Dust Mitigation Strategies for Road Construction in South Africa: An Evaluation of the Current Practices

By

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DECARATION

I declare that this research report is my own unaided work. It is being submitted for the Master of Science in Environmental Engineering by coursework and research report to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

__________________ ________ day of ____________ ______

Signature of candidate

ABSTRACT

Dust mitigation in road construction is a significant mitigation measure that is required to promote sustainability in the road construction sector. This has largely been ignored in South Africa where it is treated as an insignificant part in the road construction sector. In South Africa there has not been a comprehensive study of the application of dust mitigation strategies to determine the impact of the applied methods in relation to the pillars of sustainability. Therefore this study is set out to address this knowledge gap by evaluating the dust mitigation strategies currently applied in the road construction industry, determining their levels of implementation and evaluating their impacts on the sustainability pillars. This study applied the concept of sustainable development to the issue of dust mitigation inroad construction in South Africa. The methodology applied in this research is a mixed one that combines inductive and deductive reasoning approaches, utilizes a survey of respondents in the construction industry, and archival research that draws on data contained in Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) reports of road construction projects that have been implemented around Johannesburg and Pretoria, in a cross-sectional time horizon. A combination of qualitative and quantitative analyses of the data gathered provided insights into the various dust mitigation measures in road construction, and the perceptions of professionals in road construction industry in relation to legislation on the air quality standard of the National Environmental Management Act (NEMA).

Generally, it was found that the water suppression method is the most widely adopted dust mitigation strategy that is practiced in South Africa for road construction projects. However, this finding is at variance with the types of dust mitigation strategies proposed in the reviewed reports of Environmental Impact Assessments and Environmental Management Plans of road construction projects. This implies considerable under-utilization of the wide array of dust mitigation approaches that are available. It also implies an inadequate and minimalist approach to dust mitigation in SA. Furthermore, there is an over reliance on water, which is highly unsustainable in a water scarce country like South Africa.

Keywords: Dust, Dust mitigation, Road construction, Sustainable development

DEDICATION

Firstly, to God Almighty for His steadfastness, to my late father, Chief Nnebedum Johnbull Amalu (Odenigbo 1 of Akpakwume/Nze), Onyemechi Motors Nigeria LTD, and to all third-world countries in the struggle of achieving sustainable development, I hope we would make appreciable progress in the nearest future.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LISTS OF BOX

LIST OF ABBREVIATIONS

BAT: Best Available Techniques

CoJ: City of Johannesburg

CIBD: Construction Industry Development Board

CSIR: Council of Scientific and Industrial Research

DBSA: Development Bank of Southern Africa

DEA: Department of Environmental Affairs

DEJF: Dust Emission Joint Forum

DoE: Department of Environment

DoT: Department of Transport

EIA: Environmental Impact Assessment

EMP: Environmental Management Plans

EPA: Environmental Protection Agency

EU: European Union

GEF: Global Environment Facility

GHG: Green House Gas

IAIA: International Association for Impact Assessment

IFC: International Finance Cooperation

IM: Impact Mitigation

IPPC: Integrated Pollution Prevention and Control

ISO: International Standards Organisation

JSE: Johannesburg Stock Exchange

NBS: Nature Base Solution

NDP: National Development Plan

NEMA: National Environmental Management Act

NEPA: National Environmental Protection Agency

NGSMI: National Guide for Sustainable Development

NIOSH: National Institute for Occupational Safety and Health

NPC: National Planning Commission

OECD: Organization for Economic Co-operation and Development

PM: Particulate Matter

PRB: Population Reference Bureau

SADC: Southern African Development Community

SANRAL: South African National Road Agency Limited

SD: Sustainable Development

SDGs: Sustainable Development goals

SIA: Social Impact Assessment

SI: Social Impact

UN: United Nation

UNCBD: United Nations Convention on Biological Diversity

UNCED: United Nations Conference on Environment and Development

UNCHE: United Nations Conference on Human Environment

UNCTAD: United Nations Conference on Trade and Development

UNECE: United Nations Economic Commission for Europe

UNEP: United Nations Environmental Programme

UNFCCC: United Nations Framework Convention on Climate Change

WCED: World Commission on Environment and Development

WHO: World Health Organization

WRAP: Western Regional Air Partnership

WWAP: World Water Assessment Programme

CHAPTER ONE

1 INTRODUCTION

Road dust has been identified as a primary source of particulate matter in the emission inventory (Wu *et al*., 2018; Alves *et al.*, 2018; Amato *et al.*, 2014). This contributes to Green House Gas (GHG) emissions and should not be underestimated. The generation of dust during road construction activities is inevitable (Jones *et al.*,, 2008). Dust causes a nuisance to construction area residents, hazards to site workers, detrimental to vegetation, and generally, a form of air pollution to the environment (Wu *et al*., 2016; WHO, 2013; Jones, 2000). There are concerns about the widespread threats on the environment which call for sustainable practices in all cadres of the development sector (UNCED, 1992).

1.1 Background to the Study

Components of a healthy environment, for example, clean air, and water are considered a public good since they are non-rivalrous and non-excludable. The precautionary principal establishes that the lack of facilities shall not be a reason to defer effective preventive measures on environmental degradation in the face of threats of irreversible environmental damage (UNCHE 1992). In the global discussion on environmental issues in the 1980's, the main constraint was on the expression of the interdependence between the natural ecology, economic development, and the people (Weaver *et al.*, 2012; UN, 1987).

In South Africa, an operational strategy that is environmentally friendly, economically practicable and socially acceptable must be continually adopted to achieve sustainable development goals (SDGs) in road construction (Rudman *et al*., 2012). While the South African government plans to create a sustainable industrial sector, it is imperative that the road construction industry aligns with the development plan (NPC, 2011; Rudman *et al*., 2012; SANRAL, 2018).

Dust mitigation is in line with the National Development Plan – Vision 2030 (OECD. 2008), developed by the National Planning Commission (NPC) for South Africa. These plans align with the United Nations (UN) publication: *"Towards a*

Green Economy: Pathways to Sustainable Development and Poverty Eradication", a part of which elaborates the participation of developing countries working and aiming to meet mitigation target options towards long-term SDGs (UNEP, 2011). It is therefore imperative to evaluate dust mitigation strategies for road construction in order to foster sustainable dust mitigation strategies in South Africa.

The need for and the importance of Sustainable Development (SD) has been extensively addressed in the literature (Weaver *et al*., 2012; Soubbotina, 2004; CSIR, 2001; SADC, 1996). Swilling (2006) confirms the increasing adaptation of green practices by stakeholders and the application of SD in national policies. In this study, the concept of sustainable road construction practice implies the reduction of the impact of dust environmentally, economically and socially, throughout the project lifecycle, by adopting green dust mitigation strategies, thus, contributing to the Sustainable Development Goals (SDGs). No. 9 on the call for industries to innovate through promoting sustainable industrialization, and also, SDGs No. 11 on the call for sustainable cities and communities, which fosters sustainable infrastructure that supports economic development and human well being.

The SDGs mentioned are linked with mitigating dust during road construction in the pursuit to reduce the adverse per capita environmental impact of cities, which include paying special attention to air quality. The need to mitigate dust throughout road construction will provide access to safe and healthy environment to the people and the receiving environment, with special attention to the needs of those in vulnerable situations, women and children, persons with disabilities and older persons. SD is increasingly perceived as a necessary tool for understanding and mitigating the environmental, economic, and social consequences of human activities associated with all spheres of life (Martens *et al*., 2014; Savitz, 2006; Elkington, 1998, 2001).

The most plausible definition of SD was that of the World Commission on Environment and Development in its 1987 report: *our common future*, defined as *'development that meets the need of the present without compromising the ability of the future generations to meet their needs and aspiration'* (Beckenstein *et al.*, 1996). This implies that sustainable development seeks to establish a path along which development can progress while enhancing the quality of life of people and ensuring the viability of the natural systems on which that development depends (CSIR, 2001).

The Rio Declaration, adopted by the United Nations Conference on Environment and Development (UNCED) in 1992 (the Earth Summit) puts SD this way; ‘Human beings are at the centre of concern for SD. Humans are entitled to a healthy and productive life in harmony with nature’ (UNCED, 1992).Soubbotina (2004) opines that SD could be characterised as ‘equitable and balanced,’ which implies that for development to continue indefinitely; it should balance the interests of different groups of people and generations economically, socially, and environmentally. Therefore, SD is about equity which is defined as equality of opportunities for well-being as well as about comprehensiveness of objectives (Watkinson, 2009; WCED, 1987). All of these interests need to be met to attain holistic SD.

Based on the views of SD stated above, Environmental Impact Assessment (EIA) is recognised as a key support tool for SD, which according to Jay *et al*. (2007), is the evaluation of the effects likely to arise from a major project (or other action) that significantly affects the environment.EIA is a systematic process for considering possible impacts prior to a decision being taken on proposal approval and project execution. The EIA definition adopted by the International Association for Impact Assessment (IAIA) is “*the process of identifying, predicting, evaluating and mitigating the biophysical, social and other relevant effect of proposed development proposal prior to major decisions being taken and commitments made”*(Glasson *et al.,* 2013).

The edict of the National Environmental Management Act (NEMA) is the use of the EIA process to facilitate the incorporation of the environment as a factor in project decision making. This includes engineering and economic factors that result in an environmentally sound project (NEMA, 2014). Sadler (1996) pointed out that EIA is increasingly being positioned within a broader context of sustainability. Its original, substantive aim of contributing to more sustainable forms of development is being rediscovered (Jay, 2007; Glasson et al., 2005).

Although, an open EIA process can aid in the development of an undertaking, which comprises the identification and evaluation of the potential Impact Mitigation (IM) measures (Glasson and Salvador, 2000), its understanding, interpretations and actions by practitioners have not been well researched as evidenced by practice communities themselves (Kagstrom and Richardson, 2015).

Mitigation measures include: avoiding the impact altogether by not taking a certain action or parts of an action; minimizing impacts by not limiting the degree or magnitude of the action and its implementation; rectifying the impact by repairing, rehabilitating or restoring the affected environment; offsetting or eliminating the impact over time by a preservation and maintenance operation during the life of the action; and enhancing the impact by replacing or providing substitute resources or environment (Mitchell, 1997; Canter, 2011; Andrews, 2017; Kamijo, 2018). The definition of mitigation suggests a sequential consideration from avoidance-minimising-restore-offset-enhancing as shown in Figure 1.1 (Mitchell 1997; Kamijo, 2018). Dust causes many environmental, economic, and social challenges in the course of road construction processes, and requires proper mitigation measures.

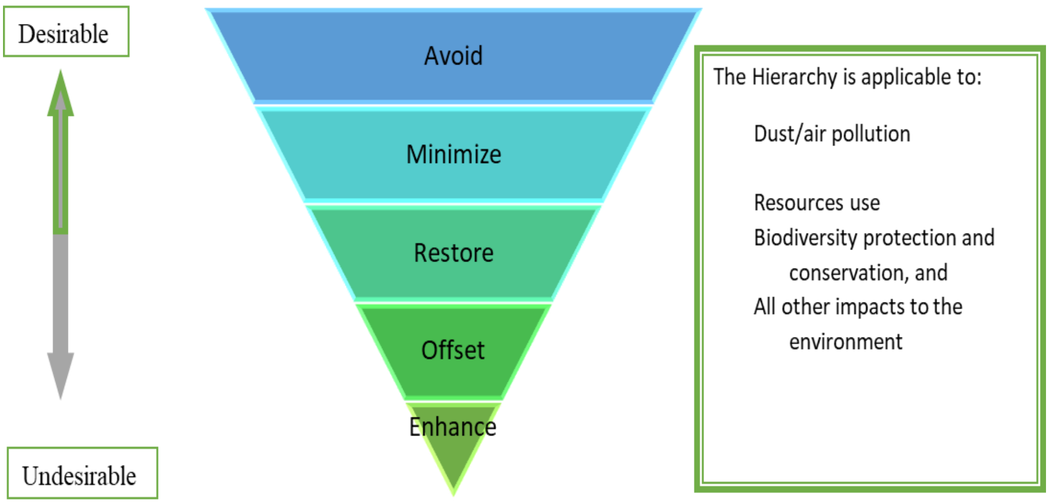


Figure 1.1: Prioritizing Management Practice through Mitigation Hierarchy, (Mitchell 1997)

1.2 Background to the Research Problem

Dust is one of the major and obvious problems associated with road construction (Igondova, *et al*., 2016). It is stirred up in the process of construction activities. This airborne dust causes nuisance and health problems such as fevers and allergies, and also affects the environment as whole (Lukacova *et al*., 2014; Jones, 2000; NIOSH, 1994; Thomas *et al*, 1993; Lentino *et al*, 1982). Besides polluting the environment, the generation of dust means the loss of fine particles of dust which acts as road surface binders and this represents a significant material and economic loss (Thomas *et al*., 1993).

Road dust has been identified as a primary source of particulate matter (PM) in an emission inventory that contributes to greenhouse gas (GHG) emission and should not be underestimated (Amato *et al*., 2014). Research conducted by Sarver and his co-workers, in a comprehensive review of the impact of dust on the use of solar energy, confirms that the impact of dust can hinder the sun's radiation and spectral content of solar energy (Sarver *et al*.2013). It concluded that the impact of dust on the viability of solar installations is overlooked. The increasing demand of sustainable power supply through solar energy across the country, and the need expansion of roads due to increase in population create the need to ensure proper sustainability practices in the road construction industry (Sarver *et al*., 2013; DBSA, 2008).

Construction of new roads and the grading of unpaved roads is almost a daily activity around the country and involves millions of Rand budgeted for these activities (Report, 2012/2013; JRA, 2018; SANRAL 2018). Road construction works and related activities amounted to approximately R430.2bn in 2018, marking construction of road as a great importance to the economic and social growth to the country.

Due to the increase in the number of road constructions around the cities of Johannesburg and Pretoria, more dust pollution is expected to occur in the future. Unfortunately, the existing research on mitigation of road construction dust is inadequate as only a few studies can be found concerning mitigation of road construction dust.

One of the earliest studies on road construction dust related in South Africa was by Jones (Jones 2000). In his research, he related road dust to be a nuisance and also an issue of road management. Jones, in further studies, researched the effect of dust on the environment, and how it can be controlled on unpaved roads (Jones 2001; 2008). He also measured dust exposure and how it can be controlled, with suggestions on environmental management with an emphasis on road expansion. However, studies on dust mitigation strategies were not found in literature despite their importance.

Current lack of sustainable development knowledge on dust mitigation strategies during road construction severely hampers reliable sustainability practices. Necessity of dust mitigation evaluation studies for road construction in South Africa to align with the global quest for sustainable development goals (SDGs) is encouraged by Rudman (Rudman *et al*., 2012).

Generation of dust during road construction activities cannot be avoided (Morgan *et al*., 2005). In order to ensure environmental and broader sustainability concerns are given consideration, periodical review of the state of practice to determine what has been achieved and is still being achieved, and what are the future goals, in other words to assess ongoing fitness (Pope *et al*., 2013).

1.2.1 Research Problem

From the background discussed above, it is therefore necessary to evaluate dust mitigation strategies during road construction projects, in accordance with the EIA process, to foster sustainability. The main gap emanates from the insufficient academic information on dust mitigation strategies for road construction. As such, there is inadequate knowledge captured, for evaluation, and improvement of practice and regulation.

South Africa is one of the few developing countries that have specific legislation with practical relevance as an environmental management tool (OECD, 2008). There are different known mitigation strategies for controlling dust during road construction for decades now (Morgan *et al*., 2005; NGSMI, 2005).Although a typical EIA may contain lots of proposed mitigation strategies, there are often no requirements for follow up and monitoring of such measures (Hussani, 2015; Jalava, 2014; Cashmore *et al*., 2004). In the absence of such follow up requirements, there is inadequate knowledge and assurance that dust mitigation strategies have been carried out sustainably with the best practices for road construction projects (Hussaini, 2015; Baby, 2011; Slotterbeck, 2008; Glasson *et al*., 2005). Therefore, the research problem can be stated as in section 1.3.

1.3 Statement of the Research Problem

There is inadequate information on dust mitigation strategies and their implementation in road construction projects in South Africa.

1.4 Study Aim and Objectives

The study aims to investigate and evaluate existing dust mitigation strategies, with a view to determining their effectiveness with focus on dust reduction for adoption in future road construction projects.

The objectives identified for this research project are:

1. To identify different dust mitigation strategies adopted during road construction projects in South Africa.
2. To evaluate the impact of the identified dust mitigation strategies (in 1 above) based on the pillars of sustainability (environmental, economic and social) and to develop a conceptual framework for sustainable road construction.
3. To assess the level of awareness and adherence of practitioners to the legislation on air quality Acts.

1.5 Research Question

What is the current state of practice for dust mitigation strategies and their implementation in road construction projects in South Africa?

In order to elucidate answers to the above question, the following questions were considered

1. What are the appropriateness of the identified dust mitigation strategies currently employed in South Africa?

2. What are the level of practitioners' awareness and adherence to the legislation on air quality Acts?

1.6 Research scope/delineation

This research identified different dust mitigation strategies adopted during road construction projects in South Africa; evaluated the impact of the identified dust mitigation strategies based on the pillars of sustainability (environmental, economic and social); and assessed the level of awareness and adherence of practitioners to the legislation on air quality Acts.

To achieve this, an evaluation was carried out of current practices of dust mitigation strategies employed in road construction sites from the Department of Environmental Affairs and NEMA documents. Questionnaires were issued to municipal workers, road construction companies, contractors, project managers, consulting firms and environmental practitioners within reach. The answers to these questionnaires were analysed. Literature was reviewed on the generation of dust, their negative impact on people and the environment. Legislative Acts that address the issue of dust and its mitigation are discussed.

This research focuses on major road construction in Johannesburg and Pretoria. It excludes dust mitigation strategies employed in construction sites that are carrying out pavement maintenance, road bricks installation site, cracked road maintenance and construction of buildings.

1.7 Assumption

1. The questions asked in the questionnaire are assumed to be well understood by the respondents and the responses given were accurate.

2. There will be higher achievement towards sustainable environment if proper dust mitigation strategies are adopted and implemented at the source of dust generation during road construction, in other to meet the intention of the environmental global summit towards SD.

1.8 Approach to Research Methodology

Mixed research method approach is adopted to achieve the research objectives stated above. The review of relevant EIA documents is the quantitative aspect of the research, while the qualitative aspect includes the views from practitioners through the issuance and analysis of questionnaires. A survey of effects of dust on sustainability pillars and dust mitigation strategies was carried out and key issues were identified.

1.9 Delimitation of scope

Data collection was limited to road contractors, project managers, environmental practitioners, municipalities, consulting firms and DEA, within reach. Data collection from individual views (local communities) on dust mitigation issue was not carried out. The EIA reports reviewed and professionals interviewed through questionnaire were from construction projects in the Cities of Johannesburg and Pretoria construction industry.

1.10 Ethical Consideration

Researcher's approach is guided by ethics with regards to the rights of subjects involved in a study and rights of people affected by the study (Saunders *et al.*, 2012). In this study, different documents, and people form the subject of this research in the form of EIA and EMP reports and respondents to the questionnaires that were conducted. Ethical approval was obtained from the appropriate authority, letter attached in Appendix C. The approach in obtaining documentation data and formulating questionnaires was done in an ethical manner. The anonymity and confidentiality were assured and personal information remained undisclosed in any form to anyone.

1.11 Rational and Significance of the Study

There is no identified study on the investigation and evaluation of dust mitigation strategies in South Africa. This has resulted in high reliance on water for dust reduction in road construction. Identification of dust mitigation strategies employed during road construction in South Africa will bring to view the current practices and how widely they are applied. Evaluation of the efficiency of the current dust mitigation strategies used in road construction in light of sustainability will help suggest to stakeholders the most efficient method and improve the legislation in this regard. The findings of this research are beneficial to road construction industries, and other construction sectors in South Africa,.

1.12 Structure of Research Report

This study contains five (5) chapters. The first chapter is a brief introduction of the research that provides background to the study, purpose and what the research is aimed on achieving. The next chapter of this thesis which is chapter 2 is the literature review. It offers detailed insights of the state of the issues of dust, dust mitigation strategies, road construction and other related issues in this research context.

Chapter 3 is the methodology. The chapter detailed the research methods chosen to carry out this research which includes pragmatism philosophy, with the choice of a mixed method by comparing induction and deduction research approach, utilising a survey, case study and archival research strategies, in a cross-sectional time horizon, and the techniques and procedures implemented for the outcome of this research are qualitative and quantitative data collection and analysis.

The research findings that were obtained from questionnaires and secondary data are analysed in chapter four and finally, chapter five concludes the whole research and the results are summarised giving answers to the research questions and gaining the aim of the study. It also highlights the contribution and limitations, and suggests areas for further studies.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter review the existing literature on the area of road construction dust, its socio-economic and environmental impact. The known dust mitigation strategies on road construction are also reviewed. Depth of implementation of these strategies is assessed. This is in order to elucidate on previous work done on dust mitigation strategies and its implementation in road construction projects in South Africa.

2.1 Introduction

Environmental quality degradation and pollution of the ambient air in cities has become a major concern caused by urbanization (Tuyan *et al*., 2014; Balaguera *et al.*, 2018). In light of the increasing demand for road construction to meet the surge of urbanization, it has become difficult to ignore the effect of such constructions on environment degradation. Road dust caused by construction activities accumulates organic and inorganic particles in the different layers of the atmosphere. (Soltani *et al*., 2015; Godish, 2005; Liu *et al*., 2014).

Dust may act as a temporary sink of contaminants from a variety of sources and may also act as a source of materials contributing to atmospheric pollution through re-suspension, and road dust re-suspension is an important source of Particulate Matter (PM) in cities (Amato *et al*., 2010; Moreno *et al*., 2013). Heavy metals that can be found in road dust can remain in the urban environments for a very long time and can also be re-suspended into the atmosphere and thus pose a potential threat to local ecosystems and public health (Li *et al*., 2014; Cook *et al*., 2005).

Zhang *et al*. (2015) confirmed that dust emissions during construction lifecycle are the main source of air pollution and are hazardous. The trace of calcium elements in PM2.5are confirmed to come from construction activities, and Moretti (2018) emphasised that construction dust contributes to the overall PM10 pollution found in the atmosphere which is detrimental to the environment and also contributes to climate change. Dust contributes to extensive air pollution which has adverse impacts on the environment and people, (Wu *et al*., 2016). As there is an increasing trend of the number of road construction activities in future (CoJ, 2012/2013), it is predicted that construction dust pollution will become more serious in the future.

Attention in the literature is given to pollution from coal combustion, motor vehicle emission, and industrial dust (like timber and cement production dust) to be sources of particulate pollution to the atmosphere. There is scarcity of literature on particulate pollution from the road construction industries and their hazards to people and the environment. The existing literature on mitigating road construction dust is inadequate. Few studies can be found concerning road construction dust. Therefore, it is of necessity and significance to investigate the measures that can mitigate road construction dust pollution effectively and also measure effectiveness of the current practices to foster SD.

2.2 Dust

With the increased awareness on the negative impact to the pillers of SD, (Cole *et al*., 2014; Eras *et al*., 2013; Steffen *et al*., 2011; Du plessis, 2003), dust from road construction activities has also been found to be an issue (Wu *et al*., 2016; Soltani *et al*., 2015; Eras *et al*., 2013; Kenley and Harfield, 2011; Morgan *et al*., 2005) and is a threat to the pillars of sustainability. Generation of dust during road construction is inevitable (Morgan *et al*., 2005) as many activities that take place in road construction sites tend to stair up dust (Kukadia *et al*., 2003; Liu *et al*., 2014).

Dust is categorized in different forms depending on the fractions/geometric size of the particles, agglomerates, and its behavior in airborne state (environments) (Sarver et al., 2013). Based on these characteristics, dusts have different impacts at different stages in the environments, depending on interest of assessment by different fields or agencies for example, health department, safety at open work place like in construction or mine sites, industrial users of metals, analytical laboratories and so on. Thus, definition of dust from different individual standards was reviewed as dust impact on all facet of the environment in its deferent state as illustrated in Table 2.1.

Dust is small solid particles which settle out under their own weight and can remain suspended in the air for some time, and are seen as particles below 75µm diameter (ISO 4225 - ISO, 1994). It is commonly made of organic minerals from geomorphic fallout such as sand, clay, or eroded limestone; it also comprises small amount of pollen (vegetation, fungi, bacteria), human/animal cells, hair, carpet and textile fibres (sometimes termed micro-fibres) (Bognold, 1965, Sarver *et al.*, 2013). The Western Regional Air Partnership (WRAP) Dust Emission Joint Forum (DEJF) created a definition of dust as PM which is or can be suspended into the atmosphere by mechanical, explosive, or windblown suspension of geologic, organic, synthetic, or dissolved solids, and does not include non-geologic PM emitted directly by an internal and external combustion process" (WRAP, 2004).

The Glossary of Atmospheric Chemistry Terms explains dust as small, dry, solid particles projecting into the air by natural force, such as wind, volcanic eruption, and by mechanical or man-made processes, such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping (IUPAC, 1990). The particles of dust size ranges from about 1 to 100µm in diameter, and they settle slowly under the influence of gravity (IUPAC, 1990). The atmospheric dust, also called aerosols, is attributed to various sources like soil elements lifted by the wind, also known as Aeolian dust (Biryukov, 1996), volcanic eruption, vehicle movement, and pollution.

Dust varies from region to region throughout the world with reference to particle size of dust, its constituents and the shape of the dust. Therefore, the deposition behavior and accumulation rates can vary dramatically in different localities (Sarver, *et al.*, 2013). These factors are based on the geography, climate, and urbanisation of a region.

According to WHO/SDE/OEH/99.14, there are different types of dust found in the work environment which include:

1. Mineral dusts: is a term used to indicate atmospheric aerosols originated from the suspension of minerals constituting the soil, being composed of various oxides and carbonates, e.g. is coal, cement dust.

2. Metallic dusts: more like the tiny remains of drilling, welding, cutting through metals, e.g. Lead, cadmium, nickel, and beryllium dust.
3. Chemical dust: is dust that consists of particles in the atmosphere that comes from various sources such as soil, dust lifted by weather (Aeolian process), volcanic eruptions and pollution e.g. many bulk chemicals and pesticides.
4. Organic and vegetable dusts: e.g. flour, wood, tea dust, cotton, pollen.
5. Biohazard that includes:

   i. A pathogen, especially one used in or produced by biological research.
   ii. The health risk posed by the possible release of such a pathogen into the environment e.g., viable particles, moulds and spores.

2.3 Determination of Impact

There are factors and measures used for explaining how impact can be determined, based on what the case may be. The determination of impacts on the environment are focused on their effect by the following factors: population, human health, climate, biodiversity (species and habitants) (Igondova *et al*., 2016; Walker andJohnston, 1999) and also, the regional geography, size and the climate of the area (Walker and Johnston, 1999).

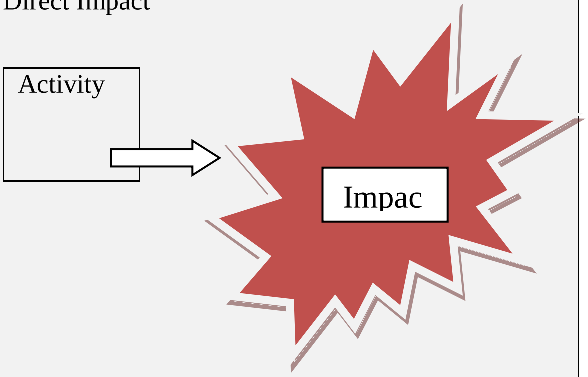
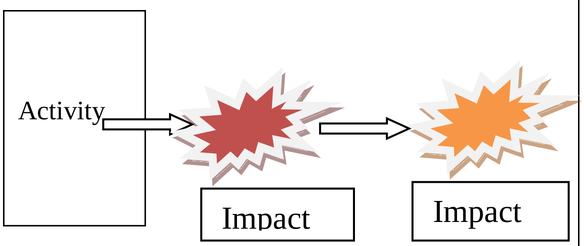
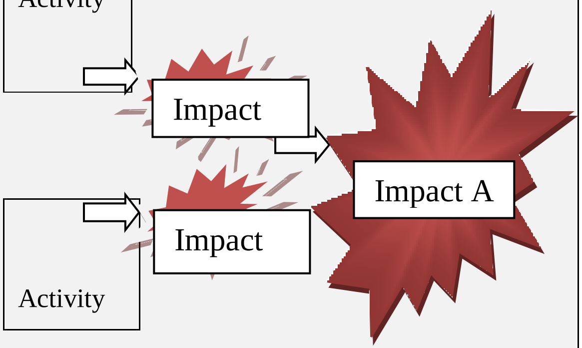
2.4 The Impacts of Road Construction Dust

Reed (2005) stated that dust emission can be found many kilometers away from the source of emission and, based on the narratives of dust in section 2.2 above; dust has an effect on all three components of SD. These three components can also be expressed as the physical and chemical environment, the biological environment, and the human environment (Abu-Ramman andAlzubi, 2015; Agrawal *et al*., 2006; Reed, 2005). The rate of deposition and the time taken for dust to deposit are an important influence on the perception of dust, dust deposition on windows, cars, vegetation, clothes-lines, outside of our homes was extensively mentioned as a major concern by Jones (2000); he also mentioned the frequent dust deposition incidence has an effect on the physical, chemical, biological, and human environment.

2.4.1 Categories of impacts of dust

Roads can require up 10 hectares (ha) of land or more per kilometer, as a large surface land of this amount is constructed, impacts of different forms occur (Seiler and Folkeson, 2006). Dust from road construction can affect the environment, economic, and social system in a number of ways. The impact depends on various factors, including the phase of road construction, size of the land being constructed, different activities and types of equipment/tools used, the regional geography and the climate (Igondovo *et al*., 2016).Typical environmental impacts includes: habitant fragmentation and modification, water pollution, soil pollution (Haddad *et al*., 2015; Iuell *et al*., 2003; Rajvanshi *et al*., 2001); social impacts include movement restriction in some cases, injury which may lead to mortality, and overall environmental contamination (Halpin and Bolivar, 2010; Chitkara, 1998; DoT, 1994). The impact is also on the economic system (DBSA, 2008). The impacts can be categorized into the following broad categories as shown in Table 2.1

Table 2.1: Impact Category

Impact Category	**Impact Description**
Direct Impact  Source: Walker and Johnston, 1999	This type of impact is directly linked to the road construction project. They are the primary effects of the activities associated with road construction and operation which is anticipated due to the immediate cause and effect related to road construction (Rajvanshi *et al*., 2001). The type of impact occurs during the construction activities and affects the soils, vegetation, water, site-works, road users, nearby residences, and the environment in close vicinity to the construction site. The effect of this type of impact is typically high (Ma, *et al*., 2017; Donaldson, 2018)
Indirect Impact  Source: Walker and Johnston, 1999	These impacts are mainly the after effect tof direct impact, which tends to be more difficult to control and measure (Walker and Johnston, 1999; Donaldson, 2018). For example; when a toxic rock is crushed in the process of road construction and the dust from this activity settles in water, it further reacts with the nutrients in the water which can further affect the aquatic life. Hence a complex pathway has occurred due to the dust deposition on water from the direct impact.
Cumulative Impacts  	Cumulative impacts are changes to the environment that are caused by combination of actions: past, present and future actions (Donaldson, 2018; Pavlickova andVyskupova, 2015; Hagmann *et al.*, 1999). This category of impact occurs when a series of road construction projects are done at the same time or due to multiple activities within the same area (IFC, 2013). This leads to multiple interactions of dust emissions occurring during the same period within a limited time and each action can induce further actions, adding to the cumulative effects already taking place (Hegmann *et al*., 1999).

Source: Walker and Johnston, 1999	

2.4.2 Effect of Dust on the Physical Environment

In the physical environment, due to wind disturbance, some of the fine dust particles raised during road construction activities can be dispersed into the air (Haihan et al., 2018; Deyu et al., 2004). Wind as means of transportation may result in tremendous waste of recourses which is a stress to the economic environment (Zhou et al., 2017) and also contamination to the natural environment.

Mitigation of dust on physical environment is paramount as stated by Said et al., 2018, as dust is increasingly preserve as a hindrance in the clean- energy technology. There is indication that dust dispersion in the physical environment reduces; light transmissivity to photovoltaic modules, hinders photosynthesis, causes respiratory health issues, impair vision, and dust accumulation in the physical environment has a considerable effect on climatic conditions with time (Said et al., 2018; Al-Maghalseh, 2018).

Jones (2001) also reported observations by the National Parks Board in South Africa stating that animals avoided grazing on dusty grass adjacent to roads; this is due to tons of dust deposited on the surfaces of grass. USA Vegetable Crop Hotlines (2007) reported that dust increases the mite population on watermelon plants due to dust deposition from roads, thus, also supporting the notion that dust inhibits the impact of insecticides on the environment, and this leads to economic loss in agriculture (Greening, 2011).

2.4.3 Effect of Dust on the Chemical Environment

It is interesting to note that dust matrix found in the environment can stimulate microbal growth, dissolve inorganic matter and form nutrients in organic systems and increase interactions in the chemical environment (Kollitz et al., 2018; Hwang et al., 2008; Walker and Everett, 1987). Owing to dust particles deposition, water can severely reduce its quality (e.g. cement dust from road construction site) and subsequently have damaging effects on vegetation that draws water and nutrients from the soil (Jones, 2008; Al-Khashman and Shawabkeh, 2006).

Dust carrying high Ph materials can undermine the physicochemical properties of soil, leading to a reduction in soil fertility (Sivakumar and Britto, 1995) and subsequently destroying the vegetation cover in the affected environment/area (Manahan, 2017). This is so because successful crop production is highly dependent on environmental conditions, with good air quality playing a major role (Agrawal *et al*., 2006).

Abiotic stresses can be caused due to dust pollutants which can lead to water deficit, salinity, alkalinity, heat, shock, freezing, ultraviolet irradiation, deficient or excess nutrients, and anoxia (Wang *et al*., 2018) and plants are frequently exposed to different abiotic environmental stress factors, which may occur separately or in combination and exert detrimental effects on plant transpiration/ecosystems and restricting agricultural productivity (Abu-Romman and Alzubi 2015; Abu-Romman and Suwwan, 2012).

2.4.4 Effect of Dust on the Biological Environment

The biological environment, also called the natural environment, can also be affected with dust from road construction. Many studies have been done regarding dust and the natural environment and are also supported by Lukacova *et al*., (2014). Sing and Charles (2010) researched on the impact of direct soil exposure from airborne dust and geophagy on human health, modes of soil exposure and their biological implications were described. An assumption was made that airborne dust and the ingestion of soil has influenced the evolution of a particular DNA sequence which controls biological systems that enable individual organisms to take advantage of, adapt and/or protect against exposure to soil materials.

Road construction dust can have an effect on biodiversity due to their vulnerable condition (UNDP/UNEP/GEF, 2001; DEA, 2001). There are known threats due to the impact of dust emission and other impacts on the South African environment reported by DoT, (1994); about 15% of South African plant species, 14% of bird species, 245 of reptiles species, 18% of amphibian species, 37% of mammal species, and 22% of butterfly species are threatened (DBSA, 2008, UNDP/UNEP,GEF, 2001).

2.5 Effect of Dust on Human Environment

In theory, the human aspects should be addressed under the biological environment, however, the profound influence human activity has on other aspects of the environment and development often justify a separate category (WHO, 1999). The study of the human environment through Social Impact Assessment (SIA) addresses the following: Aerosphere, Demographic impacts, Social-economic impacts, Health impacts, Impacts on social infrastructure, Impacts on natural resources, Impacts on life style, Impact on cultural property, Social equity of impacts, and dust has a potential effect on these environments as discussed below.

2.5.1 Dust impact on Aerosphere

Currently, air quality in sub-Saharan Africa is worsening throughout the continent (Zurita et al., 2018; Al-Maghalseh, 2018; EPA, 2012); mineral dust from construction sites transported by wind plays a critical role in the climate system through its alteration of radioactive forcing, surface albedo, significance as cloud and ice condensation nuclei, and ability to enhance biological sequestration of carbon (Jacobel, *et al*., 2017; Mahowald *et al*., 2014). Also, air quality is confirmed to be sensitive to climate change which affects physical and chemical properties of the atmosphere, thus drives some weather events with favorable conditions to the build-up of pollution episodes (Jacob and Winner, 2009) and these authors espoused that dust is more complicated and it is difficult to measure their effects due to its precipitation frequency and mixing depth driving factors. It is important to note that dust significantly increases the nutrient content of soil thereby counteract the effects of erosion of enriched soils (Alves et al., 2018; Agrawal et al., 2006). Also in the Sahara, dust is known to increase the pH of rain water which aid in neutralizing effect of acid rain (Sequeira, 1993). Furthermore, dust is very important for the dispersion of water from the rain clouds to form droplets (Min et al., 2009).

2.5.2 Dust impact on Demography

As the urban population is growing at the highest rate in the world, with a large number of residents living in low income slum neighborhoods (Arku *et al*., 2008), over the next 41 years, it is estimated that the African population will double and contain about 29% of the world's population (Saenz, 2010), and by 2030, 54% of the African population is expected to be in urban areas. This increase in population and urbanization normally leads to the quest for increases in road construction that stir up yet more dust, this will contribute to the growing urban air quality problem as explained in section 2.4.4.1 throughout the African continent, thus, population will be affected (EPA, 2012).

2.5.3 Dust Impact on Social-Economic

Social Impact (SI) is concerned about and evaluates the future Social and Economic effect of proposed policy, programme and project decisions and actions on the well-being of people and their businesses, and institutions and communities (Aucamp and Lombard, 2017). Dust has a negative impact on people, their communities and interrupts their way of life (Jones, 2000; Tan *et al.*, 2018). These concerns are visible during road construction projects and the operational phase. Dust is stirred up during construction activities and local residents may be inconvenienced, businesses and social activities will be displaced and disrupted and these may cause a loss of clients, thus leading to economic loss, and further, incur additional costs afterwards in cleaning/rehabilitating the area (Tan et al., 2018).

2.5.4 Dust Impact on Health

Detailed studies have been carried out on various impacts dust has on human health. Mostly, attention is given to dust related issues based on inhalation and skin absorbance (Lukacova *et al*., 2014; Tong *et al.*, 2018), about 70% of the studies carried out are on different occupational diseases caused by dust (WHO/SDE/OEH/99.14).

Inhaled dust particles are swallowed and ingested. This can cause complications in the respiratory and cardiovascular systems, causing cancer, asthma and morbidity (DBSA, 2008; Greening, 2011). There is evidence that suspended particulates have the potential to affect human health (UN, 1979), and dust can be a conveyor of other diseases. Morgan, *et al*. (2005) citied in the controlling highway related dust research: the health threat associated with road dust is the inhalation of microscopic particles that are able to slip through our natural respiratory air filters. In Nigeria, 33% of stroke incidences are reported to be caused by air pollution due to dust (Newspanorama, 20 June, 2016) and dust is one of the major causes of air pollution. Furthermore, exposure to dust from road construction sites contaminated with micro-organisms, fungi, viral or bacterial pathogens, when inhaled, may play a role in the transmission of infectious diseases e.g. pulmonary anthrax (NIOSH, 1994).

Airborne dust particles less than 1m in diameter are considered a health hazard, and median particle diameter of road dust has been reported to range from 0.002 mm to 0.049 mm (Garcia, 2018).This shows that wherever dust particles are deposited, either inhaled, ingested or on the skin, they have the potential to cause harm. Suggestion is made that fine solids in road dust require relatively more attention in order to avoid or minimise the overall cancer risk posed by Polycyclic Aromatic Hydrocarbons (PAHs)in dust (Ma *et al*., 2017).

2.5.5 Dust Impact on Social Infrastructure

Social infrastructure is a subset of the infrastructure sector and typically includes assets that accommodate social services (Aucampand Lambard, 2017; NGSMI, 2005). Dust has disruptive effect on infrastructure such as the solar panels for solar energy which has been highlighted. It can disrupt its efficiency or it can completely terminate the system operation. Research has been carried out in this regard and the majority of the studies observed a reduction in performance due to dust accumulation and its environmental factors (Sarver *et al*., 2013). Impact of dust accumulation on solar-thermal systems has been investigated and reported a maximum degradation on the efficiency of thermal solar collectors due to dust depositions (Hottel and Woertz (1943; Chaichan *et al.*, 2018; Li *et al.,* 2018).

Reduction in efficiency for thermal collectors and PolyVoltaic panels respectively, due to dust accumulation has also been reported (Adriana et al., 2018: Nimmo and Saad 1979; Ahmed, 2016). Biryukov (1996) in his study on the degradation of optical properties of solar collectors due to the ambient dust deposition as a function of particle size, also highlighted dust as a problem in the effective functioning of solar collectors. Hegazy (2001) also carried out research on this subject and reported that dust disrupts the accumulation on solar transmittance through glass covers. Recently, the impact of dust accumulation and its effect on solar energy generation been studied by various authors (Sanusi, 2012; Benatiallah, *et al*., 2012; Al-Sabounchi, *et al*., 2013).In their studies, they all labeled dust as a major problem and suggest that it is essential that proper dust mitigation is applied during any construction activity that stirs up dust to avoid or minimise dust effects.

Nonetheless, dust also has an effect on the historic environment, through soiling or chemical reaction between certain mineral dusts (e.g., limestone) which is potentially abrasive to delicate surfaces and finishes and could have implications for the maintenance of historic street materials such as delicate lead-work and old glass where it is not readily washed off by rain.

2.5.5.1 Dust Impact on Natural Resources

Dust emissions can include some toxic substances such as nitrogen and sulphuroxides (NOx; SO_2). These are released during the production and transportation of materials as well as from road construction site activities and have caused serious threats to the natural environment (Ofori and Chan, 1998; Rohracher 2001). High levels of dust falling into aquatic systems may adversely affect aquatic plants and fish that have not adapted to high levels of sedimentation and can also contaminate water (Infraguide, 2005).

2.5.5.2 Dust Impact on Life Style

Dust affects life style apart from discomfort for pedestrians, vehicle users and road construction site workers (Aucamp and Lambard, 2017). Dust causes an immediate visual/ aesthetic impact that may affect residents who are living nearby, it causes discomfort for people living along these roads as well, dust can also lead to grimy houses, nuisance by soiling curtains, gray laundry, and causing dusty floors (Infraguide, 2005). Figure 2.1 summarises the effect of dust to SD environments

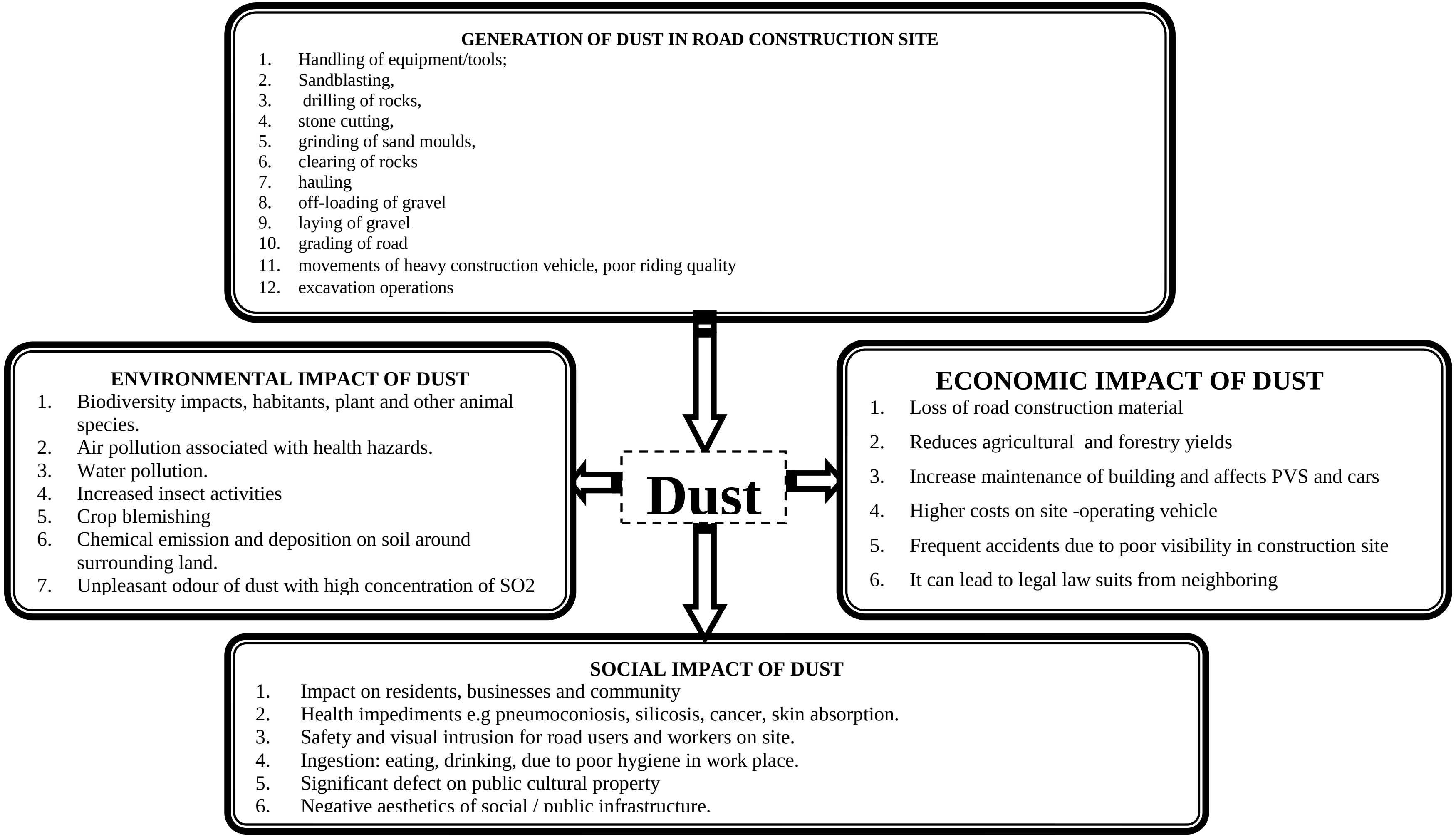


Figure 2.1: A Schematic Representing Effects of Dust from Road Construction Activities and Their Impact on All Facets of SD Pillars

Considering the enormity of the impacts, there is a need to evaluate current dust mitigation strategies for road construction. This is important especially in the case of South Africa where there is scarcity of consolidated information on the subject, even more so, in view of the set goals for sustainable development.

2.6 Road Construction

Road construction industries are one of the tools governments and society uses to achieve its urban and rural development goals (Enshassi *et al*., 2007). Road construction encompasses road design, contracting implementation, supervision, and maintenance of road and related structures, such as bridges and interchanges (World Bank and Gwilliam, 2002). Road construction typically occurs as an addition to existing networks although new major motorways are often constructed through green field areas in order to connect smaller isolated networks (DBSA, 2008; DoT, 1994).

Activities in road construction sites include clearing of the right of way (for easy movement), earthwork like "cutting and filling" to even out pronounced rises and dips in the area's topography, foundation laying like "deposition and compaction of substrate" sweeping off of unwanted sediments, batching, surfacing with either concrete or asphalt, installation of barriers, fences, lighting, traffic monitoring and control system, signage and road markings (Rudman, 2012; Jones, 2008). On large scale road construction projects, there will be a probable need for intersections with existing roads and possibly tunnels, and construction of slipways for entering and exiting of/from the main roads may also be necessary (DoT, 1994).

All these activities in road construction sites give rise to air pollution through dust emission. Road construction emissions are largely determined by the amount of earthmoving that occurs at a site (EMEP/EEA, 2016). Almost all roadway construction involves extensive earthmoving and heavy construction vehicle travel, causing emissions to be higher than that found for other construction activities, giving rise to air pollution which affects facets of SD environments (EMEP/EEA, 2016). Road construction is not an environmentally friendly process (Eras *et al*., 2013; Li *et al*., 2010; Tam, 2009) as the activities generate considerable amounts of dust that fouls road surfaces, further detracting from the safety of other road users. Major road construction often constitutes a visual impact especially where these transect an otherwise undisturbed landscape (Barclays Bank, 2015).

Road construction activities affect the environment from the initial work on-site through the construction period, operational period and to the final stage. For this reason, there is a progressive growing concern about the impact of construction activities on human and environmental health (Tjoe-Nij*et al*., 2003). Though road construction project development potentially contributes to the economic and social development and enhances both the standard of living and the quality of life, it is also associated with deterioration of the environment (Sun *et al.*, 2018).

As road construction increasingly becomes one of environmental pollution sources, so is pressure on the road construction sector to improve their environmental performance (Eras *et al*., 2013; Shen *et al*., 2005).Thus, road construction industries are associated with SD challenges (Zhao *et al*., 2012).Practitioners in the construction sectors have very little literature to work with on the issue of dust mitigation strategies and evaluation of the different practices and innovation by various countries.

Since the introduction of ISO 14001 and other related best practice standards, the concept of infrastructure is to facilitate the progress of a region towards the goal of sustainable living through a sustainable design (SABS, 2015). Sustainable living is a prerequisite to the development of a sustainable community by ensuring that infrastructural knowledge provides improvements that do not deplete the natural environment (Bodicha, 2015; EURP, 2009; UNCTAD, 2014).

The road construction industries have made important progress on the way to sustainability (Rudman, 2012). However, most of their sustainability efforts are focused on construction materials rather than on the construction activities process (Ding, 2008) like processes for mitigating dust during road construction activities. According to Wu *et al*. (2016), some guidelines/best practice for green road construction to minimize the negative influence on quality and safety are construction management, material savings and utilisation, water savings and utilisation, energy savings and utilisation, land saving and construction site conservation and environmental protection.

In road construction industries, some notable professions include construction engineer, construction manager, design engineer, site engineer, contractors, site foremen, environmental officers and project manager who oversee the whole construction activities (Halpin, *et al*., 2010). In their duties, they observed the implementation of good practice while carrying out their duties, and they are aware of the risk and other uncertainties in road construction sites (Azzopardi, 2015). These professions are part of the source for gathering data for this research study.

2.6.1 Road Construction in South African Context

South African roads are termed National road which is also refer to as national route (SANRAL, 2015). They are designated with route numbers starting with 'N', from N1 to N18 as shown in figure 2.2. These routes connect major cities and are mostly built in the 1970s but construction of new roads and repairs of existing stretches continue today (SANRAL, 2015; Nordengen et al., 2002; Jones, 2001). These routes run through national, provincial and local government communities' network and are maintained by SANRAL, provincial or local authorities depending on the route and condition of the road (SA Construction, 2013).

The South African construction industries play a vital role in the economy and the overall development of the country's infrastructure at large (CIDB, 2013). Most of South Africans' mode of transportation is by road (DBSA, 2008). South Africa spends R14.4 billion, annually on road construction, but it never seems to be enough as the population grows. There are continuous high demands for more and better roads and to a higher standard of safety, health and environmental protection (SANRAL, 2015).

South Africa is estimated to have 1 to 1.2 millionkm^2 unsealed road (Jones *et al*, 2008; Greening, 2011).This implies that more road construction needs to be constructed as demand increases and dust will be generated that will lead to air pollution, therefore, there is a need to evaluate the current strategies used for dust mitigation in road construction sites for readiness for future sustainable road construction. According to Jones (2000), dust generation in South Africa varies, based on location and also factors like surface characteristics, meteorological conditions and soil properties.

Construction of new roads in South Africa is an almost every day activity, as new roads need to be constructed, rehabilitated, and improved or specially maintained (SANRAL, 2014/2015). Contracts are being awarded to construction companies for these tasks, among many, there is a confirmation of 75 kilometers on-going road construction worth R10 billion for the Moloto road development project (GSA, 2016), a new four-lane dual carriage, section 17 of the N1 between Ventersburg and Holfontein, located in the Free State, FezileDabi District municipality worth R600 million due to start 2015/2016 (SANRAL, 2014/2015). The section of the N1 between the Holfontein interchange and Kroonstad, 45kilometres in the same province, in FezileDabi District Municipality, a new four-lane dual carriageway is on-going. SANRAL awarded the consulting engineering services in July 2012. The project, estimated to cost R559 847 160, started in February 2015 and is due for completion in February 2018.

In Gauteng alone, the freeway improvement road network project is many kilometers to compare to other South African cities; this is due to the increase in population and quest for development in this area (CoJ, 2012/2013).Due to many people and social activities going on in this area, there is need to ensure a sustainable environment. Evaluating the current dust mitigation strategies employed during road construction in this city for the purpose of SDGs for further road construction projects is essential for securing needs for future generation.

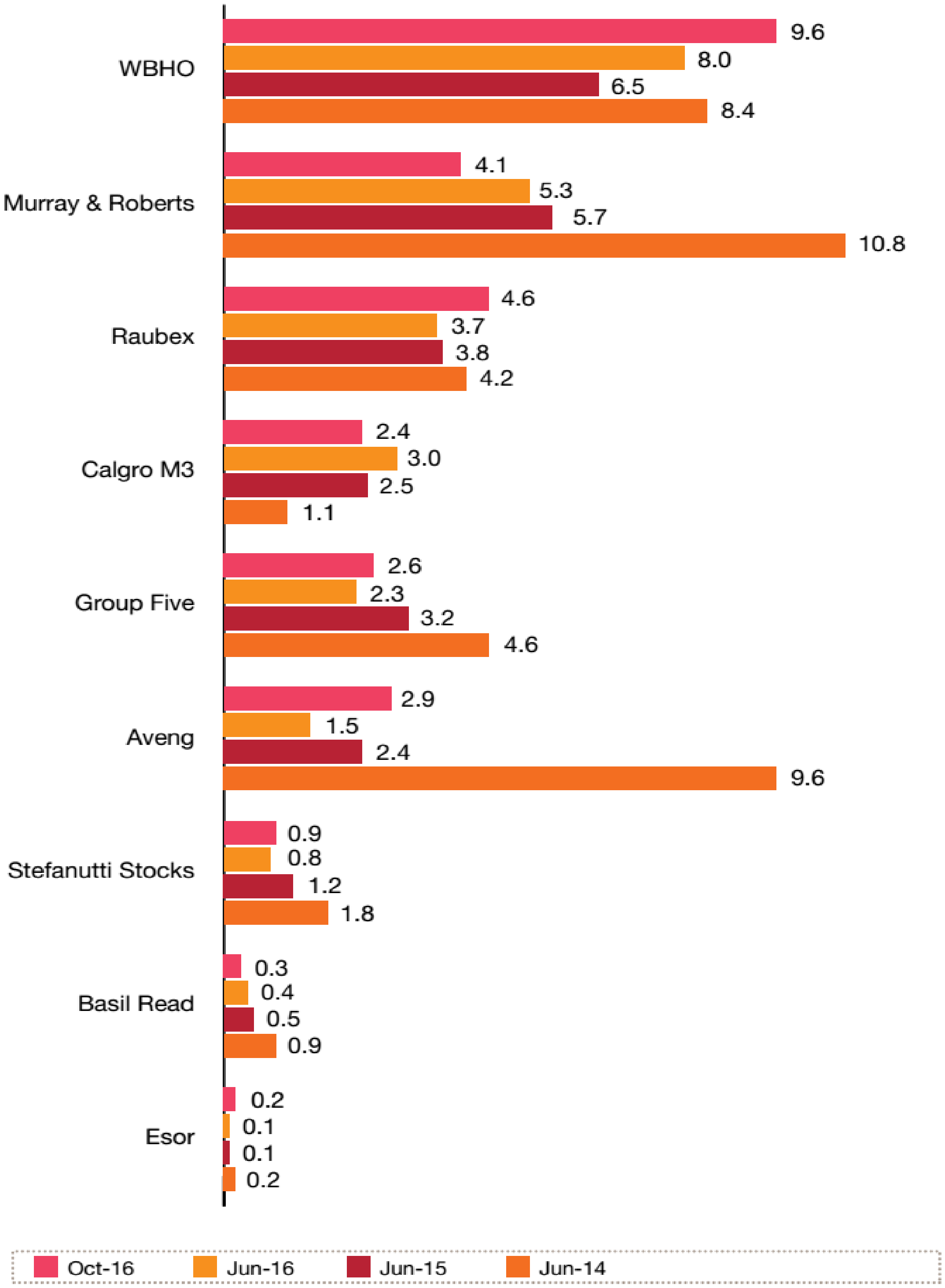
Figure 2.2: Map of South Africa Showing National Routes

2.6.2 Major Construction Companies in South Africa

Construction companies in South Africa are ranked, based on financial results by market capitalisation (which reflects the organic growth or regression, merger and acquisition activities and market expectations about the future) on the Johannesburg Stock Exchange (JSE), publicly available information (SA Construction, 2013). Annual reports of top 9 construction companies in South Africa in 2018 were rated as shown in figure 2.3.

These companies face challenges that are identified as risk, which includes risk to environmental sustainability, health, safety, transformation, followed by growth and expansion and compliance with laws and regulations (SA Construction, 2016). This study is therefore important in order to create awareness on the effect of dust on the environment, social life, and economic growth. Essentially, it will proffer solution to the identified risk in the industry via analysis and recommendation of the effective dust mitigation strategies to be adopted, thus, part of the SDGs will be achieved.

SA Construction (2016) further stated that non-compliance with environmental regulations could lead to reputational risks for the company and possible legal consequences. The industry still needs to go further to imbibe the desired environmental culture (SA Construction, 2013; 2016). In order to limit the negative impacts of road construction, the government of the Republic of South Africa in 1998, joined forces with the Department of Environmental Affairs to create the National Guides Towards SD, combined with an EIA, the guides also termed the “Acts” are to guide different sectors, and people towards best practices in decision making, technical practice, construction works, investment planning, environmental protocols, and so on (NEMA, 1998).



Source: INET BFA

Figure 2.3: Showing Top Nine Construction Companies in South Africa (SA Construction 2016)

2.7 EIA

Reassessing, identifying and prioritising key environmental issues affecting sustainable construction are achievable in EIA reports. EIA attempts to recognise a sequential process of identifying, predicting, evaluating and mitigating the facets of the environments and other concerned effects of development proposals prior to consensus decisions taken and commitments made to those actions identified in the assessment as seen in figure 2.4 (Hussaini, 2015; Baby 2011; Glasson *et al*., 2005). Many authors and international treaties around the world have recognised EIA as a tool to foster SD since its introduction at the international level in 1992 at the United Nation Conference on Environment and Development held in Rio de Janeiro (Pope *et al*., 2013; UNCED, 1992).

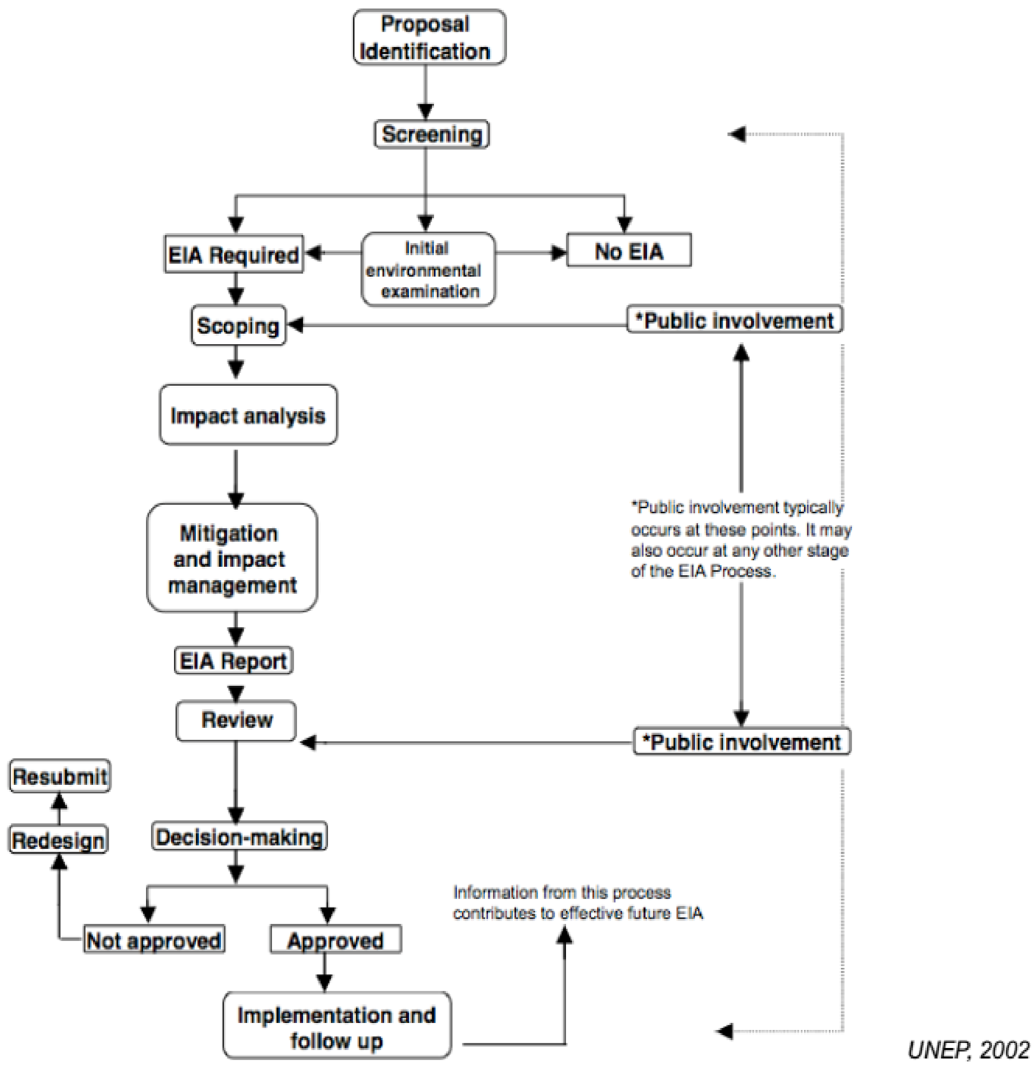


Figure 2.4: Systematic Process of EIA, adopted from UNEP, 2002.

2.7.1 EIA in the International Level

The status of EIA after 20 years and counting, from a well-trodden path by the National Environmental Protection Agency (NEPA) in the USA shows that EIA is mandated in many nations of the world.(Pope *et al*., 2013; Morgan, 2012).After these years, it seems reasonable to say that EIA is universally recognised as a key tool for environmental management (Hussaini, 2015; Wood, 2003; O'Riordan and Sewell 1981) and firmly initiated into the environmental law internationally (Morgan, 2012).This is to ensure that EIA can continue to contribute to better decision-making for SD (Adelle and Weiland 2012; Hussaini, 2015). EIA as a national instrument is undertaken for proposed activities that might have significant adverse impacts on the environments and are subjected to the decision of competent national authorities.

The Millennium Development Goals, adopted by 187 nations and signed by heads of states and governments during the UN Millennium Summit in 2000, provide a framework for the integration of the principles of SD into country policies and programmes (Morgan, 2012), which is one of the aims of EIA. Several international conventions and international development treaties exist (Morgan, 2012).They have specific requirements for EIA which are incorporated in a broad range of decision-making contexts, for example, World Bank, the International Finance Corporation (IFC), the Trade Policy, the Convention on the Trans-boundary Environmental Impact Assessment, the United Nations Framework Convention on Climate Change, etc. Their standards require EIA on major projects that might have impacts on the environments (Pope *et al*., 2012; Cashmore *et al*., 2009; Kirkpatrick and George, 2006). These treaties also apply EIA in disaster preparedness, post disaster recovery and reconstructions as seen in Srinivas and Nakagawa (2008). They believe the aim of EIA which ensures that environmental considerations are taken into account in decision making (Glasson *et al*., 2005; Sadler, 1996) and benefit the environments in many ways as shown in table 2.2.

Table 2.2: Benefits of EIA, Source (UNEP, 2001; Sadler, 1996)

Benefits of EIA
• Better environmental planning and design • Ensuring compliances with environmental standards • Reducing damage to the environment and disruption to the communities • Savings in capital and operational costs from unanticipated impacts and encouraging change in process • Improved technologies through consideration of alternatives • Reduces time and cost of approvals on developments applications • Increases project acceptance by the public, through open and transparent process and provision for involvement. • Identifies mitigation measures • Enhance environmental and social benefits • Through EIA, some adverse impacts are avoided, minimized or remedied • Restoring and maintaining environmental quality • Increase environmental awareness and learning amongst participants

2.7.2 EIA in the South African Context

The EIA has existed in South Africa since 1998,and there are a number of EIA procedures (screening and full EIA studies) completed in the country (CSIR, 2003; Wathern, 1988). Economic growth is quite prominent in many cities in South Africa and EIA procedures are required to be carried out when a development project or a strategic initiative is proposed. This requires the possibility of the environmental consequence to be considered and potential effects analysed to prevent adverse impacts (NEMA, 2010).

As many researchers and practitioners consider EIA as an essential tool and often the only tool for ensuring that quest for sustainability around environmental, economic and social concerns are taken into consideration in decision making (Morgan 2012;Cashmore *et al*., 2009; Bond *et al*., 2012).These support Jay et al. (2006 / 2007) and Taylor, (1984) who stated that EIA could be means of bringing about change in the values, rules and priorities that govern the institutions responsible for planning decisions.

With a focus on micro level application of laws and regulations, the most applicable is the National Environmental Management Act 107 of 1998 and the subsequent EIA regulations (Government Notices 543-546, June 2010 as amended) promulgated in terms of the Act. These regulations and Acts govern the execution of an Environmental Basic Assessment or Scoping-Environmental Impact Assessment process in order to identify potential impacts on the environment and to suggest mitigation measures (Morgan 1998; 2005; 2012). In the provincial level, DEA as well as provincial environmental department ensures that EIA processes attain accurate execution and timely. Municipalities are engaged throughout the process of of EIA to address concerns raised by stakeholders and inter-governmental cooperation (NEMA, 2010).The surge of environmental concern that lay behind the enactment of NEMA had wider international and regional ramifications, ultimately leading to the SADC Policy and Strategy for Environmental and sustainable Development in the year 1996.A number of other international environmental treaties, for example, Montreal Protocol, the UNCBD and the UNFCCC to which South Africa is signatory (GRSA, 2001; SADC, 1996) influenced this decision. Here, the problems of burgeoning development, pollution and destruction of the natural environment that NEMA intended to address were perceived to be a global problem.

Moreover, the EIA approach of rigorous project-by-project evaluation of significant impacts was seized upon as a means to resolve these environmental problems by many jurisdictions, which saw EIA as a key response to the increasingly large scale environmental harm being witnessed (UNDP/UNEP/GEF, 2001).For example, the South African government began reforming and assessing fiscal measures to address environmental issues in 2006 with the release of an Environmental Fiscal Reform Policy Paper. The paper lays out South Africa’s environmental initiatives, including SD, and the use of market-based instruments to address adverse environmental impacts and climate change mitigations (Rudman, 2012; Swilling, 2006). Therefore, it is agreed nationally that EIA is a tool used by regional and national development assistance with instructions to integrate environmental and social issues into development cooperation, as well as addressing public participation and good governance issues (UNCED, 1992).

2.7.2.1 Sustainable Development and NEMA not Mutually Exclusive

The preamble of the NEMA in section 1 states that SD requires the integration of social, economic and environmental factors in planning, implementation and evaluation of decisions to ensure that development serves present and future generations. Consequently, the NEMA defines SD and is the first attempt to provide a formal definition of SD in South African environmental legislation (SDEC, 1996). SD is yet again seen as the integration of social, economic and environmental factors into planning, implementation and decision-making in order to ensure that development serves present and future generations., Section 2(1)(4)(a) further establishes a number of relevant principles that should be considered by relevant authorities during the initiation and implementation of development.

These principles include: the disturbance of ecosystems and loss of biological diversity be avoided or minimised and remedied, environmental pollution and degradation should be avoided or minimised and remedied, the disturbance of landscapes and sites that constitute cultural heritage be avoided or minimised and remedied, waste should be avoided or minimised, reused or recycled in a responsible manner, the use and exploitation of non-renewable and renewable resources should be responsible and equitable, a risk averse and cautious approach should be applied during the environmental management process and the negative impacts on the environment and on peoples' environmental rights be anticipated and prevented (Du Plessis and Kotze, 2007).

Section 2 of NEMA contains the national environmental management principles which are the corner stone of environmental governance and liability in South Africa, which is based on the foundation of SD. Comprehensively, NEMA established legal liability for environmental damages as well as damage to human health and well-being (NEMA, 2014; CIDB, 2012). Mechanisms, procedures and structures to facilitate pollution prevention, minimisation and remediation also exist under NEMA, having the ultimate objectives of providing decision-makers with an indication of the likely consequences of their actions (CSIR, 2003; Wathern, 1988). Environmental legislation has subsequent Acts that protect the environment.

2.7.2.2 Construction Industry Development Act

The CIDB is a schedule 3A public entity established in terms of the Construction Industry Development Board Act (Act 38 of 2000). Their main role is to provide guidance for sustainable growth, reform and improvement of the constructions sector and the industry's enhance role in the country's economy (CIDB, 2012).

2.7.2.3 Air Quality Act

The Air Quality Act 39 of 2004 regulatory system deals with norms and standards, which reform the law regulating air quality in order to protect the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically SD while promoting justifiable economic and social development, to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government, for specific air quality measures, and for matters incidental thereto (NEMA, 2017).South African Air Quality Standards are found to be weaker than the WHO Recommendation/guideline which was published in 2000 and has remained unchanged, and are exceeded regularly (McDaid, 2014).

2.7.3 EIA as a Tool in Practice

EIA is used as a tool that captures the essential idea of assessing proposed actions (from competent authority to project establishment) for their likely impact for all facets of the environment, before decisions are made to commence the proposed project and developing appropriate responses to the issues identified in that assessment (Morgan, 1998; 2012), hence, EIA in a broader conceptual way, works extensively towards achieving a sustainable environment rather than being limited to the project operational phase EIA.

Since EIA has become an environmental management tool for achieving SD, a variety of business activities and construction projects apply EIA for environmental protection (Hussaini 2015; Morgan 2012; Baby 2011).

Road construction is like other construction projects that start with conceptualisation of ideas, planning design, financing and these processes continue until the project is completed (Bodicha, 2015; Chitkara, 1998). EIA processes have to be planned in an integrated and coherent manner to ensure maximum effectiveness and avoid shifting one environmental hazard to another (Glasson *et al* 2005). Effectiveness is how well something has been done or has been carried out as planned and how it meets the purpose for which it was intended (Sadler, 1996: 37). From the EIA perspective, effectiveness is the extent to which the EIA system achieves its objectives, with minimum delay and without bias or prejudice (Sandham *et al*., 2013). Effectiveness in EIA has long been conceptualized by many authors in the Procedural; Substantive and Transactive dimensions (Gwimbi and Nhamo, 2016).

Procedural Effectiveness is concerned with the EIA processes conforming to its intended objective, based on its aim of integration into the legislation (Theophilou *et al*., 2010; Sadler, 1996). Sadler (1996) further states that, the quality of EIS reflects the procedural effectiveness of EIA.

Substantive effectiveness is concerned with attaining the EIA objective set during the implementation process (Theophilou *et al*., 2010).The term substantive also refers to the extent stages in the EIA or EIA processes as a whole attain their intended purposes, goals and objectives. From this point of view, the mitigation stage is seen as a major part in the EIA process where decision making is critically analysed due to its significant contribution to SD (Glasson *et al*., 2005).

Transactive effectiveness evaluates achievement attained within the substantive goals of EIA, with least cost and minimum time spent being criteria in the evaluation (Theophilou *et al*., 2010). According to Sadler (1996), transactive effectiveness is said to be achieved when the EIA outcome is attained with least cost in the minimum time frame.

The important of EIA effectiveness abounds in many dimensions. Sadler (1996) suggest that a multidimensional approach to assess EIA effectiveness could be more consistent and representative in terms of the results achieved. The consensus among the scientific community is that the improvement of an EIA system must be based on empirical evidence of its outcomes, focusing on the integrative approach, considering the different dimensions of effectiveness (Peterson, 2010). The EIA process as a whole must possess the ability to deliver relevant information to decision-makers and empirical evidence of its outcome (Morrison-Saunders *et al*., 2014).

This research also wanted to know the effectiveness of EIA from the substantive effectiveness prospective, as it has been highlighted by many authors that failure to implement mitigation strategies proposed in the assessment reports is a major shortcoming of the EIA process in practice (Sanchez and Gallardo 2005; Tinker *et al*., 2005; Sanchez and Hacking, 2002), thus, affecting the achievement of SD.

Availability of EIA guidance does not necessarily correlate to good practice (Pope, 2013; Morgan, 2012). Literature reviews, there are gaps between the policy assessment system and the assessment in the project development practices (Adelle and Wieland, 2012). Furthermore, there are criticism and perceptions of inadequacy about the success of the current EIA system as a tool for environmental impact management practiced in South Africa over 20 years now as discussed at the 2018 IAIA conference held in Durban (DEA, 2018).In practice, it is noticed that the mitigation component of EIA receives less attention at implementation level (Gwimbi and Nhamo 2015; Baby, 2011).This is also confirmed by Hussaini (2015); Slotterback (2008); Sanchez and Gallardo(2005).There is little assurance that mitigation measures proposed in the EIA are implemented during the project activities as revealed in surveys of EIA practitioners. This does not overrule EIA as a tool for environmental protection, rather its influence on decision making and follow-up needs to be strengthened (Armour, 1990).

2.7.4 Mitigation- a rational decision-making tool in EIA

Mitigation is discerned as the heart of EIA (Gwimbi and Nhamo 2015; Morgan 2012; Glasson 2005; 2013).The EIA systematic process propounds mitigation measures to

Avoid; Minimise; Restore; Offset; and Enhance the negative impacts a project might have on all facets of the environment. The process may also culminate in the foreseeable positive impacts the project might bring (Hussaini, 2015; Mitchell, 1997).Mitigation strategies proposed during EIA processes are reported in the EIA report which is seen as the action-forcing document responsible for ensuring implementation of the mitigation strategies (Evans, 2013), therefore, articulation of strategies that interrelate environment and proposed development activities is established within the mitigation stage in the EIA process in which SD is fostered.

Doubt on the effectiveness of mitigation strategies proposed in the EIA has risen globally (Cashmore *et al*., 2004).The global debate pointing out what extent are mitigation strategies and conditions translated by project proponents effectively implemented to protect the environment in development activities is a key challenge (Glasson *et al*., 2005; Cashmore *et al*, 2004).They also argue that mitigation strategies proposed in EIA mismatch those found in the Environmental Management Plan (EMPs).This came to be as project proponents neglect or consider them to be of poor quality (Pinho *et al*., 2007). Challenges like little attention given to the fulfillment of the proposed mitigation strategies after the review of the EIA report and project approved has also been highlighted (Slotterback, 2008). Hence, there is a need within the EIA community to review the role EIA plays in achieving SD, therefore, an evaluation of dust mitigation strategies for road construction in South Africa is a call that conforms to this review.

2.8 Dust Mitigation

Constructions sectors are exposed to high levels of uncertainty. There are calls for mitigation within the facets of the environment as well as to achieve project objectives and ensure project success (Hanisch and Wald, 2011; Cleland and Gareis, 2006). As recognised, construction of infrastructure constitutes an important source of dust but road construction contributes even more as it involves extensive earthmoving and heavy construction vehicle travel, causing more dust emissions than found in other construction activities (EMEP/EEA, 2016; Wu *et al*., 2016).

Dust mitigation in the road construction sector has not received much attention in South Africa, (Rudman, 2012).Notwithstanding, in China, Wu *et al*. (2016) extensively discussed the *state of the art and the way forward on mitigating construction dust.* They identified two sources of dust emission (direct and underlying source) during road construction through on-site observation and interviews with practitioners.

Direct sources are visible activities and construction dust is directly produced and identified on-site through observations, and the direct source identified for road constructions during the construction stage that are ranked the most are: earth excavation and blasting of disrupting rocks, land leveling, backfilling and transporting and working with soil such as cement, concrete, lime, sands, bricks, stones, etc. (Wu *et al*., 2016).

Underlying sources generate dust indirectly and are identified and explored by experienced practitioners in the field of road construction. The source underlying the activities that was retrieved from the practitioners is that dust is not produced directly in this category, but affects the dust mitigation behavior of contractors, for example, lack of awareness, participation and collaboration from stakeholders. These lead to dust mitigation not being adopted completely by site-workers, regardless of the social responsibility the road construction company should take, hence, SD is affected. According to Wu *et al*. (2016), identifying the sources of construction dust can assist project managers in adopting targeted effective strategies to mitigate dust generation. For example, in an earthwork activity, by knowing the sources of dust generation, the project managers can pay thorough attention to the soil excavation and transportation in order to provide more specific illustrations to construction dust mitigation strategies. Wu *et al*. (2016) suggest project managers should lead a dust control team on the site to identify the major on-site dust sources in order to select corresponding mitigation strategies.

2.8.1 Dust Mitigation Strategies in Road Construction

In construction activities, dust generated can be substantially reduced through carefully selected mitigation strategies and effective management on-site (Kukadia *et* *al*., 2003) Once dust particles are airborne, it is difficult to prevent them from dispersing into the surrounding area, therefore it is recommended that prevention of dust from source before becoming airborne remains the best option (Wu *et al*., 2016; Kukadia *et al*., 2003).Dust dispersion is strongly dependent on the type of activity and material or soil moisture content. Moisture tends to promote particles to clot together; preventing particles becoming airborne but on the other hand, dust generation from road construction can also be sub-airborne, since suppression is virtually impossible once it has become airborne (Wu *et al*., 2016; Greening 2011; Jones 2000; Sanders *et al*., 1993).

There are many dust mitigation strategies applicable to a variety of dust generation types (EMEP/EEA, 2016).Watering is found to be a well-known dust control strategy that is widely used in construction sites. Besides watering, dust emission reducing suppressants and best/green practice are available for specific activities in the road construction sector (Wu *et al*., 2016; EMEP/EEA, 2016; NEMA, 2014;Morgan, 2005; World Bank, 2002; Jones, 2000; IFC, 2013; SANRAL 2015).

2.8.2 Dust Suppressants

The effectiveness and environmental impact of dust suppressants was evaluated by Sanders *et al*. (1993). A study done in Nigeria illustrates the ingenuity of road managers in developing countries to adapt local materials for road maintenance (Ndoke, 2006).The by-product, shell, of a palm kernel fruit was used as dust suppressant, and the result was effective in reducing the volume of dust generation by 75%. However, no long-term tests have been conducted to determine the durability or longevity of the material (Ndoke, 2006).Determination and evaluation of alternative methods for managing and controlling highway related dust was conducted by Morga *et al*., (2005).

Furthermore, in the 1970’s and 1980’s, control of unpaved road dust with emulsified asphalts, organic cationic and sodium chloride ware investigated, to know if they could be used as soil stabilisation additives (Lustig 1980; Butzke 1974). Laboratory study on the use of polyester and thermoplastic resins as soil stabilisers and low-cost dust suppressants has been investigated(Jones 2000; 2001)and there have been several quantitative field studies on dust suppression. In the United States, relative effectiveness and the environmental impact of road suppressants have been investigated (Sanders *et al*., 1997; Sanders and Addo, 1993). In South Africa, dust control on unsealed/unpaved road and dust management issues have been investigated by Jones (2001; 2008) respectively.

The use of dust suppressants has been utilised for decades now (Wu *et al*., 2016; Morgan *et al*., 2005; Jones, 2000).There are several widely used dust suppressants applied on different types of road and based on the type of material used, for example, unpaved road surface, alluvial sand/gravel surface, crushed limestone rock, etc. (Peterson, 2010). It is of importance to bind dust particles together and reduce dust movement through different dust mitigation strategies as listed below. :(Jones *et al*., 2008; Morgan *et al*., 2005; Tjoe *et al*., 2003; Jones, 2001, 2000).

Engineered method
Suppressants method
High technology method

2.8.2.1 Engineered Method

This involves the proper design of the road to withstand the expected vehicle load and activities, using appropriate tools. This is facilitated in the road construction through experts in the field, the use of the most appropriate grain size (for example, coarse aggregate granites or sands) of material to achieve maximum durability and roads constructed with poor quality materials tend to be dustier (Greening, 2011).

Dust reduction can be achieved by covering the roads (gravels, sand in hauling vehicle)when transporting material, constructing wind breaks such as wind fences where possible (Landcom, 2004).Other methods include ceasing work in dry and windy conditions, using temporary grassing, using jute mesh, using bitumen straw mulching, and using bitumen spraying. When an area of works is completed, the area should be re-vegetated immediately to inhibit the generation of dust in a situation where all reasonable engineered methods have failed to reduce dust emission to acceptable levels, dust suppressants will be used (Morgan *et al.*, 2005).

2.8.2.2 Suppressants Method

1. ***Water also known as wet dust suppression***: spraying with water, if available, is a widely known technique for suppressing dust (Jones, 2001; GRT, 2018). Unfortunately, this technique suppresses dust for a short period of time and frequently needs to be re-applied almost daily. Several applications are required in the hot and very dry conditions. Sea water or borehole water containing salts is considered to be more effective than salt-free water due to the hygroscopic and deliquescent properties of some salts (Greening, 2011). Water spraying has different application techniques;

a) One wets dusts before it is airborne (surface wetting)
b) The other wets dust after it became airborne.

By wet, this does not mean solely water. Surfactants or chemical foams can/are be added to the water in order to improve performance. Water sprays with surfactants lower the surface tension of the water droplets which allows the droplets to spread further over the dust material and also allows deeper penetration into the material (Peterson, 2010).

2. Chemical foam is generally water and a kind of special blend of surfactant. This dust mitigating approach increases the efficiency of the wetting.

The principle behind surface wetting is that dust is not given the slightest chance to form or escape. These dusts mitigating approach can adopt:

i. Static spreading (wetting material{construction surface} while it is stationary {before been worked on}), or
ii. Dynamic spreading (wetting material {construction surface} while it is in process).

Effective dust suppression arises by increasing the surface coverage by either reducing the droplet’s diameter (pump nuzzle) or by reducing its contact angle.

Airborne dust mitigating system involves spraying very small water droplets into airborne dust. The small droplets collide with the airborne dust particles and fall out of the air to the ground. This collision occurs due to the approach of water and dust particles by airflow moving the dust particles around the droplets have a direct hit on the droplet or barely graze the droplet.

According to NEMA, (2014), "water is an essential commodity" the Environment Protection Authority (EPA) advises developers/builders to seek alternatives to the use of mains water on construction sites. Furthermore, Nie et al 2016, confirms that water is not the most effective dust suppressant and Gibberd, 2009 stressed that water should be reduced/ conserved in the construction fields to be able to escape Sevier water scarcity in south Africa. Hence, more effective means of suppressing dust during road construction should be sourced and adopted.

Alternatives to water, dust suppression measures could include but are not limited to:

3. ***Hygroscopic Salt**:* dust mitigation strategy for major road construction such as the chlorides of sodium, calcium and magnesium as dust palliatives (Sanders *et al*., 1993), are often available as industrial bi-products. Hygroscopic materials are less effective at the low levels of humidity typical of many plateau regions of Africa and in many other places in the dry season, although some salts are reportedly 'recharged' if moisture becomes available, even in some cases just by heavy dew (Greening, 2011). Research into the use of calcium chloride in South Africa indicated a significant reduction in gravel loss to between approximately 10% and 20% that of untreated sections, a significant reduction in blading frequency and a reduction in road roughness over a 12-month period (Jones, 2001).

4. ***Organic Non-Bituminous Binders:*** Example of this product is lignin sulphonates, which are mostly bi-products of the pulping industry. Piechota *et al*,.(2004) reported on the performance of trial sections using magnesium chloride ($MgCl_2$) and lignin and a combination of both to mitigate dust. The study concluded that magnesium chloride sections in particular, require at list two applications a year due to leaching after rain (Greening, 2011).

5. ***Petroleum Based-binder:*** These consist of recycled waste oils, bituminous emulsions and tar. Although longer-lasting than some other products, they often need ‘blinding’ with dust to be more effective (*Ibdi*).

6. ***Elector-Chemicals Stabilisers:*** these consist of sulphonated petroleum products and various enzymes and are ionic stabilisers (*ibdi*). Effectiveness of this mitigation measure is dependent on the type of clay material it contains and the contents of the material in road construction site.
7. ***Microbiological Binders***: similar to electro-chemical stabilisers, these work by microbes acting on clay particles whereby a polymeric residue is produced that acts as a binder. High clay content is required for these products to be effective (*ibdi*).
8. ***Polymers***: This type of mitigation strategy is not widely known as little information is available in the Australian report, but these products are used in mitigating dust by cementing soil particles (*ibdi*).
9. ***Bentonite***: This dust mitigating strategy is reported to be used in Australia. It acts by ionic exchange mostly on clay particles, specifically limestone (*ibdi*).

2.8.2.3 High Technology Method

There are high technology dusts mitigating machines used for major construction activities, like crushing of rocks to smaller grains, constant hauling activities, multiple batching plant activities, etc. An example of this machine is DB-100, it oscillate 359’, with a throw of more than 100meters and it is able to cover 2800,000 square feet with a dust-trapping mist as shown by ”Dustboss”, and is mostly used in the United States. A tool called “DustBubble” is found to be effective in controlling dust and could reduce dust being airborne from source significantly (Zhang *et al*., 2012; Fan *et al.*, 2018).

2.8.3 Green/Best Practice of Dust Mitigation Strategies in Road Construction

In order to take effective managerial countermeasures with regards to dust mitigation during road construction, there are green guidelines formulated by several international development treaties and in developed countries, with specific requirement which are incorporated in the broad range of decision making contexts (Morgan, 2012; Pope *et al*., 2012; Cashmore *et al*., 2009).

This section outlines the techniques adopted internationally as dust mitigation strategies initiated during construction activities in developed parts of the world, and proposed dust mitigation strategies adopted by international development treaties. Box 2.1, 2.2, 2.3, 2.4, and 2.5 depict Australia, European Union, United Kingdom, United States of America and IFC respectively. The criteria are from many technical and programmatic sources.

Box 2.1: Dust Mitigation Practice for Construction Activities in the Pilbara Australia

Operations exporting bulk materials from construction sites are required to manage their dust emissions to mitigate their impact on the town. Dust management plans are parts of overall environmental management systems. They form the basis for operations in the region to effectively monitor, respond to, and manage their dust emissions. The execution of dust management plans are typically required under ministerial conditions applied to many operators in the region. Operational dust management plans for individual operators in the Pilbara region typically include the following management elements:

- Definition of operational accountabilities and responsibilities for dust monitoring
- Dust modelling (including verification) to better understand sources, controls and impacts
- Reducing cleared open areas
- Dust suppressions using water trucks
- High traffic routes sealed with bitumen
- Moisture content of bulk materials increased
- Enclose high dust plant, for example, car dumpers, major transfer stations
- Dust extraction
- Water sprays
- Fogging systems
- Belt washers and scrappers

- Water cannons on stockpiles
- Management of vehicle speeds on unsealed areas
- Education of site personnel on dust reduction
- General site housekeeping
- Community information and engagement
- Ongoing review of available dust abatement practices and technologies

Box 2.2: Dust Mitigation Practice for Construction Activities in European Union

In this part of the world, there is Integrated Pollution Prevention and Control (IPPC) in place. IPPC is a directive in the European Union, founded to organise the exchange of information and produce Best Available Techniques (BAT). BAT represents technology, processes and operations that prevent impacts to the environment, or it this is not practicable, to mitigate as best and reasonably possible. Member states are required to take into account BAT when determining air quality management techniques, both generally and in specific cases. This process and the EU air quality objectives are implemented into legislation and guidelines by Members States (IPPC, 2006). The following techniques are recognised by the EU as the best practice available for dust mitigation (IPPC, 2006).

- The use of wet suppression, temporary seeding.
- Enclosed offloading points for dusty materials with extraction to bag filter
- Enclosure storage to eliminate windblown dust
- Enclosure of high dust generation plants
- Covered transport where appropriate
- Applying protective planting or windbreak fences
- Considering prevailing winds when developing storage areas
- Avoid traffic.

Box 2.3: Dust Mitigation Practice for Construction Activities in the United Kingdom

In the UK, there are several guidelines for the control of dust emissions from construction activities. The UK Development Control Guidelines (Environmental Protection UK, 2010) and the best practice dust control guidelines for construction and demolition in London (Greater London Authority, 2006) recognise the following methods as leading practice for the control of dust arising from the construction industry.

- Air quality assessments/air quality impact evaluations are required where a development is anticipated to give rise to significant changes in the air quality and must be conducted before any activity begins on site.
- Air quality risk assessment can be used to define potential risks to air quality and determine best practice measures for mitigating dust.
- The recommendation that a dust assessment study is undertaken for all new and extended operations to identify likely causes of dust and make recommendations for mitigation measures.
- During site planning, machinery and dust causing activities should be located away from sensitive receptors.
- Stockpile location should also consider prevailing winds
- Usage of water as a dust suppressant
- Early implementation of paved haul routes
- Keep stockpiles to a minimum size and for the shortest possible time
- Erect solids barrier around the site boundary
- Cover, seed or fence stockpiles to prevent dust been blown into the air.
- Undertaking dust generating activities during favorable weather condition.
- Spray exposed surfaces of stockpiles to maintain surface moisture.
- Use dust extraction equipment such as filters where possible.

Box 2.4: Dust Mitigation Practice for Construction Activities in the United States of America

The United States Environmental Protection Agency (EPA) guidance on leading practice management of dust emissions is found in the fugitive Dust Background Document and Technical Information Document for Best Available Control Measures (US EPA, 1992). This document is designed to provide technical information on reasonable and best available dust control measures. For mitigating dust for road construction, the US EPA recommends the following:

- Vacuum sweeping for sealed road only
- Water flushing with sweeping after the road has been sealed
- Cover haul truck loads
- Wet down hauled materials
- Focus cleaning on unsealed road connections.
- Pave parking areas, driveways and road shoulders
- Limit traffic on unsealed road surface/ speed control.
- Frequent watering of unpaved roads.
- Wind shields/sheltering/enclosures.
- Increase product moisture
- Chemical stabilization
- Wet suppression systems (using foam or liquid sprays)
- For physical stabilisation, use less erodible material stacked on top and vegetation where possible to reduce dust emission.
- Increase surface roughness of unsealed area using a coarse material like lump product.

Box 2.5: Dust Mitigation Practice for Construction Activities proposed by International Finance Cooperation (IFC)

The guidelines provided by IFC contain the performance level and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. These measures are designed to be used together with the Environmental Health and Safety (EHS) guidelines documents, which provide guidance to users (IFC 2007). To minimise dust emissions during road construction, the following should be initiated:

- Installing dust suppression mechanisms for e.g. water spray or cover storage areas.
- Using telescoping chutes to eliminate the need for slingers.
- Using vacuum collectors at dust generating activities.
- Using slurry transport, pneumatic or continuous screw conveyors, and covering other types of conveyors.
- Minimising free fall materials.
- Minimising dry cargo pile heights and containing piles with perimeter walls.
- Removing materials from the bottom of piles to minimise dust re-suspension.
- Covering transport vehicles.

According to the dust mitigation measures in the best practice reviewed, dust mitigation strategies at project level can be said to be categorised based on different stages of site activities as shown in the table below:

Table 2.3: Best/Green Practice for Dust Prevention and Control, adopted from various auth**ors**

Activities	**Guidelines for Green Construction**	**References**
Earthwork Activities	The most important measure for mitigating dust in earthworks is applying best engineered method, arranging a workman for watering (avoid non-toxic chemicals) and installing standby dust trapping and misting machines for airborne dust, use of bag house and use of cyclones. Additionally, the soil loaded into the vehicle containers is compulsorily required to be compacted and covered with tarpaulins to avoid scattering during transportation.	Greening, 2011; IFC, 2007
On-site storage of material	As for the materials that are easily diffused, such as cement and limestone. They should be stored in the designated depots. In terms of the materials that are stored, tarpaulins covering and watering (avoid non-toxic chemicals) should be implemented according to weather condition at the time.	Wu *et al*., 2016; Greening, 2011
On-site manufacture	The manufacture of materials is required to be conducted in enclosing rooms. Besides, some traditional on-site manufacture is mandatorily forbidden, such as on-site manufacture of concrete, on-site decoction of asphalt, etc.	Wu *et al*., 2016;
Transportation	The arrival and departure of vehicles should be recorded and the records must be kept by the dust control administrator. The vehicles must be tidy when coming into the jobsite and should be washed to get rid of the adherent dust before leaving the construction site. In the construction field, the roads should be hardened at all time and appropriate measures adopted to prevent the scattering of materials or wastes.	Wu *et al*., 2016; Greening, 2011; IFC, 2007
On-site stacking of waste	The stacked waste is expected to be shipped out of the jobsite within 48 hours. For those wastes that could not be shipped out in time, dust mitigation measures should be conducted similarly with the ones for on-site storage of	Wu *et al*., 2016; Greening, 2011

	materials.	
Demolition Activities	It is required that a fence is built around the demolition site and cannot be lower than 2.0 m, or in terms of rocks or obstructing structures higher than two floors, potential hazardous air pollutants, for example, asbestos, should be selectively removed prior to demolition, fine mesh safety vertical net should be used, best engineered method should be applied and dust trapping and misting machines installed for airborne dust. Designated places should be particularly arranged for stacking demolition waste and should be cleaned periodically. In addition, a workman should be assigned for watering the stacked demolition waste several times a day. Besides the above-mentioned measures, weather conditions (i.e. wind force) should be taken into consideration. For example, if the wind is stronger than force four (i.e., 5.5- 7.9 m/s), activities that produces dust should cease.	Wu *et al*., 2016; Greening, 2011; IFC, 2007

Dust prevention and control in road construction has been shown to be a worldwide concern. Road construction industries are therefore required to be more sustainable in light of limited natural resources, the delicacy of the environment and restricted economic resources.

This section has shown that sustainability is not just about the natural environment. It is the integration of the environmental, social and economic attributes that need to be managed at all road construction project level to be effective and successful.

2.9 Concept of Sustainable Development in Road Construction

Globally, there has been concern over threats to the environment, and calls to all development sectors to ensure that maximum countermeasures are used to prevent adverse impacts, by using different tools, for example, the EIA in achieving the aims of SD (Alawneh et al., 2018: Martens *et al*., 2014; Alex *et al*., 2012; Glasson *et al*., 2011; Savitz, 2006; Elkington, 1998; UNCED, 1992). The widespread and global flow of SDGs introduces interdependencies between targets that can either reinforce or reduce differences between goals (Opoku, 2019). As seen in SDGs number 11 that to achieve sustainable cities and communities, one of the target is to provide safe and affordable road that is accessible for all by 2030 (Opoku, 2019;).

Furthermore, to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management(Xia et al., 2018; Opoku, 2019). This target promotes that dust having been found to cause nuisance in all the facet of environment need to be mitigated, thus promoting that dust mitigation strategies during road construct need to be given attention.

SDGs number 9 seeks sustainable industry, innovation and infrastructure, thus urging construction companies, road construction inclusive to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (Alawneh, 2018). This fosters sustainable infrastructure that will have less or no environmental impact to ecosystem services; supports economic development by sourcing for other possible means of dust mitigation strategies during road construction that will reduce stress caused to the resources as water is a scarce resource in South Africa, this is also a concern in SDGs number 6, which stress about water management and water supply for all; human well being by creating safe road construction project that will not have adverse impact to cities and community as it is a quest that SDGs 11 achieve this concern (Nerini et al., 2018). Good health and well-being for all as seen in SDGs number 3, dust pollutes the air, contaminates water, and soil that can lead to diseases spread out, although dust particles enriches biodiversity in water by providing food chain for organisms and plants, which in return, produces oxygen for human and sequester carbon that provides long-term storage of carbon dioxide and other forms of carbon, thus, deferring global warming and evading hazardous climate change (Kruk et al., 2018).

To progressively advance the SDGs agenda, governments around the world have endeavored to enact public policies for regulating concerned activities, including the road construction activities, with a view to reducing their negative impacts on the environments for public good (Rudman, 2012). Public policies are referred to as ordinances, regulations, codes of practice, standards and initiatives which are introduced by government or its executive arms (NNEP, 2011). Nevertheless, whether the policies are effective is an unanswered question among policy makers, practitioners and scholars (Hussaini, 2015; Theophilou *et al*., 2010).

The construction sectors, such as the road construction companies, are realising the adverse impacts of their practices on all the facets of the environment (CIBD, 2015; COJ, 2012/2013) and are also required to pursue sustainability in all their activities (NNEP, 2011; World Bank, 2002). In line with this development, Rudman, (2012) stressed the need to ensure that the South African road construction companies are equipped with mitigating tools to avoid causing adverse impact to all facet of the environment, in order to achieve the quest for SD.

Thus, the concept of SD in road construction sector and EIA as a tool is used frequently in the provisions of environmental framework legislation for achieving environmental success for public good. In the context of this study, the aim of EIA is to monitor and mitigate the adverse impacts of dust for the benefit of the public environmentally, economically and socially, which can lead to sustainable future development.

Literature discussions regarding environmental impacts clearly demonstrated that the consequence of poorly managed construction mechanisms can have significant impacts on sustainability (Pitt *et al*., 2009). Hence, monitoring and evaluating the impact of a project are essential in determining the outcome of EIA effectiveness, by incorporating feedback into EIA process, follow-up, and enabling learning from experience to occur (Gwimbi and Nhamo, 2015; Bond *et al*., 2012; Morrison-Saunders, 2007). Morrison-Saunders (2007) further suggested that this exercise should occur in any EIA system from time to time, to prevent EIA being just a pro-forma exercise. For this reason, an evaluation of dust mitigation strategies for road construction in South Africa is essential towards achieving SD.

2.10 Conclusion

A sustainable environment is essential (Sarver *et al*., 2013) and in achieving it, EIA is used as a tool to tackle it (Munn *et al*., 1979). There is different environmental mitigation measures applied to different types of dust impact during road construction. Dust generated during road construction is one of the numerous effects on the environment and there have been mitigation strategies in place for decades now (Padoan *et al.*, 2018; Kamijo, 2018).

A typical EIA may contain lots of proposed mitigation strategies, but are they followed, and do they effectively reduce the dust impact rate in South Africa? From literature, there is no strict requirement for monitoring these mitigation measures which was also cited in SA Construction's report that: "*It is imperative that construction companies focus on the risk landscape within which they operate. Companies now need to integrate risk and performance management, and they need to evolve risk management to be more predictive in order to anticipate and plan for negative potential events. Therefore, an appropriate control environmental tool with regular update and reporting is essential within the construction companies"*. In this regard, little or no research has been done on the evaluation of current dust mitigation strategies of road construction in South Africa to the best of the author's knowledge. In the absent of such, there is often little assurance that mitigation measures have been carried out as proposed to meet the need for a sustainable environment. Dust pollution has caused extensive adverse influences on the natural environment, social benefit and economic development and is questioned in light of environmental degradation, energy security, global climate change and health risk. Therefore, there is a need to know;

- Types of dust mitigation measures employed by road construction companies during projects execution,
- How much or what percentage of dust is reduced with the mitigation measures practiced,
- How efficient are the measures adopted, in addition, is it up to the recommended level according to the environmental management section 24 of the Constitution of the Republic of South Africa, 1996 and chapter 5 of the National Environmental Management Act of 1998 (NEMA 1998).

The literature review answered the following questions: 'What is dust?; In what ways does dust affect the environment and social-economic system as a whole?; What are the different types of dust mitigation strategies globally used?; What are the needs for evaluation?; Why EIA process should take place before road construction projects begin?; What is the need for effective EIA in relation to the issue of this study and what are the dust minimisation strategies with regard to legislation?'

Furthermore, literature clarified the tools required to acquire data such as EIA reports. Also, from literature, it has been acknowledged that mitigating dust during road construction activities with water, also known as wet dust suppression, is a stress on water resources, especially in water scarce countries. Therefore, it is important to acquire data on different types of dust mitigation strategies, used and their effectiveness. This information can further aid in the design of a sustainable solution for road construction companies in mitigating dust and also be useful to the general body of knowledge with regard to dust mitigation strategies.

CHAPTER THREE

3 RESEARCH METHODS

This chapter focuses on the methods of research in the acquisition of data that are suitable for this research report. The research method includes; philosophy of research, comparison between research approaches, different survey research strategies, choice of time horizon and finally, the logic of qualitative and quantitative data collection.

3.1 Introduction

The methodological approach chosen for this research is a mixed. This is done based on the 'onion' model from Saunders *et al*., (2009) and supported from other authors to clearly explain research strategies and choice with respect to the objectives of this study.

In details, layers of the 'onion' are explained and a description on which layer is related to this research is highlighted. Ethics for this research are outlined as well, with explanation of the expected codes of behavior for this research in order to prevent any breach to the research ethics recognised by the University of the Witwatersrand, Johannesburg.

3.2 Research Methodology

Research methodology can be defined as 'an organised critical discussion of the principles and methods of a subject area" (Hons, 2009; Creswell, 2009). The methodology that is used in a research work refers to how the research is done, and it manifests in the research design. According to Durrheim (1999), it is a strategic framework for action that connects the research questions and the implementation of the research. Saunders et al. (2012) explains that in research, the term methodology refers to the theory of how research should be undertaken.

3.3 Research Design

This section explains the stages of the research philosophies and approaches using the research onion by Saunders et al. (2012).This will provide clarity on the research question while addressing the research objectives identified. As the research onion layers is summarized, it will help in giving direction on how data will be collected and also describes why the choice of design method was adopted and is suitable for this research.

Research design is a choice by a researcher or/and an investigator about the components of his/her project and also the development of certain components of the design and the selection of research components is done keeping in view the research objectives (Singh 2006; Rose, 2013; Kumar, 2019).Research design explains how the researcher will find answers to the research questions. It sets out the specific details of a researcher's enquiry. According to Saunders et al. (2012; 2018), research design helps relate the assumptions and chosen method to their search strategy. The research design also helps to identify what will be limiting in their search. The problems faced by researchers are when the details of the answer to a research question cannot be given and there is also limited access to data. The research onion by Saunders et al.(2012) has been used by many authors/researchers and it was helpful for their research. Figure 3.1 below is the research onion framework by Saunders et al., (2009).

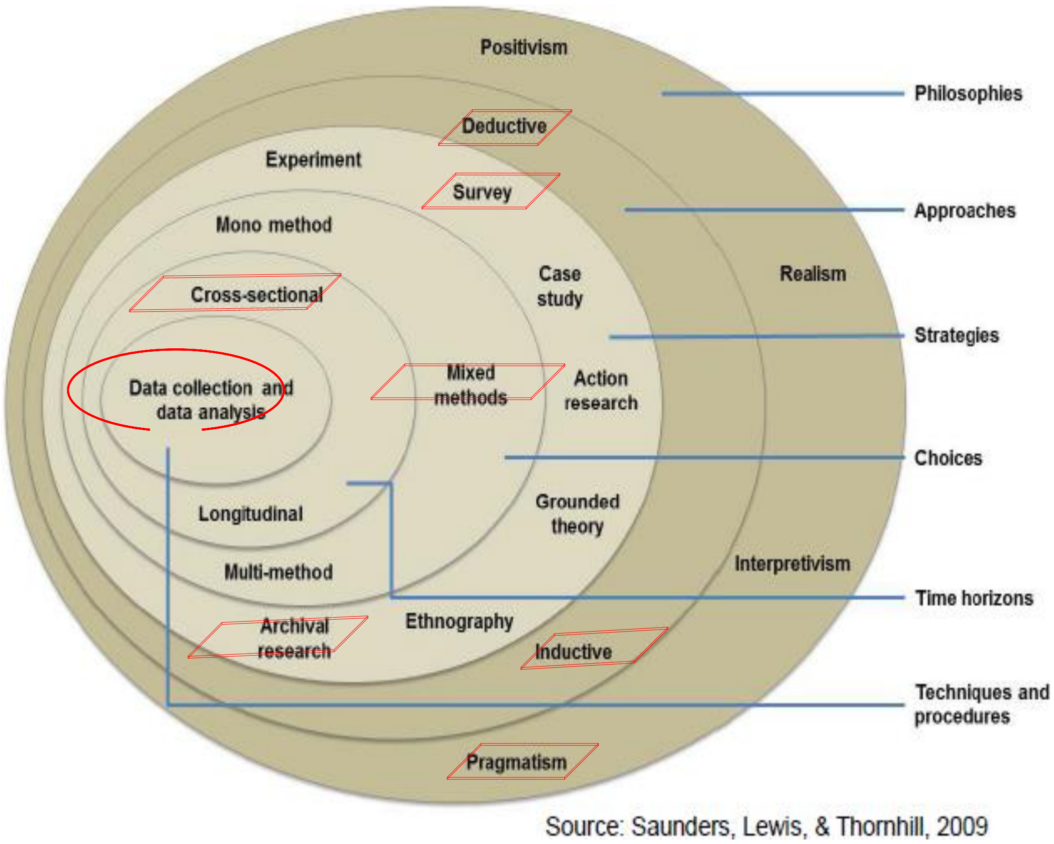


Figure 3.1: The Onion Research Framework. Source: Saunders *et al.* (2009).

This theoretical research framework describes the overall research paradigm, also termed the onion layers (Saunders *et al.*, 2012). The research onion consists of six layers, the first two layers explain the research design which is the philosophies and approaches, and the subsequent four layers relate to research methodological strategies, choices, time horizons, also techniques and procedures used in formulating the research design.

3.4 Research Philosophy

Firstly, the research philosophies are described as Ontology and Epistemology, these aspects influence how research is being done and further help the reader understand the perception of the researcher (Flowers *et al.*, 2009; Rahi *et al.*, 2017). According to Mack (2010), epistemology comes after ontology; which studies the meaning of when something is said to be in existence and these leads to the aspect of paradigm.

The research philosophies help the researcher have a better idea on what research design and approach to adopt for the research study. According to Saunders et al. (2012), research philosophy relates to the development of knowledge and the nature of the knowledge. The strategies and methods of research philosophy can differ for different researchers, also with their perspectives (Saunders *et al.,* 2012; 2018; Kumar, 2019).

Ontology; "is concerned with nature of reality" and the aspect of ontology are "Objectivism and Subjectivism", (Saunders et al., 2012)

Epistemology; "considers what constitutes the acceptable knowledge in the field of study"; these are two major ways of thinking about research philosophies; each of them gives an understandable guide of the philosophical type that should be used in a research process (Saunders *et al.,* 2012). Others are Axiology and Data collection techniques.

The research philosophical standpoints include: Positivism; Realism; Interpretivism; and Pragmatism, which deal with the theory of human knowledge and the gathering of knowledge.

3.4.1 Positivism Paradigm

This entails observations on the reality, mostly adopted by researchers on the physical and natural science (Saunders *et al*., 2012; Remenyi *et al*., 1998).

3.4.2 Realism Paradigm

This philosophical point deals with reality in the context of objective reality that exists independently of human known knowledge or beliefs which is interpreted through social conditioning, also known as "critical realist" (Saunders *et al*., 2012).

3.4.3 Interpretivism Paradigm

This deals with the researcher acting socially among people, in different forms to adapt to people he/she with whom she/he is interacting. The researcher has to "adopt an empathetic stance" that is entering the social world with our subject research and to understand the subject research from their point of view (Saunders *et al*., 2012).

3.4.4 Pragmatism

This deals with multiple methods in a study and the view is to enable answering research questions from different dimensions and that a single view point is not enough to prove the entirety of the world, and these do not mean that multiple methods must be used at all times but "method or methods that enables credible, reliable and relevant data that advances the research" (Saunders *et al*., 2012). In this study, this philosophy was applied by collecting data via questionnaire from practitioners in the field of road construction. Data was collected from practitioners in different cadres that are both field workers and managers. Age groups and highest education level were considered.

3.5 Research Approach

Research approaches can be plans and procedures of a research that shows steps from broad assumptions to detailed methods of data collection, analysis and interpretation (Creswell 2003; Page and Meyer, 2005; Creswell, 2008). There are two approaches explained by Saunders *et al.,* (2012) that helps in understanding the theories used in a research, and they are the Deductive and Inductive approach.

Deductive approach or reasoning involves developing theory and hypothesis or (hypotheses) and also designing a research strategy to test the hypothesis, this is mostly used in scientific research, and this type of approach can work with qualitative or quantitative data, but mostly a quantitative research (Saunders *et al*., 2012; Kumar 2019). Quantitative data on road construction was obtained from DEA. Analysis of the obtained data brought to light the non-availability of quality data and loopholes in the practice of dust mitigation in the road construction industry. Questionnaire was developed to plug the loopholes and get a better picture in order to propose best practice in South Africa.

Inductive approach or reasoning on the other hand, involves collecting data and developing theory base on the result of the data analysed, and data collection approach can be qualitative or quantitative (Agerfalk, 2013; Walliman, 2017). Qualitative data was collected via questionnaires.

3.6 Research Strategy

Based on Saunders et al. (2009), the research strategy consists of seven aspects which are: experiments, survey, case study, action research, grounded theory, ethnography and archival, they outline the different ways data can be collected. Data can be collected using a qualitative or quantitative strategy (Onwuegbuzie and Johnson, 2004; Leedy and Ormrod 2005; Agerfalk, 2013; Saunders *et al*., 2012;).

Survey strategy was adopted for this study as it is associated with a deductive approach. This strategy enables quantitative data collection from the identified sample group using a questionnaire, which is seen as a primary data. This also enables the researcher to compare the respondents' thoughts on different types of dust mitigation strategies. The second strategy considered for this research is the case study strategy.

According to Saunders et al. (2009), case study is an empirical investigation of a real event situation, using different sources to gather information and it is justifiable to say that a case study can be used in descriptive and investigative study. The archival strategy is also adopted for this study as it reviews historical and recent documents, in order to account for changes that might have occurred over time. Data acquired from this type of strategy is termed secondary data and on the other hand, authors refer to archival strategy as Literature Review (Saunders et al., 2009). It is essential to adopt this strategy in this study, as it forms the basis for this research.

3.7 Research Methodology Choice

This section outlines the research design that was applied for the purpose of data collection and analysis. It gives knowledge on how best to effectuate this research to best answer the research questions and achieve the research objectives. The "issue" of this research has its focus on evaluating current practice on dust mitigation strategies, employed during road construction in the "context" of South African cities. Therefore, this research adopted a combination of quantitative and qualitative research. The choice of the Mixed Method research can be justified in the bid to give more insight to the areas the research aims to achieve.

This research project adopted the mixed method research approach. Kemper et al. (2003) define mixed method research as a method that includes both qualitative and quantitative data collection that are analysed in a parallel form. As there are strategies embedded in this type of research, its data can be analysed in various design formats (concurrent triangulation design, concurrent embedded design, sequential explanatory design, sequential exploratory design and sequential, multi-phase design).

3.7.1 Quantitative Research Strategy

Research strategy can be quantitative when seeking to know; not only what, but how much, and measurement becomes the central feature of it (Singh, 2006; Kumar, 2019). This means that quantitative strategy deals with a systematic examination of current events, records, documents, etc. and may merely gather information or may also evaluate the content according to some established criteria. This research strategy mostly applied in deduction research approach which deals with testing theories subjected to lines of propositions and variables, and can be measured by using models or instrument. Also, numbered data that are been collected can be analysed using statistical processes (Leedy and Ormrod 2005; Saunders *et al*., 2012; Kumar, 2019). This type of research strategy is further explained as the dominant research approach where laws are a basis of explanation, and it allows the anticipation of phenomena, predict the occurrence of the outcome and permits them to be controlled (Saunders *et al*., 2012). They are characterised by the following:

1. Examining the relationships between variables, that are measured numerically and analysed with a range of statistical techniques.
2. Usually associated with experimental and survey research strategies, the survey research strategy is usually conducted with the use of questionnaires or structured interviews, observation.
3. Mostly uses probability sampling techniques and it has no influence on the respondent (Saunders *et al*., 2012).

4. Is objective in nature, seeking the precise measurement.
5. The researcher tends to know what he/she is looking for in advance.

This type of research is relatively flexible in nature.

3.7.2 Qualitative Research Strategy

This can be said to be philosophical as it relates to studying the fundamental nature of knowledge, reality, and existence. It is mostly related to the Inductive research strategy. According to Strauss and Corbin (1998), qualitative research is the type of research that produces findings and is not arrived by statistical procedures or other means of quantification. The characteristics of qualitative research strategies are:

1. Qualitative research approach aims for a complete, detailed description.
2. The researcher may only know roughly in advance prior to the study.
3. The source of data is from observation, documents, records, films and interviews, which can be semi-structured and in-depth (unstructured) interview (Saunders *et al.*, 2012; Kumar, 2019); these allow the nature of the problem to be understood by the researcher and the result obtained from analysing the data forms the theory that is termed “conceptual framework”.
4. Collection of data is mostly not in standard form; this gives the researcher the opportunity to meet the respondents and have one-on-one interaction with them and in the course of the interaction, knowing when the respondent is not giving a clear answer, this makes the researcher the data gathering instrument.
5. The structure of qualitative research strategy report is solely based on data collected, the data analysed and data interpreted.
6. It is relatively flexible in nature.
7. Is a way of achieving a holistic understanding of the interviewee’s point of view on the subject matter/topic and cognitive access to data (Saunders *et al.,* 2012).

Researchers are not constrained to using one method, instead two methods can be applied in a study, and this is called a ‘mixed method’. According to Johnson and

Onwuegbuzie (2004), researchers find it flexible to answer research questions at hand with the mixed method based on their approaches.

3.8 Time Horizon

According to Saunders *et al.,* (2012), there are two categories of research time horizons which are longitudinal and cross-sectional.

Longitudinal survey is usually applied for research over a long period of time and often deals with conducting several observations of the same variable over the course of time. Cross-sectional survey or study is done within a particular time and known to be time constrained; it can also be referred to as snapshot (Creswell, 2003; Leedy and Ormrod 2005; Saunders *et al.,* 2009).

For the purpose of this research, a cross-sectional time horizon was used due to the time constraints of one-year research. Primary and secondary data were collected concurrently.

3.9 Research Technique

The research technique for this study was the collection of data quantitatively and qualitatively. Quantitative data were analysed in a descriptive manner using statistics to generate numerical data or charts. Qualitative data collection was done in the form of questionnaires and analysing them by interpreting the views of the respondents (Saunders et al., 2009). This helped to properly evaluate the findings.

3.9.1 Research Site

Two cities (Pretoria and Johannesburg) in South Africa were selected as the research sites as seen in figure 3.2. The map is showing Gauteng province which Pretoria and Johannesburg are major cities in the province. It has detailed highway tracks, major routes, major and main roads with route markers. It further shows toll roads and toll positions, spot heights with names and indexes of place names and municipal areas.

The reason behind this choice is due to the time constraint of this research and they are among the major cities in South Africa. These cities have a high population of people, and high socioeconomic standard of living, resulting in increased need for roads. Road construction activities around the cities are regular to meet the connectivity demand. It would be assumed that the findings/results obtained from Johannesburg and Pretoria would be similar to the other cities in South Africa with similar geographical conditions and demography.

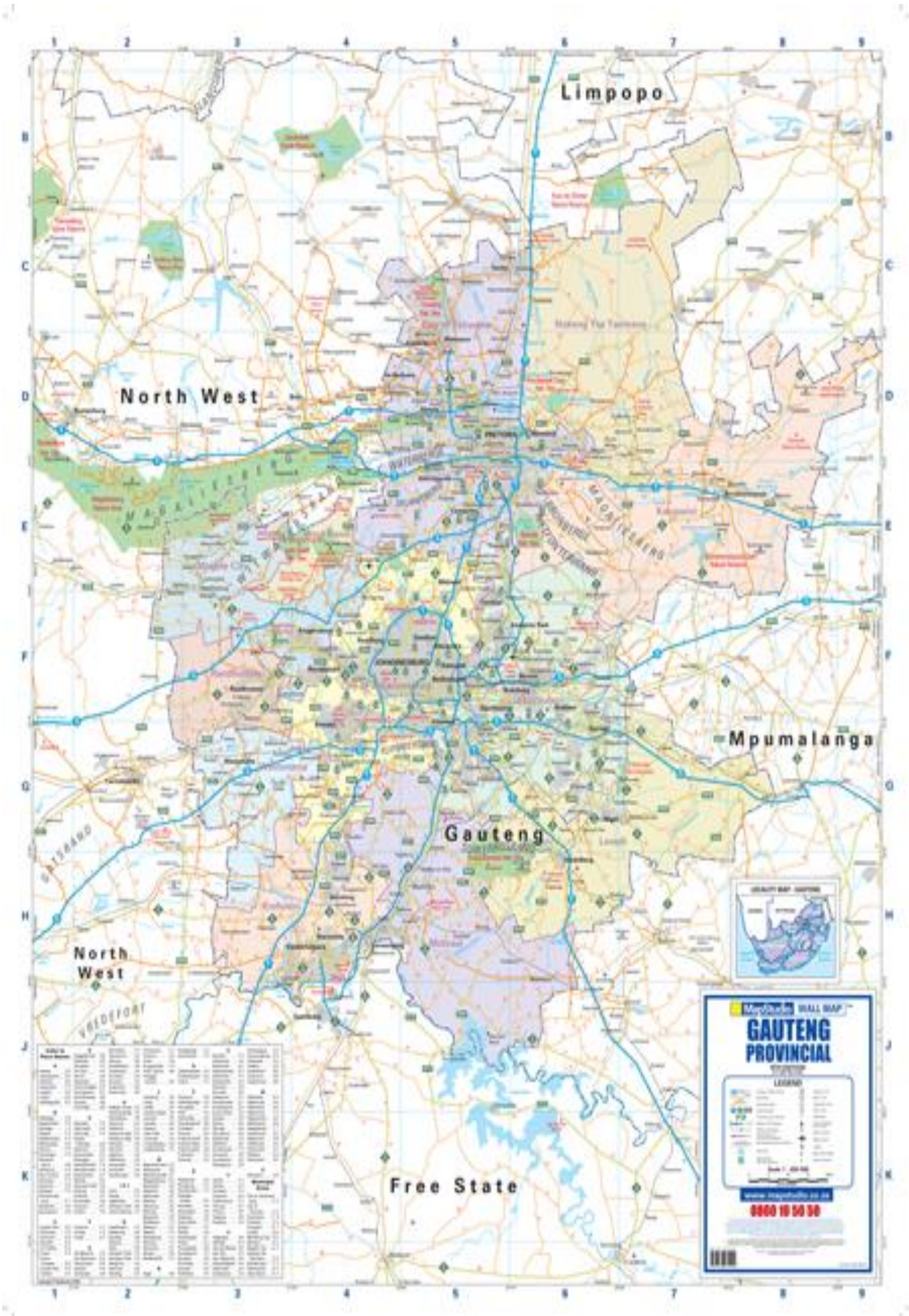


Figure 3.2 Detailed Map Covering Gauteng Province, Showing Pretoria and Johannesburg Roads

3.9.2 Population

Research population for this study includes: DEA, SANRAL, road construction companies, contractors, environmental officers, site supervisors, site foremen, consulting firms and site managers who have worked or are working on construction sites in Johannesburg and Pretoria. The justification behind including experts in this review is based on their expertise, relevance, and their knowledge in work practices. DEA was targeted to explore existing dust mitigation strategies in the EIA reports to be used during road construction proposed/authorised by SANRAl through the road construction companies that got the bid to construct roads.

Furthermore, environmental officers, site supervisors, and site foremen oversee that implementation of dust mitigation proposed in the EIA reports. This is because they are directly involved in site activities where dust is being generated and controlled and they are better at assessing different dust mitigation strategies on site. Due to the time frame of this study, it was impossible to gather data from the numerous contractors in the construction industry in these cities. This study focused on some of the major construction firms in the cities of Johannesburg and Pretoria.

3.9.3 Sampling Plan

The logic behind sampling is using a sub-set of a large population. For the purpose of this study, purposive sampling was applied which aims to select representatives of the subject. This sampling method can be called judgmental sampling (Van and Abubakar, 2001). By applying this method of sampling, we focused on those involved and affected by dust in construction sites.

To acquire information about various types of dust mitigation strategies employed during road construction in South Africa we accessed the EIA of road construction projects. The evaluation and control of the projects and also the reports of the projects were also accessed to fulfill parts of the objectives of this study. It made sense, therefore, that about 15-25 documents would be sampled in the quest for information.

Snowball sampling was also applied. Snowballing method involves identifying several people with relevant attributes and characteristics, and obtaining relevant information from them through a questionnaire. Neuman (2003) wrote that snowballing is literally identifying or selecting issues/subject matter in a networking manner. In this regard, some contractors were asked where possible; to provide some link to other major contractors as well as written documents detailing various dust mitigation strategies' information. This is because it aids to locate the subject's main characteristics or attributes (Berg, 2001; Leedy and Ormrod 2005; Kumar, 2019). According to Saunders (2012), the sampling technique adopted here is non-probabilistic sampling, linked for the snowballing sampling method.

3.9.4 Data Collection

The method of data collection employed in this project was document studies (in the form of a survey) and a questionnaire. Document studies provided insights on the existing records on different dust mitigation strategies adopted in road construction projects in South Africa. Documents can be divided into two (2) major categories; public records and personal records (Lincoln and Guba, 1985; Rosa, 2013).

Public records are materials created and kept for the purpose of "attesting to an event or providing an account" (Lincoln and Guba, 1985; Page and Meyer, 2003). Public records can be accessed from within (internal) or outside (external) where evaluations exercise is taking place.

These materials were helpful in this research work because they have concise details of dust mitigation strategies employed in road construction projects. This made it easy for the evaluation of identified dust mitigation strategy most employed and/or reported. This information was also used to generate questions for the designed questionnaire. According to Fetterman (1989), information from documents studies can be used to generate interview question(s) or identify events to be observed.

Furthermore, existing documents are/ or could be useful for making comparisons like project proposal to implementation records, documentation of body of environmental polices (NEMA) and programme descriptions prior to and following implementation of project (dust mitigation) activities.

Personal documents deal with a person’s account of events and experiences, e.g.; diaries, photographs, portfolio, letters, artwork, etc. which are not applicable for this research work.

In this study, a five (5) point rating scale system was used to interpret the most used/effective dust mitigation strategies employed during major road construction in South African cities.

Furthermore, interviews (questionnaire) are a common and powerful way of understanding issues through people. According to Lincoln and Denzin (2000), interviews are said to generate useful information about lived experiences and their meaning. There are different types of interviews e.g. individually conducted interview, face-to-face verbal interchange (Fontama and Frey, 2000; Leedy and Ormrod 2005; Rosa, 2013).

The secondary data was sourced from written work of other researchers on the subject matter or related issues, which included journals, magazines, newspaper and textbooks. This was critically appraised through the University of the Witwatersrand library, using a range of information sources including reports, eBooks, news articles, data bases, abstracts, etc.

3.9.5 Forms of data

Primary data was obtained via a survey. A comprehensive look was taken into the dust mitigation strategies being applied by practitioners in the road construction industry with a view to understanding current practices as well as get expert knowledge, opinions and suggestions. This was done by developing a questionnaire which was distributed to practitioners. The survey questionnaire was sent out via emails and some hand delivered. The survey questionnaire consisted of 3 sections. The first section was general information to authenticate the qualification and expertise of the respondents. The second section dealt with questions bordering on dust mitigation including current strategies applied and expert opinions. The third section looked at the pieces of legislation that guide dust mitigation strategies and the level of enforcement from the authorities.

To obtain the secondary data, EIA and EMP documents were reviewed and relevant information relating to the dust mitigation strategies were extracted and analysed. The review was limited to road construction work carried out in Johannesburg and Pretoria. For each review, the type of document under review was considered. Proposed and implemented dust mitigation strategies in the reports were revealed. Information about the length of road construction, economic impact, environmental significance, responsible parties and legislation were gleaned. The date of construction was not considered as the documents reviewed were all under the Acts. The time period of the data collection ran between the months of March to September 2017.

3.10 Limitation of Research

Owing to the time constraints of this research, the research concentrated on the part of the population known as the sample and it was also expected that some of the sampled subject/people (respondents) will not answer some of the questions that would be asked in the questionnaire.

3.11 Ethical Consideration

Before commencing this research, ethical approval was sought from the University of the Witwatersrand ethical committee by submitting the required applications. Every participant respondent was given an information sheet that had the full details of the research intention. Their participation to this research work was voluntary, confidential and anonymous. These are applied also when reporting findings in the thesis. The respondents could have withdrawn from the study at any time without any form of prejudice to them.

A signed consent was requested from the participants, stating that they understood the criteria of their participation. All reports of the results of this research is honest and with integrity. The respondents were treated with respect, and acknowledgement of the values they stand for even if they disagree with the questions asked. The documentation data that was collected from the DEA, SANRAL, and some consulting firms was treated fairly and protected.

3.12 Summary of Research Method and Design

The research onion by Saunders et al., (2012) was the guide in building the research design as illustrated in figure 3.3 for this study. The onion framework aided to better understand the practical reality of dust mitigation strategies adopted during road construction in South African cities. The aim is to study the relationship between the written accounts of environmental policies available, to know the extent that EIA has been implemented in practice and its effectiveness. This information aided us to answer empirical questions to fill in the gaps in the existing literature with regard to the research questions.

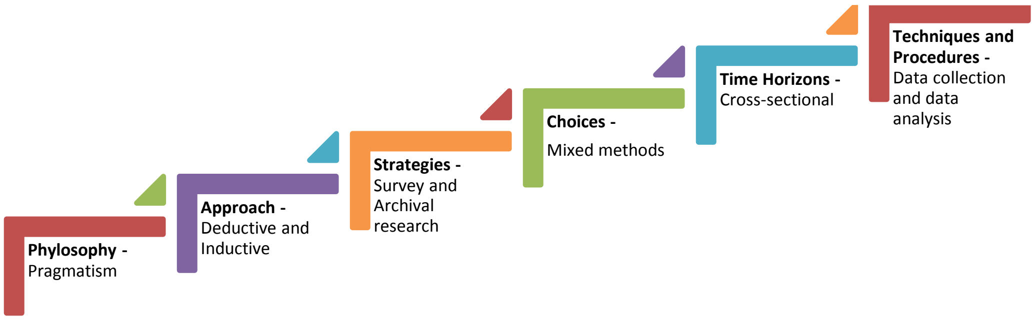


Figure3.3: Flow Design of Methodological Choice

This flow research design adopted was used because pragmatism is a mix of philosophies, where ontology, epistemology and axiology are combined in order to answer the research question. Induction and deduction research approaches were used. Survey and archival research strategies were used by examining previous information and generating new ones. Quantitative and qualitative data collections were implemented concurrently in a cross sectional time zone. Hence the research question is answered in the most realistic and valuable way and helps to give deep insight into dust mitigation strategies in road construction in South Africa. Finally, understanding the importance of ethical issues was highlighted (Saunders *et al.*, 2009).

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results obtained to meet the objectives of this study. Firstly, the chapter addresses the first objective of the research by presenting the identified dust mitigation strategies in road construction currently used in South Africa. The identification has been conducted using two approaches: the empirical study to obtain primary data (based on expert's knowledge and opinion) and extensive review of EIA and EMP documents for secondary data.

The statistics of the level of expertise of respondents are presented. The dust mitigation strategies commonly used are generated from the extensive review (secondary data) and presented. Secondly, the evaluated impact of those identified dust mitigation strategies based on the pillars of sustainability (environmental, economic and social) is presented and discussed in response to the second objective. Lastly, the third objective of the study is addressed in this chapter as the current level of awareness and adherence of practitioners to the enacted legislation on air quality Acts is presented and discussed herein

4.1.1 Analysis of responses used in study

Comparing the data collected, the response rates were slightly above average. Survey data effective response was a little below average at 46.7% owing to 9 incomplete questionnaire from the 79 respondents. In the secondary data, 35 documents were requested from the DEA. 20 documents were received 2 of which were not relevant to the study. Of the 18 relevant documents, 3 had both EIA and EMP documents. The remaining had only single reports of either EIA or EMP. This is further illustrated in table 4.1

Table 4.1: Analysis of response used in study

	Primary Data		Secondary Data	
No of documents expected	150		35	
	Frequency	**Percentage, %**	**Frequency**	**Percentage, %**
Documents received	79	52.7	20	57.1
Effective Documents	70	46.7	18	51.4
Type of Reports	**Survey**		**EIA**	**EMP**
Relevant Reports	70		12	9

4.1.2 Expert information/opinion

The profile of the road construction experts was generated using section A of the survey questionnaire (Appendix A) as shown in Table 4.2. The experts comprised project managers, site engineers, contractors, site-foremen, environment supervisors, safety inspectors, job site-worker and a quantity surveyor. Based on the level of experts' experience, about half (48%) respondents have been in the field of road construction for about 15 years. Only 5% of the experts have below 5 years of working experience. Therefore, it is expected that the level of feedback from the respondents are cogent enough to be relied upon.

About 38% of the respondents work with road construction companies and consulting firms.10%of the respondents are from road maintenance companies. This variation in company categories validates the insights into the research questions being addressed. In the literature reviewed, consulting and construction firms are conversant with different types of dust mitigation strategies (Baby, 2011; Frimpong, 2010) employed during road construction.

With respect to the experts' level of education, 49% of the respondents have Bachelor's degree which forms the majority, while only 5% have Matric qualification, supposedly the least. In this view, respondents are believed to be intellectual and cognitive. Based on field expertise and work specification, about 59% of respondents are involved in major road construction, 14% of respondents are involved in street rehabilitation, about 9% are involved in pavement installation, while 18% of respondents are engaged in other activities such as manual labour. Interestingly, none of the respondents are involved in road side walk construction, which is intrinsic in the road construction industry.

This response outcome supports delineation of this research that stated that “This research study is delineating dust mitigation strategies employed in construction sites carrying out; pavement maintenance, road bricks installation, cracked road maintenance, and focusing on major road construction in the cities of Johannesburg and Pretoria”. In total, the proportions of the experts that participated in the research consist of 31% contractors, 29% project managers,22% site foremen,17% site engineers and other related experts.

Table 4.2: Profile of the respondents/experts

	Respondent Role/Job Category				
	Project Manager	**Site Engineer**	**Contrac tor**	**Site Foremen**	**Total**
***Experience*(years)**					
0-5	0	2	0	1	3 (4.3%)
6-10	4	7	8	4	23 (32.8%)
11-15	11	2	12	8	33 (47.1%)
16 and above	5	1	2	3	11 (15.7%)
Company Category					
Construction	5	4	11	5	25 (35.7%)
Maintenance	1	1	4	1	7 (10%)
Monitoring	4	0	0	4	8 (11.4%)
Consulting	8	6	7	6	27 (38.6%)
Others	2	1	0	0	3 (4.3%)
Education					
Matric	0	0	1	2	3 (4.3%)
Diploma	4	2	7	6	19 (27.1%)
Bachelors Degree	11	7	9	7	34 (48.6%)
Masters Degree	4	3	4	1	12 (17.1%)
Others	1	0	1	0	2 (2.8%)
Work Specification					
Major Road	11	8	14	8	41 (58.5%)
Street Road	3	2	4	1	10 (14.3%)
Pavement Installation	3	0	2	1	6 (8.6%)
Side Walk	0	0	0	0	0 (0%)
Others	3	2	2	6	13 (18.6%)
Total	**20 (28.6%)**	**12 (17.1%)**	**22(31.4 %)**	**16 (22.8%)**	**70(100%)**

4.2 Currently Used Dust Mitigation Strategies in Road Construction Projects in South Africa

This section is aimed at answering the research question one "What are the current dust mitigations strategies employed during road construction in South African cities"?

4.2.1 Identified dust mitigation strategies from empirical study

This section presents and discusses the empirically based identified dust mitigation strategies currently in use in South Africa. This section outlines the outcomes of section B of the survey questionnaire (Appendix A).

Road construction experts were asked to indicate their knowledge on the types of dust mitigation strategies. Information was also generated on the most commonly employed, and challenges of dust mitigation strategies in road construction projects in South Africa. The results from all the respondents indicate that the Water Suppressant Method of dust mitigation strategy is the most practiced in South Africa during road construction. Only about a quarter of the respondents indicated they practice engineered method of dust mitigation strategy. None of the other dust mitigation strategies are currently practiced in road construction sites in South Africa as indicated by the respondents, and as shown in table 4.3.

Table 4.3: Respondents indication on dust mitigation strategies

Dust Mitigation Strategies	**Frequency**	**Percentage, %**
Water suppressant also called wet dust suppression	70	100
Engineered method	17	24
High technology method	0	0
Hydroscopic salt	0	0
Organic Non-Bituminous binder	0	0
Petroleum based-binder	0	0
Elector-Chemical Stabiliser	0	0
Microbiological Binder	0	0

This section also explored the effectiveness and challenges of the dust mitigation strategies identified. Data collected based on the effectiveness of dust mitigation strategies for controlling road construction dust were analyzed using the Likert scale ranging from extremely effective to not at all effective. The result shows that water suppression is the most frequently used among other dust mitigation strategies. This result is a representative of the survey.

Some of the identified challenges faced with the dust mitigation strategies as highlighted by the experts consisted of cost of water, access to water, water application methods (based on technology of the water suppressant techniques). Others include high rate of water evaporation due to dry weather condition (dust resurfaces in the atmosphere after water is applied), regulation request for water usage footprint in some cases, and types of construction material used.

4.2.2 Identified dust mitigation strategies from EIA reports

The second phase of identifying the commonly used dust mitigation strategies for road construction projects in South Africa involved extensive review of EIA reports obtained from the DEA. Data derived from EIA reports have different categories, which include region topography, weather condition, social-cultural and economic significance that have a bearing on the particular dust mitigation strategy proposed. The reports of the EIA analysed are for road construction projects within cities of Johannesburg-Pretoria and satellites. In total, 35 EIA reports were requested from the DEA, but the DEA only responded with 20 documents. 18 of them were relevant to the study out of which 12 contained EIA reports. Appendix B shows information on EIA gleaned from the received documents.

Based on the EIA reports, we inspected and filtered the data in order to provide clarity for answering the main research question. A number was assigned for each sub-category of dust mitigation strategies identified in the EIA report in the frequency table (Table 4.4).

In the EIA reports analysed, four (4) dust mitigation strategies were identified. In their frequency variation in table 4.4, water suppression was proposed in all the reviewed EIA reports, making it the most common dust mitigation strategy in road construction projects in South Africa. However, engineered methods were widely advised to be employed in the reviewed EIA documents. Application of the Chemical methods was proposed in 5 reports with the major consideration being the weather condition, mostly is arid areas. High technology method of dust mitigation was proposed in just one report, with the reason of the area having high air flux.

Table 4.4: Illustrates dust mitigation strategy identified in EIA report and their occurring frequency.

Proposed Dust Mitigation Strategy (EIA)	**Total Frequency**
Water suppression	12
Engineered method	10
Chemical method	5
High technology method	1

4.2.3 Identified dust mitigation strategies from EMP reports

Examination of the 18 effective documents received from DEA revealed 9 EMP reports. 6 were EMP alone while 3 had both EMP and EIA reports. The reports identified the sources of dust in road construction sites and the responsible parties for mitigation. Impact of dust from road construction sites were acknowledged in the reports.

In EMP reports analysed, four (4) dust mitigation strategies were also identified. They are illustrated with their occurring frequency in Table 4.5.

Water suppression and engineered methods were proposed at the same frequency in all the EMPs report reviewed for road construction in South Africa. These reports provided more details in terms of the sequence of mitigation hierarchy, and also detailed reasons why the practitioners have to adhere to the mitigation strategies proposed in different stages of road construction activities to foster SD (Appendix C).

Application of the Chemical methods were proposed in 5 reports with the major consideration being the weather condition (mostly is arid areas where soils/material used in road construction can easily be eroded or are mainly clay material) of the area. Chemical methods were to be considered as last option due to the possible impacts of the chemical substances on the environment. High technology method of dust mitigation was proposed in two (2) reports, with the reason of areas with high wind flow.

Table 4.5: Shows dust mitigation strategy identified in EMPs report and their occurring frequency.

Identified Dust Mitigation Strategy (EMPs)	Total Frequency
Water suppression	9
Engineered method	9
Chemical method	5
High technology method	2

A summary of the dust mitigation strategies encountered in South Africa is presented in table 4.6

Table 4.6 Summary of dust mitigation strategies identified in Empirical, EIA and EMP results

Dust Mitigation strategies	Empirical		EIA		EMP	
	Freq	%	Freq	%	Freq	%
Water suppressant	70	100	12	100	9	100
Engineered method	17	24	10	83.3	9	100
Chemical Method	0	0	5	41.7	5	55.6
High technology Method	0	0	1	8.3	2	22.2
Organic Non-Bituminous binder	0	0	0	0	0	0
Petroleum based-binder	0	0	0	0	0	0
Elector-Chemical Stabiliser	0	0	0	0	0	0
Microbiological Binder	0	0	0	0	0	0

The analysis derived from Table 4.6, all respondents in the survey know about and at some point used the water suppressant method to mitigate against dust in road construction. The EIA and EMP reports assessed also showed all construction sites considered water suppression method.

Engineered method was the second most popular method applied for dust mitigation strategy in road construction. Although engineered method was largely proposed in EIA and structured to be carried out in EMP, there is less than 25% of its implementation in the field of road construction as identified in the empirical survey.

Other identified methods of dust mitigation strategies mentioned in the reviewed EIA and EMP reports were Chemical suppressant and High technology method. Though they were proposed and structured to be used, they were not implemented as seen in the result of the empirical survey.

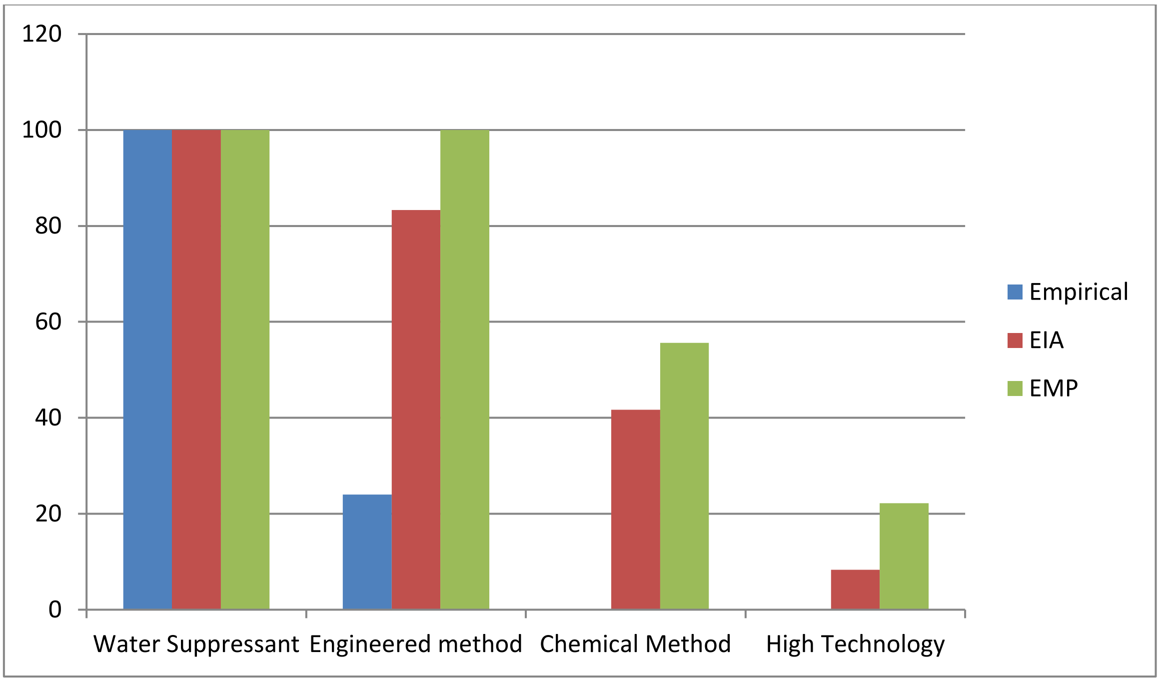


Figure 4.1 Frequency of dust mitigation strategies identified in South Africa

Analysis of the identified dust mitigation strategies is presented in the chart in figure 4.1. Water suppressant is seen to be widely proposed, structured to be used and used in all road construction documents reviewed. This is also attested to by the respondents in the survey carried out.

Engineered method is also popular in the EIA and EMP reports reviewed. However, the level of implementation on the field is very low. Chemical method was proposed in about 40% of the EIA reports and structured to be used in over 50% of the EMP reports. According to the respondents in the survey, it is not implemented in road construction in South Africa. High technology method has a similar fate as chemical method although in a lower scale where 10% of the EIA reports reviewed proposed it, about 20% structured it to be used but it is not implemented on the sites.

Other dust mitigation strategies that are not identified in the South African road construction industry include: Organic Non-Bituminous binder, Petroleum based-binder, Elector-Chemical Stabiliser and Microbiological Binder.

4.3 Impact of Identified Dust Mitigation Strategies Based on Pillars of Sustainability

This section presents the impact of the identified dust mitigation strategies based on the pillars of sustainability (environmental, economic and social). The evaluation is based on the positive and negative impacts the identified dust mitigation can have on SD pillars as illustrated in table 4.6.

Water suppression

On the environmental aspect of sustainability, water is compatible with the environment (all aspect of the bio-physical environment). This means that the earth has the capacity to accommodate water suppression type of dust mitigation strategy. However, as South Africa is currently in an unsustainable state with availability of water (Ozumba and Aduda, 2015; NEMA, 2014; DWAF, 2004), a strong shift towards the direction of adopting other types of dust mitigation strategies that useless or no amount of water should be explored and adopted.

On the social aspect of SD, water suppression type of dust mitigation can be in a positive note because water has no health related issues that can affect the social environment when used to abate dust during road construction project. On the other hand, the water used to suppress dust during road construction can affect the amount of water consumption in the social environment, thus, competing with other water users. This could lead to possible outburst of diseases and civil unrest in the community. Therefore, efficiency and effective water management should be ensured or taken into consideration while proposing using water suppression type of dust mitigation strategies to abate dust during road construction.

Economically, if water suppression method is being used mostly in South Africa, there will be benefit to the economic sectors based on the revenue is generated to water utilities from the sale of water that is used during road construction projects. On the flip side, if water suppression method is used to mitigate dust during road construction, huge amount of money would be expended to source for water where available. Ultimately, construction projects will become very expensive. For example, South Africa source for water from their neighboring country Lesotho (CoJ Repot, 2017).

Engineered Method

Engineered method of mitigating dust during road construction project supports the "avoid" section of the mitigation hierarchy (Mitchell, 1997).It involves taking precautions in every activity that generates dust during road construction. Engineered method of dust mitigation prevents health impediments to both the people on site and the neighboring community. It prevents reduction in agricultural and forestry yields as less dust is deposited on crops. Accidents caused by poor visibility due to airborne dust are avoided and less water is required to suppress dust, thus, reducing cost when engineered method is applied. However, the implementation of the Engineered method could impact negatively on the technology employed in the construction of the road.

Chemical suppressant method

Suppression of dust is achieved when chemical suppressant dust mitigation method is used. Considering that a sustainable environment is essential, chemical suppressant dust mitigation method can have adverse impacts on biodiversity. This leads to pollution when the chemical substances used infiltrates into surface water, ground water and soil, thus causing crops to have reduced yields which lead to shortage in food production. Shortage of water could result if surface and groundwater are polluted, and could lead to civil unrest.

High technology method

Reduction of airborne dust can be achieved during road construction project by using high technology dust mitigation method. The process involves extracting and trapping of air borne dust to ensure dust does not cause air pollution and avoid adverse effects to the biophysical environment. High technology method is designed to be highly efficient while utilizing less water and limiting air pollution, thus, social sustainability is achieved through high technology method of mitigating dust. This method falls short of the economic aspect of sustainability in the South African context because the machinery involved is expensive. Socially, this method still requires the use of water, although it is of very small quantity. This is still not acceptable in South Africa with the levels of draught experienced in recent years and the grim forecasts for the future. Environmentally, this method allows dust to be airborne before it is trapped. It reduces the spread of the effect of dust but fails to protect the site workers and the immediate environment.

Table 4.7: Illustrates dust mitigation strategy identified in South African Road construction sector

Identified Dust Mitigation Strategies	**Sustainable Development Pillars** **Environmental**	**Economic**	**Social**
Water suppression	Positive 1. Suppression of dust 2. Improves air quality Negative 1. Consumes a large amount of water (especially in SA where there is water scarcity)	Positive 1. Generates revenue Negative 1. Enormous cost to the economy	Positive 1. Creates conducive environment 2. Increases better visibility Negative 1. Competing with other water users 2. Intensify water scarcity 3. Civil unrest
Engineered Method	Positive 1. Reduces dust generation 2. Reduces air pollution 3. Consumes less water 4. Less effect on biodiversity	Positive 1. Reduces cost of water 2. Reduces cost for adverse managements	Positive 1. Prevents excessive nuisance of dust 2. Prevents health impediment 3. Prevents reduction of agriculture and forestry

		Negative 1. Cost of equipment/material is high	yields 4. Reduces accidents caused due to poor visibility in construction sites 5. Prevents lawsuits from neighbouring community
Chemical suppression	Positive 1. Suppresses dust Negative 1. Impact on biodiversity 2. Can lead to pollution on; i. Water ii. Air iii. Land 3. Can lead to crop blemishing 4. Leads to an unpleasant odor 5. Can cause the deposition of chemical substances to the soil	Negative 1. It increases cost for the treatment of surface and groundwater if polluted 2. Cost for the provision of medications for the affected community 3. Endangers health	Positive 1. Provides more solidification of dust Negative 1. Leads to a shortage of food if agriculture is affected 2. Leads to water shorted if surface and groundwater Is affected 3. Civil unrest 4. Health impediment
High Technology method (dust-	Positive 1. Suppresses dust 2. Less pollution	Positive 1. Less cost of water	Positive 1. Conducive environment

trapping mist etc.)	i. Air ii. Water iii. Land	management Negative 1. Cost of equipment	2. Increases visibility

4.3.1 Chemical Suppressant and High Technology Method Against Pillars of SD

From environmental point of view, chemical suppressant can have harmful effect on the air quality (air pollution) which can adversely affect both human health and crop production. When crop productivity reduces the economic gain of that society will also deteriorate. Moreover, when societal health deteriorates in addition to their poor economic prosperity their social well-being will also be deteriorated. High technology method prevents significantly amount of dust from being airborne from source and utilises dust trapping mist, thus, less water is required. This method minimizes impacts of dust to the environment and social well-being by limiting the degree or magnitude of dust impact. Economically, equipment involved are expensive which strains on the economy

Mitigating dust through chemical suppressant method impacts on good health and well-being of society which does not support SDG number 3, and 15,and also toil on SDG number 6 which stress on sustainable water management and sanitation for all. Although more solidification of dust is achieved through this method which supports SDG number 9 that promote building resilient infrastructure.

In the other hand, mitigating dust with high technology method supports SDG number 3, 6 and 15 by minimizes impact on social well-being, promotes water management and minimizes land degradation and biodiversity loss. Although this method cost of machinery, it still supports SDG number 9, which targets building resilient infrastructure through fostering innovation.

4.3.2 Conceptual framework for sustainability in road construction

The intent of this section is to develop a framework towards achieving effective outcome, particularly in dust mitigation during road construction activities which impacts in the social, environmental and economic aspect of sustainable development. Generation of dust during road construction is inevitable as confirmed from literature, and also from EIA and EMP reports reviewed. Many activities that take place in road construction sites tend to stair up dust at different stages of road construction as shown in figure 4.2. Dust causes a nuisance to construction area residents, hazards to site workers, detrimental to vegetation, and generally, is a form of air pollution to the environment.

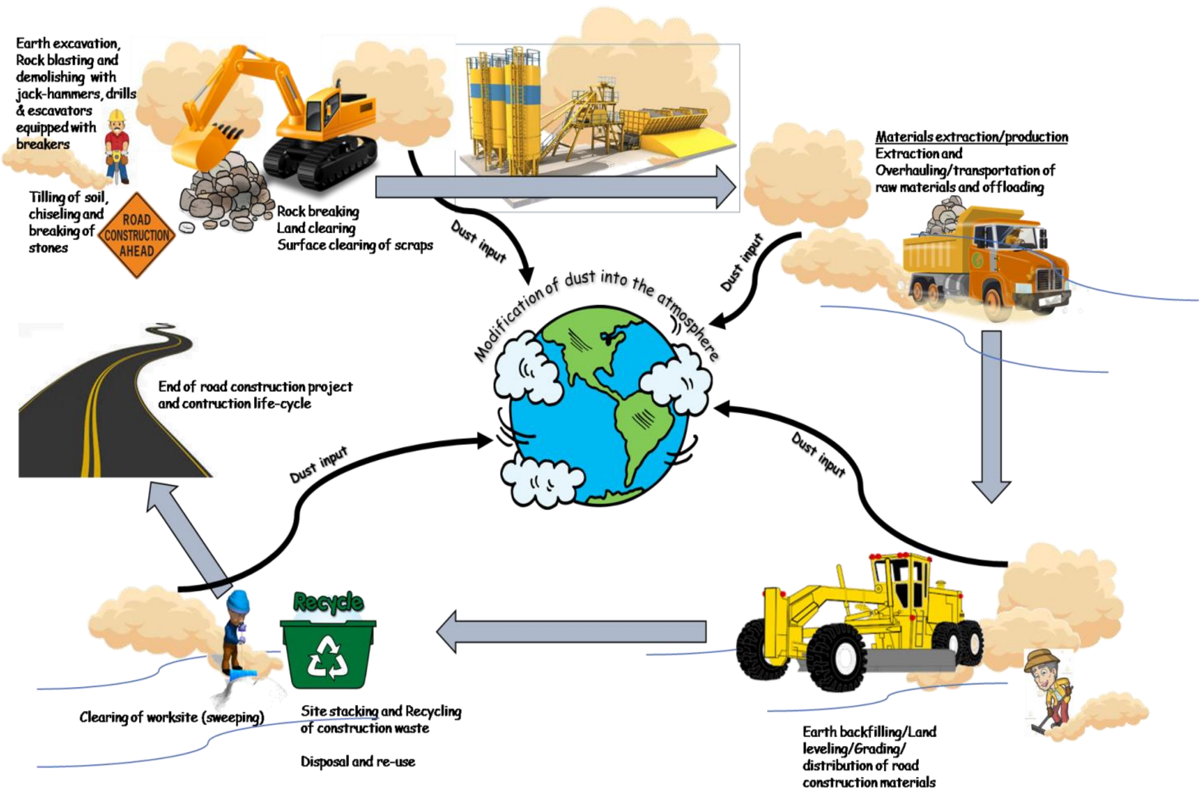


Figure 4.2: A Schematic Description of Different Sources of Dust Generation in Road Construction Site

Dust starred up during road construction is a primary source of particulate matter in the emission inventory. Dust is also found to contribute to GHG emissions. Following the effects of dust on the sustainable development pillars, dust mitigation for road construction is one of the key methods discussed to attain maximum reduction in all causes of dust on site. This supports one of the key issues discussed at the NPC for South Africa to attain maximum reduction in all causes of emissions by the year 2025 (NPC, 2012). Therefore, it is imperative that the strategies for dust mitigations are identified, evaluated and addressed in a conceptualize operational principal as seen in figure 4.3.

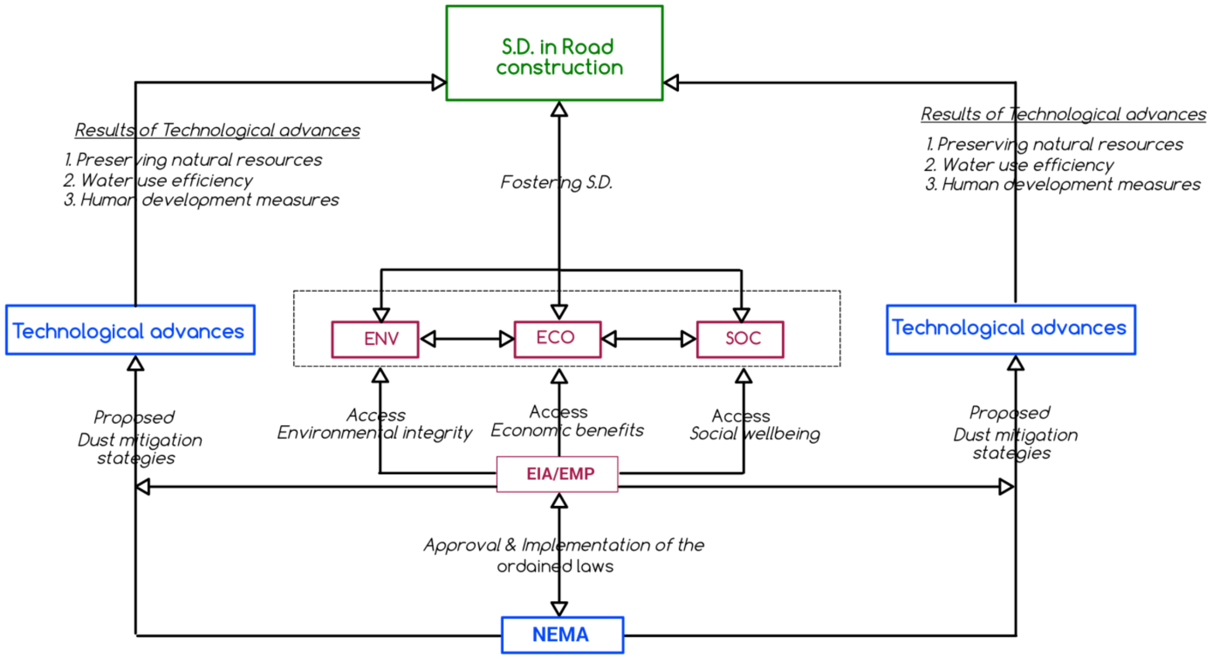


Figure 4.3 Conceptual framework for sustainability based road construction

From the diagram in fig 4.3 above, NEMA is known to approve and implement laws like EIA/EMP. In road construction sector in South Africa, during EIA processes, EIA is used as a tool to access possible impacts/effects of dust mitigation on the pillars of SD. The EIA process provides different dust mitigation strategies towards mitigating dust are being proposed.

These proposed dust mitigation strategies are further structured in the EMP reports with specifications of responsible parties for their implementation. When proposed and implemented, these technical advances help in achieving results such as, preserving natural resources, supporting water use efficiency and human development measures. All these support sustainable development in road construction by fostering SD in environmental economic and social aspects of road construction industry.

4.4 Awareness and Adherence of Practitioners to the Air Quality Acts

Section C of the survey questionnaire (Appendix A) sought information on the level of awareness that professionals in road construction field have regarding legislation on the air quality standard of the NEMA Act. It also researched on how strictly the enacted air quality standard is being adhered to in managing road construction dust, as well as their perceptions on the effectiveness of the NEMA Acts in managing road construction dust in South Africa.

A five-point Likert scale was employed to evaluate the answers of respondents. The Likert scale was adopted because, it is a known efficient multi-item measuring scale that provides optimal reliability (Ngacho and Das, 2014; Zhang *et al*., 2012; Hussey and Eagan, 2007). In the survey questionnaire, the respondents were asked to circle their corresponding value which ranging from No – Yes, numerically refers to 1-5 respectively. Table 4.8 details the observed findings, and are further transcribed in a bar chart form for more visual comparison in Figure 4.3.

Table 4.8: Professionals' views on the awareness on, and adherence to the air quality standard of the NEMA Act

Value (on scale)	Awareness	Adherence
1	3	8
2	7	19
3	19	28
4	32	11
5	9	4

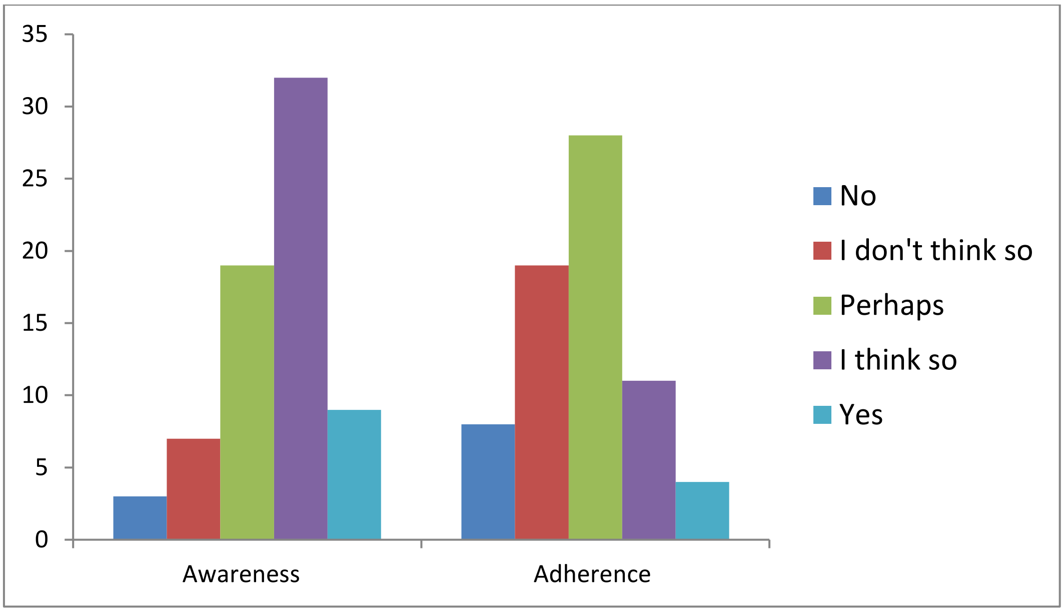


Figure 4.4: Bar Chart illustration on Professionals views on the awareness on, and adherence to the air quality standard of the NEMA Act

4.5 Findings and Discussion

Mixed research method approach is adopted to achieve the research objectives. It is considered the best suited in addressing the research problems and answering the research questions because there are quantitative and qualitative aspects of the study. The review of relevant EIA documents is the quantitative aspect while qualitative aspect includes the views from practitioners through the issuance and analysis of questionnaires. This mixed method involved secondary and primary data collection from different sources within reach. Also, views on the effects of dust mitigation strategies on the sustainability pillars were carried out and key issues identified. These issues were used to develop a questionnaire. These questionnaires were sent out to the practitioners in road construction. Outcomes and responses from the questionnaires were compiled and analyzed.

In carrying out the primary survey, we surveyed both construction and consultancy firms which is in line with best practices (Baby 2011; Frimpong, 2010). This enabled us to have an inclusive assessment of the dust mitigation methods being implemented during road construction in South Africa. In our survey, only 5% of our respondents are Matric holders with about half of the respondents holding a bachelor degree and the rest higher degree. Majority of the respondents must have had prior knowledge of dust mitigation and their effects on the pillars of sustainability. This gave them better understanding of the questions in the questionnaire, and makes their responses to be credible and reliable (Baby 2011).

It was found in the responses to the survey questionnaire that only two types of dust mitigation strategies are currently practiced in road construction activities in South Africa. Water suppression method and engineered method were seen to be used for dust mitigation in road construction. According to the respondents, water has been intensively used to suppress dust. This is a current challenge to the country considering that South Africa is a water stressed country (Ozumba and Aduda, 2015; Ozumba and Shakantu 2018). Water being extensively used for dust suppression during road construction will further trigger water insecurity around the world. In support, the World Water Development Report by the United Nations World Water Assessment Programme (UN Water), places enormous emphasis on water scarcity around the globe (WWAP, 2012a; 2018). The report further highlights that the business-as-usual approach to water issues has to substitute with more robust ones that incorporate sustainable goals.

Although all the respondents acknowledge the wide use of water suppression, about 30% of them expressed that water suppression type of dust mitigation is ineffective. They attributed this ineffectiveness of water suppression method for dust mitigation in road construction to the fact that dust usually becomes airborne shortly after the application of water to suppress lose dust particles at construction sites (Mitchell, 1997).

Another dust suppression method practiced in construction sites in South Africa is the engineered method. About 25% of the respondents have practiced and acknowledged it as a more effective way to mitigate dust. This is attributed to engineering method using the best technologies available and meeting the mitigation hierarchy sequence of Avoid – Minimise – Restore – Offset – Enhance (Mitchell, 1997). This dust mitigation method also aligns with suggestions made by the UN Assessment Programme that promote sustainable cross-sectional approaches (WWAP, 2018; UN-Water, 2018). Unfortunately, we found that water suppression is mostly practiced than engineered method. The engineered method is however not widely practiced as it more technical and time consuming (Baby, 2011; Sanchez *et al*, 2005; Sanders *et al* 1997).

Other methods of dust mitigation such as high technology method, hygroscopic salt and organic non-bituminous binders are neither recognized by the respondents nor implemented.

EIA and EMP documents that were reviewed identified water suppressant, engineered method, chemical method, and high technology methods as proposed and structured to be used during road construction in South Africa. In both the EIA and EMP reports, water suppression is most popular, followed by the engineered methods. Chemical suppressants seem to have gained popularity owing to weather conditions and soil types in the areas they are proposed and structured to be used.

Evaluation between the EIA and EMP reports shows no significant difference between the dust mitigation strategies proposed in road construction projects. The reports only vary in details concerning the need to adhere to the mitigation hierarchy for the sake of fostering SD (Appendix B).The findings show that the reviewed EIA and EMP have almost the same rate of application of each dust mitigation strategy. This is however at variance with the dust mitigation strategies that are actually practiced in road construction projects in South Africa as indicated by respondents in the empirical study.

Sustainable development pillars are impacted by the various dust mitigation strategies implemented during road construction. Water suppression method is found to be in overall negative environmentally, economically and socially. In the context of South Africa, the use of water suppression method is highly unsustainable (Ozumba and Aduda, 2015; UN-Water, 2018) owing to water scarcity.

Chemical suppressant has negative effect on biodiversity both aquatic and agricultural (Igondova *et al*., 2016) while the high technology method involves extracting and trapping of air borne dust to ensure dust does not cause air pollution and avoid adverse effects to the biophysical environment. This method falls short of the economic aspect of sustainability in the South African content because the machinery involved is expensive. Socially, this method still requires the use of water.

This is still not acceptable in South Africa with the levels of draught experienced in recent years and grim forecasts for the future. Environmentally, this method allows dust to be airborne before it is trapped. It reduces the spread of the effect of dust but fails to protect the site workers and the immediate environment.

Engineered method ensures minimal dust is air borne during construction. It involves taking precautions in every activity that generates dust during road construction. Prioritizing dust mitigation strategies impact to the environment positively by reducing air pollution and air pollution has been found to contribute to the world climate change issues (Jacobel, 2017). Engineered method of dust mitigation prevents health impediments to both the people on site and the neighboring community. It prevents reduction in agricultural and forestry yields as less dust is deposited on crops. Accidents caused by poor visibility due to airborne dust are avoided and less water is required to suppress dust, thus, reducing cost when engineered method is applied. It is found in this research to have the least impact on sustainability pillars.

In the phase of awareness and adherence to air quality standard, it was found that the level of awareness and adherence to the Air Quality standard by respondents is above average. The respondents consider the NEMA Act effective for the mitigation of road construction dust if it is being implemented. The high rating of effectiveness is as a result of the following:

a) The global awareness for environmental sustainability. Corporations are making sustainability a priority in order to be on the cutting edge.
b) A second reason for high effectiveness rating, according to the responses on the survey questionnaires, is the need to incorporate dust mitigation strategies since it is a requirement to obtain approval for project commencement. Before the commencement of any development, the proponent or developer ought to get environmental authorization (Frimpong, 2010; NEMA, 2010; Burke, 2009). The authorization is obtained after a procedural process has been undertaken according to established expectations such as EIA legislation (Sadler, 1996; Theophilou *et al*., 2010).

c) The enacted Environmental Acts (NEMA 2010) legislation is another reason indicated for high awareness of dust mitigation in road construction.

30% of the respondents are uncertain of how effective the NEMA Acts has been in the management of road construction dust. These respondents are unaware of the legislative impacts on road construction sites. These respondents pointed out that no institutional authority checks for implementation of dust mitigation measures on road construction sites. If this is the case, these respondents profess lack of efficiency in managing existing policies and regulations guiding management of dust in road construction sectors in South Africa. Rudman, (2010) highlighted a similar issue that in South Africa, there is no institutional framework with the inclusion of monitoring adverse impacts of road construction activities in place.

Lack of awareness of standards of practices by stakeholders, proponents and even professionals in construction field contributes to non-compliance of proposed mitigation measures in EIA and EMPs during construction activities(Evans, 2013; Theophilou *et al*., 2010;Cashmore *et al*., 2004). In this regard, the procedural effectiveness of dust mitigation strategies in road construction might not be implemented on-site as expected in Best practice (Greening, 2011; IFC, 2007). This lack of awareness and adherence to the enacted affects the aims of EIA and EMPs as tools for fostering SD (Sandham *et al*., 2013; Theophilou *et al*., 2010).

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents a summary of the research approach, further discussions on findings from chapter four on data analysis. The limitations and the contribution of the study to knowledge were also covered. A framework to give a clear view of the overall content of this study was developed. Recommendations for further study are proposed and suggestions are made alongside a brief conclusion.

5.2 Research Overview

The present study demonstrated strategies for mitigating dust during road construction project within South Africa context for the purpose of sustainable development. This study brings to bare the level of awareness, implementation and legislative enforcement for the dust mitigation strategies in road construction in South Africa. This study was necessitated because of the environmental, economic and social nuisance caused by dust generated during road construction in South Africa. There is also a lack of study on the issue of dust mitigation strategies in road construction industries. Dust has also been identified to cause global warming, thereby causing concern on the willingness and ability of the road construction industries on the implementation of national policies.

These reasons contributed to undertaking this research, and created the need to pursue dust mitigation practice in the road construction industries.

To achieve the research aim through its identified objectives, a combination of qualitative and quantitative survey was used to collect data. Survey questionnaire was used for primary data while a documented report instrument was for secondary data. The secondary data was sourced from EIA and EMPs report submitted for road construction projects. The primary data was generated from the answered questionnaire from practitioners involved in road construction in South Africa. This is termed mixed research approach. The survey questionnaire and the documented reports were sorted in a cross-sectional time horizon (from March 2017 to September 2017) with the targeted population being professionals in the frontline of road construction. A total of 150 questionnaires were distributed through emails and by hand to road construction companies, SANRAL, DRT, DEA, consulting firms, dust control companies, and municipalities. 79 responses were returned, being (52%) response rate. It is important to note that nine (9) questionnaires returned were not completely answered by participants in the target population. Therefore, the researcher was only able to analyse data collected from the actual number of respondents who completed the survey questionnaire. Hence, the effective response rate of questionnaire survey is 46.6%.

The survey questionnaire was developed based on identified issues in this study and to address the research objectives. The survey questionnaires consisted of three (3) sections (section A-C). In all, 12 questions were asked including not only the closed and open-ended questions. Questions bothering on practical experiences and experiences of colleagues in terms of dust mitigation strategies in road construction as well as perceptions on prevailing issues in dust mitigation strategies in road construction were asked. It was imperative that the valuable views of these experienced practitioners in the road construction fields were sought. They have observed sources of dust generation, the applications of different dust mitigation strategies, the implementation and monitoring measures on road construction sites by the proponents/regulators. The primary data was generated from the answered questionnaire from practitioners involved in road construction in South Africa

Furthermore, the documented reports were accessed by obtaining an ethical clearance certificate from the school of Construction Economics and Management, which was sent to DEA before accessing EIA and EMP reports and processed through PAIA from the DEA. EIA and EMP reports proposed for road constructions projects were obtained. The EIA and EMP reports were assessed based on a general view of the impacts of dust on the environment, and reasons to mitigate the impacts in different stages of road construction projects.

The findings from analysed data were compeered among; the literature reviewed, results from analysed EIA and EMPs report and the results gotten from the questionnaires. Analysis of data from different source confirmed evidence of the existing gaps in the literature. Therefore, without awareness, knowledge, and adaptation of better dust mitigation strategies, road construction industries will ultimately not contribute to SDGs through good health and well-being, climate action, environmental practice compliance, and resources management.

It was identified that there are adequate legislation in the area of dust mitigation. The short fall is found in the awareness, implementation and enforcement of these legislations. It was observed that more ecological, economical and socially viable strategies for dust mitigation were proposed and structured to be used in road construction projects but were not implemented.

5.3 Limitations

The study was conducted only in road construction in Pretoria and Johannesburg area. This is not an adequate representation of South Africa because the landscape and climate which determine the type of dust mitigation strategy varies from one region to the other. Secondly, the response time for sourcing data was long, and this made it difficult to acquire sufficient data which could enhance the conclusions. return for more data where the available was inadequate. The study anticipated that each construction project document should contain both EIA and EMP reports, however, this was not the case as only 3 out of the 18 documents contained both reports.

Other limitations met during the course of this research were in sourcing for literature related to the context of this research. To the best of my knowledge, very few studies have been carried out regarding dust mitigation strategies for road construction. I addressed this limitation by reviewing the available literature, getting ideas from related textbooks, review of publications on road constructions annual reports, review, and deduction of published possible best practices for dust mitigation strategies for road construction.

5.4 Addressing Key Element of the Research

Addressing the objectives of this study

The first objective was to extensively review and identify different dust mitigation strategies adopted during road construction in South Africa. This was achieved by reviewing EIA and EMP reports. Empirical survey to determine the extent of application of the identified dust mitigation strategies was also conducted. The dust mitigation strategies were proposed and structured to be used in the road construction encountered in these report include water suppressant, engineered method, chemical method and high technology method.

To evaluate the impact of identified dust mitigation strategies based on pillar of sustainability which was the second objective. Analysis of the identified dust mitigation strategies in line with their environmental, economic and social impact was carried out. Engineered method which requires best practices in road construction is found to best suit these 3 pillars of sustainability but it is sparsely practiced. However water suppressant which is the most widely applied does not meet the economic and social pillars. This is because water is a valuable resources and should be used efficiently as possible. Its application in dust mitigation in road construction will cause an increase in price resulting in social tension.

Level of awareness on the need for dust mitigation in road construction is high. Adherence on the other hand is low owing to lack of enforcement. Furthermore, the type of mitigation strategy proposed and structured to be used in most cases, according to the reviewed EIA and EMP reports are not eventually used. This is deciphered from the responses to survey questionnaires by professionals in the road construction field. This responds to the third objective of the study.

Addressing the research aim:

The aim of this research was attained by first reviewing literature to identify the various dust mitigation strategies employed globally in road construction. Further reviews of EIA and EMP reports were performed to determine which of these strategies was practiced in South Africa. Analysis of the dust mitigation strategies in road construction was accomplished in line with the 3 pillars of sustainability. A comprehensive list of missing elements in the South African reports was compiled.

Addressing the research question

In South Africa, four dust mitigation strategies were identified to be proposed and structured to be used in various road construction projects as found in the EIA and EMP reports. They are water suppressant, engineered method, chemical method and high technology method. In the proposal and road construction structuring stages, all four methods are mentioned for various road construction projects. A breakdown of the construction project into activities with the adequate dust mitigation strategy for each activity is not expressed in the EIA and EMP reports reviewed.

In practice, water suppressant and engineered methods are the only methods implemented. Water suppressant method is used over four times more and it is known to every practitioner in the field according to the results of the empirical survey. Dust mitigation in road construction in South Africa is not considered a priority as much as other emissions for example, emissions from vehicles.

Addressing the research problem

This study gleaned information on dust mitigation strategies, their implementation and legislative enforcement from various reports making it more accessible. The extent of practice of the various dust mitigation strategies was brought to light in comparison with global best practices. Knowledge on other dust mitigation strategies not being identified in South African road construction field was mentioned. Therefore, inadequate information on dust mitigation strategies and implementation in road construction projects in South Africa exist, and the lack of knowledgeon dust mitigation strategies during road construction is found to severally hamper reliable sustainability.

5.5 Summary of Findings

Empirical Survey

Diversity in respondents' views on questions asked in the three sections of the survey questionnaires was considered in reporting the data generated. They were rated on a scale of 1-5 (no-yes), (extremely effective - not at all effective) and an open-ended question that solicited more information. The collected data were statistically analysed using frequency distribution tables and further represented using bar charts. However, the quality of grades appears to vary between categories, indicating that a significant proportion of data generated needs improvement.

Water suppressant was found to be known to all respondents and used in all construction projects. Engineered method is sparsely practiced as a dust mitigation strategy in road construction.

EIA and EMP Reports

In documented EIA and EMPs report, the environmental baseline was comprehensively detailed, and it entails the physical, biological and social-economic environment of which the proposed development was established, and reasons for choosing a particular dust mitigation strategy was highlighted.

The responsible parties for the implementation of dust mitigation strategies on the field of construction were more detailed in the EMPs compare to EIA reports. Sources of dust generation, their environmental and socio-economic impacts were more detailed in EMPs compared to EIA. The gap between the details in mitigation measures in EIA and EMPs appears to be on environmental impact's specific activities.

Unequivocally, the difference in both data generated in this study supports what literature highlighted about mitigation measures proposed in EIAs and EMP. The adverse impacts of dust to the environments are not actually mitigated in construction sites as recommended in EIA/EMPs reports, therefore hindering these achieving their aims for SD. The findings in this study shows that, all types of dust mitigation strategies recommended in EIA and EMPs report are not even known to respondents in the survey carried out, nor practiced during road construction.

Furthermore, dust is identified as a nuisance. Dust stared up at different stages of road construction poses threat to the environment and its adverse impacts are extended to all facets of the SD environment. Thus, there is a need for a framework to pursue sustainable environment through dust mitigation in road construction to conform to the level of SDGs, also, to apply possible best dust mitigation strategy during road construction in South Africa.

5.6 Recommendations and contribution to Knowledge

This study covers road construction in Pretoria and Johannesburg only, and this cannot be considered as adequate to represent South Africa. Also, the acquired data is not sufficient enough for this study, thus, the following recommendations were drawn:

a) Similar study should be conducted that will cover all the regions of South Africa and this will enable more credible conclusions and plausible suggestions on how to tackle the problem.
b) Government should empower environmental law enforcement unit to ensure proper implementation of EIA laws and regulations in the road construction projects.

Contribution to Knowledge

This study is pioneering sustainable development in construction activities, by evaluating current dust mitigation strategies for road construction in South Africa. Therefore, this study can be said to provide a significant contribution to road construction sector in South Africa.

The development of Conceptual framework for sustainability in road construction can serve as a database for site workers to reckon on in construction sites, thereby enhancing implementations of proper mitigation strategies and fostering SD in environmental, economic and social aspects of road construction industry.

5.7 Conclusions

This study evaluated the existing dust mitigation strategies in road construction in South Africa using the concept of sustainable development (SD). This study employed Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) as tool, which assessed different types of dust mitigation and level of implementation of dust mitigation strategies in road construction in South Africa based on the fundamental pillars of SD, as depicted in figure 5.1.

EIA ensures that negative impact of dust during road construction are avoided or minimized to avoid diverse impact to all the facets of the environment, by proposing different methods to mitigate dust for each activity during road construction. An evaluation of the current dust mitigation strategies was carried out and water suppression method was found to be most widely used during road construction in South Africa.

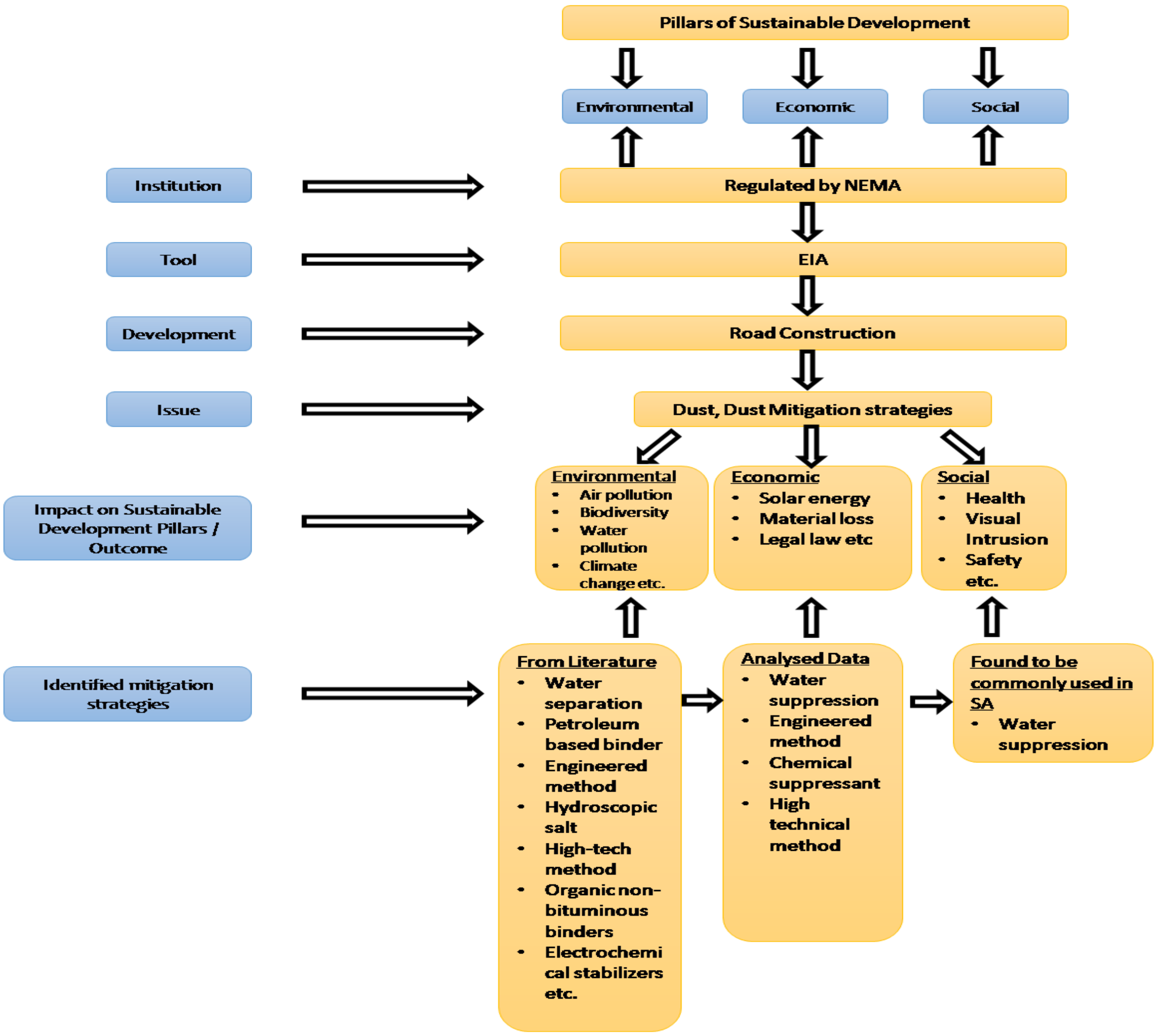


Figure 5.1: Schematic Flow and Outcome of this Study

Furthermore, in the research, the main gap identified was inadequate information on the evaluation of dust mitigation strategies for road construction, especially in the South African context. Hence, there was need for field work to investigate dust mitigation strategies for road construction in the South Africa context.

Based on the results obtained in the research, these conjectures were drawn:

i) The study shows that about 70% of road construction activities utilizes the water suppression dust mitigation strategy, 24% implements engineered method whereas the remaining 6% uses chemical suppression method or high technology method.

ii) The study found that other methods of dust mitigation strategies such as organic non-bituminous binder, petroleum based binder, electro-chemical stabliser, and microbiological binder, are not being implemented during road construction in South Africa.

iii) The water suppression method of dust mitigation shows to be more effective, however the current water scarcity in the country pose a unique challenge to this method.

Moreover, the study revealed poor implementation of the EIA and EMP regulations by the proponents as admitted by respondents. Dust generated during road construction impacts negatively to all facets of the environment. In conclusion therefore, the findings of this study, thou not generalizable to the entire country, should form bases for more in-depth studies at a national level.

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APPENDICES

Appendix A: survey questionnaire

INVITATION TO PARTICIPATE AND SURVEY

School of Civil and Environmental Engineering,
University of Witwatersrand,
Private Bag 3
Wits
2050

Dear Sir/ Madam

REQUEST FOR SURVEY PARTICIPATION ON THE FOLLOWING RESEARCH TOPIC

Research Title: Dust mitigation strategies for major road construction in South African: an evaluation of the current practices

I am Amalu Laura Festus a Masters student from School of Civil and Environmental Engineering, University of Witwatersrand. I am carrying out a research that seeks to evaluate the current practice of dust mitigation for major road construction project in the major cities of South Africa; the aim is to determine the approaches, technologies and effectiveness of dust mitigation measures currently adopted in road construction projects.

The investigation requires each consenting participant to complete a survey questionnaire. The questionnaire survey comprises of scale-based questions and also some open ended questions to give your own opinion of the questions. The survey should take about 15minutes of your time.

All ethical requirements to protect each participant has been observed, the details are contained in the consent form.

For further information on the research you can contact the researcher,

- Amalu Laura Festus, 1278198@students.wits.ac.za

  Or the supervisor

- Dr Obi OzumbaAghaegbuna, Obinna.Ozumba@wits.ac.za 0117177654

Thank you for participating.

CONSENT FORM

NAME OF RESEARCHER: Amalu Laura Festus

PROJECT TITLE: Dust mitigation strategies for major road construction in South African: an evaluation of the current practices

AIM OF RESEACH: The aim of my research study is to determine the approaches, technologies and effectiveness of dust mitigation measures currently adopted in road construction projects.

ETHICAL REQUIREMENT: I assure you that your identity and that of your company or firm will be left anonymous and your participation in this research work is voluntary and confidential. This confidentiality and anonymity is also maintained in the reporting of my findings.

If you understand the consent form please tick in the box after each statement to which you wish to consent.

1.	I confirm that I have read and understood the Consent letter attached in front for the above titled study and I have had the opportunity to consider the information contained therein.	
2.	I have been made aware of the purpose of the study.	
3.	I understand that my participation is voluntary and that I am free to withdraw from it anytime.	
4.	I understand that my participation is anonymous and confidential.	
5.	I agree to take part in the study.	

Name of person taking the consent   Date   Signature

Survey

SECTION A: General information

Please circle the latter next to your correspond answer.

1. Please state your role in the company

   a) Project Manager b) Site Engineer c) Contractor d) Site Foreman

   e) Others………………………………………………………….

2. Please indicate your years of experience (tick)
   a) 0-5 years b) 6-10 years c) 11- 15 years d) 15 - 25 years

   e) Others……………………………………………………...…

3. What is your company's main activity in the Construction field:

   a) Construction b) Maintenance c) Monitoring d) Consultant

   e) Others………………………………………………………….

4. Please indicate your qualifications

   a) Matric b) Diploma c) Bachelor's degree d) Master's Degree

   e) Others………………………………………………….…...

5. Please specify the type of construction work you are involved in.
   a) Major roads b) street roads c) pavement installations d) sidewalks

   e) Others……………………………………………..………..

SECTION B - DUST MITIGATION

6. What are the types of dust mitigation strategies you know?

Please tick the appropriate column to the best of your knowledge.	
Water suppressant (also called wet dust suppression)	
Engineered Method	
High technology method	
Hygroscopic Salt	
Organic Non-Bituminous Binders	
Petroleum Based-binder	
Elector-Chemicals Stabilizers	
Microbiological Binders	
Polymers	
Bentonite	

6b) Please write other dust mitigation strategies that you know?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………

7. What types of dust mitigation strategies are mostly used during road construction?

Please tick the appropriate column to the best of your knowledge.	
Water suppressant (also called wet dust suppression)	
Engineered method	
High technology method	
Hygroscopic Salt	
Organic Non-Bituminous Binders	

Petroleum Based-binder	
Elector-Chemicals Stabilizers	
Microbiological Binders	

7b) Please write other dust mitigation strategies you know that are mostly used?
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
…………………………

8. How effective are the strategies in suppressing / controlling dust?

Please tick the appropriate column to the best of your knowledge.	Extremely effective	Effective	Uncertain	Ineffective	Not at all effective
Water suppressant (also called wet dust suppression)					
Engineered method					
High technology method					
Hygroscopic Salt					
Organic Non-Bituminous Binders					
Petroleum Based-binder					
Elector-Chemicals Stabilizers					
Microbiological Binders					

8b. Please write how effective the once you know are.
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
…………………………

9. From your experience, what are the challenges faced in applying the following dust mitigation strategies?

	Please write against known option
Water suppressant (also called wet dust suppression)	…………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………
Engineered methods	…………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………
High technology method	…………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………
Hydroscopic salt	…………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………

Organic Non-Bituminous Binders	………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………
Petroleum Based-binder	………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………
Elector-Chemicals Stabilizers	………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………
Microbiological Binders	………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………

	……………………………………………………………………… ………………………………………………………………………

9b) From the one(s) you mention in section (8b), please write the challenges faced in applying them.

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…………………………

<u>SECTION C – LEGISLATION</u>

Please circle the latter next to your correspond answer.

10. Are you aware of Air quality standard stated under National Environmental Management Act (NEMA Act 39 of 2004)?

(a) No (b) I don't think so (c) perhaps (d) I think so (e) Yes

11. From your experience, is the legislation on Air quality strictly applied in the management of dust on road construction sites in South Africa?

(a) No (b) I don't think so (c) perhaps (d) I think so (e) Yes

12. From your experience, how effective has the National Environmental Management Act (NEMA Act 39 of 2004) legislation been on the management of road construction dust?

(a) Extremely effective (b) Effective (c) Uncertain (d) Ineffective (e) Not at all effective

12b. Please give reasons for your answer in question 12.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
Thank you very much for your participation

Appendix B: Details of extensive reviewed secondary data

Report	Type of Report	Proposed Dust Mitigation Strategies	Identified points/information	Researchers' Remarks
Report 1 12-12-20-288	EIA/EMP	1. Spray water (EIA/EMP) 2. Engineered method and (EMP) technology alternatives ; application of construction techniques to limit dust and other air pollution (a)through limiting haul trucks/vehicle speeds (b) proper designs of the road (c) use of best equipment (d) constructing wind fence to reduce the amount of airborne particulate that will accumulates from material handling operations (e) the use of trampoline to cover loaded trucks, control of vehicle speed.	*** Environmental significance points** **Total of** 55km stretch of road **Kinroass to T Richardt:** recorded events includes, heavy blasting, to generate road construction material (taged as major source of dust generation) **Leandra to Kinross: 21km** stretch of undulating hills and valleys. construction of a new fresh road on this axis, sported major source of dust generation includes (demolition/ blasting) **EMP confirms that:** dust will have impact on the local ecology; dust was confirmed to be generated from all road construction activity, (construction and operational phase) *** in legislation context,** the EMP was compiled in terms of the EIA regulations published in GNR, 385 on April 2006 in years of the National Environ, management Act (Act No. 107 of 1998), **However,** the EIA was done for N17 road axis in terms of thee Environment conservation Act (ECA) Act 73 of 1989 ***Responsible parties ensuring dust control** contractors, Implementing agents and developer	In both report, detailed impact of dust to the receiving environment was not expressed as an important pollution as emission from vehicles/trucks was expressed. Upon dust being identified in literature as massive NUISANCE to facet of the environment .***No emphasis** on particular dust mitigation was raised or assigned for a specific construction action/activity. (All abetment of dust pollution was said to be suppressed using water if need be) *** Aesthetic** impact received/have more detailed attention than dust pollution received. *** Air quality mitigation** was mostly allocated to GHG emission than dust

Report 2 12-12-20-862	EMP	Limit the generation of dust and damages caused by dust through **Regular watering** of the work area. **proposed techniques (**sprinkler or vacuum {air entrapment}**)**	*** Responsible party includes;** Implementing agent, contractor, developer, environmental planner. Making sure of full compliance **pg4o* it is noted that** dust from construction activities must not disturb economic or social activities in the vicinity of the construction site *** in the road construction of Shally Point small craft Harbou**r, blasting of rock and heavy demolition occurred	***Environmental impacts:** impacts of dust on the ecosystem was not mentioned, despite the road construction taking place in a high biodiversity environment **pg 17-18 (**208-204**) and no particular suggestion was made** to abate/mitigate dust pollution in this environmentUpon Harbour bay having high wave events that transports dust/sediments during road construction activities, still, dust was not raised as a significant issue
Report 3 12-12-20-918	EMP	*spray water, pg 14 *** Techniques** by limiting haul truck/vehicle speeds ***** water or chemical dust suppressants **pg 19**	***Dust is identified** as emission of pollutants into the atmosphere ***Detailed dust impacts was noted** in this Report; dust Impacts on natural resource; surface water pollution **pg 21** *** Noted activities that generates dust** in Buccleuch and Brakfoutein axis N1, *accommodation of traffic, * overhauling, * clearing and grubbing, *Blasting rocks, * pavement layers, * asphalt works/sealing operation **pg 22-25** *** Responsible parties for monitoring dust control,** contractors, Environmental officer	***Report** is more detailed with references to dust pollution. ***** significance points based on environmental impacts was rated as either High, moderate or low
Report 4 12-12-20-	EIA/EMP	*****Suppression of dust emission with water, and	**14th avenue, Bayers.** *** management of dust impacts were**	Dust is acknowledged to have environmental impact into the

919		chemical additives if need be, for dust caused by strong winds. **Techniques applied;** Limit speed of haul tracks. * use of trampoline to cover loaded trucks	**categorized in sequence of; ***Alternative I (tagged as, a must adherence to proposed mitigation strategy) * Alternative II (tagged as a corrective action that must be taken by contractors, proponents to correct adverse impact) * Alternative III, (seeing to the effects the impacts had on the environment), and * No-Go alternative (tagged as a compulsory adherence/avoidance). **pg 23-30*while potential impacts were categorised based on** Direct, Indirect and cumulative impacts **pg22 *monitoring parties;** contractor, site foremen, environmental control officer	atmosphere **pg55** *** concern** of reducing haul trucks is directed to making sure deterioration/damage is not made to the construction activities.
Report 5 12-12-20-920	EIA/EMP	*water spray and chemical dust suppressants * construction vehicle and equipmentsmaintained * proper designs of the road * constructing wind fence to reduce the amount of airborne particulate that will accumulates from material handling operations *the use of trampoline to cover loaded trucks, control of vehicle speed.	**N1 section 20 route** ***impacts were categorized based on;** Direct, indirect and cumulative impacts, and they emphasis on the field of natural resources *** identified activities that generates dust were;** overhauling, earth excavation, transportation/ traffic *** monitoring teams identified;** environmental officer, contractor	sequence of mitigation strategies was followed, similar as in literature according to Mitchell (1997) ***wet Dust suppression was identified as** a short term pollution control. * air pollution was more emphasised on GHG emission

Report 6 12-12-20-922	EIA	water suppression when needed, wind screens should be used to reduce wind and also dust at the site	*** proposed management is still based on Alternatives** A-I Direct impact of dust A-II corrective measures for GHG emission, A-III noting suggested for dust pollution under this alternative. **Impacts are categorized as** Direct, indirect and cumulative. dust was highlighted as a short term impact. Dust was acknowledged to have impact on the atmosphere and should be controlled by any sphere of government concerned and should be monitored by the environmental officers, contractors and developer.	*** Duration of the impact of dust was described as (**immediate**)** based on the grade of impacts in the EIA report**. pg 25 Whereas, according to lit-reviewed, dust was found to have cumulative impact on the environment, and that can even last for years in the atmospheres after the impact has occurred.**
Report 7 12-12-20-923	EIA	water suppression when needed and vehicle speed control.	**N12 section 18, uncle charleies and Elanda**duration of dust impacts was termed (local) a short term emission without corrective action. * it was highlighted that dust is expected in all construction phase. **Control parties/monitoring team** are environmental officer. for onsite implementation of mitigation measures	minimum requirements as prescribed in the EIA regulations and outline was acheived, But according to Lit-reviewed, minimum requirement in SA regulation is not good enough, as EIA as a tool can press better to effectively conform to SD standards. **Dust** is not identified as a significant impact during the operational phase. **pg**74

Report 8 12-12-20-926	EIA	Dust suppression by utilization of water carts at regular intervals (periodic water sprinkles) * maintain 80m servitude	**noted activities that generates dust** blasting, demolition, overhauling, clearing and grubbing. **Impacts measures where categorized** based on the types of road construction materials in usage. **Monitoring the dust mitigation measures proposed is** the duty of the controller, Environmental officer, and safety supervision	Dust suppression is expressed as a short term control and dust is highlighted as a short term impact,
Report 9 12-12-20-992	EIA	Water suppression, High Technology method (Vacuum truck)	**Dust is generated through** high wave event, land levelling, backfilling. Need for reduction of dusty construction site was highlighted due to concern towards social activities and business interruption. Control parties include, contractors, the developer, and the environmental control officer ensuring that proposed dust measures are made	Dust is not detailed as a significant impact to the environment, noise impact receive quite a very good attention.
Report 10 15-031-k-WaMsane-N2-Interchange BAR_FNL	EIA	suppression by wetting * construction techniques, cover trucks with trampoline, avoid the use of cheap equipment	Clearing and grubbing, blasting, earth work excavation and demolition were highlighted to be source of dust generation in this report. **Control parties,** government body that see to compliances, developer and site engineer. **Route** to construct is about 49km	According to lit-reviewed, once dust is airborne, control cannot be made, because it disperses in the air. Yet dust is not considered as important pollution to detail in this report,
Report 11 15-031-k-KwaMsane-N2_S30	EMP	Dust suppression by utilization of water carts at regular intervals * maintain 80m servitude	possible generation of dust in the construction phase is through High wave event (wind), on-site stacking of construction waste, earth excavation. **Monitoring team** that ensures compliance of the proposed dust mitigation measures is the contractor, and all site workers was encouraged to adhere to dust mitigation measures proposed. **Impacts are categorized** in sequence of direct, indirect	Dust was described as a direct impact, and stated that it cannot be avoided in road construction sites. In lit, it was sported too, but impacts of dust to the environment is further detailed into indirect and cumulative impacts, but not detailed in the report.

			and cumulative.	
Report 12 701-N2WCT NRA01N2WC	EMP	*** Barrier fence to control** air currents and blowing soils. Placing barriers to the angle of prevailing wind currents, when necessary, appropriate dust control measures (such as wetting of soils and covering potential dust sources) and use of chemical suppressants when needed.	**mitigation of dust during the blasting** activities was detailed, The contractor making sure that spillage of road construction material from surface excavations, weather by blasting or by other means of dust generation is properlly done. The contractor and ECO ensuring implemetation of a maintenanceprogramme for all construction vehicles, to ensure they operate optimally thus reducing dust generation.	Despite the effect of dust to the environment, dust was not detail under the categorized impact (direct, indirect and cumulative). Just as other impacts was emphasised on.
Report 13 701_Supplementary	EIA	apply water when needed, crate walls to control air currents and reduce blown soil.	**SP.** Significance points based on environmental impacts were rated as either **high, medium, or low** significance as on the following bases. SP>60 indicates high environmental significance. SP>59 indicates moderate environmental impact and SP>30 indicates low environmental significance. sources of **dust in the road construction site will be from** demolition activities, earth excavation, asphalt application, surface levelling, hauling. **control parties** are the	Dust is described under <30 significance impact. Indicating it has low impact to the environment. Lit describe dust as a massive nuisance to all facet of the environment and further contributes to devastating climate change.

			ECOs, contractor	
Report 14 2004_EA_2 004	EIA	Dust suppression will be instituted as required, vehicle speed should be limited to 40km/h on unpaved surface. Hauling vehicle should be covered,	Air quality management is detailed, emphasising that the contractor should adopt the required dust and exhaust emission control measures during construction phases. **Dust is steered through** demolition, earth excavation, clearing, batching plants, On-site stacking of construction waste	dust duration was termed (short) impact in the environment. In literature, sources of dust generation does not mean, dust only become airborne in source of generation, rather, dust can be transported by wind to other places, and depending on the intensity/amount of pollution, can be suspended in the atmosphere for a longer period of time, making it possible for chemical changes to occure due to some other possible compatible materials in the atmosphere ; which can lead to climate change.

Report 15 2005 _EA_2004	EIA	water spray, chemical suppressants, technical effective measures.	Emphasis on **Monitoring and auditing;** ***Environmental officer/ECO, *Design engineer *environmental planner * contractor * site engineer * environmental manager and all site workers was called to make sure that dust mitigation measures proposed will be dually applied and adhered to. **activities like** Earth excavation, debris scrabbling, batching plants, sweeping and levelling	detailed impact of dust to the receiving environment was not expressed as an important pollution, as emission from vehicles/trucks was expressed.
Report 16 4438808_R 61s8	EMP	Dust suppression by wetting the road surface, tilling should be applied on flat areas, and blasting should employ best technical method, thus maximizing dust control	recorded events that generated dust includes, heavy blasting, to generate road construction material. Dust is said to have impact on the local ecology; dust was confirmed to be generated from all road construction activity, *Responsible parties ensuring dust control includes; contractors, Implementing agents and developer	potential impact of the upgrade and rehabilitation of R61s8 have less detailed air quality impacts during road construction
Report 17 121220701	EIA	water spray, chemical suppressants, technical measures taken. Best engineering design to avoid excessive generation of dust.	**Location;** the Gonubie interchange axis, about 560km stretch, **monitoring of the proposed** mitigation measures is highlighted to be in accordance in the construction site with how it is detailed in the report, and environmental officer should see to the compliance **pg** 11. Ensure that air quality buffer zone is taken into consideration in highlighted sensitive areas.	It was highlighted that, even with a high standard of impact mitigation measures, there must be some significant residual negative effect to the environment, supporting what was found in lit-review that dust effect/impacts cannot be avoided in road construction activities. **pg** 18
Report 18 1412163311 708 Kwamsane	EMP	Dust suppression will be instituted as required by spraying water, Reducing wind speeds reduces the amount of airborne	**It is noted that Dust** is expected and will be crated during the construction phase from clearing of vegetation, earth works, hauling and laying of sub-base materials. **Duration of dust impacts** to the environment was termed	emphasis on a particular dust mitigation that should be used/applied in the cause of, for example demolition activity is not raised or assigned. All

		particulate (dust) from material handling operations such as stockpiles, trucks, rail or loader dump pockets, conveyor lines and load out silos.	as a short period **effect/nuisance**	abetment of dust pollution was said to be suppressed using water if need be * Air quality mitigation was mostly allocated to GHG emission than dust