SUSTAINABLE MAINTENANCE GUIDELINES OF NON-TOLL ROADS IN SOUTH AFRICA

By

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Declaration

I certify that the work in this dissertation submitted at the Central University of Technology is my own original work which has never been submitted to any institution. All sources used in the work have been acknowledged through citations and a list of references.

MICHAEL SELORM GAGBLEZU DATE

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Abstract

Roads are important national assets and are central to economic and social development. There is an essential need for regular road maintenance to keep them operative. Limited budgets for road maintenance are the main challenge facing road agencies such as SANRAL to meet their performance obligations. This is because of competition from other services such as education, health, etc. At the same time, another challenge is the ability of road maintenance activities to contribute to environmental sustainability since road maintenance adversely impacts land and water resources and the discharged areas. This has led to calls for incorporating sustainability principles into road maintenance activities.

This research focuses on developing practical guidelines for sustainable road maintenance. It is also focused on the understanding of how road maintenance can minimize environmental impact, particularly in South Africa. The study was carried out through interviews, questionnaires, archives and journals on road maintenance. Interviews were conducted with people involved in road maintenance. Questionnaires were distributed to road users who constantly use non-toll roads. The type of road involved in this study was National Non-Toll roads under the jurisdiction of SANRAL. The data collected were analysed and the results have proved there is a need for sustainable funding for non-toll road maintenance.

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List of Abbreviations

BE^2ST	Building Environmentally and Economically Sustainable Transportation
CBA	Cost-Benefit Analysis
COMCEC	Standing Committee for Economic and Commercial Cooperation
DEAT	Department of Environmental Affairs and Tourism
EIA	Environmental Impact Assessments
EMS	Environmental Management System
ERF	European Road Federation
FHWA	the Federal Highway Administration
GDP	Gross Domestic Product
GPS	Global Positioning System
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
LCA	Life-Cycle Assessment
LCCA	Life-Cycle Cost Analysis
LEED	Leadership in Energy and Environmental Design
MCDA	Multi-Criteria Decision Analysis
NCHRP	National Cooperative Highway Research Program
NIMS	National Infrastructure Maintenance Strategy
NTTA	North Texas Toll Authority
OCI	Overall Condition Index
PIARC	Permanent International Association of Road Congresses

PMS	Pavement Management System
PPP	Public Private Partnership
RAP	Reclaimed Asphalt Pavement
RAS	Recycled Asphalt Shingles
RCA	Recycled Concrete Aggregate
RCI	Road Condition Index
RMI	Road Maintenance Initiative
RRT	Recycled Rubber Tire
SANRAL	South African National Road Agency Limited
SSATP	Sub-Saharan African Transport Policy Program
TMH	Technical Methods for Highways
Tx-DOT	Texas Department of Transportation
UNECA	United Nations Economic Commission for Africa
USA	United State of America
VCI	Visual Condition Index
VOC	Vehicle Operating Cost

CHAPTER 1 INTRODUCTION AND BACKGROUND STUDY

1.1 Background

In low and middle-income countries, sustainable economic growth is key priority towards poverty reduction and shared prosperity. This depends on reliable and safe transportation systems (Brits, 2010). According to PIARC (2014), roads are the internationally dominant mode of transport comprising millions of kilometres across the world and make substantial contribution to the national gross domestic product (GDP). Furthermore, road networks can transport an estimated 80% of a country's total passenger-kilometres (km) and over 50% of its freight ton-kilometres (km) (Radopoulou and Brilakis, 2016). Road transport is central to general economic and social development (Brits, 2010). There is an essential need for adequate road maintenance in a timely and proper manner to sustain and achieve benefits (PIARC, 2014). This is because *"repair costs are six times maintenance costs after three years of delayed maintenance and 18 times the maintenance costs after five years"* (COMCEC, 2016). According to Radopoulou and Brilakis (2016), it is relevant for road network to be continuously monitored and sustainably maintained due to its great value as a public asset. It is evident that road infrastructure worth 40 billion US dollars had been lost in 85 developing countries due to inadequate road maintenance but twelve billion dollars could have been spent on preventive maintenance to avoid this costly loss (Heggie, 1995).

Road transportation faces many challenges such as limited budgets which deprive road agencies of the opportunity to meet their performance and road maintenance obligations. Another difficulty is the ability of road maintenance activities to contribute to environmental sustainability (Tighe, Gransberg and Gause, 2011). In 1987, the Brundtland Commission described sustainability as *"development which meets the need of the present without compromising the ability of the future generation to meet their own needs"* (Mclvor, 2007). However, Tighe, Gransberg and Gause (2011) defined sustainable transportation as "*providing exceptional mobility and access in a manner that meets development needs without compromising the quality of life of future generations. A sustainable transportation system is safe, healthy, affordable, renewable, operates* *fairly, and limits emissions and the use of new and non-renewable resources"*. Since then several forms of legislation are increasingly calling for stricter accountability and transparency as environment and sustainability have become a legitimate issue (Mclvor, 2007). According to Montgomery, Hirsch and Schirmer (2015), environment and transportation are intensely dependent and need to provide clean urban transport systems. It is important that the effect of transport be addressed clearly in all project design and implementation.

In the South African perspective, the South African National Road Agency Ltd (SANRAL), established in 1998, has been delegated by the South African government *"to provide and manage a world-class, sustainable national road network as cost-effective as possible, in order to stimulate economic growth and improve the quality of life of all South African people*" (Brits, 2010). SANRAL owns and manages all the national roads with a total length of about 21 403 km. This includes 1832 km (9%) toll roads, 1 288 km (6%) build-operate-transfer toll roads, and 18283 km (85%) non-toll roads. In addition, all national roads are paved (National Treasury, 2011). Several roads under provincial jurisdiction are currently in the process of being transferred to SANRAL as national roads (Brits, 2010). Allocation of funds by the National Treasury for National Non-Toll road maintenance is usually insufficient and it is hard pressed to meet the demands of all other public goods and services (South African National Roads Agency/ SANRAL, 2012). This is a huge setback to enabling SANRAL to provide environmentally friendly road networks in South Africa. "It is progressively imperative that road maintenance must be tackled in a sustainable manner and that sustainability be monitored, measured and assessed for improvement during maintenance activities.

This study is expected to assist road agencies and transportation practitioners to be aware of the benefits of sustainable road maintenance and develop guidelines on ways to incorporate sustainable development in road infrastructure from the design stage to the maintenance stage.

1.2 Problem statement

South Africa's entire non-toll national road network of about 18 283 km (85%) is the responsibility of the South African National Road Agency (SANRAL). The sole funding source for the non-toll national road networks is the annual allocation received from the general state budget, appropriated by Parliament through the National Treasury. The revenue for non-toll road network is hard pressed by the National Treasury to meet demands of all other public goods and services. However, SANRAL is struggling to finance the maintenance demand for existing non-toll national roads network, let alone provide for expansion as more provincial roads are being incorporated into SANRAL jurisdiction.

The key setback on existing South African national road networks concerns the R10-R20 billions of estimated national road network maintenance backlog. As new roads are being built in the Republic, the demand for road network maintenance will worsen in the years to come. In South Africa, about 60% of non-toll national road networks are older than the design year of 20 years ago. The seriousness of this is that revenue generated from the National Treasury can maintain only 40% of non-toll road network under its jurisdiction. The fear is that with limited funding, the statistics of non-toll national road conditions with time will increase way above the international benchmark of 10%. The international benchmark states that a country's roads in poor to very poor condition should not exceed 10%.

1.3 Research aim and objectives

The aim of this research is to develop guidelines to achieve sustainable road maintenance for non-toll roads in South Africa. To limit the scope of this study and avoid over-elaboration, the research has focused mainly on answering the following three key objectives to achieve the aim.

1. Conduct an intensive Literature Review on sustainable road maintenance
2. Identify the challenges in improving road maintenance of non-toll roads

3. Develop guidelines for meeting challenges identified.

1.4 Scope of study

The research scope is to focus on sustainable road maintenance for all non-toll roads under the jurisdiction of SANRAL. Road maintenance is the main focus in this research because, currently In South Africa, about 60% of national non-toll road networks are older than the design year of 20 years ago. This is because funds for road maintenance from the National Treasury are insufficient and can only maintain 40% of the non-toll road network under SANRAL jurisdiction.

1.5 Research methodology

Research methodologies used to carry out this study were dissected into four stages in a sequential method and includes literature review, data collection, data analysis and conclusion. Figure 1 shows research methodology flow chart to triumph the set objectives.

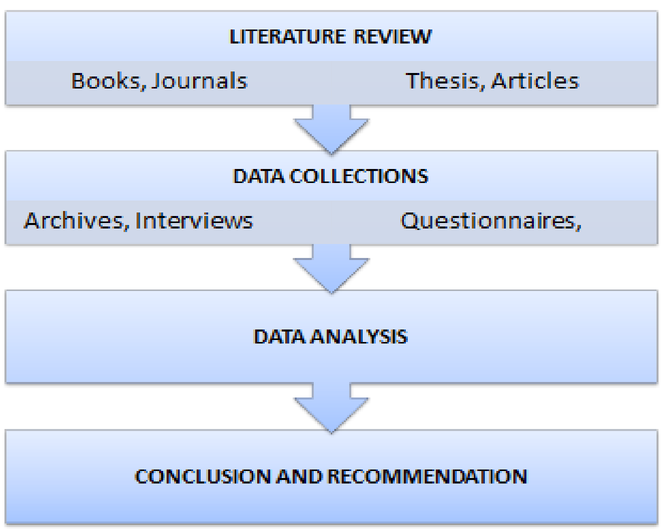

Figure 1: Research methodology flow chart

1.6 Research organization

Chapter 1: This chapter gives a detailed explanation of the background of study and the problem statement. The aim, objectives, scope of study and research methodology flow chart are thoroughly defined and highlighted in this chapter as an overall guideline for this research.

Chapter 2: This chapter discusses the literature review of this research. The chapter gives an insight into the theoretical background of the study and also elaborates on previous researchers' work scope.

Chapter 3: The research methodology implemented in this research is widely discussed is this chapter. This entails literature review, data collection, data analysis and conclusion.

Chapter 4: The data that was collected through questionnaire interviews was analysed in this chapter. Data was analysed using the Microsoft Excel program.

Chapter 5: This chapter discusses the development of sustainable guidelines on non-toll roads after a thorough review on literature and analysis on data collected.

Chapter 6: The conclusions and recommendations for this study are discussed in this chapter. The conclusions were drawn according to the study objective and recommendations for further study highlighted in this study.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction:

The purpose of the literature review was to discuss the theoretical background regarding sustainable road maintenance in existing books, articles, internets and journals.

2.2 Definition of road maintenance and sustainability

According to Burningham and Stankevich (2005), road maintenance *"comprises activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the road margins as near as possible to their as-constructed or renewed condition."* The following are road maintenance definitions from diverse sources.

- Definition from GTKP (2010): this states that *"Maintenance ensures that the asset continues to function as designed or intended, and meet the required quality standards throughout its anticipated lifetime".*
- Definition from Mohamed (2010): this describes road maintenance as the amalgamation of technical and management activities performed on a particular structure to enable the structure to perform or function at its maximum capability. Road maintenance is categorized into two namely: (1) Road maintenance involving repairing work. This involves activities to rehabilitate or replace a damaged component. (2) Road maintenance involving prevention work. This involves activities that prevent defects from occurring.
- From COMCEC (2016), road maintenance is defined as a "*series of activities designed to keep a road network serviceable by reducing the deterioration of pavements."*

In summary, the core objective of road maintenance is to provide a road network which is safe, serviceable and sustainable, thereby contributing to the objective of road asset management, corporate policy and continuous improvement.

The following basic explanations of sustainability, sustainable development, and sustainable highways have been adopted by this paper:

- Sustainability: "*Satisfying basic social and economic needs, both present and future, and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends*" (Armstrong *et al.*, 2013).
- Sustainable Development: "*Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs*" (Armstrong *et al.*, 2013)
- Sustainable Highway: "*Sustainable highways are an integral part of the broader context of sustainable development. A sustainable highway should satisfy the functional requirements of societal development and economic growth while reducing negative impacts on the environment and consumption of natural resources. The sustainability of a highway should be considered throughout the project lifecycle — from conception through construction*" (Armstrong *et al.*, 2013).

2.3 Importance of road maintenance

2.3.1. A constructed road network is a major public investment in any country and is designed to support the national economy (Levik, 2001). Road maintenance supports recuperation of preliminary investments made in the road construction. Routine and periodic maintenance cost for the entire existence of a road is evaluated to be in the vicinity of 2 and 3% of the underlying capital venture. However, when road maintenance is neglected, investment will decrease (Boamah, 2010). According to the World Bank (1988), timely maintenance expenditures of 12 billion US dollars in Africa would save road reconstruction costs of 45 billion US dollars over a decade. "*In Sub-Saharan Africa 150 billion US dollars was spent in three decades building roads. Maintenance was abandoned and a third of that investment has now been misplaced. The result is that 50 billion US dollars of key national assets are gone"* (Levik, 2001).The cost of neglected road maintenance in Africa is estimated at about 0.85% of regional GDP. In Latin American and the Caribbean, the cost is estimated at about 1.7 billion US dollars per year in 1992, amounting to 1.4% of individual countries GDP (Heggie and Vickers, 1998). To prevent such mounting expense, it is important for decision makers to allocate funds for ideal maintenance action (Burningham and Stankevich, 2005).

2.3.2. The most important assets in most countries are roads, and improvement of these assets brings an enormous benefit to its users such as improved access to hospitals and schools, improved comfort, reduced travel time and safety, and lower vehicle operating costs (Burningham and Stankevich, 2005). A well-maintained road network helps to reduce the vehicle operating cost (VOC) as fewer funds are spent on vehicle maintenance (WRA, 2014). According to Heggie and Vickers (1998), money saved on road maintenance increases VOCs by between $2 and $3 when a road network is left to deteriorate in poor condition. Boamah (2010) illustrated the relative discounted life-cycle costs of maintenance spending scenarios as shown in Figure 2. "*For, a traffic level of about 1000 vehicles/day a road in good condition will require 2% of discounted total costs to be spent on maintenance. However, if maintenance funds are reduced, VOC's are likely to increase by about 15%. If there is complete neglect of maintenance, a paved* *road will eventually start to disintegrate and annual VOC will increase by 50% and if continued will result in the need for new road development."*

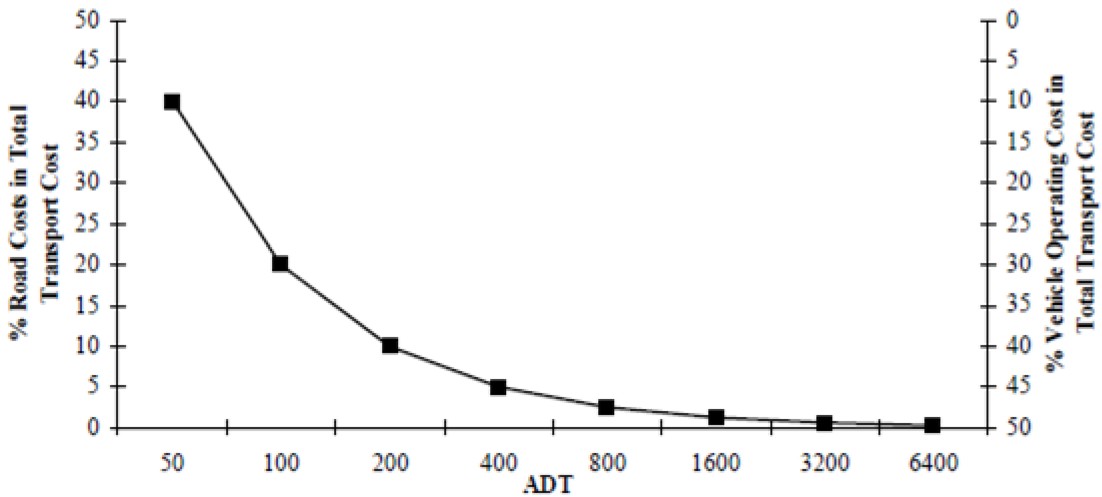

Figure 2: Relative proportions of road and vehicle costs in total transport cost (Boamah, 2010)

2.3.3. Road maintenance has a great effect on road safety. The cost of contingency is on average two times more than the costs of road maintenance, while on roads with heavily ponderous traffic is five times, and even ten times more than the costs of road maintenance (Rahja, 2008). It is extensively recognized by engineers and road safety experts that poor road condition is a huge contributing factor to road accidents and human deaths (Roodt, 2014). For instance, neglected roads with insufficient skid resistance can be a contributing factor to road accidents. Potholes pose a great danger to motorcycles and cyclists. Road maintenance can reduce road accidents when all these defects are repaired. However, the negative perspective will be that road maintenance interventions can prompt increased speeds which might bring about mishap fatalities (Boamah, 2010).

2.3.4. According to Boamah (2010), road maintenance has various impacts on the natural environment, such as water contamination from oil spillage, dust causing air pollution, noise and vibration during maintenance activities. Well-maintained roads reduce carbon emissions into the environment, while in turn, vehicle emissions are affected by the road quality and traffic speed. The level of noise in the environment also depends on the type of road surface and its degree of deterioration (PIARC, 2014).

2.3.5. Roads lead to an appropriate level of access to all places, such as tourism sites and agriculture farms especially for the poor, and create employment opportunities leading to poverty reduction (Donnges *et al.*, 2007). Reliable quality roads help to encourage and widen government policy initiatives such as health and physical wellbeing, for example, through more cycling and walking (Baril, Chamoro and Crispino, 2013). Improvement in the quality of road service will increase accessibility to school enrolment and attendance. It is also vital to note that a community with easy access to essential services and markets at all times is most likely to eradicate poverty (Baril, Chamoro and Crispino, 2013). Therefore, maintenance of roads must be a priority area for growth and development of people (PIARC, 2014).

2.4 Sustainable development and road maintenance

The term ‘sustainable highway’ is considered an oxymoron by many practitioners. This is because of the significant material requirements and the impacts on the human and natural environments due to highway development and vehicles’ use of the system. However, when considering the triple bottom-line principles, one must also consider the social and economic advantages that highways provide, including access, mobility, and the economic benefits of moving people and goods. In that framework, highways can be perceived as a more sustainable part of our infrastructure – and certainly a necessary part of our society. Road infrastructure is not just about implementing movement of goods and people, the asset allows the achievement of economic, social and environmental sustainability (Infrastructure Voluntary Evaluation Sustainability Tool: INVEST website).

For a transportation system to be sustainable is a growing challenge. This is because land and the natural resources are needed to build the roadways and the energy to move the vehicles, negatively impact the human and natural environment through the emissions, congestion and accidents created by vehicles operating in the system (FHWA, 2013). According to Simpson et al. (2014, p.2), "Building new road account for 30% of raw material usage, 12% of freshwater usage, and 30% of greenhouse gas emissions; transportation of materials and other sundry tasks account for a further 18% of greenhouse gas emissions, 45% to 65% of waste to landfills, 71% of electricity consumption and 31% of mercury in solid waste."

Many nations are planning for massive road expansion due to increasing urbanization. This poses a major potential threat to the natural environment. In light of limited natural resources, sensitive environmental conditions, and limited economic resources, there was a perception that pollution generated during construction activities has little impact. Transportation planners, engineers, and environmental scientists worldwide have, however, recognized that there is a need for progress in improving environmental performance with roadway systems. In 1987, a report – mostly known as the Brundtland report – titled "Our Common Future" and released by the United Nations' World Commission on Environment and Development, stated that there is "need for a dialogue on ways to balance the need for economic development and need to protect the environment." This led to the development of sustainability-based programmes and implementation tools to help integrate such philosophies, concepts, and actions at programme and project levels. It is very relevant that road maintenance activities are tackled in a sustainable manner; performance regarding sustainability should be measured and assessed for improvement (Montgomery et al., 2015; Leyden et al., 2007; McIvor, 2007; Suad et al., 2015).

2.5 Incorporating Sustainability into Road Maintenance

Recognizing the benefit of sustainability, several researchers have investigated bridging the gap of incorporating it into road infrastructure for a greener highway. For example, several sustainability rating systems such INVEST (Infrastructure Voluntary Evaluation Sustainability Tool), Greenroads®, Envision™, GreenLITES, Leadership in Energy and Environmental Design (LEED®) and BE^{2}ST-In-Highways (Building Environmentally and

Economically Sustainable Transportation-Infrastructure-Highways) have been designed to incorporate sustainability into roadway design and construction.

Incorporating sustainability into road infrastructure may not be achieved quickly. However, the principles of sustainability can be used as a guide towards developing sustainable road maintenance strategies. Sustainable development of road networks needs to satisfy the three-sustainability principle: reduce the impact of climate change, reduce the impact on human health and reduce the effect on biological diversity (Puodziukas, Svarpliene and Braga, 2016).

Figure 3:The three principles of sustainability (Armstrong et al., 2013)

The three principles can be defined further as follows:

The Social principle: This principle encompasses sustaining fundamental human needs impartially and effectively. It contemplates solutions grounded on factors such as human health, safety, access, mobility, mode choice, cultural resources, archeological resources, aesthetics, and recreation.

The Environmental principle supports three spontaneous laws: (1) Do not extricate materials from the Earth faster than they can be restored; (2) Do not produce waste faster or in a greater amount than it can decay and reintegrate into an ecosystem; (3) Do not harm or disturb natural processes or ecosystems with human activities.

The Economic principle: This principle espouses efficiently and industriously using public capital, avoiding depreciation of capital assets. It contemplates resolutions based on factors such as financial durability, reliability, responsibility, lifecycle costs, benefit-cost-driven decisions, and the use of natural resources.

According to Reid and Bevan (2011), the principle of sustainability should by applied by planning agencies during transportation planning, to assess the various impacts transportation can have on the environment, society and the economy. The concept of incorporating sustainable development into design and construction has already been applicable in the building construction industry, but in recent times this concept has been adopted into the transportation industry due to the benefit of lower maintenance costs (Athalia, 2012).

Sustainability is of vital importance because anything we decide to do as a society will have positive or negative impacts on the natural environment. When unsustainable action continues, they can harm the human existence by creating greenhouse gases that cause climate change, depleting natural resources that are needed for future energy and infrastructure, and polluting the air, soil, and water on which humans depend for existence. We must change the way we procure materials, construct infrastructure and conduct our daily activities for these impacts to reduce (Armstrong *et al*., 2013).

Integrating sustainability on a roadway project means "*setting goals that support the vision and are contextually appropriate for the project, and then implementing sustainable solutions that achieve these goals*". A project's lifecycle usually consists of three stages: system planning, project development, and operations and maintenance (O&M). The project development stage consists of three phases: project planning, design, and construction. It is important to know when the project is in project development. This will help determine which decisions can be influenced at that time. It is relevant to know that the opportunities to incorporate sustainability vary and eventually diminish as a project moves through development (Armstrong *et al.*, 2013).

Armstrong *et al.* (2013) developed a step-by-step approach (as shown in Figure10) for practitioners that focused on project-level planning to integrate sustainability into the planning, design, and construction of roadway projects. Though sustainability can be integrated at any time during project development, it is recommended that sustainability be implemented in the earlier stages. In that way there are more opportunities for integration. The six steps of the approach are demonstrated in **Error! Reference source not found.**.

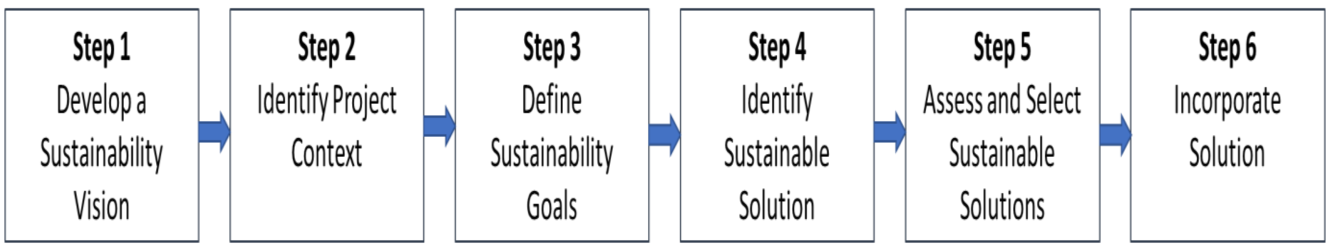

Figure 4: Sustainability approach steps (Armstrong *et al.*, 2013)

Steps 1, 2, and 3 are intended to be completed during project planning. Steps 4 and 5 are intended to be completed during project design and Step 6 is intended to be conducted throughout design and completed during construction. Sustainability vision assisted the project team and stakeholders to understand the desired outcome of a project and how sustainability could be achieved. The context helps to understand the boundaries and constraints of the project. Defining sustainability goals helps the project team to measure sustainability progress, analysing and ranking sustainable solutions. The solutions identified can be used to measure visions and goals from the previous steps on the projects. The next step is to assess sustainable solutions to help in selecting an achievable set of solutions for the project. The final step is to incorporate solutions as soon as each solution is assessed and selected.

2.6 Road maintenance strategies

Muyengwa and Marowa (2015) separated maintenance into two categories, preventive and corrective maintenance. Preventive indicates the type of maintenance intended to reduce the probability of failure or degradation of the functioning of an item and is carried out at programmed intervals or according to a prescribed condition, while corrective maintenance refers to the type of maintenance undertaken after a breakdown when an obvious failure has been allocated. This is described in **Error! Reference source not found.** below.

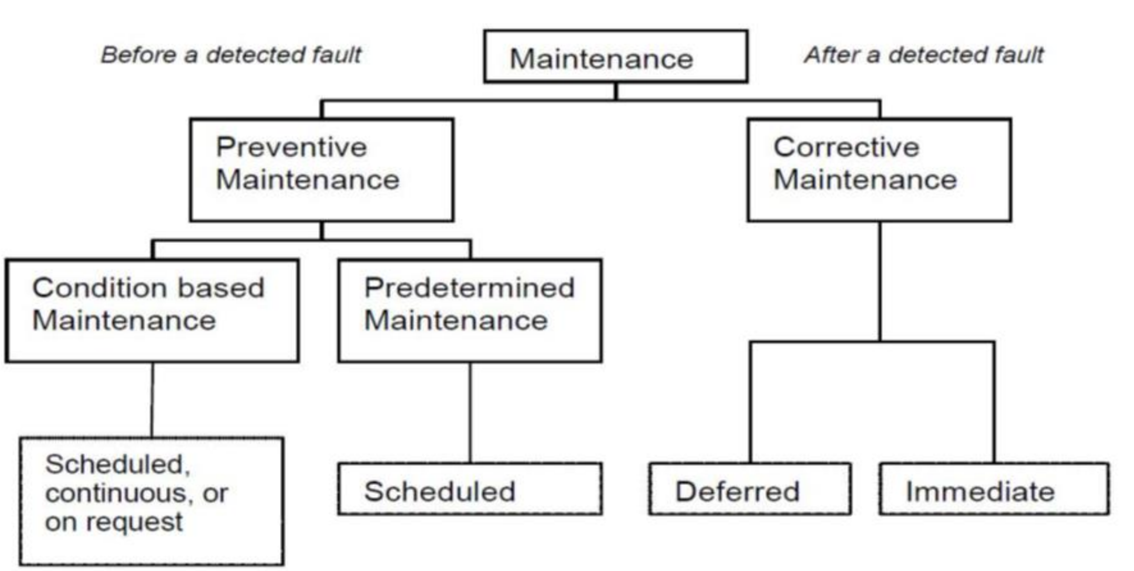

Figure 5: Classification of road maintenance (Muyengwa and Marowa, 2015)

It is important to implement all maintenance strategies to achieve comprehensive pavement preservation, but preventing pavement from reaching the condition where corrective maintenance is required should be emphasized more (Hicks *et al*., 2000). However, Ararsa (2012) included another subdivision of a maintenance strategy besides preventive maintenance and corrective maintenance, called "*design-out maintenance*". It entails redesigning a system of the component to decrease the need for maintenance by removing unwanted failure modes. From the HDM report, Watanatada *et al.* (1987) described maintenance strategies developed to be compatible with various distinctions between capital and non-capital expenditure.

Routine maintenance comprises small-scale activities that are conducted frequently to ensure that the road is functioning properly. These activities are sometimes referred to as *proactive* and/or *reactive* maintenance (SANRAL, 2012). They comprise restricted repairs (typically under 150 m in constant length) of pavement and shoulder defects, and consistent maintenance of road drainage, sideways, edges, and furniture. (Examples:

pothole patching, reshaping side drains, repairing and cleaning culverts and drains, vegetation restriction, dust control, erosion check, snow and sand removal from voyaged way, repainting pavement stripes and markings, repairing alternately displaying traffic signs, guardrails, signals, lighting standards, and so forth, roadside cleaning and maintenance of rest areas) (Watanatada *et al*., 1987).

Periodic maintenance comprises planned activities applied on pavements prior to their manifestation of distress. This activity is intended to prolong the life of a pavement by restoring (or maintaining) desirable properties while such measures are still cost-effective. Periodic maintenance can prolong future deterioration, or correct prevailing distress. It is also classified as preventative or corrective maintenance (SANRAL, 2012).

Rehabilitation is defined "*as a structural or functional enhancement of a pavement which produces a substantial extension in service life, by substantially improving pavement condition and ride quality* (Hall *et al.*, 2001)." Compared to periodic maintenance, rehabilitation tasks are more thorough and complex (Schroeder, 1990). Rehabilitation also includes full-width, full-length surfacing with selective strengthening and shape correction of existing pavement or roadway (inclusive of repair of minor drainage structures) to restore the structural strength and integrity required for continued serviceability (Watanatada *et al.*, 1987). Examples are asphalt concrete overlays, selective deep patching, and overlays, granular overlay and surfacing, surface treatment with major shape correction, recycling of one or more pavement layers. The term 'strengthening' is sometimes used for a particular category of rehabilitation works (Watanatada *et al.*, 1987). Rehabilitation is usually necessary after 20 years only if the proper routine and periodic maintenance are undertaken, but If roads have deteriorated too badly, no level of routine or even periodic road maintenance can yield benefits, and total rehabilitation of the roadway will be necessary (Schroeder, 1990).

Betterment (or Improvement) comprises work to enhance the quality of service on roads with adequate remaining pavement structural life. Such work is normally applied on routes experiencing unforeseen traffic growth, and may cover improvements to the quality of service on existing roads, such as relief of traffic congestion (South African National Roads Agency: SANRAL, 2012). Improvement also involves geometric improvements related to width, curvature or gradient of roadway, pavement, shoulders, or structures to enhance traffic capacity, speed or safety, and inclusive of associated rehabilitation or 'resurfacing' of the pavement (Watanatada et al., 1987).

Reconstruction *"is the removal and replacement of all asphalt and concrete layers, and often the base and subbase layers, in combination with remediation of the subgrade and drainage, and possible geometric changes*(Hall *et al.*, 2001)*"*. Reconstruction is highly capital intensive and its hardly performed based on pavement condition but in situation such as capacity improvement need, change of road alignment and outmoded geometrics serves a key decision to reconstruct a road network. Optimal timing of these activities depends primarily on climate, traffic levels, and the original quality of construction (Schroeder, 1990)

Resurfacing can be catergorized to in two parts according to Hall *et al.* (2001): (1) A fundamental overlay that extends the road's service life by increasing its structural capacity and serviceability, usually together with pre-overlay repair and/or recycling; A structural overlay also corrects any functional deficiencies. (2) A functional overlay, significantly extending the service life of the road by correcting functional deficiencies, without significantly increasing the structural capacity of the pavement (Hall *et al.*, 2001).

Recycling is the reuse of pavement materials for resurfacing and reconstructing a road network. For rigid pavement, pavement materials can be reused as aggregate for base or subbase layers whereas for flexible pavement, materials can be used for all pavement layers through a hot mix plant. Flexible and rigid pavement needs to be recycled separately (Hall *et al.*, 2001).

2.7 Impact of road maintenance on road value

Every country requires a core road network that carries about 80% of national traffic, including key roads within urban areas and roads providing effective access to rural areas (Burningham and Stankevich, 2005). According to COMCEC (2016), roads are one of the largest, most important, and valuable assets managed by any government. For instance, the Japanese Highway Public Corporation controls road value that equals the assets value of General Motors. The New Zealand road asset is estimated at €15 Billion, which is the largest publicly owned national asset in the country. The future value of this road network (assuming no new construction is undertaken) depends on the quality and timeliness of road maintenance. These roads, constructed at a hefty cost, should be sustainably maintained and adequately preserved (Sarkar, 2011). Sustainable road maintenance controls the depreciation value of road assets, therefore not having impact on the road user and society (PIARC, 2014). Postponing road maintenance results in high direct and indirect costs (Burningham and Stankevich, 2005). All road networks require timely and steady maintenance to safeguard construction investment (Donnges *et al.*, 2007).

It is vital to ensure that road asset is preserved timeously due to the amount of time, effort and money invested in planning, designing, and construction. Well-planned maintenance not only optimizes the use of existing road assets, but it also protects the huge amount of investments made in providing such infrastructure (Pinard, Rijn and Newport, 2016). A standard life-cycle of a pavement is shown in **Error! Reference source not found.**. The figure indicates two paths that diverge around year 14. The first path shows what happens when maintenance is performed. The pavement deteriorates slowly from excellent condition in year zero to good condition in year 14, at which time preventive maintenance is performed for $1, and the condition returns to near-excellent condition before continuing to gradually deteriorate. At this early stage, the only changes in pavement condition are slight increases in rut depth and roughness; there are only slight changes in the average vehicle operating cost due to the small increase in roughness. The second path shows what happens when road maintenance is delayed. The pavement deteriorates from year 0 to year 14 as it did in the first path, but in year 14, maintenance is delayed until year 18. The pavement deteriorates quickly from year 14 to year 18, diminishing from good condition to poor and to very poor condition. In year 18, the cost of maintenance is $4 to $5. In this illustrative example, the cost of maintenance is four to five times greater than a baseline scenario (National Cooperative Highway Research Program (NCHRP), 2011). According to Pinard, Rijn and Newport (2016), taxpayers bear the brunt of paying four to five times what the road agencies/ministries avoided spending.

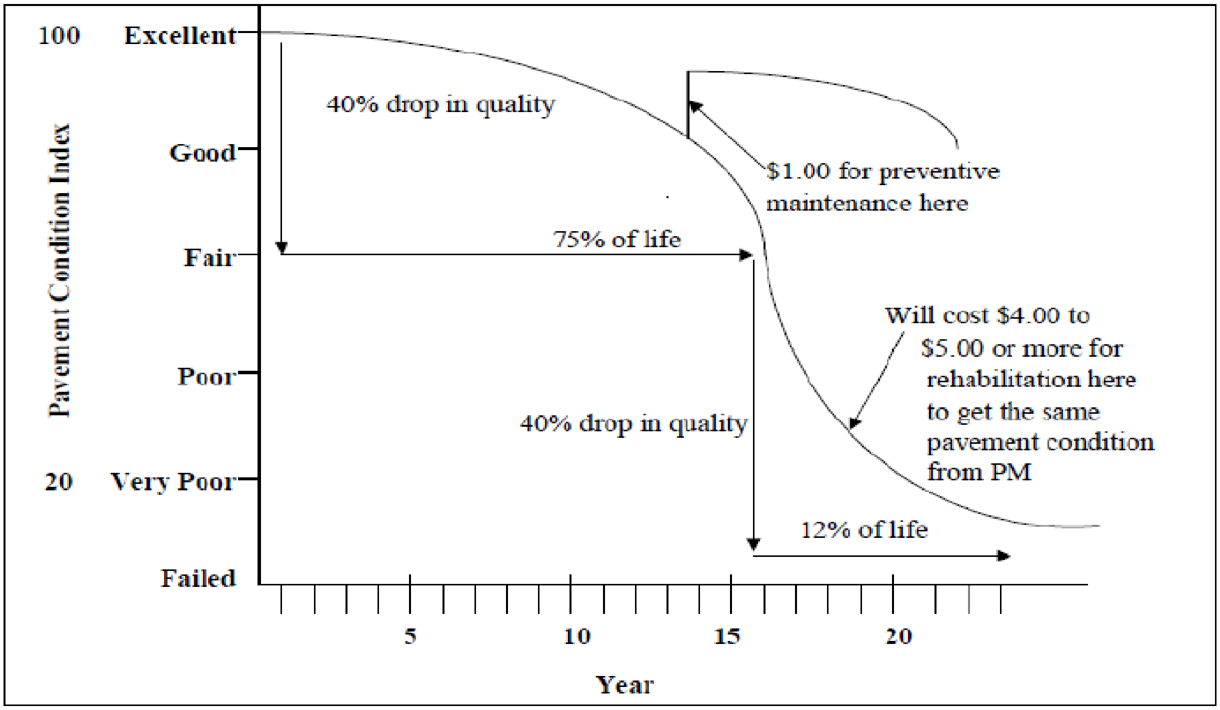

Figure 6: Cost of delayed pavement maintenance (NCHRP,2011)

2.8 Reasons for road maintenance gap

On the African continent, post-1980, a total network exceeding 2 million kilometres with an assets value of about US$150 billion was constructed. But by 2000, about 33% of the asset value has been lost due to lack of routine and periodic maintenance (Pinard, Rijn and Newport, 2016). The necessity of road maintenance is globally acknowledged, but yet it is still not sustainably executed (Jamaa, Francis and Andrew, 2016). Schroeder (1990) revealed that the World Bank has already aided 85 countries in combating one-quarter of paved and one-third of unpaved roads which are already in poor shape. In other words, to slow future deterioration, about 4 to 5 billion US dollars is needed for strengthening necessary to prevent structural failure for 40% of passable paved roads that are in their critical stage.

COMCEC (2016) stated three essential factors that are the cause for the road maintenance gap, namely: (a) The structure and nature of organizations responsible for road maintenance; (b) lack of pressure for better roads; and (c) inadequate and unreliable funding. The focus has mainly been on expanding road networks rather than on maintenance in the past decades. In support to this statement, Burningham and Stankevich (2005) stated that many countries tend to favour new construction, rehabilitation or reconstruction of roads over maintenance. This is because road maintenance is diplomatically unappealing, new road construction and road rehabilitation are more observable and generate more political esteem (Levik, 2001). Larger road construction would require funds for maintenance in the future, but this is largely ignored due to inadequate future financial resources. Mobilizing the resources needed to finance road maintenance is of paramount interest in most developing countries (Schroeder, 1990). Basically, funds for road construction come from capital budgets, whereas the funds for road maintenance come from operational budgets. In low and middle-income countries, however, the construction of new roads is often financed with loans from multi-lateral development banks, sometimes called donor funds. The contractual agreements for these loans are sometimes weak to enforce preventive maintenance (COMCEC, 2016). According to Burningham and Stankevich (2005), donor funds for road construction have a low perceived cost to a country. Experience suggests that it is easier to obtain government approval for road construction projects, especially those financed with loans, than it is to get funds approved for road maintenance (COMCEC,2016). Pinard, Rijn and Newport (2016) advised that when budgets are constrained, it is far better to invest in maintenance than in new construction or rehabilitation.

Inadequate funding for maintenance agencies responsible for maintenance has worsened the maintenance gap due to limited dedicated funds for maintenance activities. The main reason why road maintenance is in a financial crisis, is that road users pay very little for the use of the road network (Heggie, 1995). Maintenance agencies are usually not held accountable for the problems caused by the lack of maintenance. This is mainly due to limited understanding of how relevant it is to carry out long-term preventive maintenance. The fact that cost-effective maintenance requires a significant amount of planning, both administrative and managerial, is still misunderstood. Other agencies still consider road maintenance a way to remedy the situation once the road has deteriorated rather than consider it as a recurrent or preventive activity (COMCEC, 2016).

The transfer of responsibility within an organization from central to local bodies has exacerbated the situation since the technical, managerial and administrative capacity is simply lacking in the local bodies (COMCEC, 2016). Maintenance agencies do not bear the cost of poor maintenance; the road users suffer the most (Heggie, 1995). Without any public pressure from the road user to improve the condition of the road network, there is little political or administrative urgency attached to improving maintenance. Though road funds are managed by central boards, they need to be cooperative and collaborate with various agencies at the national, district and community levels (Oronje, Rambo and Odundo, 2014).

Furthermore, there is a lack of clearly defined responsibilities with managing different parts of a road network. It is usually unclear which agency is responsible for managing different parts of the road network, controlling overloading, managing urban traffic, intervening to improve road safety, or intervening to reduce the adverse environmental impacts associated with road traffic (Heggie, 1995).

2.9 Road maintenance framework prioritization

The complexity of road work makes it difficult to predict the condition of the road networks in the future since road networks are geographically spread over large areas. As road maintenance forms a fundamental part of road management, it needs to be part of the road management framework. Asset Management System (AMS) is a tool usually used by road authorities responsible for road maintenance (COMCEC, 2016). Zimmerman and Ram (2014) define AMS as "*a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost*." COMCEC (2016) listed four (4) functions for road agencies for managing road networks:

Strategic planning entails analysing the road network and preparing a long-term tactical plan needs of road network. Examples include maintenance needs, and the resource requirements for different future budgetary and economic scenarios.

Programming involves developing a multi-year programme of work and associated expenditures. This work programme identifies future maintenance needs of the road network, and prioritizes these needs based on costs and benefits and available budgets (COMCEC, 2016). If the budget is deficient for all the acknowledged tasks to be carried out, priorities should be set to decide which work should be commenced and which should be postponed (Boamah, 2010).

Preparation includes developing the details for implementing the multi-year programme of work-detailed designs and preparing cost estimates (COMCEC, 2016).

Operations management covers the management of on-going works activities of the organization on a daily or weekly basis. Operations must be monitored to ensure that work identified has, in fact, been carried out (COMCEC, 2016).

Due to possible insufficient budgetary allocation, road engineers in charge of road maintenance need to assess the importance of various maintenance activities to ensure that resources secured are utilized in the most effective manner (Donnges *et al.*, 2007). There should be a prioritization of road maintenance expenditure, as showed in **Error! Reference source not found.**. Top priority should be given to maintenance while new construction should be given the lowest priority, unless there is overwhelming economic justification for it to pre-empt other activities (Pinard, Rijn and Newport, 2016) .Among the priority boundaries are the discovery and modification of bottlenecks (spot improvements) as the second priority, followed by detection and rectification of failed sections (local reconstruction) as the third priority, and study of supply-demand disproportions necessitating improvement. The illustration also advocates that the beginning of any other activity besides maintenance leads back to maintenance. Hence, failure to maintain a road in an appropriate routine is equivalent to an act of disinvestment, for it suggests the sacrifice of previous investments in roads (Pinard, Rijn and Newport, 2016).

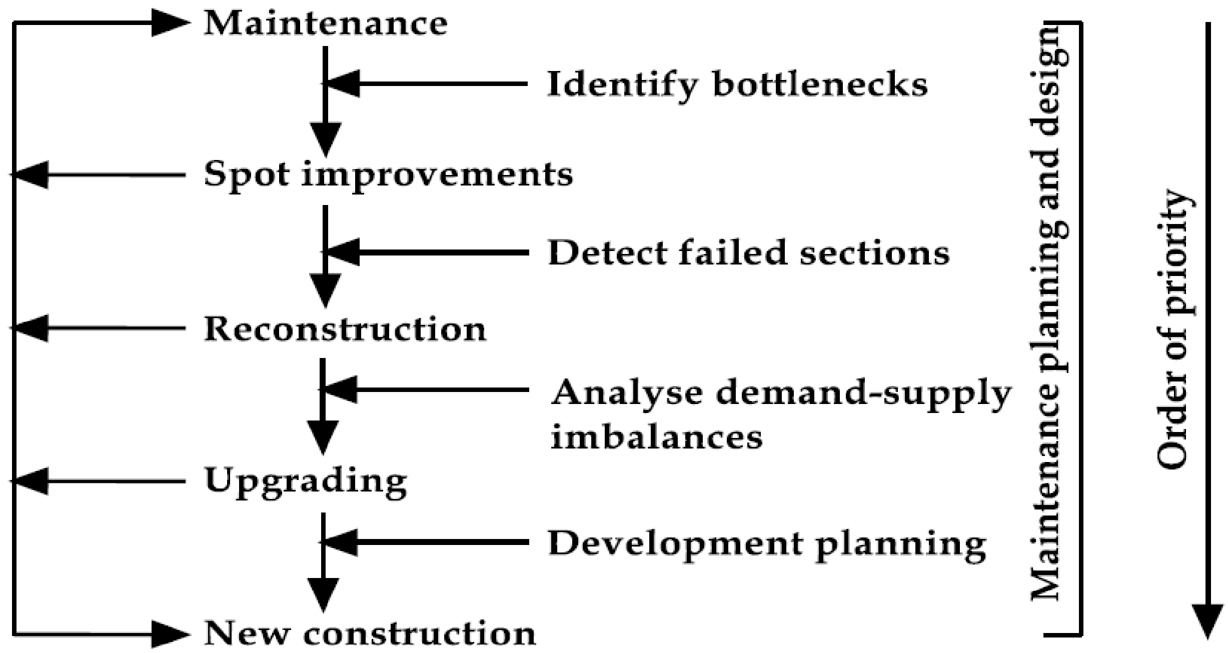

Figure 7: Hierarchy of expenditure options (Pinard, Rijn and Newport, 2016)

2.10 Causes of road deterioration and road defects

According to (Boamah, 2010), physical environment, traffic, material properties, quality of road construction, design standards and the age of the pavement are the main causes of road deterioration. Adlinge and Gupta(2009) defined road deterioration as "*the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions*". The causes of road deterioration are discussed in the following paragraphs.

2.10.1.1 Environmental factors

Rainwater and temperature are some of the basic factors that may contribute to road deterioration. Moisture in the form of rainwater can penetrate into the road structure through cracks and holes on the surface and also through the underlying water table by capillary action. This weakens the support strength of the subgrade, causes swelling and shrinkages and results in heaving and reflective cracking on the road surface. Changes in temperature may cause expansion and contraction of the road network and may result in fatigue, reflective cracks and failures on the road surface (Adlinge and Gupta, 2009; Boamah, 2010).

2.10.1.2 Traffic volume and loading

The most important factor influencing road performance is traffic. Vehicles cause significant deformation to the road structure in the form of loading magnitude, configuration and the number of load repetitions by heavy vehicles. "*The damage caused per pass to a pavement by an axle is defined relative to the damage per pass of a standard axle load, which is defined as an 80 kN single axle load (E80). Thus a pavement is designed to withstand a certain number of standard axle load repetitions (E80's) that will result in a certain terminal condition of deterioration"* (Adlinge and Gupta, 2009).

2.10.1.3 Material properties and composition

Road deterioration can also be influenced by the choice of materials used for the construction of road structure. Due to various different characteristics in terms of load-bearing capacity, gradation mix properties, elastic and resilience modulus of different materials, poor choice of road structure materials can affect the strength and performance of the road structure (Boamah, 2010).

2.10.1.4 Construction quality

Roads structures not constructed to the preferred specification will result in road deterioration. "*For example, failure to obtain proper compaction, improper moisture conditions during construction, poor quality of materials and inaccurate layer thickness (after compaction) all directly affect the performance of a pavement"* (Boamah, 2010).

2.10.1.5 Age of pavement

According to Boamah(2010), pavement distresses begins to accumulate when pavement ages and also due a continuous traffic repetition. For instance, the stiffness of asphalt increases with age due to hardening. This makes the road more vulnerable to thermal cracking.

2.10.1.6 Maintenance

The maintenance activities involved in repairing a road defect cause road deterioration. The performance of roads basically depends on the what, when and how maintenance is performed. Late maintenance leaves road structure in a very poor condition which results in increases in travel time, high VOC and limited access to social life (Boamah, 2010).

Pavement deterioration manifests itself in various kinds of distresses. An overview of different types of road defects is presented in **Error! Reference source not found.**.

Table 1: Types of Pavement Defects (Boamah, 2010)

Type of Pavement Deficiency	Description
Surface Distress	
Cracking	These are caused by fatigue failure due to repeated loads, or shrinkage of the asphalt and daily temperature cycling. They may be single or multiple with varying degrees of severity. They are expressed as a percentage of carriageways.
Raveling	Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. This generally indicates that the asphalt binder has hardened significantly. They are also expressed as a percentage of carriageways.
Potholing	Potholes are small usually less than one metre in diameter bowl-shaped depressions on the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free water collecting inside the hole. They are produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface quality, weak spots in the base or subgrade. The number of potholes per km is expressed in terms of the number of standard-sized potholes of area 0.1m2.
Shoulder Distress	Shoulder elevated over road surface or excessive gravel causes wind-rows along roadway edge. Possible causes are loose gravel on road surface combined with traffic action, poor construction, and improper maintenance. They are expressed in metres per km.
Deformations Distress	

Rutting	Rutting is characterized by longitudinal depressions in the pavement surface that occur in the wheel paths of a roadway. Poor mix stability, excessive bitumen in the mix and repetitive loading on poorly compacted mix are several causes of rutting. They are expressed as the maximum depth under 2 m straightedge transversely across a wheel path.
Depressions and Sags,	Depressions are localized pavement surface areas with elevations higher than those of the surrounding pavement. They are also created by settlement of the foundation soil or are the result of improper compaction during construction.
Profile	
Roughness	Deviations of surface from true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage expressed in International Index (IRI m/km).
Friction	
Skid Resistance	Resistance to skidding expressed by the sideways of force coefficient (SDF) at 50 km/h measured using sideways for the coefficient Routine Investigation Machine (SCRIM).
Texture Depth	Average Depth of the surface of a road expressed as the quotient of a given volume of standard material (sand) and the area of that material spread in a circular pattern on the surface being tested.
Drainage	Drainage condition defines the drainage factor as either good fair or poor.
Gravel Loss	Deterioration of unpaved roads is characterized primarily by material loss from the surface.

2.11 The Road Maintenance Initiative (RMI)

The RMI was initiated by the United Nations Economic Commission for Africa (UNECA) and the World Bank with support from the Sub-Saharan African Transport Policy Program (SSATP) to discover the foundations of poor road maintenance and develop reforms needed to transform the situation (Heggie, 1995).

The original chapter of the RMI programme was directed at raising knowledge on the demand for comprehensive road maintenance guidelines and detecting whether current guidelines were unproductive and unsustainable. The second chapter then moved on to country initiatives in nine target countries: Cameroon, Kenya, Madagascar, Nigeria, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. The country programmes primarily focused only on main roads and on promoting reforms in three main areas: (a) planning, programming, and financing; (b) operational efficiency; and (c) institutional and human resource development (Heggie, 1995).

According to Fakudze (2005), establishment of sustainable sources of funding has been one of the main blocks of the RMI programme. This comprises the following: (1) Proceeds from road tariffs should be consigned in an exclusive account or Road Fund; (2) Positioning the Road Fund under the influence of a Roads Board with representation of road users and private sector organizations; (3) The efficiency of the Road Funds and their sustainability depend on the precise legal and administrative organizations within which they function. The author further highlighted the basic essential elements needed for an efficient and sustainable Road Fund: (1) The Fund should be completely subsidized by the user fees rather than allocations from tax proceeds; (2) An independent board comprising agents of road user groups, who are nominated by the organizations they signify, should administer the Fund; (3) The Board should be permitted to set the level of the pricelist based on a fuel levy, licence fees, and/or bridge and ferry tolls, in response to changing road expenditure needs, currency devaluations and inflation; (3) The charge components should be consigned directly into the Road Fund; (4) The Fund should be managed according to comprehensive commercial ethics, with a commercial accounting system, clear disbursement procedures and independent financial audits and selective technical audits.

2.11.1 The block in road maintenance management

The Africa RMI implemented four basic building blocks designed to transform the road maintenance issues.

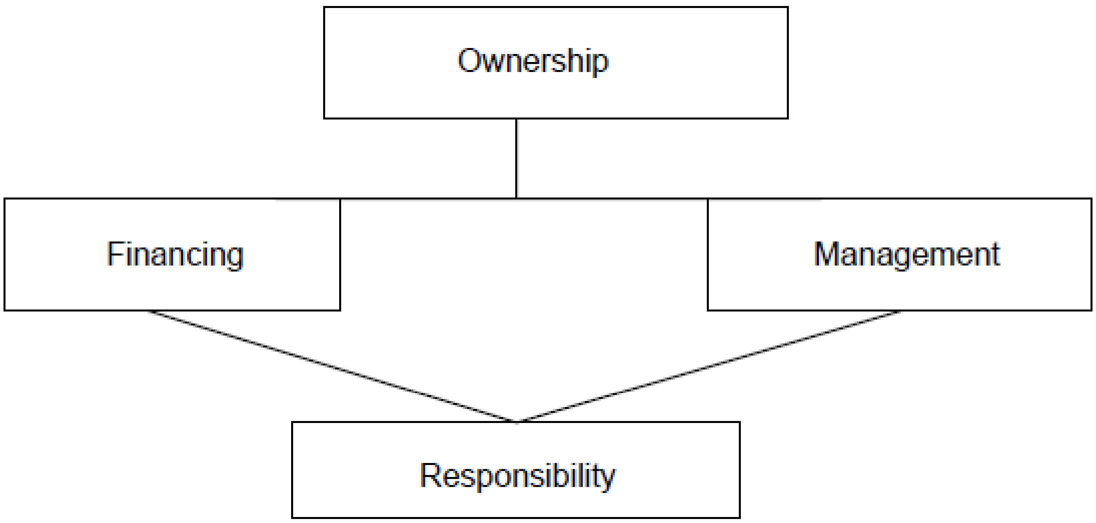

Figure 8:The four basic building blocks (Heggie, 1995).

2.11.1.1 Creating ownership

This block entails mobilizing active support from road users in order to assist in helping win public support in securing stable road funding. The road user takes an active interest in the management of roads and willing to pay for road use to solve the problem of road financing (Fakudze, 2005)

2.11.1.2 Financing

Due to the present state of fiscal conditions, most governments cannot adequately allocate budget for road maintenance. Without an adequate flow of funds, the reforms on road maintenance would be unsustainable. Establishing a secure and stable flow of funds is therefore essential. Road tariffs consisting primarily of vehicle licence fees and a fuel levy have been introduced. The tariff is generally set to cover the full cost of operating and generation of revenues needed to support the operation and maintenance of roads (Heggie, 1995; Fakudze, 2005). According to Glaister (2010))there is a distinction, though very often confused, between funding and financing. "*Funding is the fundamental* *source of resources, financing is about borrowing and lending to adjust the point in time when the capital is available to spend in relation to an available revenue stream*" (Glaister, 2010) The primary problem is funding.

It is in the interest of road users to have well-maintained roads. Queiroz (2003) discussed appropriate methods of securing funds for road maintenance since experience has shown that road users are willing to pay for road maintenance once there is assurance that revenues generated will be spent on road maintenance. Charges on road users must be economically efficient, flexible to inflation and not easily evaded.

Taxes on vehicle fuel are relatively inexpensive and a widely used method of revenue collection for road use. Government uses these taxes from fuel to raise revenue and allocate them to carry out appropriate level of road maintenance and perhaps new construction. The problem with a fuel levy is that it does not reflect the severe damage done to the road by heavy trucks. Although trucks exhaust more fuel per kilometre than cars and would, therefore, pay more fuel taxes per kilometre travelled, this is not in proportion to their higher impact on the roads. Therefore, fuel taxes need to be complemented by extra charges on heavy vehicles (Queiroz, 2003).

Vehicle licences generate revenue in the form of licence fees paid by road users annually. Revenue is easily generated, distinguishes between types of vehicle and reflects the costs of each type on the roads. The setback with vehicle licences is that they are not use-related. A truck used for only 30 000 km per year would disburse the same as one traveling 150 000 km (Queiroz, 2003).

Direct Usage Charges have been used in Norway, Sweden and New Zealand. This system is an alternative to annual licence fees generated from heavy vehicles. The problem with this system is that it requires a significant initial expenditure, hi-tech administration, and is prone to avoidance. Even in law-abiding New Zealand, the evasion is projected at 10 to 20% (Queiroz, 2003)

Tolls are charged for the use of specific facilities such as specific roads, bridges, and tunnels. They are a costly form of generating proceeds (Queiroz, 2003)

2.11.1.3 Assigning responsibility

This involves creating an articulate and consistent organizational structure with defined designated responsibilities among different individual road agencies for managing different parts of the road network. Responsibilities to be delegated include, among others, maintenance, operations, traffic management, improvements, road network development accident and claims resolution and assessment of environmental impacts (Heggie, 1995). Basically, the central government department, through the Ministry of Works, manages the main roads while the rural roads are the responsibility of the local government. Due to the shortage of both resources and technical capacity, semi-autonomous road agencies have been established to manage the main roads on a commercial basis to mitigate for the ever-rising costs of building and maintaining the roads (Fakudze, 2005)

2.11.1.4 Strengthening the management

This block focuses on ensuring that value for money is achieved in the management of roads, especially with the involvement of road users. Road users advocate for sound business practices and expect clear management objectives, competitive terms and conditions of employment, consolidated budgets, commercial costing systems, and effective management information systems. This may include outsourcing the work to the private sector, learning effective ways of contracting out, recruiting and paying capable staff and building sound management structures and appropriate management information systems (Heggie, 1995; Fakudze, 2005).

2.12 Sustainability impact factor areas

Due to the amount of energy required at different stages of road construction and maintenance, the question is, how can sustainability be achieved? This paper has adopted seven impact factors that road agencies can use to achieve sustainable road construction and maintenance:

- Virgin Material Usage examines reducing the need to use non-renewable resources. Pavement materials can be expensive, and some resources may be limited, so it is important to make good use of available materials. This can be boosted by using recycled material and the recycling of surface materials during road rehabilitation. The use of enhanced recycled materials improves construction and maintenance impacts on the environment. Furthermore, selecting a pavement mix with recycled materials tends to be cheaper than purchasing new content. Prolonging the time between major rehabilitation and reconstruction through proper pavement treatment selection is an effective way to reduce virgin material usage and can lead to substantial embodied energy savings and waste reduction since less construction-related waste would be taken to the landfill. It is also proven by several universities that asphalt and concrete with recycled material increase the life of pavement in a way of preventing natural processes that degrade pavements. However, recycled materials should be selected with care and knowledge about their weaknesses and benefits (Athalia, 2012; Thorpe, 2012; Tighe and Gransberg, 2013).
- Alternative Material Usage looks at the opportunity to recycle materials as well using other materials in the pavement structure during road maintenance. For instance, warm-mix asphalt (WMA) can be used as a substitute for hot-mix asphalt (HMA) to reduce the level of energy consumption during construction and maintenance. Though WMA is generated at a lower temperature, it is more workable. Some of the renewable materials include: reclaimed asphalt pavement (RAP), recycled concrete aggregate (RCA), recycled asphalt shingles (RAS), recycled rubber tyre (RRT), glass, or any other materials that might be appropriate. Proper processing of these materials can result in equivalent performance to virgin aggregate. Careful blending and crushing of recycled materials is required to achieve consistent gradation and performance of the material (Wall and Africa, 2009; Tighe, Gransberg and Gause, 2011; Tighe; WorldHighways, 2015).
- Programmes for Pavement In-Service Monitoring and Management assists agencies in finding the right treatment for the right pavement at the right time. Robust information systems help determine existing and forecasted pavement conditions so that decisions can be accurately made, and funds programmed for network

improvements. Pavement in-service monitoring and management would consider the life-cycle and associated serviceability of the treatment (Tighe and Gransberg, 2013).

- Noise is defined as the unwanted or excessive sound associated with pavement construction and improvements. Studies show that the most pervasive sources of noise in the environment relate to transportation. Therefore, noise is examined as an environmental sustainability factor area whereby pavement preservation and maintenance treatments are evaluated on their noise impacts (Tighe and Gransberg, 2013).
- Air Quality/Emissions examine six principal air pollutants, namely carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulfur dioxide. The intent of this factor is to assess each pavement preservation and maintenance treatment in terms of these pollutants. This would involve both calculations for the air quality/emissions for the equipment and materials. Also considered would be the associated impact the treatments have on the traveling public in terms of emissions associated with traffic delays due to the treatment placement, Part of the calculation of this factor would be the preventive maintenance treatment's service life (Tighe and Gransberg, 2013).
- Water Quality evaluates the effects of transportation-related impacts associated with alternative maintenance strategies and materials. Regulatory requirements relate to the operation and maintenance of municipal storm sewer systems, stormwater discharge associated with construction activities, and effluent standards related to the total maximum daily effluent discharge standards. Treatments and programmes should be evaluated for their individual and collective effect on these resources.
- Energy Usage relates to the quantification of cumulative energy usage of the pavement preservation and maintenance treatment throughout the life-cycle. Energy usage is important in its correlation to emissions of greenhouse gases and their relationship to climate change.

2.13 Road maintenance in South Africa

There is no doubt that road infrastructure in South Africa is comparatively well developed as compared to most Sub-Saharan African countries (National Treasury, 2014). The South African road transportation sector is a key driver towards the nation's competitiveness in global markets and for economic and social development (Gabriel, 2011). The South African road network has been planned, constructed and maintained to provide an excellent level of service. However, the integrity of this network is endangered due to the shortage of funds available for road maintenance and rehabilitation (Kannemeyer, 1993).

The road networks in South Africa are divided in four categories according to the authorities primarily responsible for their provision and operation, as stated as follows (South African National Roads Agency: SANRAL, 2012):

- "*National roads provide mobility of national importance and support economic growth. These roads are usually associated with long traveling distances at high speed, with limited access and minimum interference to the free flow of traffic.*
- *Provincial roads support regional access and mobility. These roads usually form links between towns not situated along national roads.*
- *Municipal roads provide mobility and access in urban areas.*
- *Rural roads provide mobility and access to remote communities and areas, including between and within villages*."

Several agencies such as SANRAL, provincial and local governments are responsible for the delivery and maintenance depending on the classification of the road (Gabriel, 2011). SANRAL is an independent, statutory company established in 1998 by an Act of Parliament in terms of the National Roads Act of 1998 and its mandated to finance, improve, manage and maintain South Africa's national road networks – both toll and non-toll roads (SANRAL 2016). According to Mamabolo (2013), SANRAL does not operate as a business enterprise and also is not allowed to make profits. Metropolitan areas such as Johannesburg have their own road agencies responsible for the delivery of roads although ownership resides with the city (COMCEC, 2016). The South African road network has an estimated 750 000 km of roads, of which 618 081 km are proclaimed roads national (2%), provincial (25%) and municipal roads (54%) (SANRAL, 2016). Approximately, about 131 919 km (19%) are unproclaimed roads that are primarily in the rural areas. Legally, there are no maintenance and rehabilitation programmes in place for unproclaimed roads. This is a serious challenge for many people living in rural areas that do not have access to well-maintained roads. In addition, there are none recorded in any official inventory (Department: National Treasury of South Africa, 2011, 2014). The South African road network is ranked 10th longest in the world behind countries like United States, China, India, Brazil, Japan, Canada, France, Russia and Australia in order of world ranking (Kannemeyer, Lategan and Mckellar, 2014). SANRAL owns and manages all the national roads with a total length of about 21 403 km (**see Table 2 and Map 1**) and it is expected to grow to 35 000 km in the medium to long term. In addition, national roads are all paved roads (National Treasury, 2011; SANRAL, 2015).

The non-toll national network is funded by state budget allocation from the National Treasury. Allocated funds, however, increase gradually but are usually inadequate, and this has led to maintenance backlogs. The national network toll is funded through the "user pays" principle managed by both SANRAL and Concessionaires. Concessionaires are a Public-Private Partnership (PPPs) agreement entered by SANRAL with private companies to build, operate and transfer sections of the national road network after a particular period of time, mostly 30 years (SANRAL, 2015).

Table 2: Roads managed by SANRAL (SANRAL, 2016)

Design	**Percentage (%)**	**Road Length (km)**
Non-toll	85	18 283
Toll	9	1 832
Concessionaires (BOT)	6	1 288
Total	100	21403

Map 1: South Africa’s National Road Network (Gabriel, 2011)

The Visual Condition Index (VCI) is a system used to evaluate the universal condition of paved or gravel road network in South Africa. The VCI uses a five-point scale that provides an overview of the quality and the expected quality road network. The five-point scale includes Very Good, Good, Fair, Poor, and Very Poor. Considering non-toll roads alone in Figure 9, there are about 15% of non-toll national roads that are assessed to be in poor or very poor condition. (COMCEC, 2016).

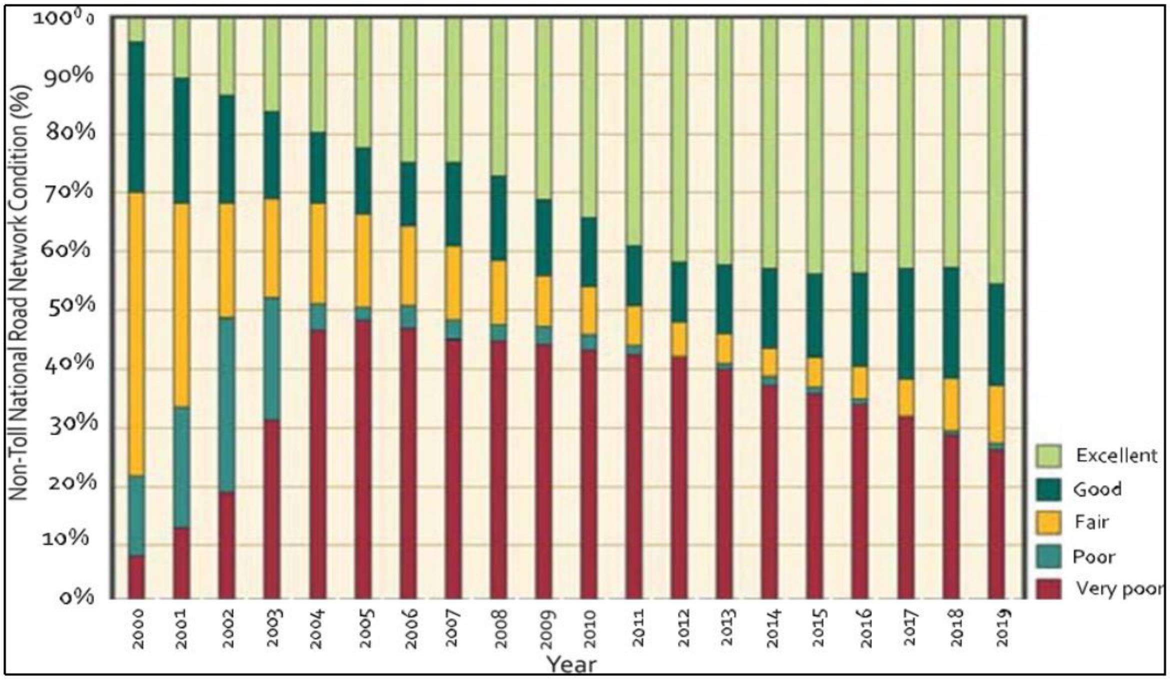

Figure 9: Forecasted condition of non-toll roads (COMCEC, 2016)

2.14 Challenges of Road Maintenance in South Africa

The general state of national non-toll roads is not very satisfactory due to lack of maintenance, large rainfall patterns in various provinces and poor drainage systems which result in standing water on road pavement. Also, the current South African pavement design is not based on maintenance activities and has resulted in breakage once water has penetrated the pavement (Parliamentary Monitoring Group, 2011).

The dreadful state of the road maintenance system in South Africa can be described by giving some examples. Thus, the modern and well developed South African road infrastructure has declined and deteriorated over the past ten years, mainly due to lack of life-cycle costing, poor budgeting and insufficient budgetary, overloading, skill shortages, weak maintenance regimes and the lack of an asset management culture leading to deferred maintenance (Gabriel, 2011). In addition, about 80% of the network is older than its original design life (Department: National Treasury of South Africa, 2014). According to Kannemeyer, Lategan and Mckellar (2014), the cost of road replacement in South Africa is more than R2 Trillion. SANRAL receives about R11 billion per year to fund the improvement and maintenance of non-toll roads. It is very important for the road agency to be innovative and smart to make the most productive use of South Africans taxpayer's money. To eradicate the maintenance backlogs on roads under provincial and local government jurisdictions, an estimate of R150 billion and R200 billion will be needed. SANRAL will need about R20 billion to reduce its own maintenance backlogs (South African National Roads Agency: SANRAL, 2005). National non-toll roads shall remain unsustain once all available budget is only spent on potholes repairs. There are available guidelines, but skilled labours are needed to implement their existence and executions (Parliamentary Monitoring Group, 2011).

Another challenge is that more strategic provincial roads are being incorporated into its network the recent transfer was about 1699 km of provincial roads in the Limpopo province. Funds received by SANRAL are inadequate, leading to the introduction of the user-pays principle on high-traffic commercials roads to narrow the funding gaps and provide a better quality of service to its road users (SANRAL, 2014). The problem is that the Pavement Management Systems (PMSs) which were implemented to assist the provinces with the planning preventive maintenance appear to have been abandoned, mostly because they were time-consuming and relatively costly to keep efficient and useful. The result of this is cracking on the road surfaces and eventually the formation of potholes because there is severe reduction in preventive maintenance activities. When these get serious, SANRAL is left to take care of these roads with an insufficient budget (Parliamentary Monitoring Group, 2011). Maintaining the value of the road assets is very important, which is vital to the economy of South Africa. According to Rapetsoa (2011), about 80% of general freight movements (i.e. excluding coal and iron ore) in South Africa take place on roads. Maintaining such assets should be of the highest priorities (Sultana, 2012). Road construction and maintenance are outsourced to highly competent contractors (SANRAL, 2014).

The South African National Road Agency Limited: Horizon Twenty Ten (2002) has grouped the challenges South Africa faces on non-toll road maintenance.

- One key challenge is the Agency's inadequate financial resources, it is of the ultimate importance to establish a primary road network in order to close or satisfy the funding gap between demand and National Treasury allocations.

- Another challenge is SANRAL obligation to continue to implement toll road programmes, enhancing it by introducing toll roads consisting of roads previously under the jurisdiction of the provinces.
- The capability to encourage investment and improve public-private partnerships in the delivery of roads – for both toll and non-toll roads.
- The incorporation of all Management Systems with the budget process, which can result in a greater value for Rand/km spent.
- The challenge of investigation and analyses of alternative funding mechanisms, which can relieve the Provinces of financial and institutional constraints.
- The challenge in promoting the 'user-pay' principle to allow for the self-funding of road infrastructure.

(South African National Road Agency Limited: Horizon Twenty Ten, 2002).

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

The principle of research methodology helps the researcher to achieve the aim and objectives of the research. The chapter underlines the sequential method of research methodology, elaborating on how the research methodology style for the objectives is to be achieved. Relevant data collected from selected focus groups is essential for the success of this study. The breakdown of acquired data from respondents is evaluated and finally conclusions are drawn based on the results found.

3.2 Research design

Research design aims at the outcome to be achieved. Research design is perceived as the efficient plan to relate together research procedures and methods towards acquiring dependable statistics for effective analysis and conclusion. Hence the research design assists the researcher with vibrant study context, and influences the approach, conclusion and the foundation for understanding (Vosloo, 2014). Gabriel (2011) defines research design as "*the overall strategy adopted for solving a research problem".*

The three universal methods of accomplishing research are qualitative, quantitative and mixed methods. The question in any research depends on the type of data to be used by the researcher, for example, whether the data required is textural, numerical or both. Quantitative methods are used if data required by the researcher is numerical, the qualitative method is used if the data required is textural, and the mixed method is used if data needed by the researcher is both numerical and textural (Williams, 2007).

The category of data needed to explain or resolve a research problem has a significant impact on the research methodology used. Different research questions pilot different types of information collected, as do the interpretations of data (Gabriel, 2011). For this research both qualitative and quantitative methods were followed. The research methodology was dissected into four stages in a sequential method as follows:

1. Literature review
2. Data collection

3. Data analysis
4. Conclusion and Recommendation

This research required data from the general road users. This can assist the researcher to evaluate the effect posed by lack of road maintenance on national non-toll roads.

3.3 Literature review

Extensive literature on South Africa's non-toll road maintenance was reviewed. For a literature review to be concluded, reading materials such as conference papers, journals, books, etc., were assessed. Secondary data needed for this research were sourced from literature review.

3.4 Data collection Instruments

The source of data was very relevant, and it is very important to obtain data from the right place for this research

3.4.1 Primary data

3.4.1.1 The questionnaire

This research utilized a questionnaire-based survey designed with structured questions to allow targeted respondents to think deeply about their feelings while considering the best assessment of the situation. According to Goh (2011), when gathering information about the opinion of a large group of people, questionnaire is the most effective method to be employed. The main objective of the questionnaire was to get a complete picture of the status quo. One hundred and eighty (180) questionnaires were distributed to road users throughout the country, a maximum of twenty (20) to targeted respondent from each province. Questions asked were focused on fulfilling research objectives such as the challenges in improving road maintenance and the solutions to these challenges. Questions are scrutinized to ensure that good responses were received from targeted respondents. Questionnaires were filled in by respondents, and the data derived was analysed to identify any inconsistencies and recommend corrective measures. The researcher received all questionnaires for analysis.

3.4.1.2 Documentation

Supporting documents obtained from SANRAL, vital scientific articles, journals, newspapers, academic books, government legislatures aided the identification of the study area. This data was used to confirm all information used in the final analysis of this research.

3.4.1.3 Interview

The targeted respondents in this study were asked open-ended questions. The interview method was utilized because it helps respondents to freely express their views. This provided a clear understanding on the issues and to give recommendations on how to improve that issues being addressed.

3.5 Data analysis

All data obtained followed both the qualitative and quantitative analysis approach, scrutinized and coded to retain only relevant components. The researcher used data filtering to analyse the collected data. In this study data collected from questionnaires was analysed with Microsoft Excel.

3.6 Population

According to Mamabolo (2013), "*a population of the study refers to a group by which the researcher wants to draw conclusions."* The nature of this study required data to be collected from road users among the general members of the public, local communities and randomly selected motorists of light and heavy-duty vehicles throughout South Africa. This empowered the researcher to illuminate the impact posed by lack of sustainable road maintenance of national non-toll roads in South Africa. The targeted population for this study was one hundred and eighty (180) questionnaires, which were distributed to road users throughout the country, a maximum of 20 to each province. All one hundred and eighty (180) questionnaires were acknowledged and analysed.

3.7 Validity and Reliability

According to Mamabolo (2013) validity refers to the prospective of a design to achieve or quantify what it is designed to achieve or measure, and reliability relates to the accuracy and consistency of measures. Before the survey commenced, questionnaires were guided with assistance, and modifications were made to the questionnaires. This allowed the researcher the prospect to quantify the validity of the questions and the possible reliability of the data collected.

CHAPTER 4 DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter deliberates on analysis of data obtained from the interviews and questionnaires from road users. The purpose of the analysis is to obtain information from the road users on their overall satisfaction on national non-toll road maintenance. This study analysed and developed best approach guidelines for sustainable road maintenance practices. One questionnaire survey form was handed to each road user. The questionnaire survey was completed in August 2017. Most respondents completed the survey form in their own valuable time and these were sent back, mostly via email address. The questionnaires were streamlined so that respondents could choose between 'yes', 'no' or 'not applicable' ('not sure'). Road users from government and private sectors and the unemployed were asked twenty-nine (29) typical questions. The responses received were scrutinized and presented in a concise format. Where important, lessons from the literature review are also unified.

4.2 Questionnaire results and findings

This study explored the sustainable maintenance guidelines in South Africa with special focus on national non-toll roads. Data was collected from road users from May to August 2017. The analysis of this study was presented in two parts. The first part focuses on data collected through structured questionnaires and the second interview with road users.

4.3 Data collected from road users through questionnaire

Data was collected from road users' survey questionnaire was obtained nationwide. Precautions were taken to ensure that the questionnaires were distributed to the relevant focus group. The questionnaire was structured in two (2) categories, namely the respondent profile and the main interview, to enable the researcher to acquire relevant data that would satisfy the research objectives. The results from the structured questionnaire were then produced using the Microsoft Excel software program.

4.3.1 Demographic profile of respondents

Respondent profile is very crucial to the study. It gives a significant characteristic of the sampled population that the researcher is dealing with and to put results into perspective. It also influences the responses of the respondents. Targeted respondents such as government workers in selected disciplines and private sectors, which include contractors, project civil engineers, drivers, passengers and planners who mostly use non-toll roads on frequent occasions. The validity of acquired data can be strengthened by their expertise on roads. The following sub-section deliberates on the profile of the participated respondent in the questionnaire survey.

4.3.1.1 Province of origin

This study was controlled to cover all the nine (9) provinces of South Africa. Twenty (20) questionnaires were distributed to each province of the study. All distributed questionnaires were returned for analysis. As a result, the useable response rate was 100%, which makes it excellent for analysis.

4.3.1.2 Gender

In the South African context, gender plays an important role in all social or economic situations. Therefore, the researcher ensured this study was not gender-biased. This led to probing the study to eliminate any cultural stereotyping. The participation of gender in this study is illustrated in the figure 14.

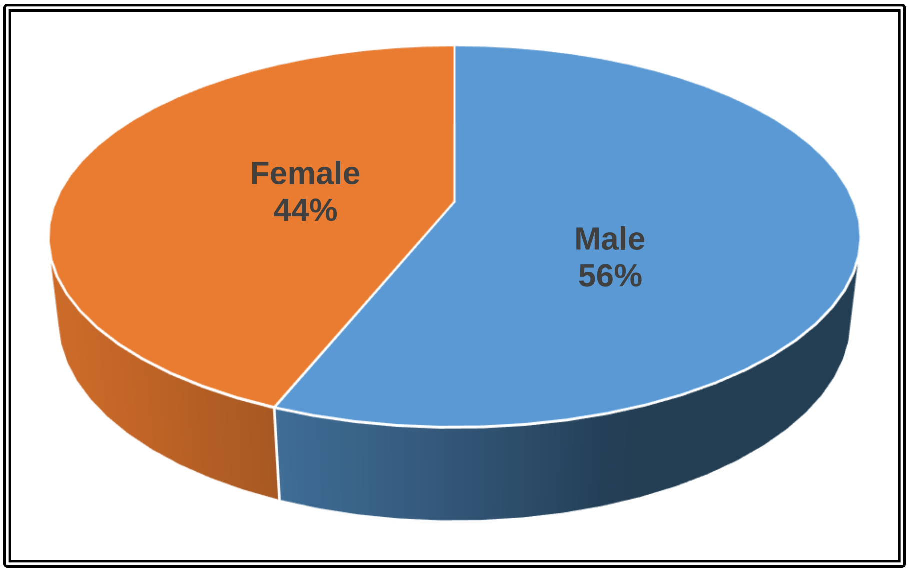

Figure 10: Gender participation in the research

The results on gender contribution in this research show that fewer females (44%) participated as compared to males (56%). The perception of this analysis could be that males care more about road conditions as compared to females. Another perception could be that most females prefer their male counterparts answering the questionnaires on their behalf.

4.3.1.3 Age group of respondents

The type of feedback from the respondents usually depends on the age group of the respondents. Age of respondents helps the researcher to understand the views on a particular problem.

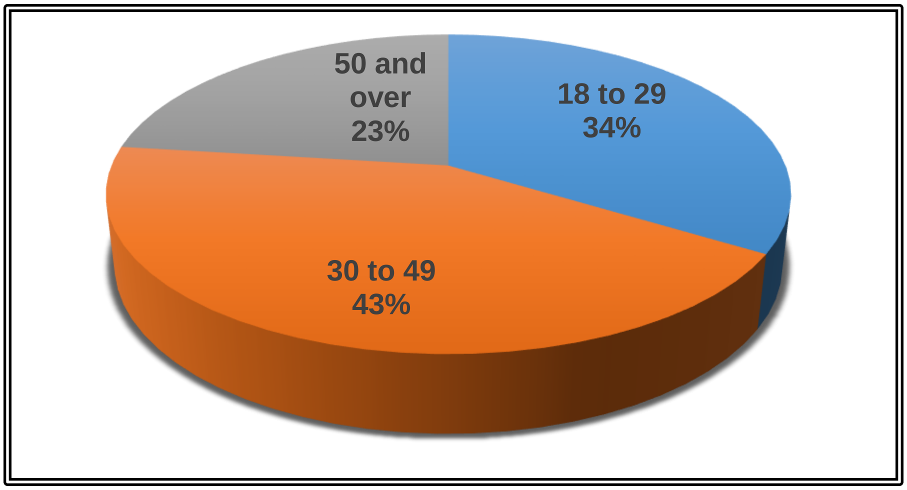

Figure 11: Age group participation

4.3.1.4 Occupations

The occupation of person affects his or her personality and the level of understanding of a specific phenomenon. The way a person responds to a question is determined by the type of occupation the respondent is engaged in, therefore the occupation of the respondent that participated in this research is presented in Figure 16.

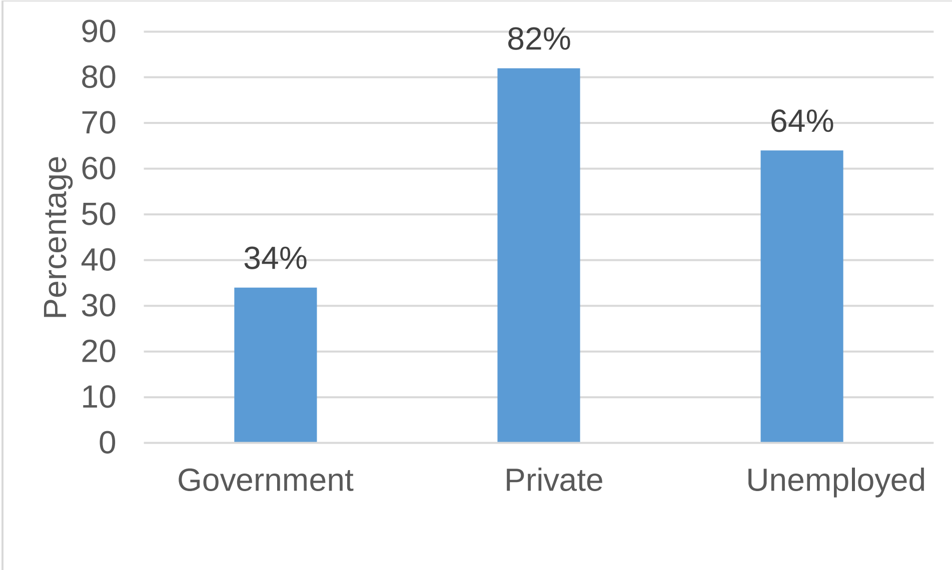

Figure 12: Occupation of respondent

4.3.2 Effects of poor maintenance on South African economy

According to the illustration in Figure 17, 50% of respondents agreed that poor road maintenance has nothing to do with the economy of South Africa. It can be concluded that most respondents are not well educated on the impact of poor roads on the economy. There is a need for efficient and effective public awareness of the effect of road defects such as potholes has on the South African economy. Mobility is vital for economic growth, hence for the demand of mobility to be met, roads need to be maintained in a timely manner.

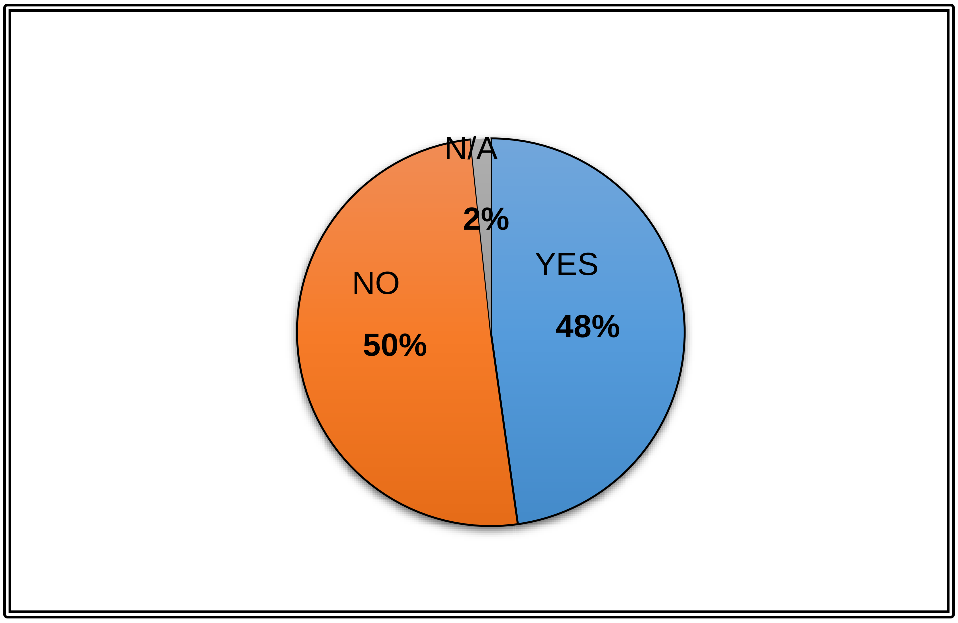

Figure 13: Impact poor road maintenance has on the Economy

4.3.3 Reporting road defects

As shown in Figure 18, 67% of road users have no idea where to make complaints with regards to road defects. About 33% of respondents know where to report road defects. Road users must show concern and report any road defects such as potholes they see on the roads which have the potential to pose a high risk to other road users. Though SANRAL is mandated to maintain national non-toll roads, road defects such as potholes can be fixed when they are reported. For national roads, the defects can be reported to SANRAL by informing them about the defects by email info@nra.co.za and the person in charge will inform the appropriate contractor to fix the defects in a short period of time. Unfortunately, not all road networks are under the responsibility of SANRAL, so roads travelled on may be under the jurisdiction of either provincial or local authorities. The Johannesburg Road Agency (JRA) as part of its strategy and service delivery drive recently launched a mobile app, “Find and fix”, that allows road users to report road-related defects.

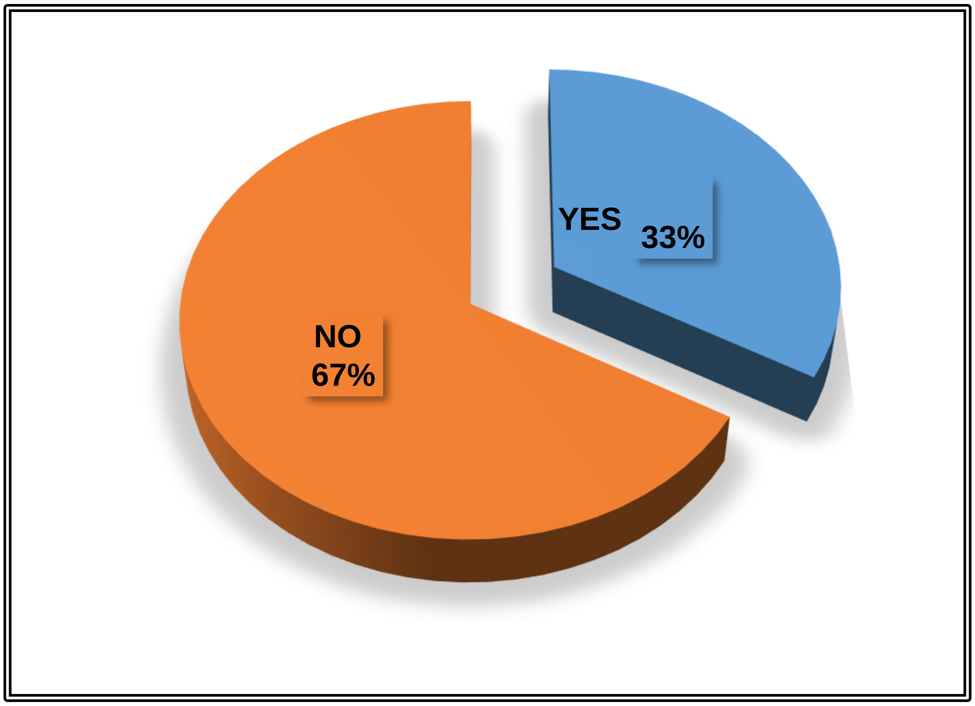

Figure 14: Reporting of road defects

4.3.4 Vehicle damage due to road defects

It is shown in Figure 19 that 54% of respondents said their vehicle or tyre was damaged due to related road defects on national roads. This concludes that non-toll national roads should be frequently monitored, and defects responded to within a shorter time where possible. It is a very traumatic experience for a motorist when his or her vehicle is damaged by potholes. The habit of having pothole warning signs should be eradicated and rather the authorities should get contractors to get the road defects fixed.

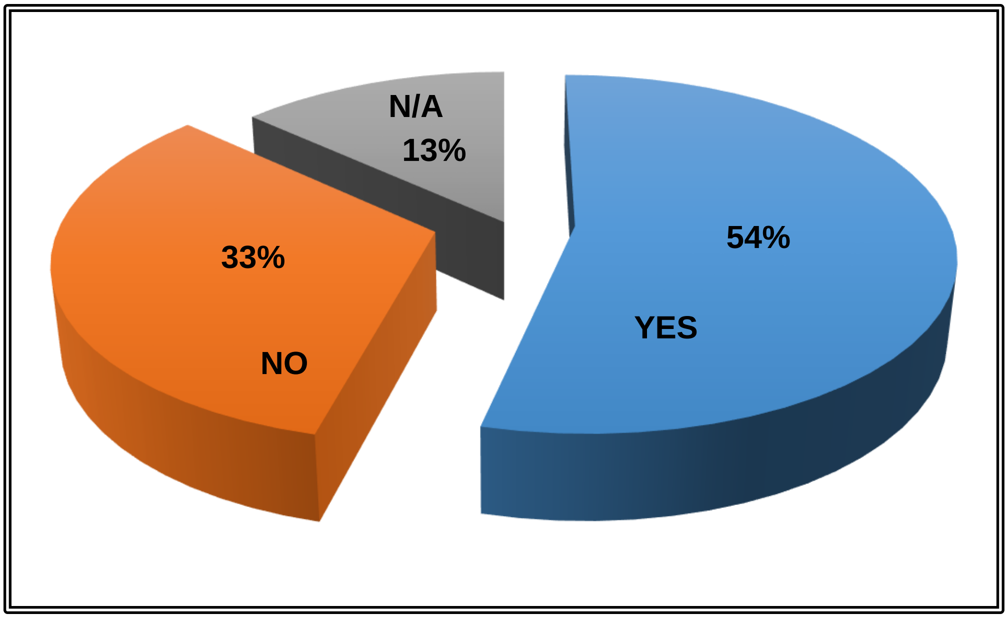

Figure 15: Vehicle damage due to road defects

The figure below figures the level of satisfaction whether road maintenance performed on non-toll roads as well engineered as compared to that on the toll roads. It shows greater rates of disagreement that maintenance of non-toll roads is better than toll roads. It can therefore be concluded that revenues generated through toll collection on toll roads are sufficiently used for road maintenance. It can also be concluded that toll roads are expected to provide better service than non-toll roads

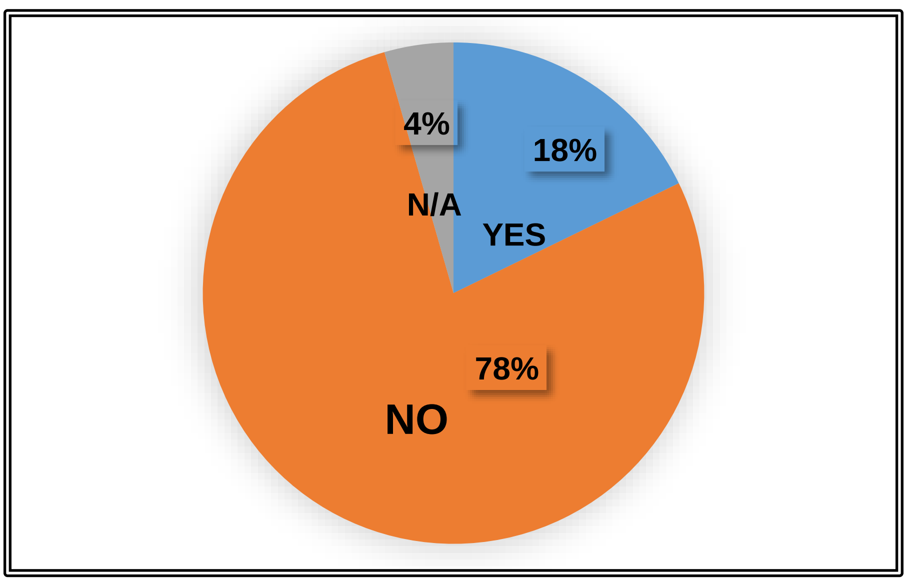

Figure 16: Maintenance on non-toll roads better than toll roads

It is very relevant to recognize the type of road infrastructure that SANRAL provides to its users. That can be judged by whether SANRAL is performing its mandates despite the road maintenance backlogs. Figure 21 illustrates that 92% of the respondents agreed that there is an occurrence of roadworks on national non-toll roads. This roadworks is usually routine and periodic road maintenance. According to SANRAL (2016), about R 3.7 billion was spent on routine maintenance practices such as crack sealing, pot hole repairs, grass cutting, crash repairs. Additionally, 210 contracts worth R14.8 billion were awarded by the SANRAL for the routine maintenance, periodic maintenance, special maintenance, strengthening, improvement, new works, community development, supervision and other activities.

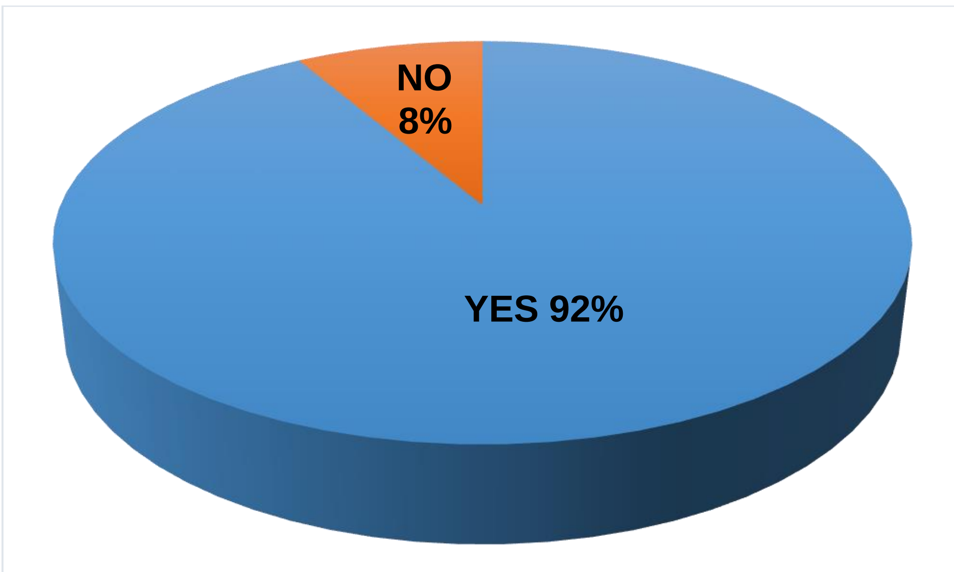

Figure 17: recent roadwork on national non-toll roads

4.3.4.1 Satisfaction of road condition

National non-toll roads face many challenges in terms of service quality. Roads play a vital role in the South African economy; hence the quality of roads infrastructure significantly affects economic activities. The researcher probed whether road users are satisfied with the road condition they travel on. It is clearly shown in Figure 22 that the majority of road users (79%) are not satisfied with the quality of national non-toll roads in the country, with just about 21% of respondents being satisfied with the road condition. It should be noted that road service attributes such as road condition, rest area facilities, safety and security, emergency response, traffic conditions all influence road user satisfaction. All these attributes were probed in this study. Although it is stated that SANRAL is doing an excellent job with road maintenance in Figure 21, it is understandable that SANRAL still has to do more to maximize road users' satisfaction on road conditions.

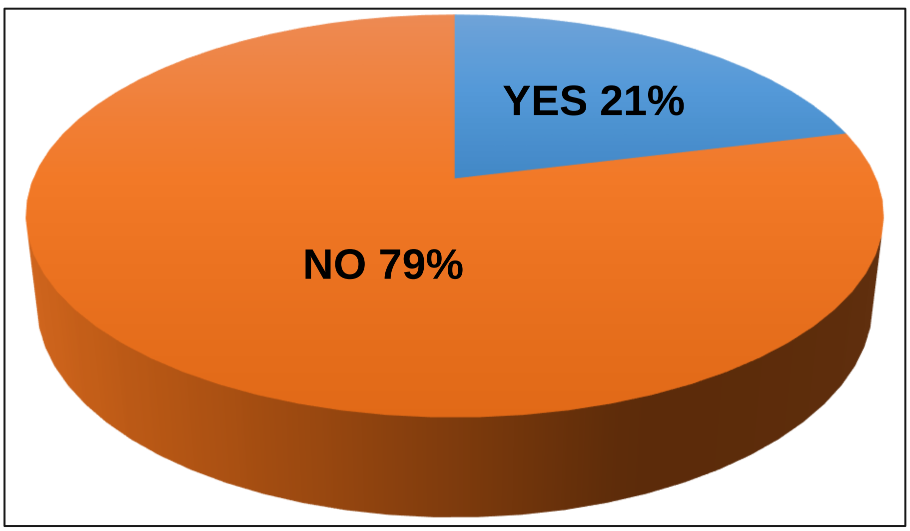

Figure 18: Satisfaction of road condition

Throughout the study, all respondents were interviewed on what they would do to improve road safety and the maintenance backlog of non-toll roads in South Africa if they have a chance. In a poll for a popular recommendation on how to increase road safety on all South African roads, many recommended that the South African government must make road safety a political priority, and adequately resource the Road Traffic Infringement Agency (RTIA) as the road safety agency and hold them accountable. The Government must also fully support non-government organizations (NGOs) advocating for road safety and appropriate safety targets must be designed to be achieved. Respondents also suggested that, for road safety to be implemented, it should start with individuals. Therefore, road users must behave responsibly by abiding with the legal speed limits on all South African roads, not drinking and driving, wearing seat belts at all times, and all motor riders should wear crush helmets. Citizens must also help to identify road safety problems and encourage the government to make roads safer.

Further recommendations were for the South African government to encourage more private investment on road infrastructure. Most respondents recommended that the solution to national non-toll maintenance backlogs would be to involve more of the private sector. They would like to see more transparent concession contracts on road improvement, but the government needs to subsidise the fees paid for road usage.

4.4 Conclusion

Data analysis was provided in this chapter. Data was gathered through both qualitative and quantitative methods nationwide, with the targeted population being the general road users. Data was then analysed and interpreted. From this study, it can be confirmed that sustainable road maintenance of non-toll is still a challenge in South Africa. From this it can be concluded that more investment is still needed for sustainable road maintenance due to the enormous benefits derived from well-maintained roads.

CHAPTER 5 DEVELOPMENT OF GUIDELINES FOR SUSTAINABLE ROAD MAINTENANCE

5.1 Introduction

This chapter elaborates on developing guidelines for incorporating sustainability into road maintenance. Concerning sustainable road maintenance, it is obvious from the literature review that non-toll roads call for more concern due to untimely maintenance in the past. The economic strength of a country is critically based on the regularity of road maintenance. However, there is a serious need for balance during road maintenance activities with regards to demands and impacts associated. There is only one solution, which is implementing sustainable measures. There is a benefit of cost reduction, protection and conservation when sustainability concepts are incorporated into all maintenance activities. The developed guidelines are important and contain performance measures that SANRAL can consider setting up sustainable road maintenance.

5.2 Guidelines

1. Incorporating long-term sustainability into road maintenance is very relevant due to the economic benefits from these assets. Maintenance should be executed in a cost-effective manner, safe and convenient for the movement of goods and services. Even though new road construction is relevant due to urbanization, it should be planned, designed and executed while taking into consideration future maintenance needs with the aim of minimizing life-cycle costs. Periodic maintenance works should be effectively planned and carried out before the road network reaches its design life. SANRAL should implement a common policy on how a sustainable development concept must be interpreted and applied to all road maintenance activities. A balanced sustainable road maintenance specification must be implemented and engineered for all road maintenance activities.
2. Road maintenance requires a substantial commitment in the aspect of finance from leaders in any road agencies. Budget for road maintenance should be increased gradually to fill the maintenance backlog. The simple fact is road maintenance can

consume two-thirds of all available funds and this replicates the resilient need for SANRAL to raise additional sources of revenue in other areas to achieve sustainable transportation system. Additional sources of funding may include increasing existing dedicated taxes or create different mechanisms to supplement fuel taxes. With government support, a new tax mechanism can also be introduced especially for roads under provincial jurisdiction. The new tax mechanism should be able to provide a sustainable funding level, should be easy and resourceful to govern, eliminate any detrimental side effects and politically feasible. The decision-making process on the type of maintenance needs is also essential due to the scarcity of funding and the growing maintenance backlogs. It is important to understand that cutting costs should not be the dominant influence on the type of treatment to use but rather engineer judgment. Modified PMS software which targets the need for pavement preservation and monitor environmental performance is needed by SANRAL.

3. New and advanced technologies in the field of recycled materials must be implemented continuously by SANRAL. The use of recycled materials must become a standard practice and by doing so, it will make road pavement more eco-friendly, durable to last much longer, and cost-effective. SANRAL must adopt Warm Mix Asphalt (WMA) as a standard practice for all new construction and road maintenance. This shall help achieve the benefits of reduced energy consumption and emission. SANRAL must adopt and differentiate between pavement preservation and pavement maintenance and accordingly allocate funding. Pavement preservation basically promotes *"environmental sustainability by conserving energy, virgin materials, and reducing greenhouse gases by keeping good roads good*." Soil compaction at areas where vegetation is to be maintained should be avoided and also only energy-efficient construction equipment must be used for all roadworks.
4. The main objective of road maintenance is to make the road safe and trafficable to the road user. Road maintenance activities can also be a problem to road users when the appropriate traffic management system is not in place. Neglected roads with insufficient skid resistance can be a contributing factor to road accidents. Potholes pose a great danger to motorcycles and cyclists. Road maintenance can reduce road accident when all these defects are repaired. Road safety in South Africa must be

developed and engineered in a sustainable manner. The approach of implementing structured Safety Management System is very relevant. This approach must be able to assess.

5. The South Africa government should share SANRAL responsibilities and recognize that there is need for more private investors due to the recent downgrade. The downgrade has left SANRAL with higher expenses and is less revenue for construction and maintenance. When road financing responsibilities are shared, it will create more room for sustainable private partnerships for both toll and non-toll roads.

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Conclusions made for this study were related to the objective

6.1.1 Intensive literature review on sustainable road maintenance

The first objective was to conduct an intensive research on sustainable road maintenance. This helped to indicate that timely and efficient road maintenance is essential to preserve and improve the benefits derived from roads. Road maintenance backlog has led to severe road deterioration leading to spiralling costs and massive financial impact on the road users and the economy. The desired level of service can only be achieved when the right treatment is applied at the right time. The importance of road maintenance should be acknowledged by all stakeholders such as contractors, transport operators, road users, road agencies and policy makers and sufficient finance provided.

6.1.2 Identify the challenges in improving road maintenance of non-toll roads

The second objective was to recognize the challenges SANRAL faces to achieve sustainable road maintenance which has been achieved. It is concluded that sustainable road financing is the vital element leading to backlog in road maintenance. Without sufficient budget for road maintenance, roads will continue to deteriorate, and it will cost considerably more to maintain them.

6.1.3 Develop guidelines for meeting challenges identified

The final objective was to develop sustainable guidelines to tackle this challenge. The pillars of sustainability must be incorporated during road designs, construction, maintenance and management. There is also the need to raise awareness, especially among people involved during road construction and the impact thereof on life. Sustainable road maintenance must be planned at the national level and appropriate financial sources identified.

6.2 Recommendation for future research studies

There is a need for future research to develop appropriate recycled materials usage standards for road maintenance operations and life-cycle assessment in South Africa.

There is an also a need for research to quantify the benefit of differentiating between pavement preservation and pavement maintenance and how SANRAL would benefit.

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APPENDICES

Appendix A: Request Letter

From:	Prof M Mostafa
To:	SANRAL
Date:	5th May 2017
Subject:	MICHAEL GAGBLEZU – M Eng study

Re: SUSTAINABLE MAINTENANCE GUIDELINES FOR NON-TOLL ROADS IN SOUTH AFRICA

This serves to inform you that Mr M Gagblezu is a registered Civil Engineering, Master student at the Central University of Technology. He works to study the maintenance of non-toll roads in South Africa and, therefore, is in need to access data related to road network conditions and similar related information. It is highly appreciated if you can contribute to his questionnaires, as they are crucial elements in his study. Any publications based on her study will acknowledge your contribution.

May I ask that you provide Mr Gagblezu with the needed assistance. I believe that his study is of most importance to the development of the country and will contribute to enhancing sustainability of roads in South Africa, thereby, improvement in the country's economy. All ethical considerations shall be duly observed in the study. This is inclusive of confidentiality of information and voluntary participation.

Should you have queries, please do not hesitate to contact the supervisor of the study on the underneath contacts.

Thank you for anticipated consideration of this request.

Prof M Mostafa
SURT Research Group Leader

Civil Engineering
Faculty of Engineering and Information Technology
Tel: +27 51 507 3454

Appendix B: Research Questionnaire

Questionnaire for Road Users

Hello,
My Name is Michael Gagblezu, I am a Masters candidate at Central University of Technology, Free State conducting a survey on non-toll roads in South Africa. Please answer the questions below. Your information and responses will be solely used for this research only or where needed will be shared with third parties with your consent, and that your participation in the study is voluntary.
I would be grateful if you could spare some time to answer these questions.

"For purposes of this survey non-toll roads are roads that users don't pay toll or fee for using it."

SECTION 1: RESPONDENT'S PROFILE

1.1 Province:
1.2 Gender: ☐ Male ☐ Female
1.3 Age Group ☐ 18-29 ☐ 30-49 ☐ 50 and over
1.4 Category of Vehicle ☐ Light vehicles ☐ Heavy vehicles

SECTION 2: MAIN INTERVIEW

No.	Questions	YES	NO	N/A
2.1	Which company are you working for? (Yes = government, No = private, n/a= unemployed			
2.2	How often do you travel on non-toll roads within the country? (Yes = Always, No = Seldom			
2.3	The purpose of traveling on non-toll roads? (Yes = Business, No = Private, n/a= Commuting			
2.4	Are you aware of the effects of poor maintenance on the South African Economy?			
2.5	Any recent roadworks on these roads during your last trip (if No, go to Q			
2.6	Was there any sign explaining that there was a roadworks ahead?			
2.7	Have you experienced any traffic congestion due to the road repairs?			
2.8	Have the road condition affected your fuel consumption?			
2.9	If you see a defect on the road, do you know where or how to report it?			
2.10	Are road signs on non-toll roads visible at all times?			
2.11	Are you experiencing delays due to poor road conditions?			
2.12	Is the maintenance of non-toll roads better than toll roads?			

2.13	Was your vehicle damaged due to poor road condition while driving on non-toll roads?			
2.14	Is the width of national non-toll roads adequate for overtaking? (Yes = Adequate, No = Inadequate, n/a= Neither Adequate nor inadequate/Not sure			
2.15	How long does it take for accident clean up on non-toll roads in your province? (Yes = Fast (below 1 hour), No = Neither Fast nor Slow (1hour – 2hour) N/A= Slow (more than 2 hours)			
2.16	Is it safe to travel on non-toll roads within South Africa?			
2.17	When last did you see or pass through a roadblock (Yes = less than a month) or (No = more than a year) or (n/a = doesn't happen			
	Do you get irritated by experiencing these on non-toll roads?			
2.18	Beaming headlights of other vehicles			
2.19	Reckless driving by other drivers			
2.20	Air/ Noise pollution from vehicles			
2.21	Animals crossing the road			
2.22	Bad roads (potholes, rutting			
2.23	Traffic jams on intersections			
2.24	Pedestrians crossing road where not allowed			
2.25	Are you satisfied with the overall condition of non-toll roads in South Africa?			

2.26 How can road accidents be minimized?

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2.27 In your understanding, what are the main causes of the poor road conditions?

- ☐ Heavy rainfall
- ☐ Heavy vehicular passage
- ☐ Poor road construction
- ☐ Damaged by construction work in the province
- ☐ Other

2.28 What do you as a road user think about private investment on road infrastructure?

2.29 Do you have any other comments regarding road maintenance, safety and traffic within South Africa?

NOTE: THIS FORM CAN BE SUBMITTED VIA EMAIL TO michaelgagb@gmail.com. MORE INFORMATION PLEASE CONTACT MICHAEL GAGBLEZU ON CELL: 0737630760

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