 2007). Still, since there were a handful of these elements in the resultant sampling frame, a purposive sampling technique was used concurrently to obtain a homogenous sample of participants who have completed the defects liability period of a municipal road project within the five years prior to 2018. It can then be concluded that this study used a stratified purposeful sampling technique (see Onwuegbuzie and Collins, 2007; Suri, 2011).

3.7 SAMPLE SIZE

Following the selection of what was considered to be the most appropriate probability sampling technique to achieve the aim and objectives of this study, a decision was made on the sample size. The sample size affects the generalizability or representativeness of a study and there are practical guides for determining effective sample size (Browne, 1995; Demidenko, 2007; Lenth, 2001; Naing *et al*., 2006). The three common criteria for sample size determination include the: (1) level of precision; (2) confidence level; and (3) degree of variability (Israel, 1992). Some other authors have recommended using data-saturation for qualitative studies (e.g., Francis *et al*., 2010; Fusch and Ness, 2015).

For this study, a sample size of 52 respondents was determined from a total target population of 60 individuals (20 each from the three categories of clients, consultants, and contractors) using the following formula by Yamane (1967). Saunders *et al*.'s (2016, p.281) table as well as Israel's (1992) similar table also support Yamane's (1967) formula.

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

Where *n* = the desired sample size, *N* is the target population size (i.e. 60), and *x* is the probability of error (i.e., the desired precision which, for this study, was 0.05 for 95% confidence level).

To improve the chances of achieving the closest possible to the sample size of 52 following from the experience from the pilot study carried out after the ethics clearance certificate was issued in which there was just a respondent each from the client, consultant, and contractor categories, a total of 75 questionnaires were distributed to the target population. A pilot study addresses a variety of issues pertaining to the preliminary scale or instrument development, including item difficulty, item discrimination, internal consistency, response rates, and parameter estimation (Johanson and Brooks, 2010). Face-to-face distribution was employed because of its higher response rate as compared to the other modes (Kaplowitz *et al*., 2004; Nulty, 2008); most notably, over the telephonic interview (Holbrook *et al*., 2003) and e-mail questionnaire (Newman *et al*., 2002). After several follow-ups within the ethical practices on which the certificate was issued, 49 valid questionnaires were returned to derive a response rate of 65%, which accorded well with Nulty's (2008) finding.

3.8 DATA ANALYSIS

As presented under Sections B1 to B3 of the questionnaire in **Annexure 2**, this study sought primary quantitative data from the respondents towards fulfilling its three objectives. Primary data are original data collected for a research goal while quantitative data are described numerically in terms of objectives, variables, and their variables (Hox and Boeije, 2005). In particular, Likert-type questions were presented to the respondents in a bid to derive respective composite scores for the respective items (Boone and Boone, 2012). Interval data were used as the level of measurement because interval data, unlike the ordinal data, allows for the difference between responses to be calculated and the numbers do refer to a measure-able ''something'' (Sullivan and Artino, 2013). The use of interval data in this study also precludes the prevailing debate on the practicality and validity of treating ordinal data as interval data, which is attributable to the superiority of the parametric statistical tests over the non-parametric alternatives (see Allen and Seaman, 2007; Murray, 2013).

Using Tan's (2011) decision table for statistical tests as presented in Table 3.2, the repeat measures analysis of variance (ANOVA) was used to test the three hypotheses linked to the three objectives in this study. This is because the list of common types, causes of, and preventive measures for the road defects were presented to the three groups of respondents (i.e., clients, consultants, and contractors); hence, a form of repeat measures. It is acknowledged that both the single and repeat measure ANOVA have their limitations based

on the assumption of normality and sphericity, respectively (see Vasey and Thayer, 1987). There are, nonetheless, ways to dealing with the limitation (e.g., see Wilcox *et al*., 2000; Quené and Van den Bergh, 2004), which is beyond the scope of this limited scope research study. A major advantage of Tan's (2011, p.101) guide for data analysis is that the systematic guide allows for manual computation even for large samples so that statistical software is not necessary, which is similar to Clarke and Warwick's (2001) stance.

Table 3.2: Table of statistical test decision

Scale	One sample			Two independent samples	*K* independent samples
	Independent sample	Single treatment (repeat measures)	Multiple treatments (repeat measures)		
Nominal	Binomial test; Contingency table (1-way)	McNemar test	Cochrane *Q* test	Contingency table (2-way)	Contingency table (*r* x *c*)
Ordinal	Runs test	Wilcoxon signed rank test	Friedman test	Wilcoxon rank sum test	Kruskal-Wallis test
Interval or ratio	*Z* or *t* test; test of variance	Paired *t* test	Repeat measures ANOVA	Unpaired *t* test; test of variance	ANOVA

Source: Tan (2011: 101)

3.9 RELIABILITY AND VALIDITY

Reliability and validity are central to judgments about the quality of research (Cohen *et al*., 2013). Reliability refers to replication and consistency while validity refers to the appropriateness of the measures used, accuracy of the analysis of the results and generalizability of the findings (Golafshani, 2003). Reliability is also the consistency of the analytical procedures, including accounting for personal and research method biases that may have influenced the findings is also the precision in which the findings accurately reflect the data while the validity is the precision in which the findings accurately reflect the data (Heale and Twycross, 2015; Noble and Smith, 2015). Participant and researcher error and bias were were guarded against as much as possible to improve reliability (Saunders *et al*., 2016). The three main sources of the error and bias guarded against include random responding, malingering, and dissimulation (Peer and Gamliel, 2011). Content validity, construct validity, and criterion validity were ensured for the research instrument (see Annexure 1) to improve the internal validity (Heale and Twycross, 2015).

3.10 SUMMARY

The research onion model was used to describe and justify the adopted philosophy, approach to theory development, methodological choice, strategy, time horizon, and techniques and procedures. The focus of the literature review was informed by the objectives of this research. Also, the questionnaire evolved from the theory. The target population was discussed including the sampling technique and sample size. Issues around ethical practices, reliability and validity were also discussed. The next chapter discusses the data gathering and analysis for the eventual 49 respondents in this study.

CHAPTER 4 - DATA ANALYSIS

4.1 OVERVIEW

This chapter presents the profile of the respondents as a measure of validity, reliability, and generalizability. It then focuses on the descriptive and inferential data analyses, findings and discussions for the three objectives and hypotheses set out to achieve in this study.

4.2 RESPONDENTS PROFILE

Following a three-month data collection phase (15 January to 15 April 2018), the profile of the eventual 49 respondents who participated in this study is presented in Table 4.1. There were 11 client representatives (about 22%), 20 consultants (about 41%), and 18 contracting firm representatives (about 37%). Out of the 49 respondents, 29 respondents (about 60%) possessed a B.Tech degree or more, 44 respondents (about 90%) possessed a professional working experience of above five years. The respondents were predominantly male (about 71%); however, the female gender was well represented (about 45%) in the client group unlike in the consultant group (about 20%) and contractor group (about 28%).

Table 4.1: Respondents Profile

Code	Category	Position	Qualification	Years of Experience	Gender
R1	Client	Director	Degree	> 10	Male
R2	Client	Director	Degree	> 10	Female
R3	Client	Project Supervisor	Degree	> 10	Female
R4	Client	Sections/Operations Manager	Diploma	> 10	Male
R5	Client	Sections/Operations Manager	Diploma	> 5 to 10	Female
R6	Client	Project Supervisor	Degree	> 5 to 10	Female
R7	Client	Director	Degree	> 10	Male
R8	Client	Project Supervisor	Diploma	> 10	Male
R9	Client	Project Supervisor	Diploma	> 10	Male
R10	Client	Sections/Operations Manager	Degree	> 5 to 10	Female
R11	Client	Project Supervisor	Diploma	> 10	Male
R12	Consultant	Design Engineer (Civil/Structural)	Degree	> 10	Male
R13	Consultant	Technologist	Degree	> 10	Male
R14	Consultant	Technologist	Degree	> 10	Female

Code	Category	Position	Qualification	Years of Experience	Gender
R15	Consultant	Design Engineer (Civil/Structural)	Degree	> 10	Male
R16	Consultant	Design Engineer (Civil/Structural)	Diploma	> 10	Male
R17	Consultant	Design Engineer (Civil/Structural)	Degree	> 10	Male
R18	Consultant	Technologist	Degree	> 10	Male
R19	Consultant	Resident Engineer	Diploma	> 5 to 10	Male
R20	Consultant	Design Engineer (Civil/Structural)	Diploma	> 5 to 10	Male
R21	Consultant	Technologist	Degree	> 10	Male
R22	Consultant	Design Engineer (Civil/Structural)	Degree	> 5 to 10	Male
R23	Consultant	Director	Degree	> 10	Male
R24	Consultant	Director	Degree	> 10	Male
R25	Consultant	Technologist	Diploma	> 5 to 10	Male
R26	Consultant	Technologist	Degree	1 to 5	Female
R27	Consultant	Technologist	Degree	1 to 5	Male
R28	Consultant	Resident Engineer	Degree	> 5 to 10	Male
R29	Consultant	Technician	Diploma	1 to 5	Female
R30	Consultant	Technician	Degree	1 to 5	Female
R31	Consultant	Design Engineer (Civil/Structural)	Degree	> 10	Male
R32	Contractor	Technician	Degree	> 5 to 10	Male
R33	Contractor	Technologist	Diploma	1 to 5	Male
R34	Contractor	Technologist	Diploma	1 to 5	Female
R35	Contractor	Project Engineer/ Construction Manager	Diploma	> 5 to 10	Male
R36	Contractor	Site Engineer	Degree	> 5 to 10	Male
R37	Contractor	Project Engineer/ Construction Manager	Diploma	1 to 5	Male
R38	Contractor	Project Engineer/ Construction Manager	Diploma	> 5 to 10	Male
R39	Contractor	Technologist	Degree	> 10	Male
R40	Contractor	Site Engineer	Degree	1 to 5	Female
R41	Contractor	Technologist	Diploma	> 10	Male
R42	Contractor	Director	Degree	> 5 to 10	Male
R43	Contractor	Technologist	Diploma	> 5 to 10	Female

Code	Category	Position	Qualification	Years of Experience	Gender
R44	Contractor	Project Engineer/ Construction Manager	Diploma	> 10	Female
R45	Contractor	Director	Degree	> 5 to 10	Male
R46	Contractor	Technician	Diploma	1 to 5	Male
R47	Contractor	Director	Degree	> 5 to 10	Female
R48	Contractor	Technician	Diploma	> 10	Male
R49	Contractor	Technologist	Degree	> 5 to 10	Male

4.3 DESCRIPTIVE STATISTICS

Descriptive statistics is useful for collecting, grouping and analyzing a known set of data called population, by assigning a proper descriptive model or distribution family to it (Vergura *et al*., 2009). Descriptive statistics is the first step of data analysis used to describe the sample and then subgroups within the sample (Thompson, 2009). The most commonly used descriptive methods include frequency distribution, mean, median, mode, range and standard deviation (Al-Benna *et al*., 2010; Thompson, 2009).

4.3.1 COMMON TYPES OF ROAD DEFECT: DESCRIPTIVE STATISTICS

For Objective 1 related to Hypothesis 1, the descriptive statistics result of the data collected with respect to Section B1 of the questionnaire is presented in Table 4.2.

Table 4.2: Level of occurrence of the common types of road defect

Types of defect	Mean scores and ranks							
	Client (*n* = 11)	Rank	Consultant (*n* = 20)	Rank	Contractor (*n* = 18)	Rank	Overall (*n* = 49)	Rank
Rutting	4.000	3.5	3.700	5	3.316	4	3.672	3
Crocodile Cracking	4.273	2	3.850	2	3.842	2	3.988	2
Longitudinal Cracking	4.000	3.5	3.750	3.5	3.167	5	3.639	4
Bleeding/ Flushing	3.636	5	3.650	6	2.632	6	3.306	6
Pumping	3.182	6	3.750	3.5	3.368	3	3.433	5
Potholes	4.909	1	4.500	1	4.158	1	4.522	1

Table 4.2 presents the mean scores per respondent group (i.e., client, consultant, and contractor) and overall. These means scores were used to rank the common types of defect in descending order per group and overall as indicated next to each column in Table 4.2. The ranks would be used, subsequently, to perform the statistical test to either adopt the group rank or overall rank for Hypothesis 1. For example, if it was found that there is no significant difference, then the overall rank would be adopted and vice-versa. This is explained in detail under the section on inferential statistical analysis.

4.3.2 DESIGN- AND CONSTRUCTION-RELATED FACTORS CAUSING ROAD DEFECTS: DESCRIPTIVE STATISTICS

For Objective 2 related to Hypothesis 2, the descriptive statistics result of the data collected with respect to Section B2 of the questionnaire is presented in Table 4.3.

Table 4.3: Level of impact of design- and construction-related factors causing road defects

Factors	**Mean scores and ranks**							
	Client (*n* = 11)	**Rank**	**Consultant (*n* = 20)**	**Rank**	**Contractor (*n* = 18)**	**Rank**	**Overall (*n* = 49)**	**Rank**
Deformation or ageing of the pavement	4.818	1.5	4.050	3	3.647	7	4.172	2.5
Non-adherence to road construction standards	3.909	7	3.900	5	3.833	3	3.881	6
Design changes during road construction	2.364	10	2.789	10	3.167	10	2.773	10
Absence of on-the-job training programmes	4.000	5.5	3.550	7	3.722	4.5	3.757	7
Inexperience and incompe-tence of the labourers	3.455	8	3.450	8	3.500	8	3.468	8
Poor super-vision and inspection for quality assurance	4.182	4	4.000	4	4.111	1	4.098	4

Factors	Mean scores and ranks							
	Client (*n* = 11)	**Rank**	**Consultant (*n* = 20)**	**Rank**	**Contractor (*n* = 18)**	**Rank**	**Overall (*n* = 49)**	**Rank**
Control over the nominated subcontractors	4.000	5.5	3.850	6	4.000	2	3.950	5
Planning and co-ordination of on-site resources	4.818	1.5	4.300	1	3.778	6	4.299	1
Motivation and commitment of the site management	4.545	3	4.250	2	3.722	4.5	4.172	2.5
The impact of the contractual arrangement	2.727	9	3.000	9	3.333	9	3.020	9

Similar to Table 4.2, Table 4.3 presents the mean scores per respondent group (i.e., client, consultant, and contractor) and overall. These means scores were used to rank the level of impact of design- and construction-related factors causing road defects the common types of defect in descending order per group and overall as indicated next to each column in Table 4.3. The ranks would be used, subsequently, to perform the statistical test to either adopt the group rank or overall rank for Hypothesis 2.

4.3.3 PREVENTIVE MEASURES: DESCRIPTIVE STATISTICS

For Objective 3 related to Hypothesis 3, the descriptive statistics result of the data collected with respect to Section B3 of the questionnaire is presented in Table 4.4. Similar to Tables 4.2 and Table 4.3, Table 4.4 presents the mean scores per respondent group (i.e., client, consultant, and contractor) and overall. These means scores were used to rank the level of importance of the literature-reviewed preventive measures in descending order per group and overall as indicated next to each column in Table 4.4. The ranks would be used, subsequently, to perform the inferential statistical test to either adopt the group rank or overall rank for Hypothesis 3.

Table 4.4: Level of importance of preventive measures

Measures	Mean scores and ranks							
	Client (*n* = 11)	**Rank**	**Consultant (*n* = 20)**	**Rank**	**Contractor (*n* = 18)**	**Rank**	**Overall (*n* = 49)**	**Rank**
Defining acceptable quality from inception	4.909	2	4.600	3.5	4.333	4	4.614	2
Training for all on road construction standards	4.636	4	4.700	1	4.389	1.5	4.575	3
Adhering to all the road construction standards	4.455	7	4.600	3.5	4.333	4	4.463	5
Attention to design and construction strategies	4.545	5	4.400	6	3.889	10	4.278	8
Standards-compliant material and equipment	3.364	10	3.350	10	4.056	8.5	3.590	10
The municipality to ensure adherence to their standards	4.909	2	4.500	5	4.222	6	4.544	4
The consultants to ensure adherence to standards	4.364	8	4.150	8	4.333	4	4.282	7
The contractors to ensure adherence to standards	4.909	2	4.650	2	4.389	1.5	4.649	1
Contract-based risk assessment for changes	4.500	6	4.350	7	4.056	8.5	4.302	6
Qualified construction manager to lead	3.636	9	3.450	9	4.176	7	3.754	9

4.4 INFERENTIAL STATISTICS

Inferential (or deductive) statistics is adopted when it is necessary to infer the behaviour of the entire population from a sub-set of sample data (Vergura *et al*., 2009). Consequently, inferential statistics is calculated with the purpose of generalizing the findings from from a sample to the entire population of interest (Allua and Thompson, 2009). Inferential statistics use statistical tests, which can either be parametric or nonparametric (Al-Benna *et al*., 2010). Parametric statistics are the most common approach to inferential statistical analysis and the use of parametric statistics requires that the variables be measured at the interval or ratio level (Allua and Thompson, 2009). The statistical test for parametric statistics include *t*-Test, analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), Pearson's *r* (correlation), simple regression, multiple regression, and canonical.

4.4.1 COMMON TYPES OF ROAD DEFECT: INFERENTIAL STATISTICS

The result of the analysis of the inferential statistical testing for H_1 is presented in Table 4.5 and explained subsequently in more detail.

> *Null hypothesis (H_1): There is no significant difference in the internal stakeholders views on the level of occurrence of the common types of road defect.*
>
> *Alternative hypothesis (H_a): There is a significant difference in the internal stakeholders views on the level of occurrence of the common types of road defect.*

Table 4.5 shows the Grand Mean (*M*); that is, the average of column or row means to be 3.760. Further, the Grand Sum of the Squares about row mean (*W*) is the total of the sum of each square about row mean (w_i). That is, $W = \sum w_i = 1.854$.

W may be further partitioned into

$W = T + r$

where *T* is the sum of squares due to treatment and *r* is the sum of squares of residual. *T* is given by

$T = n \sum$ (column means - $M)^2 = 6[(4.000 - 3.760)^2 + (3.867 - 3.760)^2 + (3.414 - 3.760)^2] = 1.134$

Thus, r = W - T = 1.854 - 1.134 = 0.720

To test for H_1, the F-ratio is

$$F = T/(k-1)/r/[(n-1)(k-1)]$$

$F = 1.134 / (2) / 0.720 /[5(2)] = 7.875$

Table 4.5: Statistical testing for Hypothesis 1 (Repeat measures ANOVA)

Types of defect	Client	Consultant	Contractor	Row Mean	Sum of squares about row mean (w_i)
Rutting	4.000	3.700	3.316	3.672	0.235
Crocodile Cracking	4.273	3.850	3.842	3.988	0.122
Longitudinal Cracking	4.000	3.750	3.167	3.639	0.365
Bleeding/ Flushing	3.636	3.650	2.632	3.306	0.682
Pumping	3.182	3.750	3.368	3.433	0.168
Potholes	4.909	4.500	4.158	4.522	0.283
Column mean	4.000	3.867	3.414	**3.760**	**1.854**

From the table of critical values for the F distribution presented under **Annexure 3**, the 0.05 critical value for F(2, 10) degrees of freedom is 4.10; hence, H_1 is rejected since the F-ratio of 7.88 is higher than the critical value. It can then be concluded that the F-ratio is likely to occur by chance with a p<.05. In other words, H_1 can only be accepted at a p-value >.05 (see Dahiru, 2008). Since H_1 is rejected, it means the individual ranks presented earlier in Table 4.2 can be accepted because the overall ranks do not hold valid based on the result of the statistical test for H_1. This means that the alternative hypothesis (H_a) holds valid in this instance that there is a significant difference, which means the ranks based on the respondent group mean scores can be adopted to conclude on the levels of occurrence of the types of defect as perceived by the different respondent group.

4.4.2 DESIGN- AND CONSTRUCTION-RELATED FACTORS CAUSING ROAD DEFECTS: INFERENTIAL STATISTICS

The result of the analysis of the inferential statistical testing for H_2 is presented in Table 4.6 and explained subsequently in more detail.

> *Null hypothesis (H_2): There is no significant difference in the internal stakeholders views on the level of impact of the factors.*
>
> *Alternative hypothesis (H_a): There is a significant difference in the internal stakeholders views on the level of impact of the factors.*

Table 4.6: Statistical testing for Hypothesis 2 (Repeat measures ANOVA)

Factors	Client	Consultant	Contractor	Row Mean	Sum of squares about row mean (w_i)
Deformation or ageing of the pavement	4.818	4.050	3.647	4.172	0.708
Non-adherence to road construction standards	3.909	3.900	3.833	3.881	0.003
Design changes during road construction	2.364	2.789	3.167	2.773	0.323
Absence of on-the-job training programmes	4.000	3.550	3.722	3.757	0.103
Inexperience and incompetence of the labourers	3.455	3.450	3.500	3.468	0.002
Poor supervision and inspection for quality assurance	4.182	4.000	4.111	4.098	0.017
Control over the nominated subcontrac-tors	4.000	3.850	4.000	3.950	0.015
Planning and co-ordination of on-site resources	4.818	4.300	3.778	4.299	0.541
Motivation and commitment of the site management	4.545	4.250	3.722	4.172	0.348
The impact of the contractual arrangement	2.727	3.000	3.333	3.020	0.184
Column mean	3.882	3.714	3.681	**3.759**	**2.243**

From Table 4.6, the Grand Mean (*M)* = 3.759 and the Grand Sum of the Squares about row mean (*W)* = 2.243. Recall, *W* = *T* + *r*

where $T = 10[(3.882 - 3.759)^2 + (3.714 - 3.759)^2 + (3.681 - 3.759)^2] = 0.232$

r = W - T = 2.243 - 0.232 = 2.011

To test for H_2, the F-ratio is

$$F = T/(k-1)/r/[(n-1)(k-1)]$$

F = 0.232 / (2) / 2.011 /[9(2)] = 1.036

From the table of critical values for the F distribution presented under **Annexure 3**, the 0.05 critical value for F(2, 18) degrees of freedom is 3.56; hence, H_2 is accepted since the F-ratio of 1.04 is lower than the critical value. It is then concluded that the F-ratio is unlikely to occur by chance with a $p<.05$.

Since H_2 is accepted, it means the overall ranks presented earlier in Table 4.3 can be accepted because the individual ranks do not hold valid based on the result of the statistical test for for H_2.

4.4.3 PREVENTIVE MEASURES: INFERENTIAL STATISTICS

The result of the analysis of the inferential statistical testing for H_3 is presented in Table 4.7 and explained subsequently in more detail.

> *Null hypothesis (H_3): There is no significant difference in the internal stakeholders views on the level of importance of the preventive measures.*
>
> *Alternative hypothesis (H_a): There is a significant difference in the internal stakeholders views on the level of importance of the preventive measures.*

Table 4.7: Statistical testing for Hypothesis 3 (Repeat measures ANOVA)

Factors	Client	Consultant	Contractor	Row Mean	Sum of squares about row mean (w_i)
Defining acceptable quality from inception	4.909	4.600	4.333	4.614	0.166
Training for all on road construction standards	4.636	4.700	4.389	4.575	0.054
Adhering to all the road construction standards	4.455	4.600	4.333	4.463	0.036
Attention to design and construction strategies	4.545	4.400	3.889	4.278	0.237
Standards-compliant material and equipment	3.364	3.350	4.056	3.590	0.326
The municipality to ensure adherence to their standards	4.909	4.500	4.222	4.544	0.239
The consultants to ensure adherence to standards	4.364	4.150	4.333	4.282	0.027
The contractors to ensure adherence to standards	4.909	4.650	4.389	4.649	0.135
Contract-based risk assessment for changes	4.500	4.350	4.056	4.302	0.102
Qualified construction manager to lead	3.636	3.450	4.176	3.754	0.284
Column mean	4.423	4.275	4.218	**4.305**	**1.606**

From Table 4.7, the Grand Mean (*M)* = 4.305 and the Grand Sum of the Squares about row mean (*W)* = 1.606. Recall, $W = T + r$

where $T = 10[(4.423 - 4.305)^2 + (4.275 - 4.305)^2 + (4.218 - 4.305)^2] = 0.220$

r = W - T = 1.606 - 0.220 = 1.386

To test for H_3, the F-ratio is

$$F = T/(k-1)/r/[(n-1)(k-1)]$$

$F = 0.220 / (2) / 1.386 /[9(2)] = 1.429$

From the table of critical values for the F distribution presented under **Annexure 3**, the 0.05 critical value for F(2, 18) degrees of freedom is 3.56; hence, H_3 is accepted since the F-ratio of 1.43 is lower than the critical value. It is then concluded that the F-ratio is unlikely to occur by chance with a $p<.05$. Since H_3 is accepted, it means the overall ranks presented in Table 4.4 are accepted because the individual ranks do not hold valid based on the result of the statistical test.

4.5 DISCUSSIONS

In addition with respect to the ranks presented in Tables 4.2 to 4.4, the level of agreement between and among the respondent groups using the client as the point of reference can also be measured by using the criterion of ± 1, where the value +1 represents a perfect positive association/agreement and the value -1 represents a perfect negative association/ disagreement (Crawford, 2006; McHugh, 2012). Where an agreement has been observed (i.e., the null hypothesis was accepted), the following Landis and Kock's (1977) benchmark for the observed value and corresponding strength of agreement from poor to perfect can be used as a useful guide: < 0.00 = poor, 0.00 - 0.20 = slight, 0.21 - 0.40 = fair, 0.41 - 0.60 = moderate, 0.61 - 0.80 = substantial, and 0.81 - 1.00 = almost perfect.

From Table 4.2, the consultant group ranked *rutting* as 5th, which is in disagreement with the client and contractor groups that have ranked *rutting* as 3.5th and 4th respectively. Consequently, it can be concluded that the client and contractor groups were in a moderate agreement, using the criterion of ± 1 unlike the client and consultant groups, which is outside of the range of the ± 1 (i.e. disagreement). However, the three respondent groups were in perfect agreement on the ranks of *potholes* and *crocodile cracking* as 1st and 2nd respectively. The client and consultant groups were in perfect agreement on the rank of

longitudinal cracking as 3.5th while the client and contractor groups were in perfect agreement on the rank of *bleeding/flushing* as 6th. Lastly, the consultant and contractor groups were in moderate agreement on the rank of *pumping* while the client group was in disagreement.

The effects of pavement condition arising from design- and construction-related factors manifest in roadway safety (Sharif Tehrani *et al*., 2017). From Table 4.3, the top-3 ranked design- and construction-related factors causing road defects can be deduced. *Planning and coordination* was ranked 1st, followed by a tie between *deformation or ageing of the pavement* and *motivation and commitment of the site management* as 2.5th. Interestingly, *design changes*, c*ontractual arrangement*, and *inexperience and incompetence of the laborers* were the bottom-3 ranked factors and reinforced with perfect agreement among the three responded groups.

On the one hand from Table 4.4, the top-3 ranked preventive measures for the road defects include: *the contractors to ensure adherence to standards* (1st), *defining acceptable quality from inception* (2nd), and *training for all on road construction standards* (3rd). On the other hand and at varying levels of agreement, the bottom-3 ranked include *standards-compliant material and equipment* (10th), qualified construction manager to lead (9th), and *attention to design and construction strategies* (8th). Granted that human errors cannot be completely eliminated, there are also automated ways to detect and prevent pavement defects (Radopoulou and Brilakis, 2016).

4.6 SUMMARY

The results for the quantitative data collected for the three objectives of this study were presented. The results served as the basis for ranking the variables under the common types of municipal road defects, design- and construction-related factors causing the municipal road defects, and the preventive measures for the defects. The repeat measure ANOVA statistical tests performed on the data collected for each objective rejected the first hypothesis that there is no significant difference in the mean scores for the common types of road defect among the respondent groups but accepted the second and third hypotheses. As such the group ranks hold valid for the first hypothesis while the overall ranks hold valid for the second and third hypotheses. The conclusion and recommendation of these statistical findings are discussed in the next chapter.

CHAPTER 5 - CONCLUSION

5.1 OVERVIEW

This chapter demonstrates how the aim and objectives of this study have been achieved including answering the main research question and testing of the three hypotheses. It provides recommendations based on the statistical results to lead to managerial and theoretical implications. Lastly, it discusses the limitations of the results as a basis for a subsequent future study as a validation for improved chances of generalization.

5.2 ACHIEVEMENT OF STUDY OBJECTIVES

The three objectives were to: firstly, identify the common types of road defect; secondly, examine the design- and construction- related factors causing road defects; and thirdly, recommend possible preventive measures.

The first objective was achieved by performing a statistical test on the common types of road defect gathered through narrative and descriptive review of the literature using the conceptual framework of internal stakeholders (i.e., clients, consultants, and contractors). The result showed a significant difference in the ranking of the levels of occurrence of the common types of municipal road defect in the North West province of South Africa among the internal stakeholders to disprove the first hypothesis. However, the three internal stakeholder groups were in perfect agreement on *potholes* and *crocodile cracking* as 1st and 2nd respectively. This perfect agreement confirms the severity of these two types of common defects on municipal roads in the North West province of South Africa for immediate priority.

The second objective was also achieved by performing a statistical test on the common design- and construction-related factors causing road defect gathered through narrative and descriptive review of the literature using the conceptual framework of internal stakeholders. The result showed no significant difference in the ranking of the design- and construction-related factors causing road defect among the internal stakeholders to accept the second hypothesis. Consequently, the top-3 ranked factors in descending order were found to be *planning and coordination, deformation or ageing of the pavement* and *motivation and commitment of the site management.* It can be reasoned that improper planning and coordination would lead to a lack of on-site motivation and commitment, ultimately manifesting itself in a premature pavement ageing and deformation. This position is further buttressed by the fact that *design changes*, c*ontractual arrangement*, and *inexperience and incompetence of the laborers* were the bottom-3 ranked factors and reinforced with perfect agreement among the three responded groups. This is because it can be assumed that these front-end bottom-3 ranked factors were not the main causes of the defects but rather the back-end factors attributable to subsequent planning and coordination.

The third and last objective was also achieved by performing a statistical test on the common preventive measures for road defect gathered through narrative and descriptive review of the literature using the conceptual framework of internal stakeholders. The result showed no significant difference in the ranking of the preventive measures for the road defect among the internal stakeholders to accept the third hypothesis. Consequently, the top-3 ranked preventive measures for the road defects in descending order were found to be *the contractors to ensure adherence to standards*, *defining acceptable quality from inception*, and *training for all on road construction standards*. All of these preventive measures related to the importance of quality standards. The bottom-3 ranked preventive measures were found to be *standards-compliant material and equipment*, qualified construction manager to lead, and *attention to design and construction strategies*. All of these preventive measures relate to the human aspect or soft side of of quality standards as supported by the idea of total quality management (TQM).

5.3 CONCLUSION ON THE OVERALL RESEARCH

By statistically proving the three hypotheses linked to the three objectives of this study as discussed in the preceding section, the research question of what is the nature of the defects on municipal pavement roads in the North West province of South Africa from the perspective of the internal stakeholders can now be answered. The common types of municipal road defect are *potholes* and *longitudinal cracking*. The most important design- and related- factors for priority include effective *planning and coordination* to boost the *motivation and commitment of the site management.* Once these factors are in place, *quality standards* should be upheld from the beginning and throughout the highway construction project between and among all the internal stakeholders. By answering the research question, the research aim of this study has been achieved.

5.4 RECOMMENDATIONS

The practical recommendations following from the results of this study include the urgent need to prioritize on addressing potholes and longitudinal cracking including identifying their causes right from the design stage. Planning and coordination across all levels of the project team is important in this regard based on the concept of TQM and to ensure safety on the municipal roads for improved productivity. Lastly, there is the urgent need for all the internal stakeholders to be trained and up-skilled in road construction standards as a systemic view. The theoretical recommendations include further in-depth research into the nature of potholes and longitudinal cracking in particular to be able to come up with customized solution. This is even more important because of the perfect agreement among the internal stakeholders on these two types of defects as most frequently occurring.

5.5 LIMITATIONS

The immediate generalizability of a quantitative study is premised on a large sample size. This study's 49 samples drawn from the North West province internal stakeholders potentially limits the extent to which the findings of the study can be generalized. In a simliar vein, since municipal roads are used daily by a more diverse group of users and maintenance agents, there is a need for a future similar study to consider the perspectives of the external stakeholders for a more holistic view of the nature of defects on municipal roads in South Africa. By so doing, a more comprehensive data-driven solution can be generated. Roads play a crucial role in facilitating and driving economic activities and developments and all the stakeholders have a role to play to minimize the defects on roads to make it safer and more secured.

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ANNEXURE 1

QUESTIONNAIRE

Section A: Participants' background information

Please provide information on your job position as applicable to your internal stakeholder category as a client, engineering consultant or contractor, followed by generic pieces of information on your qualification, working experience, and gender.

A.1: Position

Municipality Client

Director	Sections/Operations Manager	Project Supervisor

Municipality Consultant (Engineering)

Director	Design Engineer (Civil & Structural)	Resident Engineer	Technologist	Technician

Municipality Contractor

Director	Project Engineer	Site Engineer	Technologist	Technician

A.2: Post-Grade 12 qualification

Diploma (up to 3 years)	Degree (BTech or more)

A.3: Post-Grade 12 years of working experience

1 to 5 years	> 5 to 10 years	> 10 years

A.4: Gender

Male	Female

Section B1: Types of bituminous road defect

Please rate the level to which the types of flexible pavement (i.e., bituminous/asphalt) road defect presented in the following table occur on municipal roads in South Africa, on a scale of 1 (very low) to 5 (very high).

Criteria		Level of Occurrence				
S/No	**Description**	**1 (Never)**	**2 (Rarely)**	**3 (Sometimes)**	**4 (Very Often)**	**5 (Always)**
1	Rutting					
2	Crocodile Cracking					
3	Longitudinal Cracking					
4	Bleeding/Flushing					
5	Pumping					
6	Potholes					

Section B2: Design- and Construction-Related Factors

Please rate the level to which the design- and construction-related factors presented in the following table account for flexible pavement road defects in South Africa's municipalities, on a scale of 1 (never) to 5 (always).

Criteria		Level of Impact				
S/No	**Description**	**1 (Very Low)**	**2 (Below Average)**	**3 (Average)**	**4 (Above Average)**	**5 (Very High)**
1	Deformation or ageing of the pavement					
2	Non-adherence to road construction standards					
3	Design changes during road construction					
4	Absence of on-the-job training programmes					
5	Inexperience and incompetence of the labourers					
6	Poor supervision and inspection for quality assurance					
7	Control over the nominated subcontractors					
8	Planning and co-ordination of on-site resources					

Criteria		Level of Impact				
S/No	**Description**	**1 (Very Low)**	**2 (Below Average)**	**3 (Average)**	**4 (Above Average)**	**5 (Very High)**
9	Motivation and commitment of the site management					
10	The impact of the contractual arrangement					

Section B3: Preventive Measures

Please rate the degree of importance of the measures presented in the following table to prevent flexible pavement road defects in South Africa's municipalities, on a scale of 1 (not important) to 5 (very important).

Criteria		Level of Agreement				
S/No	**Description**	**1 (Not Important)**	**2 (Slightly Important)**	**3 (Moderately Important)**	**4 (Important)**	**5 (Very Important)**
1	Defining acceptable quality from inception					
2	Training for all on road construction standards					
3	Adhering to all the road construction standards					
4	Attention to design and construction strategies					
5	Standards-compliant material and equipment					
6	The municipality to ensure adherence to their standards					
7	The consultants to ensure adherence to standards					
8	The contractors to ensure adherence to standards					
9	Contract-based risk assessment for changes					
10	Qualified construction manager to lead					

ANNEXURE 2

School of Construction Economics & Management

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SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER** CEM/17/10/MD/MSC
PROJECT TITLE:	**Assessments of factors contributing to common defects on municipal roads**
INVESTIGATOR	Mukondeleli Dovhani Ronald **1275000**
SCHOOL/DEPARTMENT	**SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT**
DATE CONSIDERED	24/10/2017
DECISION OF THE COMMITTEE	Approved conditionally with respect to the declaration
EXPIRY DATE	24th Oct 2018
DATE	24th Oct 2017

CHAIRPERSON _____
Dr. Kola Ijasan

cc: Supervisor: Dr. Oluwayomi Babatunde

DECLARATION OF INVESTIGATOR (S)

To be completed in duplicate and **ONE COPY** returned to the Secretary Mrs. M. Sithole at the CEM reception desk.

I fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the committee. **I agree to completion of a yearly progress report.**

Mukondeleli. D.R
Signature

30/10/2017
Date

ANNEXURE 3

Table of critical values for the F distribution (for use with ANOVA):

How to use this table:

There are two tables here. The first one gives critical values of F at the p = 0.05 level of significance. The second table gives critical values of F at the p = 0.01 level of significance.
1. Obtain your F-ratio. This has (x,y) degrees of freedom associated with it.
2. Go along x columns, and down y rows. The point of intersection is your critical F-ratio.
3. If your obtained value of F is equal to or larger than this critical F-value, then your result is significant at that level of probability.
An example: I obtain an F ratio of 3.96 with (2, 24) degrees of freedom.
I go along 2 columns and down 24 rows. The critical value of F is 3.40. My obtained F-ratio is larger than this, and so I conclude that my obtained F-ratio is likely to occur by chance with a p<.05.

Critical values of F for the 0.05 significance level:

	1	2	3	4	5	6	7	8	9	10
1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.39	19.40
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14
10	4.97	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98
11	4.84	3.98	3.59	3.36	3.20	3.10	3.01	2.95	2.90	2.85
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49
17	4.45	3.59	3.20	2.97	2.81	2.70	2.61	2.55	2.49	2.45
18	4.41	3.56	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35
21	4.33	3.47	3.07	2.84	2.69	2.57	2.49	2.42	2.37	2.32
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.38	2.32	2.28
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.26
25	4.24	3.39	2.99	2.76	2.60	2.49	2.41	2.34	2.28	2.24
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.17
31	4.16	3.31	2.91	2.68	2.52	2.41	2.32	2.26	2.20	2.15
32	4.15	3.30	2.90	2.67	2.51	2.40	2.31	2.24	2.19	2.14
33	4.14	3.29	2.89	2.66	2.50	2.39	2.30	2.24	2.18	2.13
34	4.13	3.28	2.88	2.65	2.49	2.38	2.29	2.23	2.17	2.12
35	4.12	3.27	2.87	2.64	2.49	2.37	2.29	2.22	2.16	2.11

36	4.11	3.26	2.87	2.63	2.48	2.36	2.28	2.21	2.15	2.11
37	4.11	3.25	2.86	2.63	2.47	2.36	2.27	2.20	2.15	2.10
38	4.10	3.25	2.85	2.62	2.46	2.35	2.26	2.19	2.14	2.09
39	4.09	3.24	2.85	2.61	2.46	2.34	2.26	2.19	2.13	2.08
40	4.09	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08
41	4.08	3.23	2.83	2.60	2.44	2.33	2.24	2.17	2.12	2.07
42	4.07	3.22	2.83	2.59	2.44	2.32	2.24	2.17	2.11	2.07
43	4.07	3.21	2.82	2.59	2.43	2.32	2.23	2.16	2.11	2.06
44	4.06	3.21	2.82	2.58	2.43	2.31	2.23	2.16	2.10	2.05
45	4.06	3.20	2.81	2.58	2.42	2.31	2.22	2.15	2.10	2.05
46	4.05	3.20	2.81	2.57	2.42	2.30	2.22	2.15	2.09	2.04
47	4.05	3.20	2.80	2.57	2.41	2.30	2.21	2.14	2.09	2.04
48	4.04	3.19	2.80	2.57	2.41	2.30	2.21	2.14	2.08	2.04
49	4.04	3.19	2.79	2.56	2.40	2.29	2.20	2.13	2.08	2.03
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.03
51	4.03	3.18	2.79	2.55	2.40	2.28	2.20	2.13	2.07	2.02
52	4.03	3.18	2.78	2.55	2.39	2.28	2.19	2.12	2.07	2.02
53	4.02	3.17	2.78	2.55	2.39	2.28	2.19	2.12	2.06	2.02
54	4.02	3.17	2.78	2.54	2.39	2.27	2.19	2.12	2.06	2.01
55	4.02	3.17	2.77	2.54	2.38	2.27	2.18	2.11	2.06	2.01
56	4.01	3.16	2.77	2.54	2.38	2.27	2.18	2.11	2.05	2.01
57	4.01	3.16	2.77	2.53	2.38	2.26	2.18	2.11	2.05	2.00
58	4.01	3.16	2.76	2.53	2.37	2.26	2.17	2.10	2.05	2.00
59	4.00	3.15	2.76	2.53	2.37	2.26	2.17	2.10	2.04	2.00
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99
61	4.00	3.15	2.76	2.52	2.37	2.25	2.16	2.09	2.04	1.99
62	4.00	3.15	2.75	2.52	2.36	2.25	2.16	2.09	2.04	1.99
63	3.99	3.14	2.75	2.52	2.36	2.25	2.16	2.09	2.03	1.99
64	3.99	3.14	2.75	2.52	2.36	2.24	2.16	2.09	2.03	1.98
65	3.99	3.14	2.75	2.51	2.36	2.24	2.15	2.08	2.03	1.98
66	3.99	3.14	2.74	2.51	2.35	2.24	2.15	2.08	2.03	1.98
67	3.98	3.13	2.74	2.51	2.35	2.24	2.15	2.08	2.02	1.98
68	3.98	3.13	2.74	2.51	2.35	2.24	2.15	2.08	2.02	1.97
69	3.98	3.13	2.74	2.51	2.35	2.23	2.15	2.08	2.02	1.97
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.02	1.97
71	3.98	3.13	2.73	2.50	2.34	2.23	2.14	2.07	2.02	1.97
72	3.97	3.12	2.73	2.50	2.34	2.23	2.14	2.07	2.01	1.97
73	3.97	3.12	2.73	2.50	2.34	2.23	2.14	2.07	2.01	1.96
74	3.97	3.12	2.73	2.50	2.34	2.22	2.14	2.07	2.01	1.96
75	3.97	3.12	2.73	2.49	2.34	2.22	2.13	2.06	2.01	1.96
76	3.97	3.12	2.73	2.49	2.34	2.22	2.13	2.06	2.01	1.96
77	3.97	3.12	2.72	2.49	2.33	2.22	2.13	2.06	2.00	1.96
78	3.96	3.11	2.72	2.49	2.33	2.22	2.13	2.06	2.00	1.95
79	3.96	3.11	2.72	2.49	2.33	2.22	2.13	2.06	2.00	1.95
80	3.96	3.11	2.72	2.49	2.33	2.21	2.13	2.06	2.00	1.95
81	3.96	3.11	2.72	2.48	2.33	2.21	2.13	2.06	2.00	1.95
82	3.96	3.11	2.72	2.48	2.33	2.21	2.12	2.05	2.00	1.95
83	3.96	3.11	2.72	2.48	2.32	2.21	2.12	2.05	2.00	1.95
84	3.96	3.11	2.71	2.48	2.32	2.21	2.12	2.05	1.99	1.95
85	3.95	3.10	2.71	2.48	2.32	2.21	2.12	2.05	1.99	1.94

86	3.95	3.10	2.71	2.48	2.32	2.21	2.12	2.05	1.99	1.94
87	3.95	3.10	2.71	2.48	2.32	2.21	2.12	2.05	1.99	1.94
88	3.95	3.10	2.71	2.48	2.32	2.20	2.12	2.05	1.99	1.94
89	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.99	1.94
90	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.99	1.94
91	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.98	1.94
92	3.95	3.10	2.70	2.47	2.31	2.20	2.11	2.04	1.98	1.94
93	3.94	3.09	2.70	2.47	2.31	2.20	2.11	2.04	1.98	1.93
94	3.94	3.09	2.70	2.47	2.31	2.20	2.11	2.04	1.98	1.93
95	3.94	3.09	2.70	2.47	2.31	2.20	2.11	2.04	1.98	1.93
96	3.94	3.09	2.70	2.47	2.31	2.20	2.11	2.04	1.98	1.93
97	3.94	3.09	2.70	2.47	2.31	2.19	2.11	2.04	1.98	1.93
98	3.94	3.09	2.70	2.47	2.31	2.19	2.10	2.03	1.98	1.93
99	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.98	1.93
100	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.98	1.93

Critical values of F for the 0.01 significance level:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	4052.19	4999.52	5403.34	5624.62	5763.65	5858.97	5928.33	5981.10	6022.50	6055.85
2	98.50	99.00	99.17	99.25	99.30	99.33	99.36	99.37	99.39	99.40
3	34.12	30.82	29.46	28.71	28.24	27.91	27.67	27.49	27.35	27.23
4	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.66	14.55
5	16.26	13.27	12.06	11.39	10.97	10.67	10.46	10.29	10.16	10.05
6	13.75	10.93	9.78	9.15	8.75	8.47	8.26	8.10	7.98	7.87
7	12.25	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.72	6.62
8	11.26	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.91	5.81
9	10.56	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.35	5.26
10	10.04	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.94	4.85
11	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.63	4.54
12	9.33	6.93	5.95	5.41	5.06	4.82	4.64	4.50	4.39	4.30
13	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	4.19	4.10
14	8.86	6.52	5.56	5.04	4.70	4.46	4.28	4.14	4.03	3.94
15	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.90	3.81
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.78	3.69
17	8.40	6.11	5.19	4.67	4.34	4.10	3.93	3.79	3.68	3.59
18	8.29	6.01	5.09	4.58	4.25	4.02	3.84	3.71	3.60	3.51
19	8.19	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.52	3.43
20	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.56	3.46	3.37
21	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.40	3.31
22	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.35	3.26
23	7.88	5.66	4.77	4.26	3.94	3.71	3.54	3.41	3.30	3.21
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.26	3.17
25	7.77	5.57	4.68	4.18	3.86	3.63	3.46	3.32	3.22	3.13
26	7.72	5.53	4.64	4.14	3.82	3.59	3.42	3.29	3.18	3.09
27	7.68	5.49	4.60	4.11	3.79	3.56	3.39	3.26	3.15	3.06
28	7.64	5.45	4.57	4.07	3.75	3.53	3.36	3.23	3.12	3.03
29	7.60	5.42	4.54	4.05	3.73	3.50	3.33	3.20	3.09	3.01
30	7.56	5.39	4.51	4.02	3.70	3.47	3.31	3.17	3.07	2.98
31	7.53	5.36	4.48	3.99	3.68	3.45	3.28	3.15	3.04	2.96
32	7.50	5.34	4.46	3.97	3.65	3.43	3.26	3.13	3.02	2.93

33	7.47	5.31	4.44	3.95	3.63	3.41	3.24	3.11	3.00	2.91
34	7.44	5.29	4.42	3.93	3.61	3.39	3.22	3.09	2.98	2.89
35	7.42	5.27	4.40	3.91	3.59	3.37	3.20	3.07	2.96	2.88
36	7.40	5.25	4.38	3.89	3.57	3.35	3.18	3.05	2.95	2.86
37	7.37	5.23	4.36	3.87	3.56	3.33	3.17	3.04	2.93	2.84
38	7.35	5.21	4.34	3.86	3.54	3.32	3.15	3.02	2.92	2.83
39	7.33	5.19	4.33	3.84	3.53	3.31	3.14	3.01	2.90	2.81
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.89	2.80
41	7.30	5.16	4.30	3.82	3.50	3.28	3.11	2.98	2.88	2.79
42	7.28	5.15	4.29	3.80	3.49	3.27	3.10	2.97	2.86	2.78
43	7.26	5.14	4.27	3.79	3.48	3.25	3.09	2.96	2.85	2.76
44	7.25	5.12	4.26	3.78	3.47	3.24	3.08	2.95	2.84	2.75
45	7.23	5.11	4.25	3.77	3.45	3.23	3.07	2.94	2.83	2.74
46	7.22	5.10	4.24	3.76	3.44	3.22	3.06	2.93	2.82	2.73
47	7.21	5.09	4.23	3.75	3.43	3.21	3.05	2.92	2.81	2.72
48	7.19	5.08	4.22	3.74	3.43	3.20	3.04	2.91	2.80	2.72
49	7.18	5.07	4.21	3.73	3.42	3.20	3.03	2.90	2.79	2.71
50	7.17	5.06	4.20	3.72	3.41	3.19	3.02	2.89	2.79	2.70
51	7.16	5.05	4.19	3.71	3.40	3.18	3.01	2.88	2.78	2.69
52	7.15	5.04	4.18	3.70	3.39	3.17	3.01	2.87	2.77	2.68
53	7.14	5.03	4.17	3.70	3.38	3.16	3.00	2.87	2.76	2.68
54	7.13	5.02	4.17	3.69	3.38	3.16	2.99	2.86	2.76	2.67
55	7.12	5.01	4.16	3.68	3.37	3.15	2.98	2.85	2.75	2.66
56	7.11	5.01	4.15	3.67	3.36	3.14	2.98	2.85	2.74	2.66
57	7.10	5.00	4.15	3.67	3.36	3.14	2.97	2.84	2.74	2.65
58	7.09	4.99	4.14	3.66	3.35	3.13	2.97	2.84	2.73	2.64
59	7.09	4.98	4.13	3.66	3.35	3.12	2.96	2.83	2.72	2.64
60	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.72	2.63
61	7.07	4.97	4.12	3.64	3.33	3.11	2.95	2.82	2.71	2.63
62	7.06	4.97	4.11	3.64	3.33	3.11	2.94	2.81	2.71	2.62
63	7.06	4.96	4.11	3.63	3.32	3.10	2.94	2.81	2.70	2.62
64	7.05	4.95	4.10	3.63	3.32	3.10	2.93	2.80	2.70	2.61
65	7.04	4.95	4.10	3.62	3.31	3.09	2.93	2.80	2.69	2.61
66	7.04	4.94	4.09	3.62	3.31	3.09	2.92	2.79	2.69	2.60
67	7.03	4.94	4.09	3.61	3.30	3.08	2.92	2.79	2.68	2.60
68	7.02	4.93	4.08	3.61	3.30	3.08	2.91	2.79	2.68	2.59
69	7.02	4.93	4.08	3.60	3.30	3.08	2.91	2.78	2.68	2.59
70	7.01	4.92	4.07	3.60	3.29	3.07	2.91	2.78	2.67	2.59
71	7.01	4.92	4.07	3.60	3.29	3.07	2.90	2.77	2.67	2.58
72	7.00	4.91	4.07	3.59	3.28	3.06	2.90	2.77	2.66	2.58
73	7.00	4.91	4.06	3.59	3.28	3.06	2.90	2.77	2.66	2.57
74	6.99	4.90	4.06	3.58	3.28	3.06	2.89	2.76	2.66	2.57
75	6.99	4.90	4.05	3.58	3.27	3.05	2.89	2.76	2.65	2.57
76	6.98	4.90	4.05	3.58	3.27	3.05	2.88	2.76	2.65	2.56
77	6.98	4.89	4.05	3.57	3.27	3.05	2.88	2.75	2.65	2.56
78	6.97	4.89	4.04	3.57	3.26	3.04	2.88	2.75	2.64	2.56
79	6.97	4.88	4.04	3.57	3.26	3.04	2.87	2.75	2.64	2.55
80	6.96	4.88	4.04	3.56	3.26	3.04	2.87	2.74	2.64	2.55
81	6.96	4.88	4.03	3.56	3.25	3.03	2.87	2.74	2.63	2.55
82	6.95	4.87	4.03	3.56	3.25	3.03	2.87	2.74	2.63	2.55

83	6.95	4.87	4.03	3.55	3.25	3.03	2.86	2.73	2.63	2.54
84	6.95	4.87	4.02	3.55	3.24	3.03	2.86	2.73	2.63	2.54
85	6.94	4.86	4.02	3.55	3.24	3.02	2.86	2.73	2.62	2.54
86	6.94	4.86	4.02	3.55	3.24	3.02	2.85	2.73	2.62	2.53
87	6.94	4.86	4.02	3.54	3.24	3.02	2.85	2.72	2.62	2.53
88	6.93	4.86	4.01	3.54	3.23	3.01	2.85	2.72	2.62	2.53
89	6.93	4.85	4.01	3.54	3.23	3.01	2.85	2.72	2.61	2.53
90	6.93	4.85	4.01	3.54	3.23	3.01	2.85	2.72	2.61	2.52
91	6.92	4.85	4.00	3.53	3.23	3.01	2.84	2.71	2.61	2.52
92	6.92	4.84	4.00	3.53	3.22	3.00	2.84	2.71	2.61	2.52
93	6.92	4.84	4.00	3.53	3.22	3.00	2.84	2.71	2.60	2.52
94	6.91	4.84	4.00	3.53	3.22	3.00	2.84	2.71	2.60	2.52
95	6.91	4.84	4.00	3.52	3.22	3.00	2.83	2.70	2.60	2.51
96	6.91	4.83	3.99	3.52	3.21	3.00	2.83	2.70	2.60	2.51
97	6.90	4.83	3.99	3.52	3.21	2.99	2.83	2.70	2.60	2.51
98	6.90	4.83	3.99	3.52	3.21	2.99	2.83	2.70	2.59	2.51
99	6.90	4.83	3.99	3.52	3.21	2.99	2.83	2.70	2.59	2.51
100	6.90	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59	2.50