THE MANAGEMENT OF CLIMATE CHANGE IMPACTS ON ROAD INFRASTRUCTURE: A CASE OF THE CITY OF TSHWANE METROPOLITAN MUNICIPALITY

by

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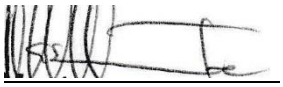
I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



SIGNATURE

24 March 2021

DATE

DEDICATION

This study is dedicated to the ***#Teamsephaphoshe***

- my husband, Puletsi Alfred (Ma-Ally)
- my son, Thapelo Konoko David (BonJo) and
- my daughter, Katlego Nthibana Joanne (Nnoza)

you kept me going and gave me strength to soldier on.

This is for us guys!!! King, Queen, Prince and Princess of ***#Teamsphaphoshe***

AND

To my mom and uncle (a sister and a brother) Mrs Mathlodi Linah Baloyi (aka Evy) and Mr Maele Silas Mothapo – in this life, no one has ever had so much confidence in me than you two. You had faith, trust and belief in my competence, so much so that when the PhD journey got tough, giving up was not an option. I could not let you down. This is for you more than it is for me. I learnt unconditional sibling love through lena bana ba Pheladi ‘a Phaahla. I love you, and am proud to be your daughter!

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"Ke leboga Modimo wa bokoko le mama, Modimo wa Thaba 'a Sione"

(I thank the God of my grandmother and mother, the God of Mount Zion)

ABSTRACT

After the South African energy sector, the road transport sector is the second largest contributor to climate change rising from greenhouse gas emissions. While the road transport infrastructure is designed to withstand typical weather patterns, evolving climate change events affect the capacity of the road transport infrastructure to withstand severe events above the usual threshold.

This thesis offers an overview of the possible impact of climate change on road networks and services in the City of Tshwane Metropolitan Municipality – specifically, the impacts of temperature increases, changes in precipitation and increased storm activity on road infrastructure. The study was carried out in the City of Tshwane Metropolitan Municipality using a mixed methodology for the collection and analysis of data. Municipal officials within selected units were interviewed face to face and others completed a structured questionnaire.

The study suggested initiatives that could help the City of Tshwane Metropolitan Municipality to develop successful climate change management measures, especially in terms of how the municipality manages its road transport infrastructure. The study recommends that the impact of climate change should be integrated into transport planning as a central factor in the planning processes of road authorities.

Keywords: climate change, road transport infrastructure, management measures, adaptation, mitigation, public policy.

KAKARETŠOKOPANA

Lekala la ditsela tša dinamelwa ke la bobedi ka bogolo, le latela lekala la enetši, mo Afrika Borwa la go ba le seabe go phetogo ya boemo bja boso ya go hlolwa ke meoya ya go se lokele tikologo. Le ge mananeo-kgoparara a ditsela tša dinamelwa a hlamilwe go kgotlelela maemo a boso ao a tlwaelegilego, phetogo ya boemo bja boso e ama gampe maemo a mananeo-kgoparara a ditsela tša dinamelwa go ka kgotlelela seemo sa boso seo se tseneletšego sa go se swane le sa mehleng. Lengwalo-thuto le le fa kakaretšo ya ka mo phetogo ya boemo bja boso e ka amago gampe dikgokaganyo le ditirelo tša ditsela Mmasepaleng-Mogolo wa Toropo ya Tshwane. Kudukudu go lebeletšwe kamo-mpe ya koketšego ya phišo, phetogo ya dipula le koketšego ya madimo mo mananeong-kgoparara a ditsela. Thuto-nyakišišo ye e dirilwe Mmasepaleng-Mogolo wa Toropo ya Tshwane ka go šomiša mokgwanyakišišo wa go kopanya mekgwa ya dipalo le ya boleng ge go kgoboketšwa le ge go sekakekwa tshedimošo. Go bile le poledišano ka sebele le bahlankedi ba bangwe ba mmasepala diyuniting tšeo di kgethilwego, mola ba bangwe ba filwe matlakala a dipotšišo-nyakišišo. Lengwalo-thuto le le tla ka dikgopolompsha tšeo di ka thušago Mmasepala-Mogolo wa Toropo ya Tshwane go hlama mekgwataolo yeo e ka šomišwago go hlokomela mananeo-kgoparara a ditsela tša dinamelwa. Lengwalo-thuto le eletša gore kamompe ya phetogo ya boemo bja boso e swanetše go ba kgwekgwe ge balaodi ba tša ditsela ba rulaganya mananeo a bona.

Mareokgolo: phetogo ya boemo bja boso, mananeo-kgoparara a ditsela tša dinamelwa, mekgwataolo, tlwaetšo, phokotšo, dipholisi tša setšhaba.

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LIST OF ACRONYMS AND ABBREVIATIONS

AR5	Fifth Assessment Report
BAU	Business as Usual
BRT	Bus Rapid Transit
C40	Control for 40 days
CITP	Comprehensive Integrated Transport Plan
CNG	Compressed Natural Gas
CoCT	City of Cape Town
CoGTA	Cooperative Government and Traditional Affairs
CoJ	City of Johannesburg
COP	Conference of Parties
CSIR	Council of Science and Industrial Research
CSU	City Sustainability Unit
CTMM	City of Tshwane Metropolitan Municipality
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs
DEAT	Department of Environment Affairs and Tourism
DoT	Department of Transport
EC	European Commission
EEA	European Environment Agency
eNaTIS	Electronic National Traffic Information System
GCMs	Global circulation models
GDP	Gross Domestic Product
GHG	Greenhouse gas
GNP	Gross National Product
IDP	Integrated Development Plan

IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRI	Industrial Research and Innovation
ITP	Integrated Transport Plan
IPTN	Integrated Public Transport Plan
KPI	Key Performance Indicator
LGP4CC	Local Government Programme 4 Climate Change
LTMS	Long-Term Mitigation Scenario
MDGs	the Millennium Development Goals
MIG	Municipal Infrastructure Grant
NAPA	National Adaptation Programme of Action
NCRWP	National Climate Change Response White Paper
NCCR	National Climate Change Response
NEMA	National Environmental Management Act
NLTTA	National Land Transport Transition Act
NMT	Non-Motorised Transport
NPM	New Public Management
OECD	Organisation for Economic Co-operation and Development
PRASA	Passenger Rail Agency of South Africa
R&D	Research & Development
RAF	Road Accident Fund
RTMC	Road Traffic Management Corporation
SACN	South African Cities Network
SAICE	South African Institute of Civil Engineering
SALGA	South African Local Government Association
-SANRAL	South African National Road Agency Limited
SPLUMA	Spatial Planning and Land Use Management Act

TDM	Transportation Demand Management
TIEP	Tshwane Integrated Environmental Policy
UNEP	United Nations Environment Programme
UNISDR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
VCI	Vegetation Condition Index
WHO	World Health Organisation

CHAPTER 1
GENERAL INTRODUCTION

1.1 INTRODUCTION

In South Africa, as in most other countries, public infrastructure is pivotal for the good functioning of the government and its citizens (Economic and Social Council 2017: 1). Public infrastructure includes roads, storm water, electricity, telecommunications, water supply and waste management systems (Tighe 2008: Online). Public infrastructure enables the delivery of critical services that are essential for governance, the economy and the social fabric of places (ibid). The current study considered the public road infrastructure in the administrative capital of South Africa. Climate change has transformed life on earth (Intergovernmental Panel on Climate Change [IPCC] 2013). This is visible through the seasons shifting, and temperature and sea levels that are rising. Actions need to be taken in responding to climate change otherwise it will alter the environment and heavily affect people's livelihood. Climate change is a global problem with adverse consequences and unique characteristics (Denchak 2016: Online). IPCC (2007: 781) refers to climate change as a state of the climate that can be identified by change in the mean and variability of its priorities.

Furthermore, DiMento and Doughman (2014:5–6) assert that climate change involves change in both average conditions and change in variability, including extreme weather events. Like all other developing countries, South Africa has a large stake in inverting ways to mitigate climate change, because of the vulnerability of the country to the adverse effects of climate change. The focus of this study was on the road transportation sector, which contributes to the climate events by producing fossil fuel-related carbon dioxide emissions in 2010 (IPCC 2007: 793; Oswald 2011: 11). The carbon dioxide (CO_2) emissions related to transport are expected to increase by 57% worldwide in the period 2005–2030 (IPCC 2014). The relationship between transportation and climate change is a growing concern, as scientific evidence on climate change continues to support the connection between human activities and global warming. In South Africa, greenhouse gas (GHG) concentration continues to rise at a rate of more than two parts per million each year. Climate change is an issue of concern to policymakers and of consequence to transportation safety. Some of the consequences are infrastructure damages, traffic delays and road accidents.

The geographical area of responsibility of the City of Tshwane Metropolitan Municipality (CTMM) has 60 roads classified as national, provincial and municipal roads. Out of the 60 roads, three are national roads, 13 are provincial and the remaining 44 are municipal roads (Department of Transport [DoT] 2018: 8). Each sphere of government is responsible for its own roads. Thus, the CTMM is responsible for repairing and maintaining 44 roads within the jurisdiction of the municipality. This poses a challenge to the CTMM, with a population of approximately 3 275 152 residing in an area of 6 368 square kilometres and a city with numerous political, social and economic activities taking place.

Figure 1.1 depicts a map of the City of Tshwane (CoT), entailing all roads within the area and their numbering.

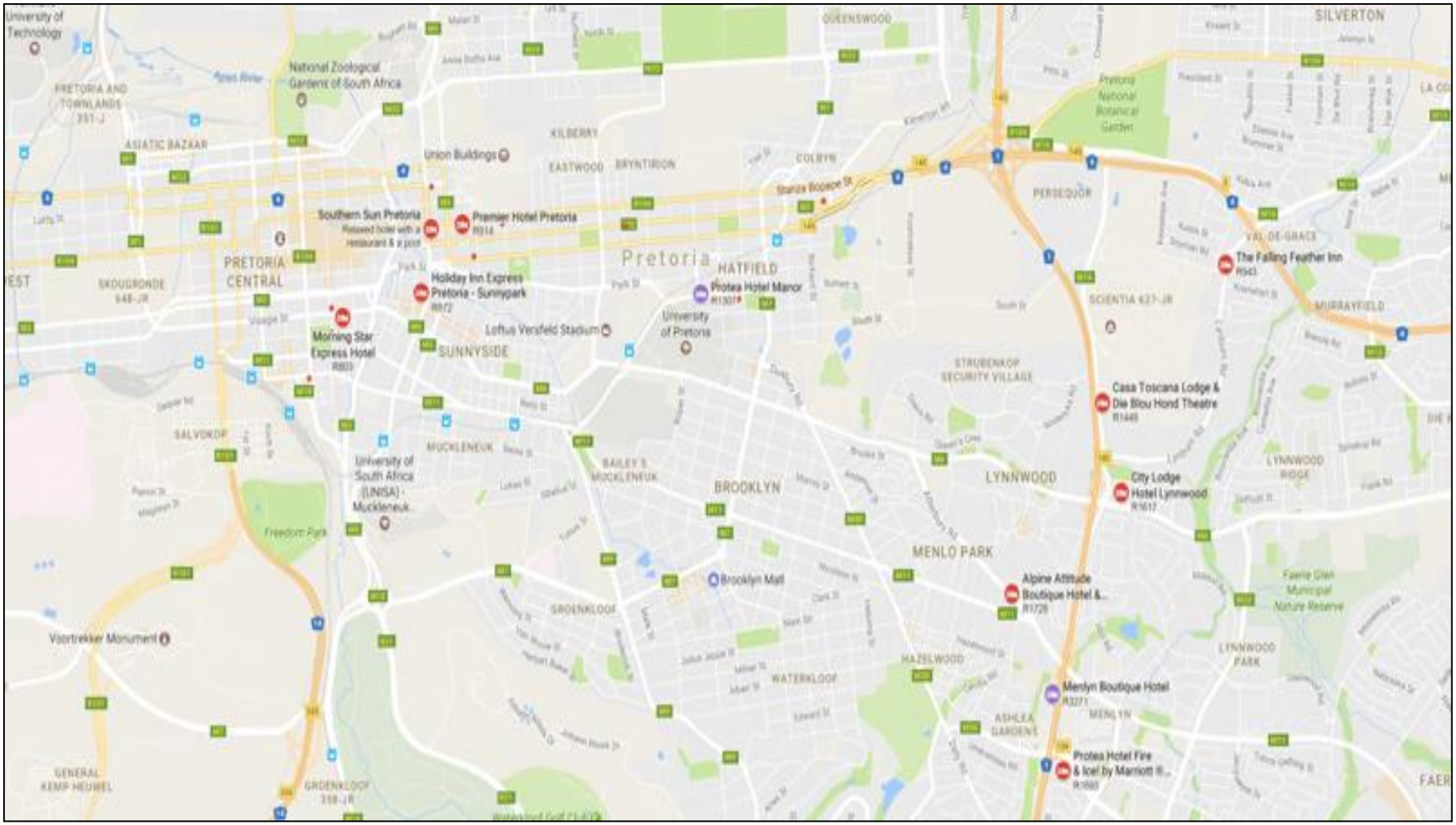

Figure 1.1: Map of the City of Tshwane

Source: CTMM (2018)

The City of Tshwane Metropolitan Municipality (CTMM) provides a wide range of public services to satisfy the diverse needs of its residents within its borders. Moreover, the city is vulnerable to climate change and has the likelihood of experiencing the impact of climate change, such as increased average temperature, changes in average rainfall, and increased frequency and intensity of extreme weather events (CTMM 2014: 27). Furthermore, climate change has the potential of challenging the management and planning of road infrastructure and the road networks within the city. For instance, roads facilitate movement within the city, and the effects of climate change, such as floods and heat, will affect trade, business and the lifeline of society, for example, damaging evacuation routes.

Decisions by public policymakers on the location of road infrastructure have long-term implications for land use and development. The decisions also have implications for infrastructure investments and determining the adaptation strategies of the road infrastructure to climate change (Jenelius 2008: 48). Planning of road infrastructure therefore has to consider climate change to enable its adaptation. To ensure that road infrastructure adapts to climate change, it is crucial to understand the current planning and management of the CTMM road network and infrastructure, and to identify its weaknesses and strengths.

1.2 BACKGROUND OF THE STUDY

According to IPCC (2007: 823), the underlying cause of climate change is the increasing atmospheric concentrations of the greenhouse gas (GHG) emissions, such as carbon dioxide. Furthermore, IPCC (2007: 823) reports that scientists proved that human and natural activities contribute significantly towards climate change because of the GHGs emitted from burning fossil fuel. This scientific fact disputes the possibility that climate change is caused by biogeographical cycles of the planet only. Hence, McLusky and Sessa (2015: 9) argue that, if climate change were indeed just a natural problem, it would mean that there is nothing that can be done about it except accepting it and coping with it.

The United Nations Framework Convention on Climate Change (UNFCCC) commits all signatories to stabilise their GHG emissions. Signatories have a moral and legal obligation under the UNFCCC and the Kyoto Protocol to contribute their fair share to global GHG mitigation efforts (IPCC, 2011: 827). After ratifying with the UNFCCC and Kyoto Protocol concerning emission, the South African government started focusing

on developing mitigation techniques and promoting renewable energy as well as energy efficiency. However, the IPCC (2011: 796) indicates that, despite the actions taken by most countries, a certain degree of climate change is unavoidable regardless of future emissions. Climate change is an issue of concern to policymakers and of consequence to the public infrastructure. The GHG emissions have global impact because they disperse rapidly across the globe. Consequently, the effort to respond to climate change requires global collaboration and agreement with the primary forum for international climate change action through the United Nations, which led to the UNFCCC and the Kyoto Protocol.

The South African government has a constitutional mandate to protect the environment and ensure safety of all citizens in terms of section 24 of the Constitution of the Republic of South Africa (1996). In executing this mandate, the government is faced with numerous challenges and difficulties, such as climate change, which is incalculable, impossible to compensate, and often invisible (it requires experts to recognise and measure it), uncontrollable, and its impact is often irreversible (McLusky & Sessa 2015: 1). The public infrastructure is vital to the sustainable economic development of any country. Efficient public infrastructure provides socio-economic opportunities and benefits that result in positive outcomes, such as improved accessibility to markets, employment and additional investments (Jaroszweski 2012: 5). However, social, economic and environmental factors affect public infrastructure. Environmental factors, such as climate change, will have a significant impact on the public infrastructure globally (IPCC 2007: 822; 2014: 826).

The impact of climate change is more acute in cities with rapidly growing populations (United Nations Environment Programme [UNEP] 2013: 18). Cities have a fundamental role to play as far as population, economic growth and energy consumption patterns are concerned. Moreover, cities contribute to employment and poverty alleviation, and have the potential to reduce GHG emissions. At the same time, cities are a major contributor to pollution that leads to climate change (UNEP 2013: 24). All South African municipalities are responsible for responding to climate change and transport planning. South Africa has eight metropolitan municipalities. These metropolitans are big in terms of population and are found in cities. The cities and their municipalities are:

- Buffalo City in East London;
- City of Cape Town in Cape Town

- Ekurhuleni Metropolitan Municipality in the East Rand;
- City of eThekwini in Durban;
- City of Johannesburg in Johannesburg;
- Mangaung Municipality in Bloemfontein;
- Nelson Mandela Metropolitan Municipality in Port Elizabeth; and
- City of Tshwane Metropolitan Municipality (CTMM) in Tshwane.

The case study city fell under the jurisdiction of CTTM, and this municipality is the largest in South Africa with economic activities that are service-based and led by financial service sectors and the government (CTMM 2015a: 6). The city hosts a number of manufacturing firms, of which the largest is the automotive industry with manufacturers such as Volvo, Nissan, Ford and BMW. The activities of these manufacturing firms contribute vastly towards the GHG emission levels of the city (CTMM 2015a: 6). GHG emissions from these industries are primarily from burning fossil fuels for energy and from certain chemicals used to produce goods from raw materials. These emissions are primarily responsible for global warming. Municipalities across the country are responsible for investments in local infrastructure, including the construction and maintenance of roads and streets that are within their jurisdiction and proclaimed as municipal roads. The municipal infrastructure departments have a roads and storm-water unit, which has a mandate to carry out routine maintenance of road infrastructure.

1.3 MOTIVATION OF THE STUDY

Climate change affects many sectors of the economy, such as agriculture, tourism, forestry and transport. The current study sought to explore the management of the impact of climate change on the public infrastructure, particularly the road infrastructure. The road infrastructure comprises roads, bridges, pavements, rest areas, streets, tollgates, road tunnels and storm-water drainages. These infrastructures are vulnerable to climate change. The study investigated how the CTMM attempts curbs the impact of climate change on its road infrastructure. An investigation on adaptation and mitigation strategies implemented in the municipality was undertaken. The study further reviewed international practices on road infrastructure adaptation strategies and GHG mitigation strategies in order to learn from them and enhance the existing strategies in the CTMM. The knowledge acquired is relevant and may contribute to the successful implementation of management

measures, such as the adaptation and mitigation strategies and climate-resilient road infrastructure.

1.4 RESEARCH PROBLEM STATEMENT

Climate change poses a serious threat to public infrastructure, putting cities at risk. In the past three decades, natural disasters have quadrupled globally. As a result, economic and human losses escalated (United Nations Office for Disaster Risk Reduction [UNISDR] 2012: Online). Despite uncertainties of the magnitude and frequency of climate events and their potential impacts, climate change will inevitably increase the susceptibility of societies if adaptation and mitigation strategies are not developed and implemented effectively (IPCC 2007: 823; United Nations Human Settlement Programme [UN-HABITAT] 2015: Online). The road infrastructure is the pivotal aspect of communities, and the pillar for the economic and social life of people. Climate change-resilient and reliable road infrastructures are crucial to transport goods, people and emergency response to disaster areas. However, the potential impacts of climate change on the roads are not fully taken into consideration when planning, designing, and constructing infrastructure (Mashamaite, 2018a:585). There is therefore a gap in terms of mainstream climate change consideration of road transport planning.

Municipalities have a mandate to provide refuge from disasters and act as buffers against climate change. However, cities are now risk and disaster hotspots (UNEP 2013: 24). The CTTM officials are faced with the challenge of mainstreaming adaptation strategies in their road transport planning. However, adaptation is a relatively new concept, therefore, knowledge and competence on adaptation strategies are limited and fragmented (UNISDR, 2010). As climate change becomes eminent, pressure to respond rises in the CTMM. Failure to respond to climate change is problematic and could make the city to remain vulnerable to the predicted climate change. In terms of the South African National Climate Change Response White Paper (South Africa 2011), addressing climate change could result in co-benefits such as improved air quality, reduction of time between trips, decrease in accident rates, and an increase in economic production (Klausbruckner, Annegarn, Henneman & Rafaj 2016: 72). Therefore, the CTMM should increase its investments in adaptation strategies to address climate change events that are likely to be linked to the extreme weather conditions associated with climate change. In brief, the research problem was

that it is unknown how the CTTM currently manages the impacts of climate change on road infrastructure.

Climate change is a threat to the road infrastructure across all spheres of government; therefore, climate-proofing the road infrastructure can be a long-term solution (Pasquini, Cowling & Ziervogel, 2013: 226). However, the challenge becomes the cost implications of climate-proofing the road infrastructure. The coordination and financing of climate change impact is not clearly indicated in any of the government documents that are available for the public. Each sphere of government has a budget allocated for infrastructure and disaster management. Each sphere is responsible for its own budget while the disaster often cuts across the jurisdiction areas. Moreover, the budget constraints and competing interests such as basic service delivery add to the challenges of responding to climate change.

1.4.1 Research questions

In addressing the problem stated above, the researcher formulated a general research question as follows: How does the CTTM manage the impacts of climate change on its road infrastructure? The specific subsequent research questions that were formulated from the general research question are as follows:

- What are the impacts of climate change on the road infrastructure in the CTMM?
- What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?
- How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?
- How is climate change mainstreamed in the road transport planning and policy in the CTMM?

1.5 RESEARCH AIM AND OBJECTIVES

The main aim of the study was to investigate the CTTM's management of climate change impacts on its road infrastructure. The following were specific objectives:

- to evaluate the impact of climate change on road infrastructure in the CTMM;
- to ascertain the administrative challenges faced by the CTMM in managing the impacts of climate change on road infrastructure;

- to evaluate how the management measures relating to the impacts of climate change on road infrastructure are financed in the CTMM;
- to assess how climate change is mainstreamed in road transport planning and road transport policy in the CTMM; and
- to propose ways by which management measure could minimise the impact of climate change on road transport infrastructure in the CTMM.

1.6 RESEARCH APPROACH

In this study, a case study design was employed to describe and explain climate change and its impacts on the road transport infrastructure in the CTTM in Gauteng Province, South Africa. According to Van Thiel (2014: 4), public administration researchers focus on cases that yield to daily applicability. Kumar (2012: 799) states that a descriptive study allows the researcher to describe the problem studied, while an explanatory study allows clarification of why and how there is a relationship of aspects under study. A mixed-method approach was used in this study. The mixed-method approach collects and analyses data by mixing both quantitative and qualitative methods in a single study (Schoonenboom & Johnson 2017: 109). A qualitative approach is one in which the researcher develops knowledge based on constructivist perspectives, while a quantitative approach uses post-positivist claims for developing knowledge (Kaushik & Walsh 2019: 2; Creswell 2013: 18; Phillips & Burbules 2000: 8). The mixed-method approach has a potential to produce rich data if correctly applied. Furthermore, Morse and Niehaus (2009: 14) indicate that the mixed-method approach is the best method to apply when the phenomenon under study is considered complex, and single method may not produce the desired data.

1.6.1 Research methodology

There are various approaches to using mixed methods, and this study has utilised the concurrent triangulation mixed method, whereby different perspectives of a phenomenon are tested (Ingham-Broomfield 2016: 46). Hothersall (2019: 4) and Creswell (2013: 62) explain concurrent triangulation as a process whereby both quantitative and qualitative data are collected simultaneously, and then data are integrated into the interpretation of results. In relation to this, Creswell and Plano Clark (2011: 65) state that in concurrent triangulation, qualitative and quantitative items are mixed in a survey. This does not result in rigorous qualitative data. However, Creswell and Plano Clark (2011: 45) provide quotes that can be utilised to validate the

quantitative survey findings. This method is appropriate in investigating the impact of climate change on road transport infrastructure because of its ability to use complementary data collection methods on the same topic at the same time seeking answers for different aspects, as explained by Creswell and Plano Clark (2011: 45). In this study, documentation, observation, a structured questionnaires and semi-structured interviews were used to test the problem management theory, which measures the level at which the performed tasks result in attainment of the set goals. The primary aim of the problem management theory for this study is to minimise the impact of negative climatic changes.

A qualitative research approach allows the researcher to probe responses and observations as needed and enables him or her to gather detailed descriptions and explanations of experiences and attitudes of the respondents on the subject matter (Kaushik & Walsh 2019: 10; Welman, Kruger & Mitchell 2009: 195). Employing both qualitative and quantitative methods in this research assisted the researcher to cross-validate responses obtained via the aforementioned methods. Consequently, mixed methods helped to compare responses that emerged during the data collection process, as described by Kaushik & Walsh 2019: 10. This study focused on three variables when collecting data:

- evaluation of scenario, response capacity and impact assessment;
- inventory of road infrastructure (specifically damaged infrastructures); and
- evaluation of existing management measures within the road transport sector in the municipality.

Probing these variables helped the researcher to identify gaps in order to make recommendations on how to manage the impact(s) of climate change on road infrastructure effectively.

1.6.2 Research study area, target population and sample

The City of Tshwane is the administrative capital of South Africa and is based in the CTTM, in the northern part of Gauteng. The city has a humid subtropical climate with long hot, rainy summers and short cool to cold, dry winters. The city experiences the typical winters of the summer rainfall regions in South Africa with cold, clear nights and mild to moderately warm days (International Conference on Information Law and Ethics [ICIL] 2016: Online). Although the average lows of rain during winter are mild,

it can get bitterly cold due to the clear skies, and in recent years, this has caused the City of Tshwane to experience temperatures in the range of 2–5° degrees C at night. The average annual temperature is 18.7° C (65.7 °F) (Pretoria City Info 2018: Online).

This study used purposive random sampling. In the light of this form of sampling, two departments were selected based on their roles in the municipality as far as climate change, road transport infrastructure, mitigation of GHG and adaptation to climate change were concerned. This strategy enabled detailed exploration of this research objectives. The selected departments were the Mayor's Office- City Sustainability Unit and the Department of Roads and Transport. The researcher discovered the challenges faced when managing climate change impacts. Managers of projects, finances and programmes within the selected units in the DoT and Mayor's Office were respondents as they are well positioned to provide accurate information, as they deal with the matter daily.

At the time of the study, the DoT was divided into seven divisions namely –

- Transport Development;
- Transportation Planning;
- Transport Infrastructure Design and Construction;
- Tshwane Bus Services;
- Tshwane Airport Services;
- Integrated Rapid Public Transport Network; and
- Licensing Services.

Out of the seven divisions, two were relevant in terms of this study, namely transport planning and Transport Infrastructure Design and Construction. Moreover, these divisions had sections within themselves at the time, such as the Transport Planning division, which had three sections, Integrated Transport Planning, Intelligent Transport Systems and Traffic Engineering, and Transport Infrastructure Planning. Of the three sections, only two were relevant for the purpose of collecting data for this research study, namely Integrated Transport Planning and Transport Infrastructure Planning. Transport Infrastructure Design and Construction also had three sections, Transport Infrastructure Provision, Transport Infrastructure Construction Management, and Stakeholder Management. All these sections in this division were relevant to the study because of their role in the municipal management of road infrastructure. It should be brought to the attention of the reader that all these sections have various sub-sections

and functional units; thus, the organogram of the DoT in the municipality is a very long chain consisting of posts ranging from two to four in a functional unit.

At the time of the study, the total population of the DoT was 57 municipal officials and eight in the City Sustainability Unit in the Mayor's Office. Thus, the total population size was 65, and the sample population for the study was 60. Fourteen municipal officials were interviewed face-to-face across the relevant divisions, sections, subsections and functional units of the municipality, and 60 questionnaires were distributed. Questionnaires were issued to all personnel within the relevant units except the support staff, such as administrators and interns.

The purpose of employing the municipality as a case study was to enhance data by learning more about what's going on at the local level, which might help develop a better plan for managing the impact of climate change on road infrastructure in a municipal environment. It should also be mentioned that the majority of the roads within the City of Tshwane are the responsibility of the municipality, which made it relevant to use a municipality as a case study as municipalities are faced with the challenge of maintaining and replacing roads damaged as a result of climate change events. CTTM was selected to be a case study due to its large jurisdiction size, the fact that it is the administrative capital of South Africa, and the largest municipality in South Africa. Numerous activities take place there, from political to social and economic aspects of life. In general, the results can be contextualised to other metropolitan municipalities in South Africa.

1.6.3 Data collection methods

Data were collected via the following data collection techniques: documentation, observation, structured questionnaires and interviews.

1.6.3.1 Documentation

The documents that were taken into consideration were those that dealt with issues of climate change, road projects and programmes, bylaws, strategies, transportation and road transport infrastructure and legislative frameworks. Documentation was not only limited to those of CTTM, but the search was expanded to other institutions, such as South African National Road Agency Limited (SANRAL), the National Department of Transport (NDoT) and the Department of Environmental Affairs (DEA) as well as other

disciplines, such as those dealing with the environment and geography because of their relevance in this study. Moreover, the documents are in public domain and accessible.

1.6.3.2 Observation

Field observation often provides data which surveys are unable to provide. Observational means are used to gather information on behaviour of interest. According to Bryman (2008: 257), there are two types of observations, namely structured observation and unstructured observation. Structured observation adopts explicit rules about what to record and observe and for how long, while unstructured observation establishes a narrative account of the observed behaviour where researchers record as much as possible of what they see. Bryman (2008: 257) indicates that structured observation is effective in quantitative research. Therefore, this study applied unstructured observation, because the researcher needed to get as much information as possible. Therefore, the researcher identified areas to concentrate on as the research (observation) progressed in order to narrow the focus. It was necessary to classify the unit of observation for data collection purposes. Consequently, human behaviour and products of human behaviour were used as explanatory units for the analysis, as recommended by Bryman (2008: 257).

1.6.3.3 Structured questionnaire

A questionnaire comprises a series of questions asked to individuals to obtain statistically useful information about a given topic (Merriam, 2009: 4). Sixty (60) officials from the two departments identified in the CTMM were issued with questionnaires. The questionnaire issued paid attention to the role of the department and its relevance to this study and the studied phenomenon. The questionnaire method employed consisted of a population of interest, a sample, a construct and data collection tools utilised to measure the construct in the sample. According to Ingham-Broomfield (2016: 48), the questionnaires used in a mixed-method approach allows for detailed enquiry. The questionnaire is a popular method in social research. According to Bhattacherjee (2012: 73), the survey method has the following strengths:

- The method may quantify a number of non-observable data, such as beliefs, evidence, attitudes and preferences of individuals. The survey used thus helped

the researcher to find evidence, opinions and desires that could not be observed.

- The survey method has the ability to pay special attention to sampling to ensure adequate representation of the research target population.
- Respondents prefer questionnaire surveys because of its convenience and its unobtrusive nature.

Questionnaires were given to respondents few weeks before the actual interviews. This allowed the respondents time to prepare and answer questions at a convenient time.

The structure of the questionnaires was the same across all departments. The questionnaire was divided into five sections:

- **Biographic information section** – this was aimed at determining the number of years that the respondents had been working at a specific department and to determine the level of qualification. The purpose of determining these two aspects was to establish the level of experience that the respondents had. The assumption was that the longer the period of employment, the better the chance of the respondents providing accurate information, as they were familiar with the subject at hand.
- **Impacts of climate change** (see section 2.8 of this thesis) – enquired about the impacts of climate change on road transport infrastructure. Therefore, in order to confirm or contest what literature is saying, the questions under this section were designed to establish regional impacts of climate change on the road transport infrastructure of the CTMM. In addition, the respondents could provide answers based on their personal experience in the city.
- **Climate change management and its challenges**. This section intended to determine the management measures in place to address climate change impacts on road transport infrastructure. Over and above determining these measures, the section sought to determine the administrative challenges faced by the CTMM with the intention of recommending possible solutions.
- **Nature of the financing of climate change-related management measures**. Section 3.6 of this thesis discusses in detail the financing of the management measures of climate change regarding road transport infrastructure, and

highlights the challenges faced in financing the measures. Section D in the questionnaire intended to establish the role players in financing of the measures, the challenges in acquiring funds as well as the extent to which the CTMM financially considers climate change measures as a priority. Moreover, section D in the questionnaire intended to gather information that could assist in addressing the following research question:

How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?

- **Mainstreaming climate change into road transport infrastructure planning and policies**. Literature indicates that it is essential to mainstream climate change into policies and planning (Mashamaite, 2018a: 585). The questions asked therefore had to determine whether the CTMM was integrating climate change considerations into the planning processes and policies at the time of this study. In all selected departments, altogether 60 questionnaires were issued. This number excluded the support staff, such as the secretaries, because the nature of their role in the respective departments was not relevant to this study.

1.6.3.4 Semi-structured interviews

Semi-structured interviews are well suited for case study research because case study researchers ask predetermined questions. Responses provide tentative answers to the researchers' questions giving the researcher an opportunity to probe deeper (Algozzine & Hancock, 2011: 45), and to build on interviewees' reactions. Interviews are regarded to be the "gold standard" for qualitative research (Barbour, 2008: 113).

The researcher has to do proper planning regarding questions to ask. Griffe (2012: 53) states that semi-structured interviews are flexible and more likely to provide information that the interviewer had not planned to ask. Semi-structured interviews offer the researcher an opportunity to hear the views, beliefs and experiences of the interviewee for some time and to ask probing questions to expand the idea further. Fourteen respondents in the City of Tshwane municipality were interviewed on different days and times depending on availability of both the researcher and respondents.

1.6.4 Triangulation

Triangulation implies usage of multiple data collection tools. The selected data collection tools enabled the researcher to explore, describe and explain the impacts of climate change on road transport and the management by the CTTM in detail. In addition to the data collection tools employed in this study, the researcher conducted a literature review in order to understand climate change and its impacts on road transport. Moreover, the global response to the phenomena was studied. According to Korstjens & Moser (2018: 121), triangulation signifies that dealing with a problem from various angles is useful in successfully finding precise and suitable solutions. The focus of triangulation is not to obtain the same results through various data collection tools but to ensure consistency in application of data collection methods (Cottrell & McKenzie, 2011: 242). Through triangulation, the researcher aimed to gain a precise and broader insight of the phenomena, and that could best be achieved using both methods rather than just one.

1.6.5 Data analysis

Descriptive analysis was used to provide preliminary insight into the nature of the responses that were obtained. Griffe (2012: 52) asserts that the mistake most students make is to neglect giving thought to effective analysis of data, in the sense that the way data is analysed effectively answers research questions. When analysing data, one goes through the process of identifying themes and describing what has been found during data collection. Vaismoradi, Jones, Turunen and Snelgrove (2016: 102) contend that data analysis is at the core of the research aim as it enables one to derive a description of the essential feature of a specific experience. Quantitative data was analysed by means of the Statistical Package for the Social Sciences (SPSS) where the responses from questionnaires were calculated. Furthermore, the researcher transcribed the recorded interviews and noted significant themes and re-read the responses for analysing purposes to enhance validity.

1.6.5.1 Validity and reliability

According to Creswell (2013: 63), for a data collection instrument to be considered valid and reliable, it has to be precise, accurate and relevant. In addition, data collection methods to be regarded as valid should provide reliable responses; thus, reliability is a precondition of validity (Vaismoradi *et al.,* 2016: 102). This study can

claim to be relevant, accurate and precise, as the statistician verified reliability and validity of the data collection instruments. A statistician, as well as ethics clearance committee, was consulted before the instrument was utilised.

1.6.5.2 Authenticity

Authenticity is the real description of places, events and people. Authenticity is more relevant in qualitative research where it indicates the interconnection of description and explanation. According to Cottrell and McKenzie (2011: 242), authenticity is the ability of the researcher to report a situation through the perspective of the respondents.

1.7 RESEARCH ETHICS

Ethical guidelines form the basis against which a researcher is supposed to evaluate his or her conduct. These are aspects that must be taken into consideration on a continuous basis, and these standards are supposed to be internalised by the researcher at all times. The following ethical issues were discussed, namely avoidance of harm, informed consent, voluntary participation, confidentiality and debriefing of participants. Babbie and Mouton (2010: 497) indicate that the principle of good qualitative research is based on trustworthiness. Four indicators determine trustworthiness, namely credibility, transferability, dependability and confirmability (Kumar, 2012: 791).

1.7.1 Voluntary participation

Participation in any research project should at all times be voluntary and no one should be forced to participate in the project (Polit & Beck, 2012: 353). The participants in this research study were allowed to terminate their voluntary involvement in the research project if they felt uncomfortable. All respondents were advised that their participation was voluntary.

1.7.2 Informed consent

The research subjects must provide informed consent both verbally and in writing. This implies that adequate information on the purpose of the study was expected –

- for the duration of the participant's involvement;
- about the procedure that was followed during the investigation;

- about the possible disadvantages and advantages; and
- in terms of the credibility of the researcher and dangers to which the respondents might be exposed (De Vos, Strydom, Fouche & Delport. 2011: 121).

Participants who indicated willingness to participate in the study voluntarily were given a consent form to sign before the commencement of the study. Anyone who met the inclusion criteria and who volunteered to take part in the study was required to sign the consent form individually to confirm consent. Before the commencement of the study, each participant was given enough time to ask questions about the study, and they were reminded about their rights regarding their participation and their freedom to terminate the interview at any given time.

1.7.3 Violation of privacy, anonymity and/or confidentiality

The violation of privacy, the right to self-determination and assurance of confidentiality can be viewed as synonymous. Every individual has a right to privacy as protected by the South African Constitution of 1996. Privacy implies the element of personal privacy, whereas confidentiality indicates the handling of information in a confidential manner. Confidentiality is also viewed as a continuation of privacy (De Vos *et al*, 2011: 120). The issue between anonymity and confidentiality implies that only the researcher and possibly few of his or her staff should be aware of the identity of the participants, and that the staff should also make a serious commitment with regard to confidentiality. Anonymity implies that no one – except the researcher and his or her assistants – can identify the identity of the subjects. It can be argued that the privacy of the subjects can be ensured by using proper scientific sampling (Polit & Beck, 2010: 340).

Babbie and Mouton (2010: 495) believe that a research project will guarantee confidentiality when the researcher cannot identify a given response for a given participant. In this study, the researcher ensured that information obtained throughout the study was treated with a high degree of confidentiality. Access to the data collected was limited to the researcher for the duration of the study. The data collected through interviews and recorded on the voice recorder as well as the answered questionnaire, will be kept in a password-protected locker for a maximum of five years after completion of the study.

1.7.4 Debriefing of participants

According to Babbie (2010: 71), debriefing of participants entails interviews to reveal any problems generated by the research experience to resolve those challenges. In this study, the participants were debriefed after each interview and they were asked about their views and their experiences of the interview. They were also asked whether they had any additional information they would like to share, comments and suggestion related to the study. The researcher ensured that all ethical considerations were strictly adhered to at all times.

1.8 LIMITATIONS OF THE STUDY

The primary focus of this study was on the road transport infrastructure sector of the City of Tshwane Metropolitan Municipality. All other means of transport, such as aviation, maritime and rail, were excluded. The road transport infrastructure sector was selected as the case study due to its significant contribution to GHG emissions compared to any other type. Other types of transportation contribute minimally to GHG emissions; hence, they are even recommended as better types to use in order to minimise the magnitude of climate change. In this instance, Dikgang (2013: 2) recommends that the South African government of the day should move many of the bus commuters and goods transporting heavy trucks from the roads to the rail infrastructure.

1.9 SIGNIFICANCE OF THE STUDY

The significance of this study is two-fold: practical and theoretical. The practical contribution of this study is that it revealed the impact of climate change on road transport infrastructure in the CTMM. Furthermore, the researcher found that climate change threatens and challenges the road transport infrastructure and recommends solutions to these problems. Theoretically, the study contributes to the knowledge of climate change and its relation to road transport infrastructure in a metropolitan municipality within the discipline of Public Administration.

The study provided a unique perspective and experiences of climate change events in the CTMM, and implications of these for the functioning of the road transport sector. The study further contributes to public policy. As far as climate change is concerned, there are two means of responding: mitigating and adapting. This study determined the extent to which mitigation and adaptation could assist in managing climate change

by curbing GHG emissions that can be achieved through road transport infrastructure policies and planning. Moreover, maintaining the road transport infrastructure effectively, efficiently and economically (that is, cost-effectively) will allow the public to adapt to climate change.

This study advanced the understanding of the phenomenon by investigating the capacity of CTTM to plan, build, maintain, repair and renew its road infrastructure in relation to the impact of climate change. Furthermore, the study also examined the allocation and management of finances and budgeting of the public road infrastructure in the municipality. The study brought under scrutiny the strategic issues in relation to infrastructure management, planning and potential implications for climate change adaptation. In order to meet the foregoing demands fully, the study employed a mixed-method research approach and a case study design. The literature review covered the concepts of climate change, public policy, transport policy, road infrastructure, adaptation to climate change and mitigation of GHGs, but was not limited to these. Lastly, the study offers recommendations on enhancing the planning, designing of the adaptation strategies and more climate-resilient road infrastructure. The benefit of this study to Public Administration as discipline lies in the recommendations made.

1.10 CLARIFICATION OF CONCEPTS

Road transport: Road transport refers to transportation of humans, goods and services from one point to another by means of road-based types of transportation (Walters, 2008: 99). In this thesis, road transport refers to transport for both public and private usage.

Adaptation: The IPCC (2011: 768) defines adaptation as an adjustment of a natural or human system to a changing environment. Thus, adaptation to climate change is an adjustment to natural and human systems in response to climatic stimuli. Adaptation involves perceptions of inter alia climate risk, practices to reduce risks, changes in social and environmental processes, and exploring new opportunities to deal with the changed environment.

Mitigation: For the purpose of this study, mitigation referred to the minimisation of the effects of climate change. According to Harris and Birjandi (2011: Online), mitigation measures involve the reduction of GHG emissions, either reducing the level of

emission-related activities or by a shift to energy-efficient and renewable energy technologies that permit similar levels of activities at a lower level of CO_2 emissions.

Climate change comprises a long-term change in the statistical distribution of weather patterns over periods that range from decades to millions of years (Coumou & Rahmstorf 2012: 491). This may relate to a change in the average weather conditions or a change in the distribution of weather events with respect to an average, for example, greater or fewer extreme weather events. Climate change may be limited to a specific region, or may occur across the whole earth.

Global warming refers to an increase in the earth's atmospheric and oceanic temperatures widely predicted to occur due to an increase in the greenhouse effect resulting especially from pollution (National Research Council of National Academies [NRCNA] 2008). Global warming comprises an increase of the earth's average surface temperature due to the effect of GHGs, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise have escaped from the earth.

Greenhouse gases (GHGs): Doll and Baranski (2011: 1) view GHGs as gas in the air that absorbs and emits radiation within the terminal infrared range. These gases essentially act as a blanket, making the surface of the earth warmer than it otherwise would be.

Management: According to Uzuegbu and Nnadozie (2015: 59), management is the process of realising institutional goals through people and other institutional resources.

Public policy: According to Cochran, Meyer, Carr and Cayer (2009: 1), public policy refers to government's actions and its intentions that determine the government's actions. McConnell and Hart (2019: 647) explain public policy as an action that employs the authority of government to commit resources supporting a preferred value. A set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them within a specified situation where those decisions should, in principle, be within the power of those actors to achieve (Head 2014: 144).

1.11 FRAMEWORK OF THE THESIS

This section provides a breakdown of chapters of this thesis.

Chapter 1: GENERAL INTRODUCTION

This chapter dealt with the introduction and background of climate change and further looked at the relationship between climate change and the road transport sector. The focus was on the impact that climate change has on the road infrastructure in the City of Tshwane Metropolitan Municipality (CTMM) specifically. The background to and description of the municipality and its perception of and reaction to climatic events were discussed in this chapter. The problem statement was stated, and the research aim and objectives were highlighted. The study area was identified and explained, and the motivation of this study was explained. Furthermore, the chapter dealt with the research questions and research design and methodology, and the limitations of this study.

Chapter 2: IMPACT OF CLIMATE CHANGE ON ROAD TRANSPORT INFRASTRUCTURE: THEORETICAL FRAMEWORK

This chapter will look at problem management theory and administrative management theory as a framework for this research. This chapter explains and discusses the concepts of climate change and road transport infrastructure, as well as the relationship between the two concepts. The historical development and international environmental management of climate change will be described briefly. Furthermore, the chapter provides a brief overview of the causes of climate change. The impacts of climate change on the road transport infrastructure are also discussed in detail.

Chapter 3: CLIMATE CHANGE MANAGEMENT MEASURES: CHALLENGES OF ROAD INFRASTRUCTURE

Chapter 3 focuses on the implementation of the climate change response measures for the road infrastructure. Furthermore, the challenges that arose during the implementation process of management measures were studied in detail and are discussed. The chapter also focuses on the financing aspect of climate change at local government level against the background of a developing South Africa.

Chapter 4: SOUTH AFRICAN LOCAL GOVERNMENT RESPONSE TO CLIMATE CHANGE: LEGISLATIVE FRAMEWORKS

This chapter focuses on the responses of the South African local government to climate change. The responses of two metropolitan municipalities, the City of

Johannesburg and the City of Cape Town were considered in terms of the management measures, such as mitigations and adaptations measure. Furthermore, the chapter reports on South African legislation available for addressing issues of climate change and road transport and its infrastructure at national and local level .

Chapter 5: RESEARCH DESIGN AND METHODOLOGY

The primary aim of this chapter is to outline the research design and methodology adopted in conducting this study. Issues are discussed, such as population sampling where the number of the population is given, data collection where the researcher decided to use a mixed-method approach, data sampling employing purposive sampling, and data analysis.

Chapter 6: RESEARCH FINDINGS, DATA PRESENTATION AND ANALYSIS

This chapter deals with the research findings about the nature and extent of climate change affecting the road transport infrastructure in the CTTM. The findings were analysed, and interpretation of the situation based on the findings was performed.

Chapter 7: CONCLUSION AND RECOMMENDATIONS

This chapter is the last one in the thesis. Here, the researcher provides recommendations based on all information gathered while researching and doing the study.

1.12 SUMMARY OF THE CHAPTER

Climate change poses serious consequences for the transport sector at large, and little attention is being paid to that as compared to other sectors, such as forestry, health and agriculture. Yet, it is common knowledge that South African transport systems perform worse under adverse and extreme weather conditions. Climate change shifts and adverse weather conditions affect infrastructure. In terms of the road transport infrastructure sector, most studies found focused on traffic safety and congestion only. In the literature consulted, little focus was put on the impact of climate change on the road infrastructure as such. The next chapter (Chapter 2) focuses on the theoretical framework of the study as a foundation for the research study. The chapter further contextualises climate change and explores its causes and impacts.

CHAPTER 2
THE IMPACT OF CLIMATE CHANGE ON ROAD INFRASTRUCTURE: THEORETICAL FRAMEWORK

2.1 INTRODUCTION

Road transport infrastructure is crucial in enabling interaction socially, economically and politically through the movement of goods, services and people (Friedrich & Timol 2011: 14). In addition, all sectors and communities are dependent on a well-functioning road transport infrastructure as an auxiliary in their functions (Department of Transport [DoT] 2018) However, despite the critical role of transportation in the economy of South Africa, transport also bears negative effects, such as pollution, congestions and accidents, resulting in increased GHG emissions. Furthermore, the transport sector is vulnerable to climate change and its effects. It is projected that climate change will have significant impact on the transport infrastructure globally (Fatima, Wilbanks, Abeysinghe & Burton 2015:16). Therefore, managing the impacts of climate change on road transport infrastructure becomes a necessity. A transport system is of importance to the socio-economic activities of all governments due to its ability to move people and goods (South Africa 2011). In terms of the South African Climate Change Response White Paper (South Africa 2011), climate change response measures could result in co-benefits, such as improved air quality, reduction of time between trips, and a decrease in accident rates (Klausbruckner, Annegarn, Henneman & Rafaj 2016: 72).

The purpose of this chapter is to discuss the impacts of climate change on road transport infrastructure in a municipal context. First, the theories underpinning this study are discussed. This is followed by an examination of the relationship between Public Administration and Management as a discipline, public administration as a practice and climate change. The significance of establishing this link is derived from the fact that this study was undertaken under the discipline of Public Administration, which is multidisciplinary in nature. The discipline of Public Administration coincides with many other disciplines such as Political Science, Public Policy, Public Finance Management, Environmental Management, and Transport Economics. It is important to understand the multidisciplinary nature of Public Administration because some scholars within the discipline such as Thornhill 2006; Denhardt & Denhardt 2009; Maserumule 2013 refer to it as a field that has enabled them to deal with complex

issues effectively. While Denhardt and Denhardt (2009: 12) maintain that the Public Administration has made scholars maintain balance between political and administrative issues.

This chapter conceptualises climate change and the researcher briefly discuss the causes and trends of climate change. The impacts of climate change on road infrastructure are visible through the effects on the infrastructures and the influence on the road operation. This chapter will address one of the research questions identified in Chapter 1, namely

> *What are the impacts of climate change on the road infrastructure of the City of Tshwane Metropolitan Municipality (CTMM)?*

Cochran *et al*. (2009: 1) indicate that the impacts of climate change are linked directly to the location. For one to understand the climate change impacts on a particular infrastructure, an analysis of various factors, such as geographical location and construction characteristics of the infrastructures, thus needs to be carried out. In this chapter, the researcher therefore discusses the vulnerability of the road transport infrastructure of the CTMM to climate change.

2.2 THEORIES UNDERPINNING THE STUDY

A theoretical framework was employed in this study to analyse three variables: management, climate change and road transport infrastructure. Climate change is a cross-cutting issue that affects the entire economy and other specific industries, such as agriculture, energy, forestry and transport. The impacts of climate change, such as damaged road surfaces due to severe rain downpours, require effective and efficient management from government. However, Madzivhandila and Niyimbanira (2016: 97) attest that, even though the existence of climate change and its irreversible impacts have been acknowledged, the South African government is still struggling to design a comprehensive, strong and integrated policy to manage the anticipated impacts.

2.2.1 Administrative management theory

This study employed the administrative management theory by Fayol (1949: 45). Administrative management theory seeks to find a cogent manner to establish an institution. Generally, the theory calls for a formalised management structure with comprehensible vision of labour and delegation of power and authority to officials with

applicable responsibility. The theory was fit for this research study because the study focused on an institution (i.e. City of Tshwane Metropolitan Municipality) and every institution requires management to succeed. Management entails the process of maintaining and designing an environment in which people can work together efficiently and effectively to realise the set aim and objectives (Mohaghar, Jafarnejad, Ghodsipoor & Maleki 2013: 1834). The importance of management as a determinant factor for institutional success has been reinforced in order to strengthen desirable behaviours. (Uzuegbu & Nnadozie, 2015: 59). Different people, such as Max Weber (1905), Frederick Taylor (1911), Elton Mayo (1923), Henri Fayol (1949), Abraham Maslow (1998), among others, conducted various studies on management. These theorists are now regarded as the predecessors of management scholarship. These studies have led to the establishment of other management principles referred to as theories, such as the problem management theory. This study applied the principles of the problem management theories referring to the administrative principles of management. Henri Fayol (1911) created administrative theory, which consists of 14 management principles:

1. **Division of work:** This principle is about division of labour amongst the employees.
2. **Authority:** The manager must be able to give the order. Authority gives the manager this right to the subordinates.
3. **Discipline:** Employees must obey and respect the rules and regulations that govern the organisation.
4. **Unity of command:** Every employee should receive an order or direction from only one upward or superior.
5. **Unity of direction:** Each group of the organisation should be directed by one manager using one plan.
6. **Subordination of individual interests to the general interest:** Management must see that the aims of the businesses are always supreme.
7. **Remuneration of personnel:** Labourers must be paid a reasonable salary for their work.
8. **Centralisation:** The process of transforming and assigning decision-making authority to a higher level of an organisational hierarchy. It is the centralisation that should follow this.

9. **Scalar chain:** Line of authority from top management to the lower ranks represents the hierarchy or scalar chain.
10. **Order:** People and materials should be in the right place at the right time.
11. **Equity:** A balance of kindness and justice is required when running a company.
12. **Stability of tenure of personnel:** Staff work is well if job safety and career improvement are guaranteed to the team.
13. **Initiative:** Allowing all personnel to show their initiative in some way is a source of stretch for the organisation.
14. **Esprit de corps:** Promoting team spirit will build unity and harmony within the organisation.

The above principles were applied during the current study. The application is discussed in detail in Chapter 7. Administrative management theory focuses on the management principles, and especially on managing growth that gives the managerial framework a constructive impact.

2.2.2 Problem management theory

Problem management is primarily about solving problems that often emerge in an institution making it difficult to achieve its set aim and objectives (Uzuegbu & Nnadozie 2015: 59). For instance, provision of adequate public road transport infrastructure that is reliable, safe and economical is the aim of municipalities (Uzuegbu & Nnadozie 2015: 59). However, climate events, such as flooding and hail due to precipitation, pose additional challenges to municipalities in realising the above aim. Problem solving entails problem identification, analysis and remedy implementation (Pine n.d.). Thus, the application of the problem management theory is crucial in managing the impact of climate change on road infrastructure. Below are the seven-steps for an effective problem management process as indicated by Pine (n.d.):

- identify the issues;
- understand everyone's interests;
- list the possible solutions (options);
- evaluate the options;
- select an option or options;
- document the agreement(s); and
- agree on contingencies, monitoring and evaluation.

The public road infrastructure is a special field of activity, and attention should be on the specifics ascribed to different activities. The problem management theory was especially appropriate to the study because of the nature of climate change that is unpredictable and uncontrollable.

Thoughts across various disciplines view climate change as a 'perfect' problem (Stern 2016: 3; UNEP 2016). Stern (2006: 2) in his review of the economics of climate change describes climate change as the "perfect market failure". Stern (2006: 2) also describes climate change as a "perfect moral storm". From these descriptions, it can be deduced that climate change is a real problem and that the impacts thereof need to be managed. According to the UNEP (2016: Online), climate change impacts are amorphous, with no deadlines, no geographic location, and no single cause or solution. Public policymakers and practitioners are beset with problems. Some of these problems are concrete, structured, solvable and easily definable. However, climate change is difficult to define because it is ill-structured and there is no lasting solution because climate events keep on changing and vary with geographical location and season (UNEP 2016: Online). The research topic at hand can be viewed as a non-public administration topic given the fact that climate change is an environmental issue in nature; thus, it falls within the environmental and geography studies. In the next section, the justification of the undertaking of this study within the discipline of Public Administration is presented.

2.3 CLIMATE CHANGE IN THE PUBLIC ADMINISTRATION DISCIPLINE

As a discipline, Public Administration has limited boundaries and theories that are exclusive to its field. Most conceptual frameworks adopted in Public Administration are borrowed from other disciplines (Maserumule 2013: 478). Due to this flexibility, the current study fitted in the discipline from two angles. Firstly, this study focuses on management as a field within the discipline; and secondly, it considered government functions in providing services through road infrastructure and road transport as services that ought to be provided to the public by government. Therefore, the importation of theories from different disciplines has resulted in Public Administration becoming a field of applied sciences in practice.

As a field of practice, public administration comprises the implementation of government policies, while as an academic discipline, it studies the implementation and capacitates civil servants to serve in the public sector (Denhardt & Denhardt 2007:

90–94). Public Administration assesses the phenomenon of management, organisation, decision-making and implementation phases, and explains political, social and economic changes. It refers to the social reality of people, budget and administrators (Denhardt & Denhardt 2009: 14). The locus of this study was local government activities and services to the public to satisfy the needs of society, particular the residents of the CTMM; thus, the process of public administration within the discipline of Public Administration.

An appropriate point of departure in addressing the locus of this study is to apply the public administration and public management approach. Public administration and public management are concerned with different categories of management, and it was argued that combining the categories would add value to the investigation intended by this study on the management of the impacts of climate change on road infrastructure. Public administration focuses on policies and generic functions (Denhardt & Denhardt 2009: 14). As Thani (2012: 28) explains, Public Administration studies the way government functions and scrutinises the activities of government. While public management focuses on the coordination of activities and support processes, management can be viewed as the way a system is operated (Thornhill 2006: 794). Government has a constitutional responsibility to provide public services, such as road transportation services, which include but are not limited to road infrastructure, road transport planning, public road transportation and weather forecasting. All these constitute the management activities of government. In this study, Public Administration was concerned with public policies and all their processes, while public administration was regarded as involved with services provided, such as road transport and weather services.

Public Administration scrutinises and studies the functions of government and its activities. In this study, the scope covered administrative theory and applied administration. Public Administration as a field of study addresses real-world problems; hence, Simon (1996: 7) calls it a “science of design”. From the publication of Woodrow Wilson’s “The study of administration” in 1887 to date, Public Administration as a discipline, has found its rightful place in both social and management sciences (Sahni 2003: 26). Maserumule (2013: 477–497) argues that the theory of Public Administration is not yet established if there are still unanswered questions around it. He further theorises that the discourse on the theory of public administration is also embedded in the New Public Management (NPM). Fatemi and

Behmanesh (2012: 42) state that Public Administration has developed since the days of Woodrow Wilson's studies (see above) and the developments are additions of management to the field of study.

The discipline of Public Administration has developed and is contributing to the enhanced quality of public service. The discipline revealed itself to the theories and practices perceived to be of the private sector (Denhardt & Denhardt 2007: 12; Thornhill 2006: 800). According to Diefenbach (2009: 894), New Public Management emerged from different paradigm of thinking about governance. It can be concluded that the introduction of New Public Management was meant to change something that was wrong in the governing system, particularly in the public bureaucracy. The traditional Public Administration discipline structures and public administration often did not produce the anticipated outcomes on social development; therefore, the development of New Public Management seemed to be an appropriate and better approach. Disappointing enough, the New Public Management did not deliver the expected results (Diefenbach 2009: 893). Consequently, most countries are no longer applying New Public Management principles because they contradict the core values of Public Administration and management. According to Thornhill (2006: 797), the focus of Public Administration is on government activities, which relate to the functions for which government accepts responsibility.

The South African government has a constitutional mandate to protect the environment and to ensure the safety of the citizens. In terms of the Constitution of the Republic of South Africa (1996), section 24(a) and (b) –

> [E]veryone has a right to an environment that is not harmful to their health or wellbeing and to have the environment protected, for the benefit of the present and future generations, through reasonable legislative and other measures that include the following:
>
> - Prevent pollution and ecological degradation.
> - Promote conservation.
> - Secure ecologically sustainable development and use of natural resources.

In executing this mandate, the South African government is faced with numerous problems and difficulties, such as climate change, which is incalculable, impossible to compensate and often invisible (requires experts to recognise and measure),

uncontrollable, and its impact and effects are often irreversible (Ferreira, Martins, Barbi & Ferreira 2011: 51). In managing the climate change problem, government has two options policy-wise, namely, mitigation and adaptation. Policy response is often divided along jurisdictional lines (see section 43 of the Constitution of the Republic of South Africa). In South Africa, this will be across the three spheres of government, namely national, provincial and local governments.

2.3.1 Generic administrative functions

Omotoye (2011: 37) argues that public administration is a systematic ordering of affairs, such as provision of housing, education, health and transport amongst others. Public administration consists of six generic administrative functions, namely public policymaking, organising, financing, control, staffing and work procedure.

Sections 2.3.1.1–2.3.5.5 present brief discussions of each function:

2.3.1.1 Public policymaking

Public policymaking is a process that involves stakeholders with various roles, interests and resources (Lemke & Harris-Wai 2015: Online.). Public policymaking is a process where the first phase is to identify the problem, which in this case is a "policy problem". According to Head (2017: Online), a public policy problem is the identification of complex social issues that require either government's response or dissatisfactions expressed by the people, and government ought to take action to address the matter. Thus, it is a goal-oriented course of action taken by government to deal with identified problems of the country. Hoornbeek and Peters (2017: 366) argue that there is a need for structuring the identified problem in order to enable governance.

The fact that climate change is seen as a threat to human wellbeing, economic and sustainable development spells out the necessity to have public policies that will address the threat and protect the threatened. Chapter 4 of this thesis describes the available legislative frameworks that address and protect the road infrastructure against climate change. Furthermore, the severances of the impacts and the consequences for future generations are more reasons to consider climate change response in public policies to regulate the climate change mitigation actions.

Nations around the world have taken initiatives to reduce their energy use and CO_2 emissions (IPCC 2014: 668). The initiatives are seen in policymaking and action plans. In some countries, national government is not effective in responding to climate change, and cities have taken upon themselves to act, even in the absence of the national government. For instance, the CTMM, Ekurhuleni Metropolitan Municipality, City of Cape Town Metropolitan Municipality and City of Johannesburg Metropolitan Municipality have each developed climate change strategies. They are therefore now in line with the national climate change imperatives to reduce the rate of change in the climate to naturally occurring levels, and to reduce the atmospheric concentrations of GHGs (Reddy & Wolpe 2018: 14). Public policy process has numerous stages such as agenda setting, policy formulation, implementation and evaluation. The stages are discussed below.

⇒ Public policy agenda setting

Agenda setting is a process whereby public policy problems are identified, defined and prioritised for actions (Berger 2001: 91; Cloete & Meyer 2006:105–108). Various definitions of agenda setting agree that agenda setting is a list of problems to which government officials and relevant stakeholders are giving attention at any given time (Cloete & Meyer 2006: 105–108). According to Cloete and De Coning (2011: 87), agenda setting is twofold: narrow and wide. In the narrow sense, agenda setting is preceded by identifying a problem and the ability to articulate the problem, while in the wider sense, it is the process of planning and action that defines and prioritises policy problems, mobilises support and lobbies decision-makers to appropriate actions. Governmental agendas relate to issues or problems that government officials and relevant stakeholders must address. For example, government interventions in mitigating the emissions of GHG and adapting to climate change through public policies are efforts to protect the public from experiencing severe impacts of climate change. Climate change is a global environmental problem that has a negative impact on the wellbeing of society and has costly implications. Unless addressed, the adverse effects of climate change have the potential to endanger economic and sustainable growth. For government to mitigate emissions effectively, policies need to be formulated and implemented to ensure effective actions and regulation of such actions.

⇒ Public policy formulation

When a policy problem has been identified, the policymakers need to decide on actions to be undertaken; thus, policy formulation. This stage encompasses declaration of intent as well as goal statement (Head 2017: Online). This stage marks the shape and direction of public policy. Policy formulation involves experts, policymakers and stakeholders. According to Head (2017: Online), the formulation stage is where the writing of public policy takes place before it is formally adopted. Mokhaba (2005: 78) indicates that during the formulation stage, acceptable and pertinent courses of action are proposed and formulated. Policy formulation involves assessing and exploring possible solutions or options to the identified policy problem.

A working group or committee is developed to address a policy problem. They (working group or committee) meet, discusses and sets the goals, priorities, actions, implementation strategies and monitoring tools in preparation and planning for policy formulation. In the context of climate change, the working committee discusses the mitigation and adaptation actions as the two available options to manage climate change to subsequently formulate a policy. Thereafter, the draft plan – known as a Green Paper in South African context – is published and disseminated for public opinion or participation; thus, recommendations from the public will be brought forward at this stage. The committee should prioritise policy that would be politically and financially feasible to have the largest emission reduction (Department of Cooperative Governance and Traditional Affairs [CoGTA] 2016: Online).

It is at the formulation stage where policymakers must identify areas where actions can result in multiple benefits. It is also at this stage where measurable benchmarks must be developed. The first appropriate step in developing such benchmarks for climate change in the transport sector would be to develop an inventory of GHG that identifies emissions from the transport sector. It is of great importance to integrate climate change with transport frameworks and plans to reduce the emissions rapidly. The implementation of the mainstreaming of climate change into transport policies is a prerequisite for climate-resilient infrastructure (Mashamaite 2018a: 584). This integration has a potential to reduce GHG emissions than the climate strategies that are not integrated into the existing mechanisms.

One of the policy challenges in responding to climate change in South Africa is the multilevel nature of governance (Lemke & Harris-Wai 2015: Online). South Africa has three levels of government, known as 'spheres', namely national, provincial and local. These spheres are constitutionally independent of each other but interrelated. Therefore, it is of utmost importance for these spheres to work closely together in responding to climate change. Local government is a sphere close to the people and serves as a vehicle for the implementation of nationally driven policies. Furthermore, climate change impacts are manifested and affect people at local level. Therefore, it is crucial for national government to empower, capacitate and enable local government to address issues of climate change (Madzivhandila & Niyimbanira 2016: 93). Each sphere of government has a significant variation across scales, opportunities and challenges. For instance, local government has autonomy over planning (i.e. the Integrated Transport Plan [IDP]) but the autonomy is limited. Local government has authority to make decisions on provision of service, such as public transport, but does not have any power in provision of roads which public transport has to utilise. The administrative management theory needs to be applied in this regard by delegating powers to the local sphere.

The local government is only expected to maintain the roads provided by the provincial government (Pasquini, Cowling Ziervogel 2013: 225). The division of autonomous authority limits the potential of lower spheres to act. Therefore, it is important for the national sphere to understand how to clarify goals in local context and to work closely with the lower spheres of government in implementing policies and actions. For instance, the Chinese national government is responsible for policies addressing climate change in that country but they allow local administration to interpret the policies to their own advantage (Parry, Shang, Wingender, Vernon & Narasimhan 2016: 22). This flexibility has assisted China in implementing their climate change policies at local level (ibid). After a policy has been formulated, the next step is to implement such policy.

⇒ Policy implementation

It is at this stage that the ideals and intentions of policymakers are tested (Howlett 2011: 6). The implementation stage appears to be the most problematic one in terms of practical policy execution. Good public policies are formulated in government consistently in order to develop and restructure change in government, with a well-

designed programme on implementation practice. Roux and Van Rooyen (2002: 221) view failure to implement policies as a symptom of policy failure. Climate change has been declared problematic globally because of emissions and their impacts. In order to reduce emissions and to manage the impacts, dedicated policies are needed. In managing the impacts of climate change, it is crucial to reduce GHG emissions. This can be done through policy interventions. Creutzig and He (2009: 122) believe that policy interventions will ensure that emitters change their behaviour, which will assist in reducing the GHG emissions. However, it should be borne in mind that successful mitigation and adaptation policies will be visible when GHGs are reduced and the impacts are managed. This process takes place through law enforcement to ensure compliance. After implementing the policy, the next step will be to assess whether the policy is achieving the set objectives or the intended purpose, in a process called 'policy evaluation'.

⇒ Policy evaluation

Policy evaluation has to do with evaluating the effectiveness of policy in line with its intended purpose and outcome (Gerston 1997: 120). Policy evaluation is a process of comparing set policy objectives with anticipated outcomes to assess whether the policy is working. According to Shafritz (1998: 820, cited in Cloete & Wissink 2005: 212), the following are reasons for undertaking policy evaluation:

- for purposes of public relations;
- to test the feasibility of a principle, theory, assumption, model or strategy;
- to measure progress made in the achievement of set policy objectives;
- to provide financial or political accountability;
- to redesign or implement strategies; and
- to learn lessons from a programme or project.

Government prefers to incorporate evaluation into the policy process for effective evaluation process (Bennear & Coglianese, 2004: 27).

2.3.1.2 Organising

According to Du Toit and Van der Waldt (1997: 4), organising involves development of institutions responsible for different operational areas and grouping of certain operational activities. Establishing structures responsible for a specific functional unit to achieve policy objectives. When people cooperate to achieve policy objectives

administration becomes visible, and for people to work together, there should be organisation. In responding to climate change, different structures must work together, i.e. there must be organisation. South Africa (2011) has set some objectives but for the country to achieve them, there must be operations involved in creating and maintaining organisational units.

According to Thornhill (2012: 126), organising includes comprehensive coordination to ensure that tasks are channelled at achieving the set objectives of the institution. Organisational structure provides workers with a detailed chain of command that clearly stipulates who is responsible for what and who reports to whom (ibid). It is a common practice for superiors to often delegate responsibilities to their subordinates but accountability cannot be delegated as clearly stipulated in the Public Finance Management Act (PFMA) (No. 01 of 1999) (South Africa 1999) and the Local Government: Municipal Finance Management Act (No. 56 of 2003) (South Africa 2003). For set objectives to be achieved, workers must perform necessary tasks. However, every department in every sphere of government has an obligation to mitigate and/or adapt to climate change.

The CTMM, like any other municipality, has the responsibility to mitigate the impacts of climate change on road transport infrastructure by reducing GHG emissions through various programmes, strategies and actions. In executing this responsibility, the municipality must apply comprehensive coordination and create and maintain units responsible for addressing climate change. For instance, in 2013, the CTMM has created a City Sustainability Unit responsible for climate change response measures working together with every other unit to address the issues of climate change (Hrechyshkin 2016: Online). Policies concerning the environment, infrastructure and transport must be promulgated and objectives set. Therefore, organising becomes crucial for achieving the set environmental climate change policy objectives. Additionally, financial resources are important for achieving set policy objectives.

2.3.1.3 Financing

Financing is the process by which the finances of the organisation or department are administered (Moeti, Khalo, Mafunisa, Makondo & Nsingo 2007: 43). Government needs money to undertake any activity. For government to provide in terms of basic needs, such as health, education, housing and transport, financing is needed.

According to Gildenhuys (2017: 86), government depends on its people to generate money through income tax. Another means that the government departments use to generate money is by raising loans nationally and internationally as well as attracting international and national donors (Moeti et al., 2007: 40). In terms of section 5 of the Public Finance Management Act 1 of 1999, the National Treasury, through its monitoring process, must ensure that the funds provided are utilised effectively and are accounted for (South Africa 1999). Thus, the National Treasury must see to it that the government departments utilise funds efficiently and effectively.

To ensure the effectiveness of the financing function, the National Treasury has developed treasury regulations that are amended regularly in line with any amendment of the PFMA to guide government departments, public entities and constitutional institutions on the best management of public resources (Gildenhuys 2017: 56). To give effect to this, new financial management and reporting systems are continuously being developed to move away from those systems that are based on the old Exchequer Act, No. 66 of 1975 (RSA, 1975). The budget and the annual allocation of funds should be on the Medium-Term Expenditure Framework basis (Thornhill, 2012: 127). This budget allocation mechanism ensures that managers know in advance the amount of money allocated to their departments (indicative allocation) during a particular rolling three-year period, based on their strategic plans. According to Mashamaite (2018b: 450), indicative allocation enhances planning, and allows managers to plan their three-year future activities. Therefore, service provision is ensured to continue, and chances of possible disruptions are reduced to the minimum.

Climate finance, like any other government service, is also sourced from public funds and other sources, such as private funders and international funders through the UNFCCC. The South African government has established finance systems across its three spheres to deliver on the agreed outcomes for the mainstreaming of climate change in the development mandate and for catalysing climate investments. Currently, the government climate finances are the National Treasury, the Green Fund and the South African Renewable Initiatives (DEA, 2014). Public finances are handled in a predetermined manner to ensure that funds are applied cost-effectively for the intended purposes. For all services to be efficiently provided, control has to be exercised as will be discussed below.

2.1.3.4 Control

Government activities should always be conducted lawfully and legitimately. Control ensures that public officials act responsibly and carry out activities in terms of the prescribed standards. According to Cloete and Rabie (2008: 67), control is linked to governance with specific reference to openness, participation, accountability, effectiveness and coherence. Control is applicable to financing, staffing, procedures and methods, and organising (Cloete & Rabie 2008: 66). Furthermore, Cloete and Rabie (2008: 67) assert that control measures comprise reporting on the outcome of set goals, and auditing to determine whether income and expenditure comply with legal requirements. In order to ensure that all administrative and functional activities are performed effectively and efficiently in order to achieve objectives, control has to be exercised (Du Toit & Van der Waldt 1997: 15). The significance of exercising control in terms of the administration of government departments and public entities as well as constitutional institutions is that control enhances accountability and transparency of government activities.

There are two types of control, namely internal control and external control. According to Cloete and Rabie (2008: 66), internal control is exercised through institutional situations created by policymaking, organising, work procedure, finance and prescribed rules. This control is exercised by the executive functionaries. Internal control includes inspections and standard working procedures. External control, on the other hand, is exercised in South Africa by the national legislature through its committees, the Auditor-General and the Public Protector (Cloete & Rabie, 2008: 66). As far as climate change is concerned, control is critical to manage the GHG emission levels and the impacts of climate change. In an attempt to control the challenges posed by climate change, different governments have various mitigation and adaptation policies, strategies and plans. Controlling is a long-term ongoing process with different complexities and impacts across the globe.

2.3.1.5 Staffing

Government departments often have a division that deals with staffing based on legislation by the government of the day (Van Dijk 2013: 4). The unit responsible for staffing in government departments is usually referred to as human resource management. The Human Resource Management has to do with employee

satisfaction, motivation and performance. Staffing involves hiring and training of personnel and maintaining favourable working conditions in the institution. All South African municipalities have to capacitate themselves by hiring experts on climate change and enhance capacity building. Furthermore, training and education about climate change and its impacts can be provided to municipal personnel to equip them to best manage the impacts of climate change.

2.3.1.6 Work procedure

Work procedures serve as a guideline for officials, as they determine which official carries out which function. The determination of work procedures involves drafting of instructions to be followed when carrying out functions. Determination of work procedures makes systematic coordination of functions and other work procedures necessary. According to Cloete (2012: 246), workers and/or officials should strive to establish an appropriate work procedure to carry out the legislative and administrative functions. Work procedures entail exactly the tasks to be performed and how the tasks should be performed. In managing climate change, the CTMM first has to carry out their functions of managing the environment (this element will be discussed in detail in section 3.4). There are other environmental challenges, which – if work procedures are not followed – have the potential to exacerbate the impacts of climate change on road infrastructure. These environmental challenges (to be identified in section 3.3) often create the wrong impression that they are the climate events while they are issues of management and maintenance. Climate change was one of the variables for this study; therefore, understanding what climate change is and what are its causes became an important aspect in this study. Section 2.4 conceptualises climate change to give it a meaning for this study. Its causes and impacts are also discussed.

2.4 CONCEPTUALISING CLIMATE CHANGE: CAUSES AND TRENDS

Climate change is defined as “any change in climate over time, whether due to natural variability or as a result of human activity” (Pielke 2019: Online). Mahmood (2012: 223) defines climate change as an average weather condition of an area characterised by its own internal dynamics and by changes in external factors that affect climate. Allen *et al*. (2018: 2) and DiMento and Doughman (2014: 5–6) expand their definitions of climate change to the involvement of both changes in average conditions and changes in variability including extreme events. Climate change is therefore long-term shifts in weather patterns in specific region. Therefore, from the above-mentioned definitions,

it can be deduced that climate change are shifts in weather conditions recognised by changes in weather conditions. Climate change implies change in addition to increasing temperatures, while global warming refers to warming of the planet earth because of human activities. The IPCC (2013: 22) sees global warming as an unequivocal and continuing rise in the average temperature of the earth's climate system.

Climate change is a state of the climate that can be identified by changes in the mean and the variability of its properties due to natural variability or human activity (IPCC 2007:17). There are various definitions of climate change from different authors, but they all emphasise that climate change is a change in the climate over time due to natural and human activities. Climate change can be defined as changes in the earth's weather, such as changes in the atmosphere because of increases in GHGs and carbon dioxide (Mahmood 2012: 223; McLusky & Sessa 2015: 2). The UNFCCC (2011: Online) defines climate change as a change in climate that is directly or indirectly attributed to human activities, which damage the global composition of the atmosphere in addition to observed natural climate variability over different times.

A deduction from various definitions of climate change indicates a relationship between climate change and human activities. Scientific studies prove that climate changes are due to GHGs emitted from burning fossil fuel (see, for instance, DEA 2011; UNEP 2016; Allen *et al.,* 2018). This fact disputes the possibility that climate change is caused by biogeographical cycles of the planet only. McLusky and Sessa (2015: 11) argue that, if climate change was indeed just a naturally caused problem, it would mean that there is nothing that can be done about it except accepting and coping with it. Stern (2006: 3) warns that climate change is a cross-cutting challenge with consequences for economic development, social cohesion and the human environment. Climate change and global warming are often used interchangeably, although climate change implies changes in addition to the increasing temperatures (IPCC 2014: 826), while global warming on the other hand refers to the warming of the planet as a result of the human activities, such as burning of fossil fuel and deforestation, which ultimately form GHGs in the atmosphere.

Figure 2.1 below illustrates the natural warming process based on the greenhouse effect where the majority of sunlight emitted onto the earth's surface is absorbed by the ocean and the land. The remaining infrared energy radiates outwards from the

earth, and is either absorbed by the GHGs emitted into space or reflected back towards the surface of the earth (National Research Council of National Academies [NRCNA] 2008):

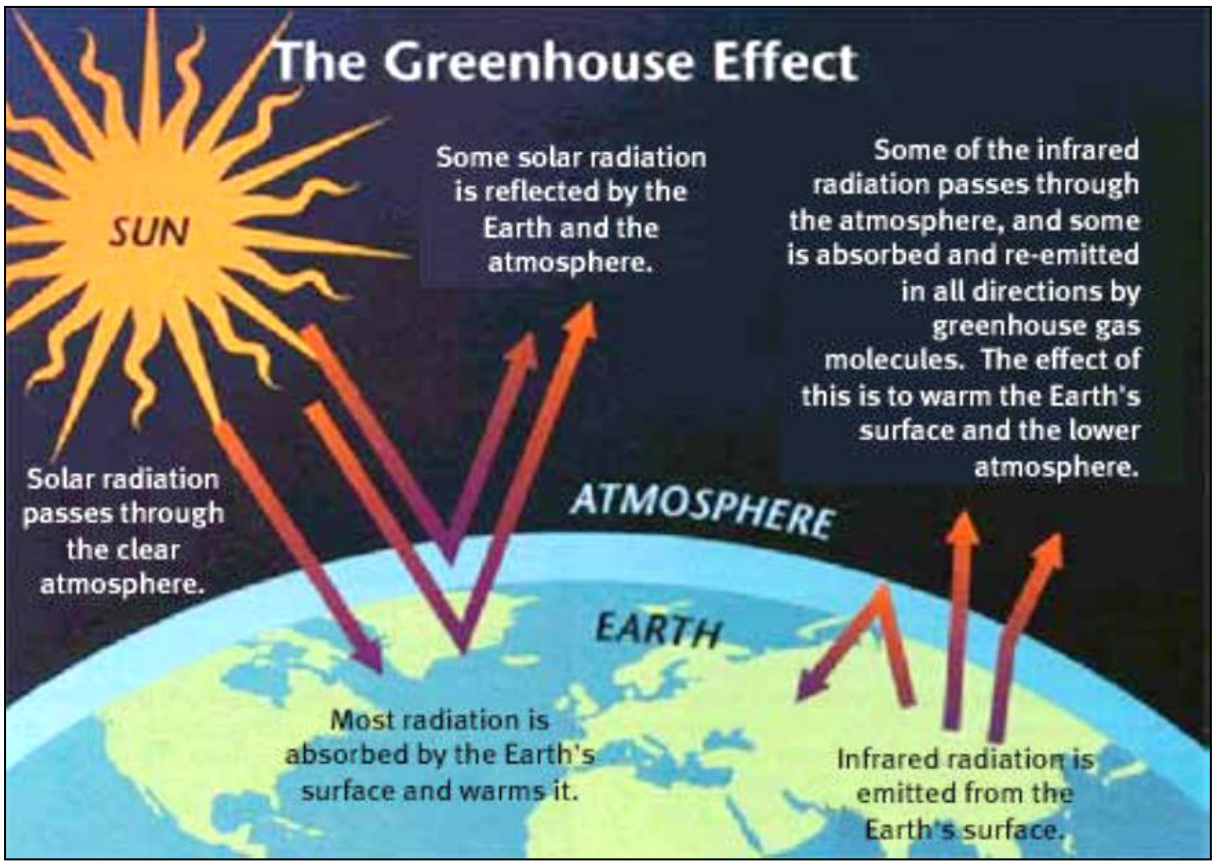

Figure 2.1: The greenhouse Effect

Source: NRCNA (2008: Online).

The strong global warming observed since the middle of the twentieth century has been largely attributed to human influences on the climate. Global warming refers to the observed long-term rise in global average surface temperature and is one manifestation of climate change (Denchak 2016: Online). Over the last half of the twentieth century, the rate of global warming was about twice that for the whole century (Allen *et al.*, 2018: ii). Recently, scientific evidence has proved that global warming has occurred at a rate of 0.2 °C per decade, leading to observable changes, such as varying rainfall patterns, rising sea levels, melting of ice and snow, and an increase in the intensity and frequency of extreme weather events (Bacchus, 2019: 2). Climate change is a global issue, and it will affect everyone, although the impacts, the costs and degree of the impacts will vary, based on regional context.

Climate change has the potential to affect the environment and the economy adversely unless action is taken to reduce the GHG emissions and to prepare for climate change impacts, because these will alter global and local climates. Despite the dominant role of the oceans in energy storage, the term ‘global warming’ is also used to refer to increases in average temperature of the air and sea at the surface of the earth (IPCC 2011: 687; I2013: 677). Land use changes, such as deforestation and conversion of land to agriculture, have also contributed carbon dioxide to the atmosphere (Mastrandrea & Schneider 2010: 25). The human influences on the climate system have increased substantially. Global warming is the overall warming of the planet, based on average increases in temperature over the entire land and ocean surface (Denchak 2016: Online). The NRCNA (2008) asserts that the release of GHG emissions, including carbon dioxide, methane, nitrous oxide and halocarbons causes global warming.

Global warming is the increase of the earth’s average surface temperature due to GHGs, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap the heat that would otherwise have escaped from the earth. Global warming refers to an unequivocal and continuing rise in the average temperature of the earth’s climate system (IPCC, 2013: 680). South Africa has relatively high emissions for a developing country, measured either per capita or by GHG intensity (emissions per unit of GDP). By any measure, South Africa is a significant emitter of GHGs in Africa (Economic and Social Council 2017: Online). Currently available analyses indicate that, unchecked by climate mitigation action, South Africa’s emissions could grow rapidly by as much as fourfold by 2050 (Busayo, Kalumba, & Orimoloye 2019: 2). Most South Africa’s emissions arise from energy supply (electricity and liquid fuels) and use (mining, industry and transport).

2.4.1 Climate trends

Climate change is a phenomenon that affects all economies globally at all spheres, although the effects and impacts are not equal (IPCC 2007: 35). For one to understand the regional trends of climate change, the global trends, effects and impacts should be explored. The IPCC (2014: 35) reports that, because of climate change, planet Earth will experience more frequent hot days and nights and fewer cold days and nights. The IPCC report further warns that these increases in temperatures will head to significant changes throughout the Arctic, which will result in heavy floods. The

International Energy Agency [IEA] (2016) alerts that there is a 90% chance that global temperatures will rise by 3.5 °Celsius to 3.7 °Celsius in less than one hundred years. This increase in temperatures could result in rising sea levels, volatile weather patterns, water shortages and other secondary effects.

2.4.1.1 Global trends

Climate change is having a significant impact on economies, ecosystems and communities (Houghton 2009: 175; Sango 2013: 20). Climate models have been developed to provide accurate stimulations of climate trends (Adelsman, Ekrem, Binder, Cook, Cooper & Helbrecht 2012: 203; IPCC 2013: 645). These models have proved that climate change trends observed over the years are the results of increased concentrations of GHGs. The gases are mainly carbon dioxide and methane, resulting from human activities, such as burning fossil fuels. Climate models project trends, such as increased precipitations and increased variable weather events, including severe storms, floods, tornados and hurricanes (Adelsman *et at.,* 2012: 205). These variable weather events have been very disruptive to the transportation systems and operations in the period. Globally, transport systems have experience climate change impacts. For instance, India, Japan, China, South Africa and Brazil (the BRICS countries) experience severe precipitation events, flooding and hail that damaged roads, bridges and vehicles. It is projected that in the coming years, the transportation sector will be affected by changes in precipitation and extreme weather events globally (Moretti & Loprencipe 2018: 4). Thus, the transport infrastructure designs will be affected.

Developing countries are under a serious threat of climate change and must devise means for adaptation and mitigation of climate change because they are most prone to harmful impact of climate change (Busayo, Kalumba, & Orimoloye 2019: 1). For instance, transport infrastructures are damaged as a result of the effects of climate change. In fact, Busayo, Kalumba, & Orimoloye (2019: 2) assert that climate change adds stress to the already existing strain on budgets for maintaining and replacing transport infrastructure. Extremely high temperatures cause road surfaces to develop cracks more easily early in their lifespan (Twerefou, Chinowsky, Adjei-Mantey & Strzepekvan 2015: 11951). Furthermore, precipitation causes roads to develop potholes and existing potholes to deepen more rapidly (ibid).

2.4.1.2 Trends in Africa

Africa is exposed and vulnerable to climate change and variability (IPCC 2011: 259; Serdeczny, Adams, Coumou, Hare & Perrette 2016: 1). Africa's economic profile makes it difficult for the continent to adapt to climate change predicted by the models as described above (see sections 2.4.1.1). According to Kraemer-Mbula and Scerri (n.d.: Online) –

- South Africa has a relatively developed economy;
- Angola is a large oil producer;
- Lesotho, Zambia, Tanzania, Malawi and Mozambique are the least developed countries;
- Swaziland, Botswana and Namibia have small to medium economies; and
- Zimbabwe is experiencing economic problems.

With this kind of profile and development indicators, Africa is highly vulnerable to climate change.

The vulnerability of Africa to climate change is a result of a number of influences, such as:

- mountainous topographies in countries such as Rwanda;
- heavy rains and floods contribute to erosion in the northern region of Africa;
- climate change impacts are already vivid in Tanzania, and they threaten to harm the registered achieved developments (UNFCCC 2014: Online).

Africa is therefore generally regarded to be the continent most vulnerable to climate change (Serdeczny *et al.,* 2016: 5). African nations have a low response rate to climate change because of their limited financial resources, high levels of poverty as well as shortages of skills and technologies (Serdeczny *et al.,* 2016: 6).

It is reported that from 1970, the African continent has experienced over 2 000 natural disasters (UNISDR 2010: Online). Moreover, the Africa Growth Initiative at Brookings Institution (2018) reveals that seven out of ten countries that are considered the most vulnerable to climate change globally are found in Africa. African cities are experiencing increased extreme weather events. Countries such as Ghana, South Africa and Rwanda will experience change in rainfall patterns and increased temperatures because of climate change (Kraemer-Mbula & Scerri nd: Online). The road transport infrastructure is susceptible to damages. According to UNFCCC (2014),

the change in rainfall patterns will cause damage to bridges and roads and increase landslides and potholes, while, the increased temperatures will increase pavement buckling.

It is projected that climate change will increase the intensity of extreme weather events in Africa. Heat waves are projected to become more severe (Leard & Roth 2015: 17). These changes will increase road infrastructure damage, disruptions, traffic delays and failure across the road transport system. Moreover, these changes have the potential to develop new potholes, expand the existing potholes, create rutting (caused by repeated passage of vehicles) and will put stress on bridge joints. Heat waves will limit the activities of construction in regions with high humidity. Maintaining, building and rebuild roads are costly enterprises.

Heavy rains will result in flooding, which will disturb traffic, delay construction activities, and weaken or wash out the soil and culverts that support roads, tunnels, and bridges.

2.4.1.3 Trends in South Africa

The emissions from the transport sector are mostly from road transport usage, such as driving of private, freight and public transport vehicles (Merven, Stone, Hughes & Cohen 2012: 3). South African economic growth is causing increased urbanisation and use of road vehicles. The increase in cars leads to traffic congestion, pressure for road space, and a reduced availability of parking. The pressure put on the road surface, together with weather events, leads to damaged road infrastructures, which may lead to an increase in road accidents. This adds to difficulties of providing reliable, safe and efficient public road transport as well as safe facilities for pedestrians and cyclists. In terms of the South African National Climate Change Response Strategy (South Africa 2011), there are identified transport sector mitigation programmes that combine energy efficiency and emission reduction programmes for vehicles. Few studies have been conducted on the impact of climate change on transportation in South Africa, such as Schade (2011), EEA (2013) and Serdeczny *et al.,* (2016). As a result, projecting the potential impacts of climate change is a complex challenge for transportation decision-makers.

For decades, South Africa has experienced flooding in some areas, such as Durban, Johannesburg and Tshwane, which resulted in badly damaged roads. The northern parts of the country are warmer than the southern parts, while local predictions indicate

that by 2050 the average temperatures will rise by two degrees and the winter temperatures by three degrees (Department of Environment Affairs and Tourism [DEAT], 2009). These temperature increases will cause heat waves that may contribute to heavy rainfall leading to flooding and storm waves. Climate change impacts also have the potential to affect the South African road transport infrastructure and operations negatively. The infrastructure such as subway, bridges and roads are vital attributes of the cities. However, if the ecosystems on which these infrastructures are based are unable to adapt to climate change, they will become liabilities (World Bank, 2010).

The occurrence of droughts, floods, heat waves and severe storms and hailstorms are expected to increase in intensity and frequency (CTMM, 2015a: 38). This will affect road transport infrastructure, consequently, road transport operations and demand will be affected. As climate change occurs, the CTMM experiences some impacts, such as flooding and heat waves. In 2018, flooding in some instances has already resulted in damaged roads and bridges, which were closed for some time in areas such as Centurion and Mabopane (The Citizen 2018: Online). The city has also experienced hailstorms that have damaged public and private properties, such as solar heating systems and vehicles. The picture below shows one incident where a road and a bridge were washed away by heavy floods in Mabopane Township within the jurisdiction of the CTMM.

Figure 2.2: The collapsed Mabopane road and bridge

Source: The Citizen (2018: Online)

Due to the collapsed bridge and damaged road, access to the city was limited and the communities were affected in terms of access to the work place, schools, shopping centres and health facilities (CTMM 2015a: 33). In its annual financial report of 2016, the municipality indicated that the recovery measures of constructing affected road infrastructures to full functionality is financially strenuous to the municipality as they do not budget for such risks. This area of Mabopane is amongst the areas with high levels of vulnerability due to the geography and the socio-economic status of the inhabitants.

2.5 URBANISATION AS A CONTRIBUTORY FACTOR TO CLIMATE CHANGE

Climate change and urbanisation are inseparable (Miller & Hutchins 2017: 345). Urbanisation is a pivotal factor because of the potential to grow the economy and increase connectivity (Miller & Hutchins 2017: 346). However, the researcher has observed that urbanisation is increasing both problems and opportunities for metropolitan municipalities and complicates the management of the impacts of climate change on road infrastructure. IPPC (2014) notes that many of the key and emerging climate-related risks are concentrated in urban areas and are linked to rapid urbanisation and associated with communities living in informal settlements. The

South African National Climate Change Response White Paper (South Africa 2011) also recognises the urban climate change challenge. It specifically mentions the vulnerability of informal settlements to hazards, such as floods, and the rapid growth of water demand in urban centres.

According to UN-HABITAT (2015), urban areas are vulnerable to severe impacts, such as earthquakes, rainstorm surges and impacts caused by climate change. The people in urban areas produce waste in solid, liquid and gaseous form for self-sustainability and pursue business activities, such as manufacturing or services. Due to the high population density in urban areas, neither food nor raw materials nor energy can be produced locally.

Urban areas are prone to flooding when rainfall occurs. Buildings, roads, infrastructure and other paved areas prevent rainfall from filtering into the soil; thus, producing more runoff. Heavy and/or prolonged rainfall produces high volumes of surface water in the CTMM that overwhelm storm-water drainage systems. In the United Kingdom, the City of London, rarely experiences this problem because good provision for storm and surface drainage is built into the urban fabric, with measures in place for flood protection (Folberth, Butler, Collins & Rumbold 2015: 238). For example, parks and other open space areas are used to cater safely for floodwaters due to unusually violent storms.

This study acknowledges the existence of climate change and argues that there is no debate over its existence. However, the study postulated that a lack of environmental management (see section 3.3) escalates the severity of the impacts of climate change. Consequently, the management of the impacts of climate change becomes a daunting task for the cities in South Africa. This argument will be proved throughout the thesis, specifically in the next chapter. To form a foundation for this argument, it would be beneficial to the reader if the researcher paints a picture of which other environmental challenges affect the sector, and the link to the Millennium Development Goals (MDGs).

In 2000, all 191 United Nations member states adopted the MDGs, reflecting the contribution by the international community to the growth of the world's poorest regions and to help the most vulnerable (World Health Organisation [WHO] 2018). Six priorities are central to the MDGs, each with a set of objectives and metrics to ensure a

consistent assessment and to monitor progress at national and local government spheres towards achievement of the MDGs (WHO 2018):

- quality material for road infrastructure;
- regulations;
- incorporating climate change issues into design and building;
- land use policies;
- financial incentives; and
- public awareness about climate change

The above are essential in addressing climate change in an effective, efficient and cost-effective manner.

2.6 THE INFLUENCE OF ROAD TRANSPORT ON CLIMATE CHANGE

Road transport plays a pivotal role in energy use and emissions of GHG globally. The IPCC (2013: 658) reports that road transport accounts for over a third quarter of global GHG emissions, private cars and freight trucks being the main contributors. The road transport sector is reliant on oil-based fuel, consequently, the CO_2 emissions from the sector is proportional to its energy use. Well-designed road transport policies and infrastructure can reduce risks associated with climate change, such as air pollution and traffic injuries (Klausbruckner *et al.,* 2016: 73). Under the 'Business as Usual' scenario, global transport energy use is projected to grow by 80% until the year 2030 with parallel rise of emissions, while the number of vehicles is projected to triple by 2050 (Economic and Social Council, 2017: 1). Figure 2.3 below illustrates the global GHG emissions per sector. It is clear that the road transport accounts for a large portion of emission within the transport sector globally. The figure shows that out of the 17% of emissions from the transport sector, road transport accounts for 10% while air and others are responsible for only 7%.

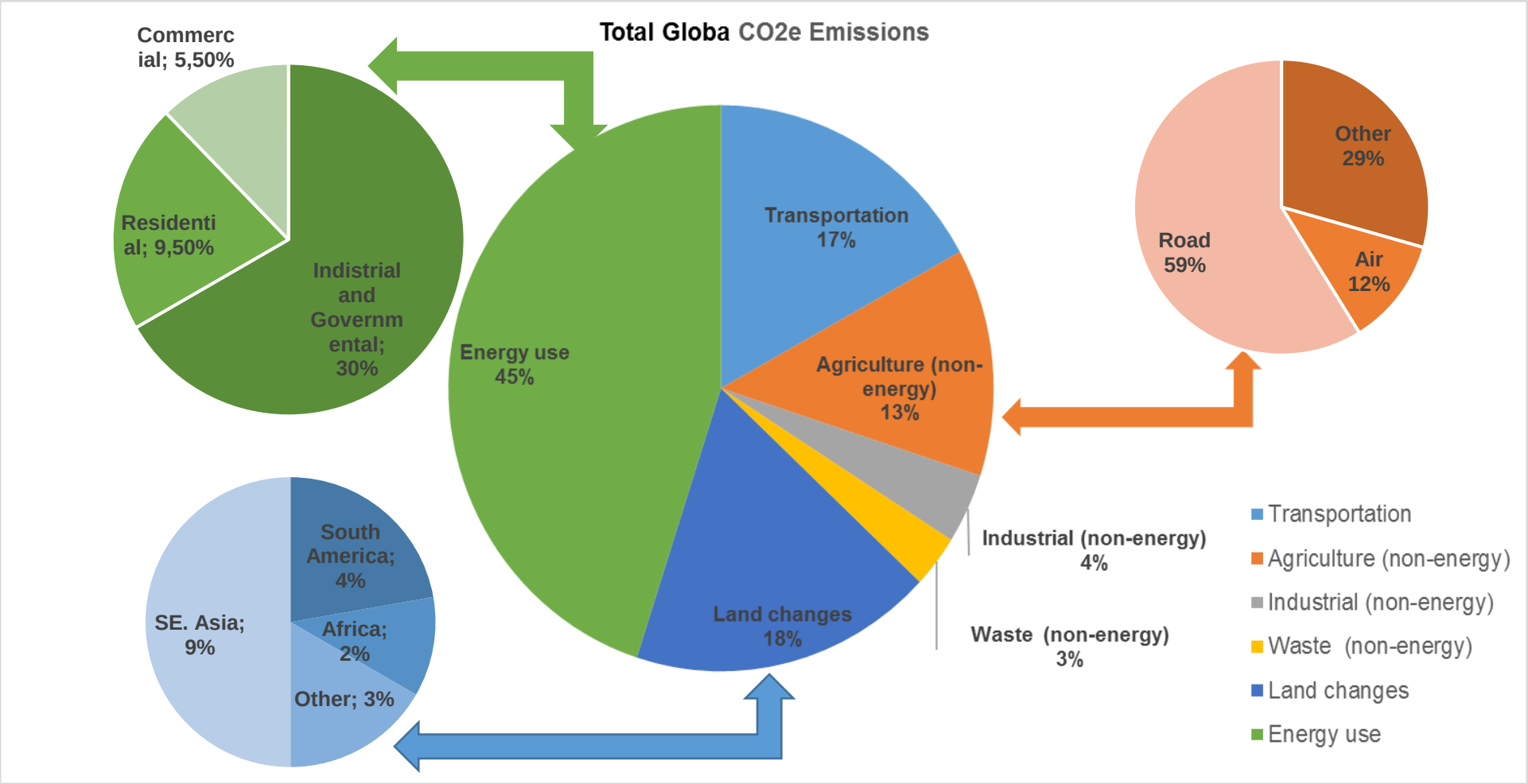

Figure 2.3: Total global CO_2 emissions

Source: International Energy Agency (IEA) (2016)

Growing urbanisation and the demand for mobility are amongst the world's challenges which indirectly influence climate change. Usage of private vehicles is expected to develop exponentially at an unprecedented pace because of urbanisation, affordability and vehicle availability. This growth will contribute considerably to air pollution, road traffic accidents and congestion, resulting in GHG emissions increasing (Miller & Hutchins 2017: 349). Ribeiro and Kobayashi (2007: 329) argue that the growth of passenger vehicles in terms of size, weight and power increases transport energy use and carbon emissions. Vehicle technology has notably improved, but the improvement is on size and power rather than on fuel efficiency, which would be more beneficial.

According to the UNISDR (2012: Online), if power and size of the vehicles are not increased but rather decreased, fuel consumption will drop or decrease; carbon emissions will therefore be reduced. Currently, the situation is the opposite of what the UNISDR envisages. The size and power of vehicles are increased and fuel consumption is very high. As a result, emissions are increasing. Bartholomue and Filho (2008: 1179) are of the opinion that the age of the vehicle, its technology, weight and the driving habits of the owner, such as speeding, contribute to vehicle emissions. Other characteristics, such as traffic volume, average speed, types of vehicle, number of lanes and road conditions also affect vehicle emissions. For instance, poor road conditions could lead to accidents. As a result, there will be congestion on the affected road and consequently more emissions. Mashoko, Bean and Steyn (2014: Online) attest that when the road is rough due to a lack of maintenance, it increases GHG emissions.

According to Mashoko, Bean and Steyn (2014: Online) the CSIR conducted research to show the environmental effect on carbon emissions of South Africa's various road infrastructures and how road roughness raises carbon emissions when calculated against the International Roughness Index (IRI), the kilometres per hour rise on the road. In their article, they presented Table 2.1 to indicate the effects of road roughness on GHG emissions:

Table 2.1: Effect of road roughness and GHG emissions at different speeds

GHG emissions (kg/km)					
	Weighted IRI (m/km)	**60 km/h**	**80km/h**	**100km/h**	**120km/h**
Very good	1	0.68	0.94	1.28	1.76
South African (SA) average	2.1	0.68	0.94	1.28	1.76
Poor	2.7	0.68	0.94	1.29	1.77
Very poor	8.1	0.93	1.19	1.57	2.13

Source: Mashoko *et al.* (2014: Online)

The table 2.1 above indicates that in bad conditions, road networks contribute significantly to high GHG emissions per kilometre. Therefore, regular road maintenance is crucial in reducing GHG emissions. As indicated in Table 2.1, South African roads are not in best of conditions; thus, emissions will be increasing rapidly. The table 2.2 illustrates the effect of road roughness on GHG emissions for South African national and provincial road networks:

Table 2.2: Effect of road roughness on GHG emissions for SA road network

			GHG emissions (kg/km)		
	Weighted IRI	**60 km/h**	**80 km/h**	**100 km/h**	**120 km/h**
SANRAL	1.68	0.68	0.94	1.28	1.76
Limpopo	1.64	0.68	0.94	1.28	1.76
Gauteng	1.85	0.68	0.94	1.28	1.76
Northern Cape	1.89	0.68	0.94	1.28	1.76
Western Cape	2.12	0.68	0.94	1.28	1.76
Eastern Cape	2.2	0.68	0.94	1.28	1.76
North West	2.27	0.68	0.94	1.28	1.76
Mpumalanga	2.5	0.68	0.95	1.29	1.77
Kwa-Zulu Natal	2.91	0.68	0.95	1.29	1.77
Free State	3.7	0.71	0.96	1.31	1.80

Source: Mashoko *et al.* (2014)

Table 2.2 indicates that an increase in speed and road roughness increases GHG emissions. Even though the increase seems to be smaller, the effect is significant in poor road conditions considering the annual traffic volume on these roads. The impact of transport on the environment is threefold: positive, negative and neutral. A positive impact is found when the transport development enhances the quality of the environment; a negative impact relates to when these developments damage the environment; and lastly, a neutral impact is found when the development does not enhance or damage the environment (Everett, Ishwaran & Ansaloni 2010: Online). From the three impacts stated above, the most disturbing, costly and common is the negative impact. Negative impacts refer to a wide range of geographical scales, such as global effects. There is considerable traffic growth in South Africa. This growth allows access to life necessities, social activities and employment but it has negative impacts, such as air pollution, GHG emissions, road congestion, noise and land space as more road infrastructure and parking are needed (Road Traffic Management Corporation [RTMC] 2018). These negative impacts are public knowledge but there is no comparable, reliable, safe, accessible and affordable substitute for private vehicles available for South Africans.

2.7 VULNERABILITY OF THE CTMM ROAD NETWORK TO CLIMATE CHANGE

Climate change as a growing global problem will be approached according to three principle elements: vulnerability, impacts and mitigation (Mehrotra, Natenzon & Omojola 2009: 8). Vulnerability refers to the physical elements and socio-economic conditions that determine the responsiveness of governments to changes in climate, while, impacts refer to climate-induced forces, including floods, heat waves and storms, which lead to physical and operational impacts on road infrastructures. Mitigation refers to the minimisation of the effects of climate change. According to Harris and Birjlandi (2011: 29), mitigation measures involve the following:

- reduction of GHG emissions, either by reducing the level of emission-related activities or by a shift to energy-efficient and renewable energy technologies that permit similar-level activities at a lower level of CO_2 emissions; and
- carbon sinks enhancement: preserving forested areas and expanding forestation.

The focus of this section is on the vulnerability of the road transport in the city to the potential climate change impacts as described in Figure 2.3 above. Vulnerability to climate change is the task of sensitivity, subjectivity and mitigation capacity. According to Komen (2016: 40), the degree of vulnerability to climate change is based on the projections of changes in mean temperatures and precipitation, extreme events and climate variability. Therefore, defining the term 'vulnerability' is necessary, since it is a relatively new concept applied in transport network studies. There are debates around the meaning of the term (Cochran *et al.*, 2009: 2; Jenelius 2008: 48). In general, these authors agree that vulnerability is connected to incidents, risks, serviceability and reliability.

Enei *et al.* (2011: 20) define vulnerability as "potential negative effects of the exposure on the system". Jun-qiang, Long-hai, Liu and Zhao (2017: Online) define vulnerability in the road transport system as a sensitivity of events that results in substantial reduction in road network serviceability and reliability. These events are predictable and caused – voluntarily or involuntarily – by both human beings and nature. According to Francoise and Hande (2012: 13), transport is vulnerable to various types of weather conditions, which are aggravated by climate change, such as storms, extreme precipitations and extreme temperatures. These weather conditions may result in severe consequences for the environment, such as sinkholes, droughts and floods, which are hazardous in terms of road transport infrastructures and operations.

A literature review on the vulnerability in the road transport system indicates that vulnerability assessments in road transport networks have been sufficiently performed at international level and some national levels, but little has been done on vulnerability at local level. Various studies (Council for Scientific and Industrial Research [CSIR] 2006: Online; Enei *et al.,* 2011: 21; Francoise & Hande 2012: 17) suggest that an increase in the projected frequency of natural hazards, such as extreme weather events, flooding and rising sea levels, is expected at local level. Consequently, critical assessment of existing road transport infrastructure and operation systems and their capacity to handle such changes becomes necessary. Figure 2.4 depicts a map of the regions in the CTMM, entailing all seven regions and their numbering.

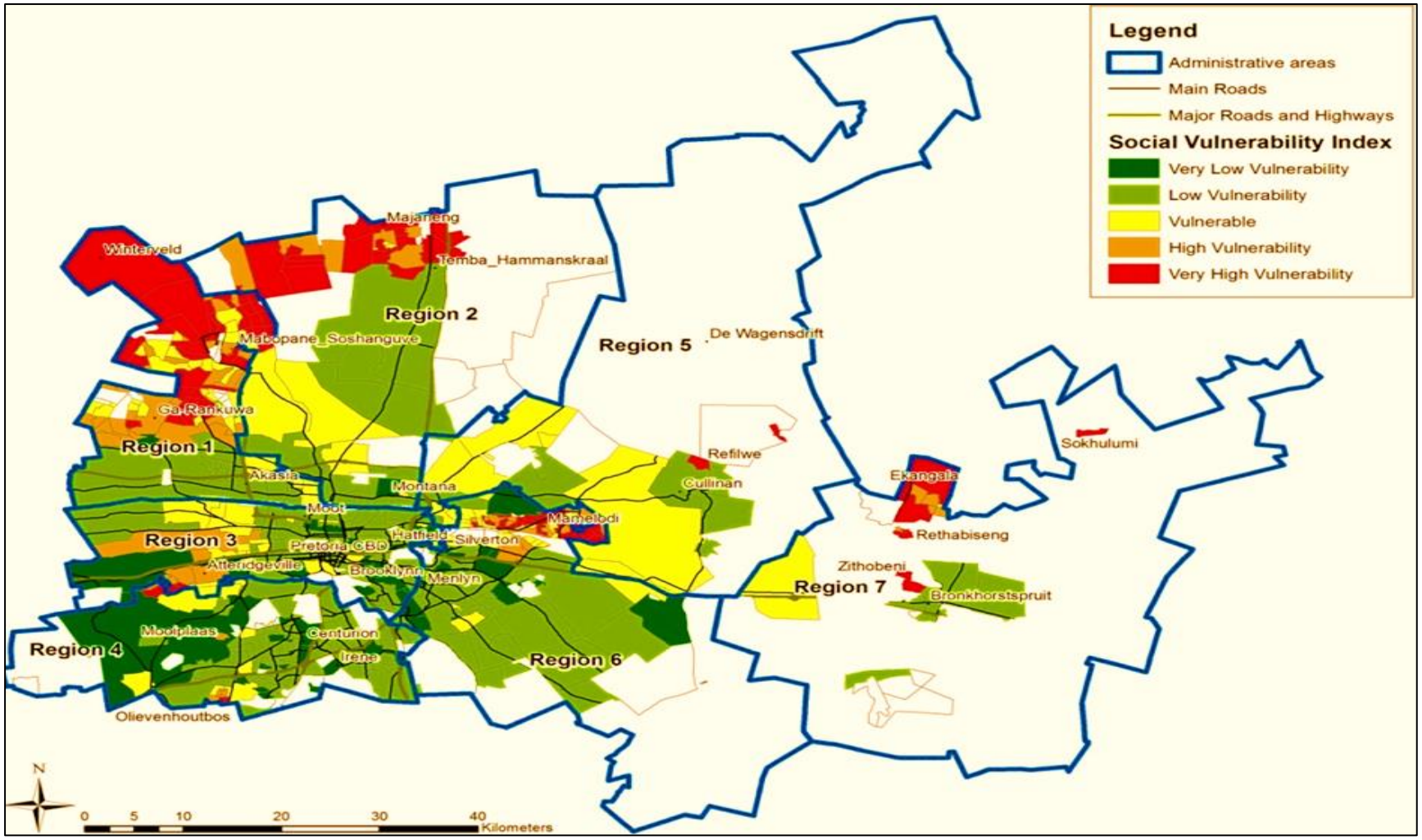

Figure 2.4: Map of the CTMM regions

Source: CTMM (2015b: iv)

- **High vulnerability**

Region 1 of the city is based on the north-west side of the city. The region is considered extremely vulnerable to climate change due to its geographical location. As far as human settlements are concerned, the areas within this region are situated within the flood lines; consequently, they are vulnerable to annual floods (South Africa 2016). The region therefore has a high vulnerability for human wellbeing and road transport, highlighting high vulnerability for impacts of further climate change, extreme precipitation and extreme temperatures.

- **Medium to high vulnerability**

Regions 2, 3, 5 and 6 are medium to highly vulnerable in terms of climate change, and their locations are mostly the determinant of the level of vulnerability. The regions are characterised by high and dense populations, and are based on vulnerable zones, such as within or below the flood lines (South Africa 2016). For instance, the eastern two-thirds of region 3 is mostly urbanised and the western third is mostly rural with about 20% of the population of the city residing within the region. The region is located within flood lines and dolomitic rock and surface ground making it vulnerable to flooding and the forming of subsidence and even sinkholes.

Region 5, on the other hand, has a poor spatial structure with high traffic volumes. It consists of nature conservation areas, tourism areas and areas for agricultural land use. The region is mostly rural and prone to the effects of climate change, such as floods and drought (South Africa 2016). Regions 2, 3, 5 and 6 have weak mitigation capacity due to low income of the people living there. Additionally, region 6 has development pressure, with most developable land within the region being developed. This development puts a burden on saturated road infrastructure. All four these regions are vulnerable to the impacts of climate change, extreme precipitation and the extreme temperatures.

- **Low to medium vulnerability**

Regions 4 and 7 have low to medium vulnerability to climate change. The borders of region 4 are situated within the jurisdiction of the Ekurhuleni Metropolitan Municipality, City of Johannesburg Metropolitan Municipality and Mogale City Local Municipality,

which results in the region being small. Region 7 also has the lowest population of 3.8%. Furthermore, the region has no flood line data available (South Africa 2016). However, the region is rated medium in terms of gradual climate change and extreme heat events.

Transportation infrastructure is vulnerable to weather extremes, and climate-proofing is needed to increase resilience. Infrastructures are designed to handle the various stresses along their existence, such as extreme weather events as previously experienced (Francoise & Hande 2012: 15). Transport services have to be developed to reduce disruption and maintain minimum safety standards in times of adverse weather conditions. Like several other cities or local governments around the world, the CTMM has not yet carried out a vulnerability assessment of road transport networks, although it has a city vulnerability assessment based on the vulnerability of the population to climate change in different regions, but very little on road transport (CTMM 2015a: 36). Vulnerability assessment in road transport networks therefore needs to be conducted in the city, but that was beyond the scope of this study. The CTMM road transport system is affected by extreme climate events, and the road transport operational systems contribute to global warming, which in turn aggravates the extreme climate events. The relationship between road transportation and climate change is a growing concern because scientific evidence on climate change continues to support the connection between anthropogenic[1] activities and global warming (UNEP, 2016). One of Jaroszweski's (2012: 326) concerns relates to an issue that has been largely overlooked by researchers, namely that climate change will also impact on the transport sector through a change in the frequency and intensity of hazardous and disruptive weather events.

2.8 THE IMPACT OF CLIMATE CHANGE ON ROAD INFRASTRUCTURE

The impacts of climate change on roads have been studied and documented by numerous studies in countries such as Australia, Canada, Scotland, the United Kingdom, and the United States (Harvey *et al.,* 2013: 47; NRCNA 2008). These studies documented various types of potential impacts. Although, none of the above

studies covered South Africa, the nature of impacts due to similar climate events would be similar in most countries, including South Africa.

Climate change has the potential to affect the livelihoods of people. The scientific agreement is that climate change exists and there is a need to accept its existence and the seriousness of its impacts (IPCC, 2013). Various studies, for example, Van Vleit *et al.* (2012), Bollenger *et al.* (2013) and Chappin and Van der Lei (2014) indicate that infrastructure is prone to the impacts of climate change. The extreme weather events in the world have brought additional challenges in keeping the world moving. Delays and increased costs as a result of flooding, heat waves and storms have affected the wellbeing and the economy of various countries. Climate change is an issue of concern for all. Miller and Hutchins. (2017: 260) predict that climate change will raise the intensity and frequency of extreme weather over and above the trend towards warmer, wetter winters and hotter, drier summers.

Mills (2009: 332) asserts that an increase in temperatures and precipitation increases the chances of the frequency and severity of thermal cracking, flooding and premature deterioration of the road infrastructure. Furthermore, Mills (2009: 333) found that permanent rutting on asphalt roads, cracking will be increased by climate change. Thus, maintenance and rehabilitation will be needed early in the design life of roads. Although climate change is directly linked to infrastructure deterioration, little research on its potential impacts on the infrastructure, especially on roads and bridges, could be found at the time of this research. These potential impacts need to be identified and addressed due to the importance of roads and bridges infrastructure on economic and social activities of the nations.

Scientific evidence shows that transport is one of the sources of GHG emissions (Stern 2006: 3). Nations therefore develop a wide range of measures to encourage a sustainable balance of road transport through mitigation projects and programmes such as Bus Rapid Transit (BRT), compressed natural gas (CNG), use of public transport, and promoting walking and cycling. However, it is of the utmost importance to consider the impacts of climate change on road infrastructure and the response strategies to these impacts. For example, as hotter summers become frequent, the feasibility of cooling and ventilation of various modes of road transport is assessed. The impacts of climate change on road infrastructure require a readjustment of road

design, construction and maintenance (Tighe 2008: Online). Thus, the underlying concern with climate change and road infrastructure design and management is the potential failure of premature design and maintenance.

The road infrastructure design assumes a static climate (Anyala 2011: 17). Road infrastructure is designed and constructed to withstand events in the climate according to specific events based on experience, named as “reference events”. Many environmental changes have been happening due to global warming, for example, an increase in temperature and changes in precipitation patterns, the frequency of rainstorms, with the associated changes in surface and groundwater regimes (Twerefou *et al*., 2015: 11951). None of the above are mentioned as reference events, though they have a high probability for floods and erosion and a high risk of slides and avalanches. Road infrastructure challenges include but are not limited to:

- insufficient drainage capacity;
- landslide risk and its consequences on traffic safety;
- deterioration of roads; and consequently
- a high demand for repair measures because of environmental effects of precipitation increase.

The impact of climate change on roads increases in temperature, rain, floods, stormwater surges, and a rise in sea level will affect road transport infrastructure and operations (Pande 2015: 9). Particular impacts of climate change on road transport include:

- thermal expansion of bridge joints;
- breaking down of asphalt pavements;
- higher maintenance of roads because of high temperatures;
- overflow of side drains and cross drainage works;
- wetting of bridges during flooding; and
- road closures because of landslides.

Table 2.3 lists the potential climate change and its impacts on road infrastructure. According to Pande (2015: 9), it is often not possible to quantify the impacts of climate change; therefore, a qualitative assessment can be used to express the degree of the impact.

Table 2.3: The impacts of climate change on transport

POTENTIAL CLIMATE CHANGE	IMPACTS ON ROAD INFRASTRUCTURE
Increases in very hot days and heat waves	Deterioration of pavement integrity, such as softening, traffic-related rutting, and migration of liquid asphalt due to an increase in temperature (sustained air temperature over 32° C is identified as a significant threshold). Thermal expansion of bridge expansion joints and paved surfaces.
Increases in very hot days and heat waves, and decreased precipitation	Corrosion of steel reinforcements in concrete structures due to an increase in surface salt levels in some locations.
Increases in temperature in very cold areas	Changes in road subsidence and weakening of bridge supports due to thawing of permafrost. Reduced ice loading on structures such as bridges.
Later onset of seasonal freeze, and earlier onset of seasonal thaw	Deterioration of pavement due to increase in freeze–thaw conditions in some locations. Reduced pavement deterioration from less exposure to freezing, snow and ice.
Increase in intense precipitation events	• Damage to roads, subterranean tunnels and drainage systems due to flooding. Increase in scouring of roads, bridges and support structures. •Damage to road infrastructure due to landslides. •Overloading of drainage systems. • Deterioration of structural integrity of roads, bridges and tunnels due to an increase in soil moisture levels.
Increases in drought conditions for some regions	• Damage to infrastructure due to increased susceptibility to wildfires. • Damage to infrastructure as a result of mudslides in areas deforested by wildfires.
Increase of storm intensity	• Damage to road infrastructure and increased probability of infrastructure failures. • Increased threat to stability of bridge decks. • Increased damage to signs, lighting fixtures and supports.
Increase in wind speed	Suspension bridges, signs and tall structures at risk from increasing wind speeds.

Source: TRB (2008) and IPCC (2013)

In other regions, high temperature extremes may lead to more frequent pavement buckling. (Friedrich & Timol 2011: 14; Neumann & Price 2009: 7). Serrao-Neumann et

al. (2011: Online) found in their study that changes in average rainfall, temperature and evaporation patterns had the potential to damage the moisture balance in the pavement foundation of roads. They consequently recommended that the manner in which roads are designed, constructed and maintained should be changed to make them climate resilient. TRB (2008) states that storm-water management is a particular cause of concern for governments, predominantly due to an increase in urban flash floods and the knock-on effects of poorly managed storm-water flows on receiving surface waters (i.e. resulting in sewage discharges). The study by the TRB (2008) identified climate changes that are of importance to transportation as follows:

- increases in very hot days and heat waves: high temperatures damage road shoulders and beds;
- rising sea levels: inundation of road networks; and
- increases in intense precipitation events: increased run-off washes away roads and overwhelms the drainage systems.

Roads are built based on the standards of historical climate (Kunene & Allopi 2009: 14). Hence, when climate stressors exceed the levels of the climatic design parameters of the road, damage occurs. Climate change affects road transport through an increase in weather and climate extremes, including very hot days, intense precipitation events, intense hurricanes, droughts and rising sea levels, coupled with stormwater surges and land subsidence. The impacts differ by mode of transport and location. However, they are widespread and costly in both human and economic conditions and, as Tighe (2008: Online) suggests, enough changes in the planning, designing, constructing, operating and maintenance of road transport infrastructure and operations are required. Climate change is a challenge in achieving sustainable development, and it threatens to drag people into grinding poverty. According to the DEAT (2009: 22), the South African government regards climate change as the greatest threat to sustainable development. The government increased economic development, which leads to increased urbanisation and increased use of private vehicles, which result in more people buying cars. Most of the motorised transport relies on the availability of fuel and being almost completely dependent on oil, which is a non-renewable source of energy (IPCC 2007; Oswald 2011: 56); thus, increasing the GHG emissions.

As more people buy and drive cars in South Africa to meet their independent mobility needs, fewer people will walk, cycle or use public transport (Moss 2015). The increase in cars leads to traffic congestion, pressure for road space and a reduced availability of parking. The pressure put on the road surface, together with weather events, leads to damaged road infrastructures, which in turn may lead to an increase in accidents. This adds to difficulties of providing reliable, safe and efficient public transport as well as safe facilities for pedestrians and cyclists. In terms of the predictions of climate change and its impacts, there is a consensus amongst scientists that, together with the available policies on mitigation, the GHG emissions will grow (Agrawal, 2005; 2008; IPCC, 2001; 2007).

It is important to understand the extent to which climate change will affect the economy in order to estimate its costs effectively and to develop adaptation and mitigation measures and strategies. It is equally important to identify the effects of climate change on road accidents because of the extent of the social and economic costs of road accidents. The WHO (2018) reports that on average, 1.2 million people die globally in road traffic accidents per annum. Weather conditions are contributors to these traffic fatalities. For instance, rain reduces visibility and makes braking of vehicles difficult due to slippery road surfaces. Another example would be that a sunny day could make the road surface reflective, which might also hamper visibility. Furthermore, heat affects vigilance, tracking and multitasking.

Transportation is the backbone of any economy in the world. Comparative studies across the globe have indicated that inefficient and unreliable transportation could have a severe influence on economic growth (Chapman 2009: 331). Despite the important role of transportation in the economy, enough research on how vulnerable transport is to climate change has not been conducted, particularly not in South Africa. However, research studies prove that effects of climate change on road transport are severe. Leard and Roth (2015: 16) argue that climate change events are associated with a significant increase in fatal road accidents. The losses associated with the effect of road accidents on the economy are estimated to be 2.5% of the gross national product (GNP) in South Africa (RTMC 2018). Even though road accidents are caused by numerous factors, such as human error and reckless driving, the influence of weather conditions on accidents is also a contributory factor to car accidents.

2.9 SUMMARY OF THE CHAPTER

The first point of departure for this chapter was to underpin this study to a theory that had to shape the thesis. Secondly, to place this climate change analysis in the context of Public Administration discipline. The multidisciplinary nature of Public Administration was discussed in order to demonstrate how and why the current topic fits in the field of Public Administration. Climate change was explained and defined, and its causes and trends were discussed in three different contexts: global, regional and local. Road transportation infrastructure, however, experience of the impacts of climate change.

This chapter partially answered the following research question “What are the impacts of climate change on road infrastructure in the CTMM?” A detailed discussion of those impacts was provided based on literature review. This research question (“What are the impacts of climate change on road infrastructure in the CTMM?”) is partially answered because the confirmation of the reality of the impacts of climate change on road infrastructure is done through collection of empirical evidence. In order to realise one of the objectives of this study, namely “to evaluate the impact of climate change on road infrastructure in the CTMM” the study employed a mixed-method research approach in collecting data to ascertain the specific impacts that the CTMM is experiencing. Although everyone is at risk of the impact of climate change, the costs and degree of impact will vary based on regional context.

The next chapter focuses on the challenges of managing the identified impacts as well as the financing of the projects and programmes implemented as management instruments. Two research questions will be answered: first, what are the challenges faced in managing these impacts, and second, how are the response measures financed?

CHAPTER 3
CLIMATE CHANGE MANAGEMENT MEASURES: CHALLENGES OF ROAD INFRASTRUCTURE

3.1 INTRODUCTION

The immensity and cost of climate change is partly dependent on future global GHG emissions. Hence, global mitigation actions to lower GHG emissions comprise the primary strategy by the United Nations Framework Convention on Climate Change (UNFCCC) and various mitigation policies. In South Africa, the transport sector is the second largest contributor to GHG emissions after the energy sector. As a result, mitigation actions have been the primary focal point of the transport sector in addressing climate change (IPCC, 2014: 854). The severity of the expected impacts depends on the outcomes of global efforts to mitigate climate change. Sustainable developments are a priority of the global agenda, but climate change undermines the progress that has been attained (World Bank, 2010: 45).

The World Bank (2010) indicates that developing countries and poor communities are the most vulnerable to the impacts of climate change. However, cities have the capacity to gather productivity, wealth and people. Cities are equally vulnerable to changes in climate as to natural disasters. On the one hand, inland cities – including their people and productive activities – are vulnerable to climate change-related natural disasters. On the other hand, coastal cities are vulnerable to rising sea levels, which lead to hurricanes and sea-related storms (Folberth, Butler, Collins, & Rumbold 2015: 236). The vulnerability of populations to changes in climatic and weather conditions are likely to increase due to changes in land use, migration and spatial development. Globally, adaptation to climate change is therefore crucial for cities.

Climate change is likely to have a significant impact on the ability of metropolitan municipalities to finance and deliver services (South African Local Government Association [SALGA] 2018: 2018). SA metropolitan municipalities finance their operating budget through service tariffs, property rates and equitable share from the national government's budget allocation (Gildenhuys 2017: 124). Other funding mechanisms are from external loans, the Municipal Infrastructure Grant (MIG), donations, and private partnerships. Metropolitan municipalities are important in the efforts to mitigate climate change. They are also responsible for two thirds of global

energy consumption, and this proportion is expected to increase further (IEA 2016; IPCC 2014: 821) Moreover, due to their density, efficiency, innovations and new technologies, metropolitans municipalities can provide solutions for lowering emissions. A few factors influence the emissions profile of any city in complex ways. These factors differ from the trends of urban shape and land use, climate, building design and technology. The enormous investment in buildings and infrastructure that will be tackled in the coming years by cities in developing countries will protect urban shape and structure – from transport modes to income levels (Snieska & Simkunite 2009: 27).

After discussing the impacts of climate change in the previous chapter, it became clear that there is a need to establish management measures for the identified impacts. The primary focus of this chapter is on climate change management measures and the challenges thereof. However, the chapter first presents an overview of the quality of SA road infrastructure. Furthermore, the financing aspect of the management measures of the impacts of climate change is considered. In this chapter, the researcher addresses the following two research questions:

- What are the administrative challenges of managing the impacts of climate on road infrastructure in the City of Tshwane Metropolitan Municipality (CTMM)?
- How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?

In order to gain a clear picture of the challenges facing the CTMM in terms of road transport management, this study focused on the impacts of climate change on infrastructure within the road transport sector. It is important to address other environmental challenges facing the sector beyond climate change.

3.2 OVERVIEW OF THE ROAD INFRASTRUCTURE QUALITY IN SOUTH AFRICA

Road infrastructure quality can be referred to as the improvement of the performance of the existing infrastructure stock, such as patching roads and paving (Fourie 2008: 3). The development of the land transport sector in South Africa is guided by legislation, such as the –

- National Land Transport Transition Act, 2000 (Act No. 22 of 2000) (South Africa 2000);
- National Land Transport Act, 2009 (Act No. 5 of 2009) (South Africa 2009); and
- National Road Traffic Act, 1996 (Act No. 93 of 1996) (South Africa 1996).

SA roads are broadly classified as the national roads network (N) comprising national highways and freeways; and the provincial road network (R) comprising roads that are feeders to the national roads and the municipal roads (M) (CTMM 2015a: 5). M roads serve as feeders that connect towns and cities to both national and provincial roads (DoT, 2014a). SA roads fall under the jurisdiction of the three spheres of government, namely national, provincial and municipal roads.

The most predominant type of transport infrastructure in South Africa is roads (Kgamanyane 2015: 52). The SA road network is estimated to cover approximately 747 000 km with approximately 153 719 km tarred (SANRAL 2016: Online). The DoT is responsible for roads in the country, and executes this responsibility through other agents, such as SANRAL, provincial departments and municipalities. The SA government considers the road transport sector as the key contributor to its competitiveness in global markets (DoT, 2014a). Hence, the country spends billions of rand in improving the quality of road networks and infrastructure. In its annual performance report (2017), the DoT prides itself in its well-developed infrastructure and good road conditions. According to the Integrated Report Committee of South Africa (2018: Online), the public sector infrastructure can be classified as satisfactory for now, at risk of failure and unfit for purpose.

Fedderke and Garlick (2008: 2) argue that the quality of SA road infrastructure is relatively high (world class); however, accessibility of the infrastructure varies significantly between rural and urban areas. Fourie (2008: 4) attests that measuring the quality of infrastructure is extremely difficult. Infrastructure quality can be defined as performance improvement of the infrastructure stock, such as maintaining sewages, patching and paving roads (Fourie, 2008: 3). Quality infrastructure has a positive impact on economic growth. Such infrastructure supports economic growth, enhances quality of life and is of importance for national security (Snieska & Simkunite, 2009: 19). The road infrastructure promotes trade and the delivery of goods; additionally, it provides access to basic needs and services. Road infrastructure has

a positive impact on the economy when it is in good condition, relating to infrastructure quality.

Lumsden (2008: 102) indicates that the Automobile Association of South Africa (AASA) conducted a study, which indicated that the conditions of SA roads have declined from a Visual Condition Index (VCI) of 65 in 1998 to 46 in 2008. However, in 2011, the South African Institution of Civil Engineering (SAICE) conducted a similar study, and the findings were that there had been improvement, but the roads are 'on average', and awarded the overall grade of C: satisfactory for now. Nevertheless, it can be argued that the marginal improvement in the average condition of South Africa's infrastructure before 2011 could be ascribed to the major investment in national assets in preparation for the 2010 FIFA Soccer World Cup. In 2017, the overall condition of the SA road infrastructure was lowered to "D: at risk of a failure" by a similar study conducted by SAICE (2017: 2). Thus, the poor attitude to maintenance continues, and is reflected in the downturn on the current overall grade (SAICE, 2017: 5). The SA government has provided a quantifiable number of road infrastructure that is arguably poor (Economic and Social Council 2017: 45). As a result, more accidents are experienced emanating from potholes. Therefore, it is of utmost importance for government to provide quality infrastructure to reduce accidents caused by poor road infrastructure.

Since the past century, there has been a debate between politicians and policymakers on the role of transport in improving the quality of life of the people. The debate revolves around road infrastructure networks (Mamabolo, 2013: 47), specifically on the impact of vehicle overloading on the road network. The loading magnitude, the number of load repetitions by heavy vehicles and configuration influence the performance of the road infrastructure (Adlinge & Gupta, 2015: 11). According to SANRAL (2016: Online), overloading of vehicles causes asphalt or tarred roads approximately R600 million damages per annum. Moreover, the road infrastructure is affected by the improper moisture condition during construction, layer thickness and quality of the material. According to Adlinge and Gupta (2015: 11), the following are causes of road deterioration found in most developing countries:

- Sudden increase in traffic loading, especially on new roads where the design was based on less traffic, is a major cause of cracking of the road. After construction of good roads, traffic from other roads also shifts to that road.
- Temperature variations – ranging from 50 ºC to below zero in the plain areas of North and Central India – lead to cracking of roads.
- Provision of poor shoulders leads to edge failures.
- Provision of poor clayey subgrade results in corrugation at the surface and increases in unevenness.
- Poor drainage conditions, especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface. In case of an open-graded bituminous layer, this phenomenon becomes increasingly dangerous and the top layer is detached from the lower layers.
- If the temperature of bitumen and/or bituminous mixes is not maintained properly, this also leads to pavement failure. Overheating of bitumen reduces the binding property of bitumen. If the temperature of a bituminous mix is lowered, the compaction will not be proper, leading to longitudinal corrugations.

In South Africa, well-provided road infrastructure often leads to continuous travellers to commercial areas and hence promoting economy in the area concerned (Economic and Social Council 2017: 12). Generally, infrastructure is a determinant of many factors of production in a typical economy. Road infrastructure plays a pivotal role in improving the economy and people's lives. People rely on road infrastructure to travel to and from work, home, school, health facilities, shopping and any other area for other activities. Thus, road infrastructure of good quality is a pre-requisite for a thriving economy, which is to the benefit of the people. However, the public road infrastructure in South Africa needs improvement and more investments.

South Africa has quality road networks that are unique and attractive but they claim the lives of many citizens due to a high accident rate despite their uniqueness and attractiveness. Snieska and Simkunite (2009: 19) argue that infrastructure predicates the quality of life of the people. Quality road networks will therefore reduce accidents

and improve the safety of people. In fact, Escribano, Guasch and Pena (2010: 2) attest that it is important to improve the road infrastructure because this will assist in penetrating the international markets and realising sustainable development goals while reducing poverty and improving the welfare of citizens.

Kunene and Allopi (2009: 1) argue that roads are the most important mode of transport in South Africa. Therefore, it is essential for the SA government to ensure that people have access to road infrastructure of high quality. However, government realised that having access to quality road infrastructure without a management system is not an effective solution to improving the welfare of people. It therefore, established a Road Transport Management System (RTMS) in 2003 to implement management system that will safeguard the road infrastructure.

The RTMS is an industry-led, voluntary self-regulation scheme that influences transport businesses to engage in the road logistics value chain to implement a vehicle management system that preserves road infrastructure, improves road safety and increases the productivity of the logistics value chain (RTMS 2018: Online). Furthermore, the RTMS is concerned with overloading of vehicles and trucks as this causes premature road deterioration. This scheme also supports the National Freight Logistics Strategy of the DoT. The RTMS has standards on loading, driver wellness, vehicle operations and productivity. The RTMS offers support for:

- implementation of national standards, auditors (accredited by South African National Accreditation System [SANAS]);
- tools (manuals, templates, implementation guidelines), information portals, recognition and concessions;
- promotion to create meaningful recognition among public and industry stakeholders);
- special projects (selected by the RTMS stakeholders and which are aligned to RTMS objectives and
- research and technology innovation.

As part of their quality management systems to address the current problems in road transport, transport businesses can use the RTMS. In terms of the Medium-Term

Strategic Framework 2014–2019 (see South Africa 2014) and the National Development Plan 2012–2030 (see South Africa 2012), the establishment and maintenance of a modern and competitive road transport infrastructure and system is a crucial objective for sustainable development. The Constitution of the Republic of South Africa (1996) stipulates the legislative functions of the three spheres of government regarding the provision of transport. In terms of Schedule 4A, the national and provincial spheres of government are concurrently responsible for international and national airports. Schedule 4B indicates that local government is solely responsible for municipal airports and municipal public transport. Thus, CTMM is responsible for transport planning within its jurisdictions.

The CTMM exerts its influence through the Comprehensive Integrated Transport Plan (CITP) and the Integrated Transport Plan Network (ITPN). The CTMM has a mandate to provide and promote accessible, reliable and affordable integrated municipal public transport network services (South Africa 2015). The road transport system is a segment of economic development and it plays a pivotal role in economic growth. An efficient road transport system gives access to attractive centres for consumption and production, which enhance economic growth (Pande, 2015: 4). Not only does the road transport system affect economic development, but also social coherence. No economy can be competitive with an inefficient road transport system.

Flexible working hours for different sectors could influence mobility demand. Indeed, the more people move, the higher the demand for a user-friendly transport system and infrastructure (Rodrigue 2017: 14). Chinowsky, Schweikert, Strzepek and Strzepek (2015: 54) further state that planning, designing and construction of infrastructure have been done the same way for ages. Chinowsky et al. (2015: 55) suggest that there is a need for considering research on new construction processes and materials aiming to advance the road transport sector. Indeed, a paradigm shift is needed, and the research should significantly focus on finding construction processes and materials that would minimise GHG emissions from the transport sector. Road transport contributes positively to social, political and economic development; however, it also contributes negative elements towards climate change (Twerefou, Chinowsky, Adjei-Mantey, K & Strzepekvan 2015: 11951).

Road transport is one of the largest emitters of GHGs. The contribution transport makes to emissions can be attributed to the rising demand in passenger travel. In South Africa, there are currently 20 150 531 registered vehicles on South African roads (National Transport Information System [eNaTIS] 2020: Online). This number has increased considerably from 9 970 381 in 2011 (National Transport Information System [eNaTIS] 2020). This increase means more emissions result in climate change, and in an attempt to reduce emissions, this number needs to be reduced, thus intervention by government is needed and cooperation by road users. After a detailed discussion on road infrastructure and the impact of climate change on the road infrastructure quality, the focus moves to implementation measures. Section 3.3 focuses on the environmental challenges of the road transport sector in the South African context.

3.3 ENVIRONMENTAL CHALLENGES OF ROAD TRANSPORT SECTOR IN SOUTH AFRICA

Transport and environmental issues are paradoxical in nature because, on the one hand, transport bears considerable socio-economic benefits, while on the other hand, it affects environmental systems. According to Rodrigue (2017: 15), transport influences the increasing mobility demand; however, the activities are linked with the increasing levels of environmental externalities. Thus, there is a cyclical relationship between transport and the environment; moreover, they have negative effects on each other. The negative effects from transport are, inter alia, air pollution, noise, road traffic accidents and GHGs emissions.

Road transport has gradually grown globally and made major contributions to the development of economies. In South Africa, road transport growth has led to extensive road infrastructure and upgrade, including tollgates to accommodate the increase (DoT, 2014b). The increase in road transport is an indication of increased traffic. Unfortunately, the increased traffic leads to increased roads traffic causalities and mortality rates. These road traffic mortalities affect the lives of the people related to those involved in the accidents. According to the Road Traffic Management Corporation (RTMC 2018: Online), more than 4 500 people die on South African roads annually. This has human, economic and financial costs attached.

Medical rehabilitation for the injured are incredibly expensive, even for those with medical aid, while those without medical aid become the responsibility of government for patients in public hospitals. When people cannot afford to pay their medical bills, the economy suffers, because the money must come from government and the National Road Accident Fund (RAF), throwing the nation into deeper debt. Road accidents often result in gas and fluid leaks, emitting harmful chemicals into the environment, which could poison grass and neighbouring plants and harm wildlife. Major oil leaks from wrecked vehicles are one of the biggest environmental problems following traffic accidents (RTMS 2018), as they leave the road surface slippery and poison the vicinity.

Due to the increased number of vehicles, there is an increase in road network demand. As a result, severe congestions are experienced on the roads, especially in and around the cities. In addressing the issue of congestion, the Gauteng provincial government has upgraded the tolling system and introduced the e-toll system on all national roads within the province. However, both civil society and the public argue that it is expensive for road users, and they significantly opposed e-toll. Tolls on the transport system are not only for additional revenue generation but also to manage demand, congestion and pollution along heavily used roads and corridors.

Road freight transport also poses a serious challenge to the environment. Freight transport contributes over 13% of the South African gross domestic product (GDP) (CSIR 2015: Online). This contribution is higher than the international average in developed countries, which is between 8 and 10% of GDP. The prominent use of road infrastructure by freight transport contributes to poor road safety and reduces the lifespan of roads because huge overloaded trucks are too heavy for the road and they damage the roads.

The South African government needs to make a modal shift (Dikgang 2013: 2). The government plans to move freight transport from road to rail (DoT, 2014a). Rail transport has considerable potential to provide cost-effective freight transport. This modal shift will make the economy more efficient as rail will provide access for freight movements and simultaneously provide an environmentally sustainable transport solution. However, rail transport has its limitations. According to Havenga and Pienaar (2012: 5), rail freight transport has the disadvantage of limited flexibility due to its

location being far from the main freight movement corridors. This is significant when non-corridor movements in metropolitan areas, such as City of Tshwane, are considered.

Another environmental problem is air pollution. Transport is the major contributor to air pollution (Hitchcock, Conlan, Kay, Branningan & Newman 2014: 2). According to Hitchcock et al. (2014: 4), air pollution shortens life expectancy of a road by approximately 8.6 months on average. Contributory factors to air pollution from road transport include age of the vehicle, increased use of private vehicles and low-quality fuel. Excess speed in driving is another environmental challenge and road safety problem. Speeding contributes one third of fatal accidents in South Africa and aggravates the severity of the non-fatal ones. The estimated costs of road traffic deaths and injuries for 2015 are 3.4% of the GDP (Labuschagne, De Beer, Roux & Venter, 2017: 479). Literature on road crashes and deaths indicates that large numbers of victims are young people. This amplifies the economic losses in productivity and earnings. Cyclists and pedestrians are prone to road crashes due to insufficient infrastructure to accommodate their activities. Limited land space does not allow sufficient accommodation for cyclist-dedicated lanes.

The more motor vehicles there are on the road, the more energy consumption grows. The carbon dioxide from the road transport will continue to grow. The IEA (2016: 128) reports that, in the period of 2006-2016, emissions by road transport sector have increased by over 30% worldwide. Increased road transport further exacerbates problems of scarcity of oil and energy security. Economic sectors are increasingly relying on alternatives, such as renewable energy sources, but the transport sector has fewer opportunities available to them (DiMento & Doughman, 2014: 6). GHG emission is a pressing environmental challenge as opposed to other identified challenges.

From the above discussion, it is clear that the environmental challenges within the transport sector are many; climate change is an addition to the already existing problems. According to IPCC (2014: 842), the Fifth Assessment Report (AR5) shows that since the mid-twentieth century, minimum and maximum temperatures over land have increased. Among other systems, the transport sector is vulnerable to climate change. According to Koetse and Rietveld (2009: 205–221), climate change is

anticipated to have a significant impact on the transport sector. The above-mentioned AR5 confirms that climate change will negatively affect the road infrastructure in various ways (IPPC 2014: 851). For instance, road surfaces are prone to negative impacts of rising temperatures. In addition, Oswald (2011: 2) indicates that frequent strong storms and floods affect the drainage capacity and cause systems to overflow. Furthermore, storms and floods have an impact on the lifespan of road bridges.

3.4 MANAGEMENT MEASURES OF THE IMPACT OF CLIMATE CHANGE ON THE ROAD INFRASTRUCTURE

South Africa is the leading economy in sub-Saharan Africa, and it is also a leading emitter of GHG on the continent (South Africa at a Glance, 2011). The South African emission profile is connected with its economic growth and development. South Africa is vulnerable to climate change because of its population density (DEA, 2014). Potential changes in climate have consequential impacts and effects on different sectors. In 2009, at COP15 (Fifteenth meeting of the Conference of the Parties), the SA government pledged a GHG emission reduction target of 34% by 2020 and 42% by 2025 below the 'business as usual' trend towards a peak, plateau and decline trajectory range (UNFCCC, 2011).

For South Africa to meet its pledged targets, changes such as policy intervention, new programmes and projects on improving transport for mitigating GHG emissions are required in the transport sector. These changes however cannot undermine the contribution by transport to the prosperous functioning of a modern economy that meets society's need for connection and mobility. In responding to the challenges posed by climate change, the SA government decided to do the following as stipulated in National Climate Change Response White Paper (South Africa 2011):

- continue to put in place transport policies and developments that would result in a modal shift in passenger transport to public and low carbon forms of transport, including plans to move freight from road to rail over time;
- encourage the integration of land use and transport planning in cities in a manner that encourages public transport, non-motorised transport (i.e. walking and cycling) and promotes alternative communication methods, such as tele-commuting, in order to reduce long-term transport fuel use patterns;

- improve the efficiency of the vehicle fleet across the board through a range of measures, including the use of fuel standards;
- invest in the further development and deployment of cleaner technologies for the transport sector such as electric vehicles (EVs) and hybrid vehicles;
- build capacity to deal with transport mitigation in the areas of planning, engineering and relevant technical skills;
- support the production and use of cleaner fuel technologies and alternative fuels away from current fossil fuels;
- implement the flat rate-specific excise tax based on passenger vehicle carbon emissions, which applies to each gram $C0_2$ vehicle emissions above a target range and investigate expanding the emissions tax to include other categories of motor vehicles;
- consider further incentives in the form of lower fuel taxes to encourage cleaner fuels, e.g. cleaner diesel fuel; and
- integrate climate change information into transport planning, in order to minimise the potential risk to infrastructure from extreme weather events.

Even though all these proposals stated above are outlined in the National Climate Change Response White Paper, others have yet to be implemented or are incomplete. For example, although alternative fuels are being developed, the South African road transport system is still heavily dependent on fossil fuels. Electric vehicles have been launched, but they are still prohibitively costly. Another proposal is the incorporation of climate change data into transportation planning in order to reduce the likelihood of infrastructure damage from severe weather events. On paper, this is well-thought-out, but in practice, it is ineffective. Rain conditions continue to threaten road infrastructure, and the CTMM has seen collateral damage to road infrastructure as a result of weather events. The plan to gradually shift freight from road to rail is also a pipe dream. Due to the rail station's inaccessibility, it is practically impossible to reach. Even though it is not ideal for reducing GHG emissions, road infrastructure is more efficient for freight than rail.

South Africa knows that stabilisation of GHG emissions at levels that prevent dangerous interference with the climate system needs international cooperation. Hence, it has ratified the UNFCCC and Kyoto Protocol (DEA, 2014). Developing countries face more challenges when addressing climate change than developed countries (IPCC 2014: 886). Emission reduction in developing countries is therefore not a viable option because their income levels are far below those of developed countries and their per capita emissions are just one sixth of the industrialised world. Thus, developing countries will continue increasing their emissions while they strive for economic growth.

The SA cabinet has commissioned a process of examining the country's potential to mitigate the GHG emissions (Winkler, 2010: 3). The aim was to develop a Long-Term Mitigation Scenarios (LTMS) that would assist in drawing up a long-term climate policy. Such policy was said to give a SA negotiator in the UNFCCC a mandate and position for negotiations. In terms of the LTMS the target limit for global average temperature increase was up to 2 °C. During the negotiation, the transport sector did not commit to any target for GHG emission reductions, but it was made clear that the sector would contribute to significant GHG emission reductions until the year 2050. This was a challenge for South Africa because of the increasing traffic and transport demands, Sperling and Gordon (2009: 336) warn that stabilisation of transport emissions in the coming decades would pose a significant challenge.

The National Climate Change Response White Paper (South Africa 2011) identifies a modal shift from road to rail as a flagship carbon mitigation programme for South Africa. According to DEA (2014), rail transport has a potential to provide cost-effective services, whether it be freight or passenger transport. The government has made yet another hollow pledge. Again, the government ignored the fact that the rail stations are inconvenient for both passengers and freight since they are not close to either work or home. This will promote an environmentally sustainable transport system in the country. Havenga and Pienaar (2012: 5) however argue that rail transport offers non-flexible destinations when it comes to freight and passenger movement corridors. The move from road to rail, however, would save the roads because a number of factors – such as the climate and the high number of vehicles on the road – impact road infrastructure and the lifespan of roads is shortened.

South Africa requires a number of initiatives to give effect to emission reductions ranging from policies to strategies, targets, voluntary agreements, regulations, standards, economic instruments, financial mechanisms, subsidies, programmes, projects, pilots, market initiatives, capacity development, information generation, innovation, institution-building, centres of excellence, partnerships, training and skills development. These initiatives are diverse and broad, and are at different phases of development. Some are at an early phase of conceptualisation (i.e. carbon tax and SARI). Others are fully developed standards, policies or outputs, such as South African National Standard (SANS) 204. Some are implemented, such as the Bus Rapid Transit (BRT) system and the Gautrain in Gauteng. These initiatives took time before they were active from the conceptualisation to implementation; hence, Tyler, Boyd, Coetzee and Winkler (2011: 12) state that it is unclear whether the length of time it takes to develop and implement a mitigation initiative is an indication of its strength, scale, mitigation potential or anything else. All these initiatives have a unique and complex context.

A developing country needs to respond to the Sustainable Development Goals (SDGs), and priorities towards economic and social development as well as poverty eradication (UNFCCC 2015: Online). The UNFCCC therefore introduced the Nationally Appropriate Mitigation Action (NAMA) as another tool for developing countries to mitigate climate change. NAMA is a set of policies and actions that developing countries could undertake voluntarily to reduce GHG emission. In terms of NAMA, countries may take different nationally appropriate action based on equity and in respect of their common but differentiated responsibilities and capacities. With reference to NAMA, there is a need for financial aid to developing countries by developed countries for the former to implement the national action effectively to reduce emissions. South Africa does not use NAMA extensively in its climate change mitigation policies, but it is considered as one of the most active countries in international NAMA negotiations, offering yet another example of a well-thought-out policy that has yet to be implemented, if at all.

In terms of reducing GHG emissions, rail transport is three to four times more effective than road transport (Francoise & Hande 2012: 4). GHG mitigation benefits are expected to arise from the shift from private passenger vehicles to mass transit electric

rail (ibid). In Gauteng, the Gautrain is established and it is a catalyst for the passenger modal shift (Dikgang, 2013: Online). This shift brought on by the Gautrain electric rail carries GHG mitigation benefits through the provision of an efficiently managed mass transit system. The Gautrain can easily measure its mitigation impact, and it represents a GHG emissions shift from road to rail.

According to data gathered by the South African Weather Services under the National Climate Change Services Framework (UNFCCC 2011: Online), increasing municipal climate change adaptation capabilities would necessitate a rising investment in climate change adaptation. The Local Government Partnership for Climate Change (LGP4CC) values the measures of sufficient emphasis on climate change adaptation, which are critical considerations for municipalities and their vulnerabilities (CTMM 2017: 41). Municipalities are faced with the most notable risk to infrastructure, especially those that are prone to higher incidences of flooding. Socio-economic disparities in urban areas pose risks for municipalities. The LGP4CC supports South Africa in the following areas:

- balanced attention and merit of initiatives to both mitigation and adaptation efforts;
- setting of country-specific mitigation targets (i.e. intended nationally determined contributions);
- increased financial contribution to the Global Climate Facility (financing mechanism);
- adequate technology transfer mechanisms for developing countries, with financing also extended to meet reporting requirements and R&D (Research and Development); and
- a legally binding agreement for all parties under the Kyoto Protocol's second commitment period.

Although metropolitan municipalities have progressed in planning for climate change response, capacity at both human and financial capital levels is limited. The LGP4CC supports the United Nations Framework Convention on Climate Change (UNFCCC) on its move towards enhancing mechanisms for capacity building.

According to Pande 2015:9), road transport infrastructure is prone to the negative impacts of climate change. Events such as floods, temperature changes and droughts directly affect infrastructure. There are mainly two options available in responding to the impacts of climate change, namely mitigation and adaptation. In terms of the Stern (2006; 2007) review reports, mitigating the effect of climate change is a long-term measure, whilst adaptation to climate change is a short-term measure. Mitigation is important because failure to mitigate might result in high long-term costs. According to Harris and Birjlandi (2011: Online), mitigation measures involve –

- reduction of GHG emissions, either by reducing the level of emission-related activities or by a shift to energy-efficient and renewable energy technologies that permit similar level activities at a lower level of CO_2 emissions; and
- carbon sinks enhancement, i.e. preserving forested areas and expanding forestation.

However, mitigation and adaptation are complementary response measures. Mitigations address the causes of the problem while adaptation deals with the unavoidable impacts of climate change on the environment, and, in this case, road infrastructure. There are various explanations in the literature as to what adaptation is. For instance, the IPCC (2007: 86) explains adaptation as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". The European Environment Agency [EEA] (2013) explains adaptation as the protection of infrastructure against negative impacts of climate change by building climate-resilient infrastructure. South Africa's Green Transport Strategy (South Africa 2018) explains adaptation as actions responding to the existing and future impacts and vulnerabilities within societal changes. It can be inferred from the above reasons that adaptation is the response to climate change in an effort to minimise social vulnerability to change in an effort to neutralise the impact of climate change (Busayo, Kalumba & Orimoloye 2019: 4). There are three types of adaptation as indicated in the IPCC (2007) Fourth Assessment Report, namely:

- **anticipatory** adaptation – this type is also referred to as proactive adaptation, and is an adaptation before the climate change impacts are observed;

- **autonomous** adaptation – a spontaneous adaptation, which does not entail a conscious response to climatic stimuli but is triggered by ecological changes in natural systems; and
- **planned** adaptation – the result of policy decisions taken deliberately, based on climate change conditions awareness by the decision- or policymakers. This is a **reactive** type of adaptation. Although adaptation in natural systems is reactive by nature.

The sooner adaptation plans are developed and implemented, the less the costs of responding to climate change (European Commission [EC] 2013). Adaptation policy design requires considerations in time, at spatial and decision level. In fact, location assessment of current and future impacts is essential –

- to identify adaptation capacity;
- to gather information about the timeframe of impacts;
- to implement appropriate adaptation actions at appropriate levels of decision-making (EEA, 2013).

On the other hand, delaying action will increase the economic, environmental and social costs. It has been demonstrated that the costs of taking immediate action to address climate change, both in terms of mitigation and adaptation, will be much lower than the costs of inaction over the medium to long term (European Commission [EC] 2009: Online; Stern 2006: 3). Thus, timeous planning will reduce costs.

Mitigation is a global concern, however, adaptation is a local concern (CTMM 2017: 11). Climate change impacts are manifested at local level. While climate change is perceived as a global concern, resulting in an increase in global temperatures, the effects have a local dimension, affecting local livelihood, economic activities, and environmental, social and economic systems (Twerefou *et al.* 2015: 11951). A global problem is translated into local phenomena based on various environmental, social and economic factors (Snover *et al.* 2007: Online). Climate change, together with existing urban problems, worsens some problems and has the potential to create new ones (Ecologic Institute, 2011: 293). Municipalities are close to the communities and have the responsibility for areas related to adaptation. Therefore, municipalities can

facilitate the participation of different stakeholders who are involved in promoting solutions.

Policy actions on responding to climate change have been focused mostly on mitigation; thus, reducing the GHG in order to limit the long-term consequences of climate change (Klausbruckner, Annegarn, Henneman & Rafaj 2016: 71). Adaptation shows that, despite any action taken, a certain degree of climate change and an increase in extreme weather are already inevitable because of past emissions (Chappin & Van der Lei, 2014: 12). As a result, it is prudent for all spheres of government to consider their vulnerability to climate change impacts and to implement adaptation strategies. Literature (see Enei *et al.* 2011; Fatima *et al.* 2012; Tighe 2008) portrays adaptation as secondary to mitigation, especially within the transport sector. Future policy development must address this to ensure that a balance between mitigation and adaptation is realised. Therefore, actions such as building climate change resilience (i.e. adapting) should be parallel with efforts aimed at mitigation.

In some developing countries, such as China, considerable initiatives have been taken in preparing for a climate-resilient road transport system. The National Adaptation Programme of Action (NAPA) (see UNFCCC 2015: Online) was established to expedite resilient development plan preparations and to enhance adaptation of people to unfavourable impacts of climate change in China. The NAPA identified other climate change issues (i.e. its drivers), and it highlighted the mitigation and adaptation options to realise sustainable development under climate change scenarios and threats (UNFCCC 2015: Online). Howey, North and Martinez-Botas (2010: 4) recommend three ways to reduce road transport emissions, namely improved vehicle efficiency, improved efficiency of vehicle use, and road transport demand reduction. However, reducing the demand for road transport is complex due to the socio-economic opportunities provided by the road transport sector. Improving efficiency of vehicle use would require law enforcement to be effective on speed limits, as undoubtedly, reduction of speed will reduce emissions (Leard & Roth 2015: 16). Improved vehicle efficiency can be realised by reducing the existing fleet or producing vehicles with reduced engine power and weight.

Climate change impacts are diverse and far-reaching. Impacts are however, mostly felt at the local level, where communities have to deal with the impacts first-hand.

Hence, cities have to be the focal points of climate change adaptation. The majority of people live in the cities (CTMM 2018: Online). Urban populations have to deal with impacts of increased temperatures, erratic rainfall, floods and droughts, insurance losses and increased demands on disaster relief resources, among others (ibid). It is anticipated that by the year 2050, almost about 70% of the world's population will be living in cities; thus, cities will be faced with worse situations than now in terms of population growth and emissions (WHO 2018: Online).

The IPCC (2014: 843) assessment report indicates that cities are crucial in responding to climate change. The report also indicates adaptation efforts of cities. Cities across the globe are developing adaptation plans, but research reveals that the implementation of these plans is limited (Heinrichs, Krellenber & Fragkias 2013: 1868; Ziervogel & Parnell, 2012: 224). Furthermore, literature reveals that government processes and structures have the potential to limit the capability of human systems to adapt to climate change (Ziervogel & Parnell, 2012: 224). However, there is a gap in knowledge on how government structures may limit the response capacities. According to Fatti and Vogel (2010: 57), enhanced understanding of both current and past climate phenomena can be invaluable in enhancing the dialogues needed to improve adaptation to future climate change.

The researcher identified a similar knowledge gap in the CTMM, where there is no insight into adaptive governance in the context of road infrastructure. As climate change becomes increasingly eminent, pressure to respond rises in the CTMM. Failure to respond to climate change is problematic and therefore the city may remain vulnerable to the predicted climate change. In terms of the National Climate Change Response White Paper (South Africa 2011), addressing climate change could result in co-benefits, such as improved air quality, reduction of time between trips, a decrease in accident rates and an increase in economic production.

Reducing GHG emissions is an international controversy led by the UNFCCC through the Conference of the Parties (COP). Through the UNFCCC, agreements and negotiations are concluded by countries (referred to as 'parties' by the UNFCCC) to reduce GHG emissions. The UNFCCC has been presenting the COP on an annual basis since 1994. The latest COP was in December 2019. At these conferences, negotiations on emission reductions take place. Developing and developed countries

are at loggerheads, and there is no consensus on mitigating GHG emissions and adapting to climate change. As a result, the need for developing countries to make efforts to reduce the risk of climate change increases. Developing countries are reluctant to accept binding emissions targets; requesting richer countries to take a lead and act first (Pielke 2019: Online).

Mukonza and Mukonza (2015: 90) assert that climate change has created a need for policies to address and minimise the impacts and effects of such change. Joseph (2000: 40) argues, however, that road transport policies are environmentally unsustainable. The current researcher argues that policies aimed at reducing congestion by building roads are being counterproductive. When a road is built, there is increased provision of road space and car parking; thus, changes in land use patterns alongside this space and a decline in public transport services, which results in increased levels of car dependence. However, without policy intervention, projected reductions of emissions will be surpassed by the annual traffic growth, resulting in an annual increase in CO_2 emissions. In order to reduce these emissions substantially, new policy frameworks need to be developed. Although it is worth noting that policy development will not necessarily decrease GHG emission, there is more that needs to be done as will be discussed in this study.

SA climate change mitigation policies, such as reducing vehicular emissions and lowering energy emissions require a change in individual lifestyle (CTMM 2017: 9). South Africa proposed to reduce emissions below business as usual (BAU) of 34% by 2020 and 42% by 2025 (Climate Action Tracker 2016: Online). Although the Climate Action Tracker (2016) indicates that, in terms of current mitigation policies, SA emissions show an increasing trend, the Tracker predicts that SA emissions are expected to grow by 110% and 141% by 2020 and 2025 respectively (Climate Action Tracker 2016: Online). It can therefore be concluded that, without an introduction of new policies, South Africa runs a high risk of not meeting the target it pledged at the Copenhagen negotiations in 2009. The UNFCCC and Kyoto Protocol range their members in different categories from Sufficient to Medium, Inadequate and Not Rated countries (UNFCCC 2014: Online). South Africa was ranged Inadequate together with the following countries: Australia, Canada, Chile, Japan, New Zealand, Russian Federation, Singapore, South Korea and Ukraine (UNFCCC 2011). The mitigation

policies of countries in the Inadequate range have little effect on the emissions trend compared to BAU (NiklasHöhne & Elzen 2014: 137). South African local governments, whilst paying attention to an inclusive international climate regime, are at the same time involved in international initiatives to establish and integrate local government commitments to climate change response. Section 3.4.1 focuses on management measures in place within the CTMM.

3.4.1 CTMM management measures

The local government sphere acknowledges that mitigation should remain a key focal area at both national and local government level. Ongoing research (see, for instance, Pielke 2019: 14) illustrates that, without intervention, energy consumption in the main urban areas will double in the next two to three decades, something that would result in an untenable situation. The renewable energy and energy-efficiency initiatives will not stop energy consumption; however, it would rise at a much slower rate (IPCC 2013: 44). There is an opportunity to mitigate GHG emissions effectively. Developing a legally binding regulatory framework for municipalities and providing support with skills, resources and funding should be a priority for local government. However, adaptation should not be neglected. According to Winkler (2010: 11), there is a high proportion of vulnerability to the impacts of extreme weather events in the urban setting.

The CTMM has grown from strength to strength in responding to climate change, from policy and planning to implementation through to the resolute projects that have climate change mitigation and adaptation at their forefront (CTMM, 2015a: 16). The municipality is a member of the C40 Cities Climate Leadership and was accepted as the 70th member of the Leadership in September 2014 (CTMM 2017: 38). C40 is networks of the megacities across the globe devoted to address climate change issues and challenges (CTMM 2018: Online). The C40 networks are a vibrant working group of cities categorised around a set of similar priorities and challenges. They have a few thematic networks and create a forum where cities collaborate, share knowledge and push for measurable and sustainable climate change response measures and actions (C40Cities 2018: Online).

In responding to climate change impacts amongst other things, the municipality established the City Sustainability Unit in 2013 as a catalytic driver of the green economy innovations (CTMM 2015a: 2). The unit has to ensure that sustainability is being mainstreamed into city operations as part of the drive of transitioning towards a low-carbon, resource-efficient and climate-resilient city. The city has embarked on interventions to drive the green economy through sustainable procurement.

Maintaining road infrastructure is expensive. However, providing quality road infrastructure could promote a sustainable economy; therefore, it is necessary to invest in and maintain the infrastructure (CTMM 2015b: 156). Certain parts of the city have inadequate and old infrastructure that are vulnerable to heavy rains and which are prone to flooding (ibid). The CTMM has identified the following adaptation actions:

- use information from vulnerability assessments to identify vulnerable areas, make use of resilient designs and building material as well as the relocation of existing developments in high-risk areas;
- continue with the urban core projects, which are high-density activity nodes that present economic, social and residential potential in integrated environments, linked to public transport facilities, e.g. Mabopane. This cuts down spending on provision and maintenance of infrastructure as users and systems are in a manageable space;
- promote projects that provide sustainable road infrastructure to allow residents of CTMM to experience tangible socio-economic and spatial transformation. Road and storm-water infrastructure has since been built in Soshanguve and Mabopane;
- increase operational budget for maintenance of infrastructure, such as storm-water drainage systems; and
- upgrade and maintain water and sewer infrastructure to reduce backlog and meet new demand (CTMM 2015b: 232).

In order to protect road infrastructure, emission levels have to be reduced. However, emission reduction plans without implementation on the ground is just an empty gesture. The City of Tshwane is amongst the biggest emitters of GHGs in South Africa mainly from industrial, transport and residential (domestic) activities (see CTMM 2018:

Online). Transport emissions can be curbed by reducing travel demand, improving transport technology and shifting from high-carbon to low-carbon modes of transport (ibid). Brendan, Barrett and Fien (2016: 6) argue that improved urban planning could reduce travel demand; thus, bringing essential facilities closer to the communities to reduce the need for people to travel.

Improving transport provision will also reduce travel demand. According to Dalkmann and Huizenga (2010: Online), transport can be improved by shifting to modes of transport that have low negative impact on the environment; thus, shifting from high-carbon to low-carbon emitting modes. This shift implies that public transport and non-motorised transport (walking and cycling) should be used rather than the private vehicles. The DoT (2014a) suggests that public mass transit should be improved. Public mass transit refers to systems such as the BRT, Integrated Public Transport, carpooling and park and ride. The DoT (2018) indicates that road vehicle efficiency can be improved by utilising alternative fuels and technologies, such as smaller engines, plug-in hybrid and electric vehicles.

In terms of the White Paper on National Climate Change Response (2011), facilitation of the development of an enhanced public transport programme under the short-term Transport Flagship Programmes is an option for. The CTMM has implemented several initiatives, such as the Bus Rapid Transit (BRT), compressed natural gas (CNG), Gautrain, park and ride and non-motorised transport (NMT).

The Gautrain, although not a municipality initiative, operates between Johannesburg and Tshwane, and protects the City of Tshwane against additional GHG emissions.

- Bus Rapid Transit (BRT) is important in enhancing public transport and promotion of lower carbon. The city has developed and implemented the A Re Yeng (‘Let’s go’) BRT, which started operating in 2014. This system is aimed at providing safe public transport, improving air quality within the city, and reducing traffic congestion. The buses used for the BRT are 100% CNG-powered, which eliminates carbon emissions that are a health risk, as it does not rely on fossil fuel. In 2016, it was estimated that if 15% of existing car users who lived in the radius of 500 m of the A Re Yeng corridors used the system, there would be savings of tons of carbon dioxide (CO_2) equivalent emissions

(CTMM 2017: Online). It is expected that the BRT will save 1.6 million tons of carbon dioxide equivalent emissions by 2020 (CTMM, 2015b:23).

According to the DoT (2014a), the use of public transport by citizens could assist in mitigating climate change. Public transport not only has the potential to mitigate climate change but can also enhance economic growth through job creation. For instance, a few jobs could be established in vehicle manufacturing, infrastructure construction and public transport operations. Improved public transport has the potential to attract users to public transport, resulting in less private car usage, which will reduce the carbon emissions. The municipality is committed to reduce the emissions from the transport sector. Consequently, it attempts to improve air quality by introducing low- and ultimately zero-emission buses in its fleet and signing the C40 Clean Bus Declaration (CTMM, 2015a:16). Currently (i.e. 2018), the fleet of buses of the municipality operates on low-emission diesel Euro V engines, and the next fleet order is moving towards CNG engines. Not all bus fleets however will be powered by CNG engines, as it is an ongoing project and it is envisaged that, by 2025, 30% of the 350 buses in the fleet will be powered by CNG engines and the remainder by Euro V or V1 diesel engines (CTMM 2018: Online).

In 2014, the CTMM launched the Tshwane Green Outreach Programme aimed at encouraging residents to lead sustainable lives. According to the City Sustainability Unit (CSU), the role of an awareness and education programme is pivotal in mobilising and residents to be active citizens and champions in realising a resource-efficient, climate-resilient and low-carbon city as anticipated in the Tshwane 2055 vision document (CTMM, 2015a: 13). The CSU collaborated with the South African Cities Network (SACN) in implementing the Green Outreach Programme. The programme had primarily two activities: the establishment of a baseline on carbon emissions for the city, and its vulnerability to climate change (SACN, 2016: Online). Moreover, an in-depth education and awareness campaign on climate change impacts was integrated into the programme with the aim of making a difference to people's lives by educating them.

One of the mitigation actions taken by the municipality is the NMT, which involves activities such as walking, cycling and running. To reach the demands of a rapidly growing city, the municipality has to establish and encourage NMT as way of

commuting and a means to encourage and grow liveable communities. The CTMM developed a pedestrian safety master plan that provides a comprehensive framework for improving pedestrian safety and mobility in the city (CTMM 2015b: 12). The objectives of the plan are:

- improving safety and efficiency for pedestrians through the implementation of the traffic calming measures;
- provision of formal public transport facilities;
- provision of road markings;
- provision of road signage; and
- building pedestrian walkways.

The City has undertaken the city rejuvenation project called Operation Reclaim (CTMM 2015b: 12). This project involves development of NMT facilities and infrastructure to create a cycle- and pedestrian-friendly environment. The municipality, together with the DoT and the Gauteng Department of Roads and Transport (GDRT), has made provision for cycling infrastructure under the Shova Kalula ('pedal easy') project (CTMM, 2015b:20). In 2014, the GDRT as key driver of the project procured and provided 1 650 bicycles to the municipality to distribute to schools across the Tshwane area (CTMM 2015b: 14).

Electric vehicles (EV) are another mitigation measure in place in the CTMM (CTMM 2015b: 14). In the 1970s, South Africa – like the rest of the world – experienced an oil crisis and began to do research on EVs as an alternative to petrol-driven vehicles (Council for Scientific and Industrial Research [CSIR], 2006). The CSIR then planned further technological developments and implemented them, such as sodium-nickel chloride batteries and lithium-iron technologies. These developments assisted with the oil crisis and interest in EVs started fading. In 2008, South Africa's National Energy Research Institute (SANERI) again started doing research on EVs. The EV project is implemented (CTMM 2015b: 11). The CTMM has invested in EVs with 10 electric cars already bought for their city messenger services. Furthermore, the municipality is busy working on the introduction of the EV infrastructure and solar-powered chargers. Successful implementation of said projects and programmes requires collaboration with multiple stakeholders. Implementing the projects and programmes brought with it

a number of challenges. Section 3.5 provides an overview of challenges faced when implementing the response measures identified and discussed above.

3.5 CHALLENGES OF IMPLEMENTING CLIMATE CHANGE MANAGEMENT MEASURES

Literature such as IEA (2016) and IPCC (2014) reveals a number of factors that have the potential to pose risks in implementing climate-resilient road projects and programmes. These factors refer to finance, economic analysis, capacity, social acceptance of the projects and programmes, a lack of awareness and a lack of political will.

The International Energy Agency [IEA] (2016: Online) has established a range of obstacles to implementing NMT, firstly, including but not limited to private vehicle-oriented spatial and transportation planning in cities.

- Secondly, the public perception on walking and cycling –South Africans tends to perceive walking and cycling as mode of transport for the poor.

- Thirdly, the safety aspect in utilising NMT – cyclists and pedestrians are vulnerable to crime incidents in South Africa, such as robbery. Moreover, NMT users are more prone to accidents than car users (IPCC, 2014).

- Fourthly, the ineffective integrated transport planning, which means NMT becomes an auxiliary to public transport, such as BRT.

- The fifth barrier relates to infrastructure planning and availability of land use. NMT requires specially designated areas and lanes for cycling and walking. The challenge here is there is not sufficient land space to address this need

- Lastly, there is the financing aspect. It is expensive to provide safe and effective NMT and its special infrastructure. The cost of NMT includes bicycle and pedestrian paths (i.e. construction and maintenance) and public awareness campaigns. Moreover, despite the quality of public transport and NMT provided, some behaviour, such as the use of single-occupancy private vehicles, is difficult to change. Successful implementation of NMT depends on a number of factors, such as culture, political commitment, public awareness and policy efforts. Serrao-Neumann et al. (2011) argue that the geographical aspects and

climate are also factors that have an influence on the success of the NMT implementation.

Bus Rapid Transit (BRT) is a specialised bus system aimed at providing a quality rapid mass transport system (Munoz & Paget-Seekins 2016: 107). However, in pursuit of this aim, the system encounters numerous challenges:

- the system does not have support from the road public transport industry;
- public transport operators, such as minibus taxi owners and bus companies, does not support the project because it is competitive and they fear losing commuters;
- according to Munoz and Paget-Seekins (2016:107), BRT further has a challenge in attracting users, especially private vehicle users, since the buses are predominantly operating in cities and do not reach most nearby areas;
- the system has dedicated lanes, which minibus taxis are not allowed to use. This has led to inefficient transport in affected areas since minibus taxis cause traffic congestion because of fewer taxi lanes than before; commuters are consequently delayed and late for work; and
- the BRT is an expensive project to maintain, and developing a financial model for future maintenance of the system is a challenge.

Compressed natural gas (CNG) is classified as an alternative fuel (Mehrotra *et al*., 2011:28). The cost of implementing CNG is a challenge because –

- such vehicles are expensive due to on-board fuel storage as well as modification of the vehicle engines;
- the engines and vehicles are still only available in limited numbers; and
- refuelling is only available in selected areas, and the City of Tshwane is still busy with infrastructure constructions for such refuelling.

In executing the green outreach programme, there were numerous challenges such as –

- obtaining and maintaining sponsorship and partnership for the project; and

- the project was launched during the election season; therefore, the project did not have as much impact as anticipated (CTMM, 2015a:15).

Capacity building is a challenge. The capacity to respond to climate change necessitates a degree of expertise in technical and political skills. Capacity building is extensive and applicable to various disciplines as climate change is transversal (Kainuma *et al.* 2018: 73). However, although capacity in the municipality is growing and diversifying in response to the impacts of climate change, an abundance of growth and progress is needed (Kainuma *et al.* 2018: 74).

Municipalities have to make difficult decisions to find balance between competing interests of the communities with limited resources and funding (South African Cities Network 2015: Online). Other challenges faced by municipalities include high transaction costs, competitiveness, costs related to emission reduction, availability of investment capital and little progress in technological development (CTMM 2018: Online). Overcoming these challenges to implementation of management measures requires policy intervention and incentives. Most importantly, municipal spending patterns should be adjusted to accommodate mitigation strategies. Implementation barriers for the municipality are additional barriers, including knowledge gaps, law enforcement, and implementation evaluation and monitoring programmes, and financial incentives. There is a range of policy instruments in place to overcome these major barriers to implementation of management measures. Policy instruments are discussed in detail in the Chapter 4.

3.6 FINANCING MUNICIPAL MANAGEMENT MEASURES – IMPACT OF CLIMATE CHANGE ON ROAD INFRASTRUCTURE

This section aims to address one of the research questions, namely how the response to the impact of climate change is financed. Furthermore, this section will discuss the sources of finance in municipalities as well as the challenges of accessing the funds, more particularly, for climate-resilient road projects and programmes. Hallegate, Heal, Fay and Treguer (2012: Online) state that implementation of mitigation actions is important for sustainable development. Climate-resilient road projects and programmes require financing mechanisms to cater for each phase. Hammer, Kamal-Chaoui, Rober and Plouin (2011: Online) assert that regulatory authority and financial

tools are important policy instruments necessary for municipalities to achieve the outcome of climate-resilient projects and programmes.

Climate-resilient road programmes and projects aim to address the impact of climate change and provide safe road transport for the community (Miller & Hutchins 2017:347); however, public funds alone are not adequate in achieving this aim. Municipalities rely largely on allocation from national government. Municipalities have to source income from other incentives such as energy efficiency, grants and subsidies, local taxes, service fees, revenue, municipal tariffs and property taxes. Other financial options for municipalities are funds from private investments, carbon markets and bilateral and multilateral organisations such as climate investment funds (CIFs), global environment facilities (GEFs), and clean development mechanisms (CDMs) to fund the mitigation actions. However, there are requirements to entice organisations to finance climate-resilient programmes and projects at municipal level (South African Cities Network, 2016: Online). At national level, Nationally Appropriate Mitigation Actions (NAMAs) are mechanisms for communicating and attracting funding for climate change mitigation projects from the climate finance funders (Dikgang 2013: Online). Identifying how and where to attract the funding is often a challenge. The bilateral and multilateral organisations focus on specific sectors, such as transport projects that promote enhanced fuel economy standards and an efficient public transport systems.

There is disagreement on climate finance. Developing countries insist that developed countries should take a lead in responding to climate change and finance developing countries to increase their capacity in responding to climate change. Thus, the issue of financing the cost of climate change is a global dilemma. However, developed countries are reluctant to lead in this regard. For most countries, climate mitigation is not the main target, but it is the efforts driven by economic, security or local environmental concerns (Jaroszweski & McNamara, 2014: 16). Municipalities face challenges posed by global finance crises; thus, innovation is crucial in sourcing private funding for projects and programmes.

Lindfield and Steinberg (2012: Online) and New Climate Economy (2014: 15) identify four elements in the financing system in order to attract financing as follows:

- fiscal structures for energy efficiency and reduction of GHG emissions;
- regulatory procedures for local and international markets for enhancing access to climate funds;
- capacity building for developing countries from the international public structures; and
- involvement of government agencies and private sector.

Lindfield and Steinberg (2012: Online) state that these elements are not often utilised by sub-national governments globally. As a result, there is a need for the upper spheres of government to coordinate the planning and oversight for the lower sphere to function optimally (Lindfield & Steinberg, 2012: Online). South African Cities Network (2015: Online) indicates that municipal grants and revenues are outweighed by the infrastructure needs of cities; thus, leaving municipalities with borrowing funds as the only option. Unfortunately, the World Bank reports that just below 5% of 500 cities in developing countries are found creditworthy enough to have access to global financial markets (UNEP, 2016: Online). The WHO (2018: Online) urges the private sector to be involved in infrastructure projects. Private sector involvement will also encourage skills transfer to the public sector. Moreover, the private sector has advanced technological instruments that can be useful in the public projects.

3.7 SUMMARY OF THE CHAPTER

Numerous innovations are taking place worldwide to enhance the capability of road infrastructure to address climate change-related challenges, such as an increase in extreme weather events and changes in weather patterns. The innovations show that there are positive opportunities for transforming road infrastructure construction, maintenance and usage. CTMM road transport is not as integrated as it could be, and there is a growing rate of car ownership. This growth poses capacity challenges in terms of the road transport sector with regard to land use and space to accommodate vehicles. Road conditions directly influence GHG emissions; thus, poor road maintenance results in increased emissions. Due to all the negative outcomes the sector has on and from climate change as there is a cyclical link, it is only appropriate to respond to the impact(s).

This chapter presented a discussion of the implementation of response measures to climate change with specific reference to the CTMM. Literature revealed that the city has a number of initiatives in response to climate change. The city is vulnerable to climate change due to its geographical location and diverse human activities. There are many road transport activities in the city and the city has more vehicles on its roads. The researcher further looked into the financing aspect of the response measures, and it was found that financing is an ongoing challenge for the municipality. The municipality has no easy access to finance for implementing the response measures, which become increasingly challenging as certain projects and programmes are often delayed due to a lack of funding. In responding effectively to climate change, public policies should be formulated and effectively implemented.

The next chapter briefly reviews the implementation of existing South African policies and strategies regulating the issue of climate change in terms of road transport.

CHAPTER 4
LOCAL GOVERNMENT MANAGEMENT LEGISLATIVE FRAMEWORKS FOR CLIMATE CHANGE

4.1 INTRODUCTION

In chapter 2 and 3, the pertinent literature on the impact of climate change on road infrastructure and the management measures of the impact as well as the challenges of implementing the identified management measures in the CTMM were studied and analysed. Chapter 2 presented the impacts of climate change on road infrastructure, in order to make recommendations on how better to address such impacts as required by the National Climate Change Response White Paper (South Africa 2011). From the previous chapters, it was clear that climate change is a global problem that requires governments across the globe to be interrelated and interdependent in addressing it.

As the international framework for climate change negotiations continues, vast activities are taking place globally to reduce GHG emissions. The South African government has developed various strategies to address climate change, particularly in cities focusing on the need both to mitigate and to adapt to climate change. This chapter primarily focuses on policy regarding adaptation and mitigation within the road transport sector in the CTMM. The chapter seeks to answer one of the research questions: How is climate change integrated in the road transport planning and policy in the CTMM?

The South African government has established a number of goals, measures, strategies and initiatives with which to reduce emissions of GHGs as stipulated in the National Climate Change Response White Paper (South Africa 2011). At local government level, municipalities have developed their own strategies, plans and initiatives in accordance with the national level of standards and procedures (CTMM 2017: 3). The researcher established that South African government has elaborated on various actions and plans for climate change and has also developed a climate change response strategy but has no coherent legislation regarding climate change and the road transport infrastructure sector. As the country braces itself for climate change impacts, there is a growing solidarity that the role of local government in managing climate change is indispensable. However, local government relies on capacity building and financing to manage climate change effectively and efficiently.

Local government is vulnerable to climate change, as it is first to experience the effects and to manage the impacts. In 2011, at the seventeenth Conference of Parties (COP17), the South African Local Government Association (SALGA), the South African Cities Network (SACN) and the 278 South African municipalities established a Local Government Partnership for COP17 (South African Cities Network 2015: Online). The Department of Cooperative Governance (DCoG) and the DEA supported this partnership.

This chapter further reports on the interrelationship of public policies, strategies, frameworks and plans to manage the impact of climate change on road infrastructure within two other South African metropolitan municipalities, namely the City of Johannesburg (CoJ) and the City of Cape Town (CoCT). CoJ was selected because it is in the same province as the CTMM; therefore, there is a high probability that they experience similar weather changes, whilst CoCT was selected because of its considerable initiatives from which this study drew lessons.

4.2 MANAGEMENT OF CLIMATE CHANGE BY SOUTH AFRICAN METROPOLITAN MUNICIPALITIES

South Africa has eight metropolitan municipalities as part of the local government system, namely –

- Buffalo City in East London;
- the City of Cape Town in Cape Town;
- Ekurhuleni Municipality in the East Rand;
- the City of eThekwini in Durban;
- the City of Johannesburg in Johannesburg;
- Mangaung Municipality in Bloemfontein;
- Nelson Mandela Municipality in Port Elizabeth; and
- the City of Tshwane in Pretoria.

Local government is primarily concerned with service delivery, and its constitutional mandate is to provide services in a sustainable and equitable manner (Pasquini, Cowling & Ziervogel 2013: 226). Furthermore, local government has to facilitate social and economic development and promote a safe and healthy environment for every community (Stern 2016: Online). Climate change has a direct impact on the ability of local government to meet this constitutional mandate.

Climate change impacts, such as dry seasons, increasing temperatures, extreme storms and flooding could result in drought, crop failure, livestock death and damage to infrastructure (Stern 2016: 315). According to the Organisation for Economic Co-operation and Development (OECD), mitigation of and adaptation to climate change by both public and private sectors, depend on three pillars (OECD 2008: 11):

- the development of relevant policies;
- investment in infrastructure and technologies; and
- behavioural change.

The CoCT has formulated a climate change policy to enable the city to prepare for and curb the impacts of climate change. Moreover, the policy enables all the stakeholders of the city to understand how to reduce GHG emissions and to try to minimise global climate change.

4.2.1 Mitigation response of the Cities of Johannesburg and Cape Town

Local governments, particularly cities, have a major role to play in reducing GHG emissions; thus, contributing to effective management of the impacts of climate change (Creutzig & He, 2009: 121). To balance the effects of road maintenance while also providing basic and other services, local governments must prioritize resources, capacity building, and funding. Mitigation measures could refer to lowering emissions, urban development and sustainable transport (Parry 2016: 13). According to Folberth et al. (2015: 237), the major aspects of sustainable transport are eco-mobility and integrated rapid public transport network. The primary aspect of low carbon is development, which is the functionality of the urban environment (Reddy & Wolpe 2018: 23).

One of the origins of dysfunction of urbanisation is the residual effect of the apartheid spatial planning system (Reddy & Wolpe 2018: 20), which enforced the disconnection between workplace and home (Dikgang, 2013: 1). As a result, South Africans have to travel long distances to and from work, which is costly, and contributes to the increasing informal settlements. Although spatial transformation might take long to realise, cities are developing their integrated rapid public transport networks to ease the traveling burden on daily commuters and provide them with a safe, efficient, comfortable and affordable mode of transport (CTMM 2015b: 18). The apartheid

spatial planning system has left the City of Johannesburg (CoJ) to be a socially, spatially and economically disconnected and segregated city. The current government attempts to transform CoJ through provision of efficient spaces that are liveable around public transport, such as BRT system.

CoJ is among the biggest emitters of GHGs in South Africa mainly from industrial, transport and residential (domestic) activities (South Africa 2018: Online). The city has developed and implemented the Rea Vaya ('We are going') BRT system. It was estimated that, if 15% of existing car users who live within a radius of 500 m from the Rea Vaya corridors use the system, there will be savings of great tons of carbon dioxide (CO_2) equivalent emissions. In terms of the Integrated Transport Plan (2013–2018) of the City of Johannesburg (South Africa 2013a), the municipality will focus on the following flagship programmes to try to mitigate climate change:

- reduction of the carbon footprint addressing road traffic congestion;
- purchasing alternative fuel vehicles, such as electric vehicles
- the BRT; and
- improving public transport.

The City of Cape Town (CoCT) also implemented a BRT system similar to the Rea Vaya system, known as MyCiTi buses, which provide rapid public transport services that are connected to non-motorised transport networks, such as cycling and walking. Moreover, CoCT facilitates a Smart Driver Training Programme for the fleet personnel to link driving patterns to NMT (CTMM 2015b: 147). Eco-mobility is essential for sustainable transport. Despite the provision of public transport and non-motorised transport infrastructure, some habits are difficult to shift, such as the use of single-occupancy private cars. CoJ, in partnership with the International Council for Local Environment Initiatives promotes eco-mobile urban transport systems Taylor, Davies, Oelofse, & Roux 2016: Online). According to the Johannesburg Declaration on Ecomobility in Cities, no GHG emissions reduction strategy is complete without including low carbon urban transport solutions. In terms of the climate change policy for Cape Town (City of Cape Town 2017: 22), the city has done the following:

- Developed and introduced Phase 1 and the N2 Express service of the MyCiTi bus network in support of the Integrated Public Transport Network (IPTN). Phase 2A planning is underway.

- Introduction of a long-term citywide non-motorised transport (NMT) programme, which started in 2010, and is aligned with a road- and rail-based transport network.
- Developed a cycling strategy, which aims to contribute towards a reduction in congestion and emissions in the City by 2030.
- Detailed design and planning underway for transit-oriented development (TOD), enabling the creation of greater density and mixed-use development along public transport routes.
- Actively working with partners to improve integration between MyCiTi, the rail service, the bus service and the mini-bus taxi industry, including a signed memorandum of action with Passenger Rail Agency of South Africa (PRASA)
- Developing a Travel Demand Management (TDM) Strategy, which aims to influence travel behaviour in order to reduce peak-period car travel (particularly single-occupancy vehicles), shift modal share towards public transport and NMT, and reduce energy consumption and emissions.
- TDM projects implemented to date include the upgrade of rail park-and-ride facilities and the introduction of the City's travel behavioural change programme (Travel SMART). New TDM projects to be introduced include the flexible working programme and the development of high-occupant vehicle priority strategies, such as carpooling.

4.2.2 Adaptation response of City of Johannesburg and City of Cape Town

According to the National Climate Change Response White Paper (South Africa 2011), climate change places additional stress on the South African road transport infrastructure and road networks, ultimately placing pressure on disaster management systems and resources. South Africa experiences intense rainstorms and floods, droughts and fires, and extreme climatic events are causing severe damage to the road transport sector with a devastating impact on the road infrastructure. Climate change is an additional stressor projected to increase in intensity; therefore, adaptation measures are essential to support more resilient road infrastructure in the short and longer term.

In 2013, the South African government published the Long-Term Adaptation Scenarios, which describe South Africa's potential vulnerability to the projected climate change in the medium and long term (2020–2050). The scenarios indicate the importance of integrating the potential biodiversity and ecological infrastructure to realise the sector-specific adaptation benefits (Taylor, Davies, Oelofse & Roux. 2016: Online). Municipalities are at the base and have the potential to build communities' resilience in adaptation to the impacts of climate change (Pasquini, Cowling & Ziervogel 2013: 225).

Flooding due to extreme rainfall is a high risk for the road infrastructure in the CoJ as it affects the provision of road transport services and affects the sustainability of the transport systems (Brundrit 2009: 8). Flooding affects the road infrastructure by placing strain on its maintenance and development. Additionally, there are major concerns on the side of the CoJ about the economic impacts of increasing mobility disruptions because of increased rainfall. In 2009, the CoJ developed a Climate Change Adaptation Plan, aiming to address adaptation requirements for the city. The plan is in accordance with the National Climate Change Response Policy (2011); thus, the CoJ has taken the necessary measures to address climate change. However, the plan did not include measures to adapt to climate change within the road transport infrastructure; thus, the CoJ also viewed adaptation as a secondary to mitigation measures in managing climate change impacts within the transport sector.

The City of Cape Town Climate Change Policy (see City of Cape Town 2017: 22) promotes an ecosystem-based adaptation strategy that considers the maintenance and use of natural areas and public open spaces and promotion of non-motorised transport. Section 4.3 focuses on regulations and policies available for regulating climate change and road transport in South Africa.

4.3 REVIEW OF REGULATIONS AND POLICIES ON CLIMATE CHANGE AND ROAD TRANSPORT

Climate change has an effect on a variety of municipal services. As a result, climate change adaptation initiatives within a municipality cut through and integrate a variety of other sectors' regulations, policies, and procedures. (Busayo, Kalumba, & Orimoloye 2019: 13). Acknowledging the potential of municipalities – particularly metropolitan municipalities – to undertake climate change management measures

requires a review of environmental laws and local government laws as well as laws dealing with spatial planning, land-use management, transport and disaster-risk management. This section reflects a review of South African policies and regulations that provide the mechanisms and impetus for municipalities to undertake climate change management measures. It highlights the cross-cutting nature of managing climate change impacts and reveals the fragmented nature of the legislative framework within which they have to operate. In order for South African local governments to address climate change effectively, climate change has to be integrated into sectoral policies. Integrating climate change refers to incorporate climate change mitigation and adaptation measures into all phases of policymaking and other sectors (Mickwitz, Aix & Beck 2009: 3). Integrating climate change into transport planning and policies could help manage the impact of climate change.

4.3.1 The Constitution of the Republic of South Africa, 1996

The South African government has a constitutional mandate to protect the environment and ensure the safety of the citizens. In terms of the Constitution of the Republic of South Africa, 1996*,* Section 24(a) and (b i–iii) –

> [E]veryone has a right to an environment that is not harmful to their health or well-being and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
>
> i. prevent pollution and ecological degradation;
> ii. promote conservation; and
> iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic social development.

In executing this mandate, the government is faced with numerous challenges and difficulties, such as climate change, which is incalculable, impossible to compensate and often invisible (requires experts to recognise and measure), uncontrollable, and its impact and effects are often irreversible (Ferreira, Martins, Barbi & Ferreira 2011: 51). Various legal opinions outline the mandate of local governments in terms of climate change response measures. According to Ferreira *et al.* (2011: 53), the aspirations of municipalities for climate change response measures are delayed by

the interpretations of their mandate. Government policy has two options, namely mitigation or adaptation. Policy response is often divided along jurisdictional lines. In South Africa, this will be across the three spheres of government, which are the national, provincial and local governments.

Section 152(d) of the Constitution of the Republic of South Africa, 1996 emphasises the importance of promoting a safe a healthy environment, while section 152(e) encourages the involvement of communities and community organisations in matters of local government. These are critical in the implementation of climate change response measures by municipalities. In fact, the objects of municipalities as indicated by section 152 of the Constitution establish a critical framework for the implementation of climate change response measures. Section 152 (1) stipulates that local government must:

a) provide democratic and accountable government for local communities;
b) ensure the provision of services to communities in a sustainable manner;
c) promote social and economic development;
d) promote a safe and healthy environment; and
e) encourage the involvement of communities and community organisations in the matters of local government.

In terms of section 153(a) of the South African (SA) Constitution, local governments are obliged to organise and administer their administration and planning processes according to the interests of the community's basic needs and to foster community social and economic growth. Municipalities thus have a mandate to promote social and economic development, and climate change threatens such developments. Schedule 4 parts A and B of the SA Constitution list the services with which local governments are mandated, among others, that local governments should ensure the provision of municipal roads and road development and maintenance. However, developing and maintaining roads remain critical challenges for municipalities. According to Mokale and Scheepers (2011: 1), constitutional failure to abide by the rule of law and policies of the local government by the responsible officials has the potential to result in failure of service delivery.

4.3.2 White Paper on Local Government, 1998

Local government is constitutionally obligated to advocate development. The White Paper on Local Government (1998) acknowledges the historic challenges faced by municipalities as embedded by apartheid. These challenges include but are not limited to –

- service infrastructure backlogs;
- an inability to get private sector resources for development because of the broken relationship between capital markets and municipalities; and
- poor creditworthiness of municipalities.

Koma (2010:114) attributes the violent protests by communities to the challenges faced by municipalities, which include among others deteriorating road infrastructure, unfinished developmental projects and misuse of municipal resources.

The White Paper sustains the concept of developmental local government, which is undermined by climate change. Developmental local government is defined as committed local government willing to work with members of the community to find sustainable ways to address their social, material and economic needs and improve their quality of lives (Havenga & Pienaar 2012: 14). The White Paper emphasises the importance of the Integrated Development Plan (IDP), which is a plan that municipalities establish for the development of short-, medium- and long-term goals. However, for the purpose of this study, the researcher focused on the Integrated Transport Plan (ITP), which serves a similar purpose as the IDP but is limited to the transport sector. The ITP furnishes powerful mechanisms for municipalities to ease the coordinated and integrated transport system within their geographical area of responsibility.

The White Paper further stipulates that environmental sustainability is a challenge to local government. Therefore, in order for municipalities to enhance environmental sustainability, environmental issues must be included in their planning processes and tools. Planning for environmental sustainability is not an isolated task, but an integral part of the process of developing the ITP. Climate change considerations should therefore be considered in the development of the ITP. According to Mashamaite

(2018a: 585), transport planning at an operational level is concerned about technical issues in relation to traffic estimation and network planning. Climate change impacts, such as an increase in intense precipitation events, floods and droughts are not always taken into account during the planning process for transport systems and operations. Mashamaite (2018a: 588) found that not all eight metropolitan municipalities in South Africa address climate change issues with a formal policy intervention in terms of their ITPs. Non-inclusion of climate change consideration in the ITP leaves municipalities vulnerable to the impacts of climate change.

4.3.3 National Environmental Management Act, 107 of 1998

The National Environmental Management Act, 107 of 1998 (NEMA) (South Africa 1998) aims to promote environmental protection for the benefit of current and future generations. Furthermore, the NEMA promotes conservation and secures ecologically sustainable development and utilisation of natural resources. At the same time, it promotes economic and social development as stipulated in section 24 of the SA Constitution.

The NEMA obligates municipalities to comply with a range of environmental principles in preparing any policy, programme or plan, such as ITPs. Principles relevant to management measures require development to be socially, environmentally and economically sustainable (South Africa 1998). The NEMA presents numerous principles to guide South African municipalities on how to undertake climate change adaptation as an important part of environmental management and sustainable development. Moreover, the NEMA promotes an integrated environmental management that considers the effects of decisions on environmental aspects (South Africa 1998). Decision-makers therefore have to be cautious in their decision-making processes and consider the limited capacity and knowledge to manage climate change impacts. This is pertinent in terms of the unpredictability of the timing and scale of future climate change and its impacts.

One of the principles included in the NEMA is the principle of environmental justice, which ensures that communities are capable of adapting to climate change. The adverse impacts of climate change are often mostly felt by poor communities as they are the most vulnerable due to a lack of resources and capabilities, and most are

reliant on natural resources and the ecosystem, such as fuelwood. The unpredictability of climate change should be taken into account in long-term decisions, and environmental and socio-economic needs should be balanced in order to respond to climate change. Municipalities should employ the principles stipulated in section 2 of NEMA and ensure that they supply their communities with natural resources, reduce the impacts of floods and ensure that the road infrastructure is thermally efficient and flood-proof. Accordingly, NEMA articulates a number of principles and provisions that have the potential to enhance management measures that should be adopted by municipalities.

4.3.4 Tshwane Integrated Environmental Policy (TIEP) (2005)

The Tshwane Integrated Environmental Policy (TIEP) 2005 (see South Africa 2005) was developed with the intention to promote environmental responsibility. General policy principles of the TIEP are sustainable development, environmental justice, community wellbeing and empowerment, ecological integrity and minimisation of negative environmental impacts, amongst others. The policy stipulates a holistic framework for integrated environmental management within the CTMM (see South Africa 2005). This framework is structured around strategic issues, goals and objectives. The goals and objectives inform all units of the CTMM about the importance of integrating environmental issues and considerations in the planning, maintenance and operational functions and responsibilities. The CTMM's Comprehensive Integrated Transport Plan (CITP) is a valuable tool that the TIEP could implement. The implementation of the TIEP at different levels within the CTMM identifies education and awareness as necessary tools. Moreover, the CTMM State of the Environment Report (SoER) and the Environmental Management System (EMIS) enable the effective implementation of the TIEP, which is a flexible policy that has the potential to adapt to the constantly changing environment of the CTMM. Therefore, TIEP has to be audited and revised for relevance, accuracy and practicality continuously.

4.3.5 National Land Transport Transition Act (NLTTA), Act 22 of 2000

The National Land Transport Transition Act (NLTTA), Act 22 of 2000 (South Africa 2000) requires authorities to compile plans to give effect to the requirements and

provisions of the Act. The minimum requirements and regulations for the preparations of Integrated Transport Plans (ITPs) were published in 2007 in the *Government Gazette No. 30506:*

> *To provide further the process of transformation and restructuring the national transportation system initiated by the National Land Transport Transition, 2000 (Act No. 22 of 2000); and to provide for matters connected therewith* (South Africa 2009).

The objectives of the Act are as follows:

- to further the process of transformation and restructuring the national land transport system initiated by the National Land Transport Transition Act; 2000, Act No. 22 of 2000.
- to give effect to national policy;
- to prescribe national principles, requirements, guidelines, frameworks and national norms and standards that must be applied uniformly in the provinces and other matters contemplated in section 146 (2) of the Constitution; and
- to consolidate land transport functions and locate them in the appropriate sphere of government.

In terms of this Act, the municipalities are responsible for:

i. land transport policy and strategy development for their area of jurisdiction in accordance with the national and provincial guidelines that includes its vision for the area and incorporating spatial development policies on densification, and development corridors;

ii. enacting municipal by-laws and concluding agreements, as appropriate, in the municipal level;

iii. promoting co-ordination of departments and agencies in the municipal level with responsibilities that impact on transport and land use planning,

iv. developing transport plans, ensuring the implementation thereof and monitoring the performance in realising the set goals and objectives; and

v. financial planning for land transport particularly for transport planning, infrastructure, maintenance, monitoring, operations and administration, primarily focusing on rehabilitation and maintenance of infrastructure.

Primary principles for transport planning and integration must integrate land development and land-use planning. In terms of the NLTTA, ITPs must provide structure for the function of municipal planning indicated in Schedule 4 (Part B) of the SA Constitution. This structure should form an essential part of integrated development plans (IDPs), taking into account legislation applicable to local government and its integrated transport. In terms of section 18 of the NLTTA, transport planning must be a coordinated and continuous process. Importantly, land transport planning should integrate land development processes. Moreover, land transport planning primary focus must be to move goods and people in an effective and economic way. The adverse impact of transport on the environment must be curbed.

The NLTTA governs the planning and management of transport at National, Provincial and Local government sphere. The Act provides guidelines and regulations for the provision of regulatory bodies (SANRAL 2015: Online). The local transport authorities have powers to monitor and regulate the provision of public transport and transport infrastructure within an integrated development environment. This, along with a principle of curbing adverse environmental impacts, provides a space for transport planning officials to promote energy and environmentally sustainable transport network and systems. In terms of section 32(a) of the Act, the planning authorities in the municipalities must prepare integrated transport plans. The CTMM has developed one for the five-year period called the Comprehensive Integrated Transport Plan (CITP). This plan is discussed below.

4.3.5.1 CTMM Comprehensive Integrated Transport Plan (2015 to 2019)

The CITP (2015 to 2019) (CTMM 2015b) is a detailed five-year plan for transport infrastructure and public transport. It provides details on the status quo of transport systems and highlights strategies associated with projects in place to address transport and infrastructure challenges. The CTMM CITP aims to reduce environmental impacts, to promote public transport, and to improve access and mobility. If the CTMM realises this aim, it will result in improved energy efficiency in

the future. Due to the influence of the utilisation of public transport on the use of energy, the emission of GHG and the requirements for environmentally damaging infrastructure, public transport planning included in the CITP is relevant to any study of energy consumption in CTMM. The CITP of the CTMM clearly stipulates their strategy for provision, improvement and maintenance of road transport infrastructure. The NLTTA requires that ITPs include plans for spatial planning and land use. The next piece of legislation reflects this NLTTA requirement.

4.3.6 Spatial Planning and Land Use Management Act, Act 16 of 2013 (SPLUMA)

The Spatial Planning and Land Use Management Act, Act 16 of 2013 established a new framework for governing the planning permissions and approvals. The SPLUMA stipulates processes and provides broad principles for spatial planning decisions by both local and provincial authorities. Furthermore, the Act stipulates that the adaptation measures in municipal land-use systems should be prioritised. The primary objective of the SPLUMA is to provide for the sustainable and efficient use of land (section 3(d)). The SPLUMA refers to numerous development principles to bind municipalities in governing land use and development. In terms of section 6 of the SPLUMA, municipalities are legally bound to adhere to the contemplated development principles during preparation and implementation of a spatial development framework, land-use scheme and by-laws regarding the spatial planning. Moreover, the Act includes numerous development principles that are relevant to climate change adaptation. These include but are not limited to the principles of spatial justice, sustainability and resilience (Taylor *et al.* 2016).

The primary focus of the principle of spatial justice is to redress the past spatial imbalances by including informal settlements in spatial development frameworks (SDFs) (Taylor, Davies, Oelofse & Roux 2016: Online). Informal settlements are therefore considered in municipal long-term transport planning to cater for the transport needs of communities. Informal settlements are vulnerable to climate change impacts due to their location on hazardous land. Municipalities therefore need to address climate change in their SDFs.

In as far as climate change is concerned, the principle of spatial sustainability requires that spatial planning and land-use management protect agricultural land, which is critical to food security and local employment. Moreover, the costs of providing infrastructure and social services (for example water provision taking into account lower annual rainfall and higher temperatures) should be considered. The principle of efficiency included in the SPLUMA requires that municipalities minimise financial and environmental impacts in the decision-making process. Consequently, it is necessary to integrate the impacts of climate change and adaptation measures into development planning decisions. Every year, people in some flood-prone areas around the country are washed out of their homes, posing an additional mandate and obstacle for municipalities to provide shelter and food packages, as families also lose their livelihoods.

The transport sector addresses climate change through mitigation actions. Boyd and Coetzee (2013:5) however argue that mitigation actions become empty efforts unless integrated into public policy. An integration of climate change into sectoral policies across all spheres of government is needed. Section 24 of the SA Constitution stipulates that everyone has the right to an environment that is not harmful to their health or wellbeing. This constitutional right is at the core of governance frameworks formulated by government. The aim of the National Development Plan (NDP) aim is to grow the economy by 2030 (see South Africa 2012), and the plan dedicates a chapter to low-carbon and climate-resilient economy. The plan indicates that the country should develop a low-carbon economy by means of adaptation and mitigation policy measures. Furthermore, strategies to reduce GHG emissions in South Africa are identified, such as a renewable energy programme, pricing mechanisms, regulations to promote green economy and investment in a public transport system.

The National Climate Change Response White Paper for South Africa, 2011(NCCRWP) (South Africa 2011) is of the same view with the NDP. The NCCRP clearly stipulates government's vision for climate change, transition to a climate-resilient economy and a low-carbon economy. Again, the NCCRWP (South Africa 2011) indicates that, in responding to climate change, the SA government should continue to participate in international climate change negotiations with the aim of concluding an equitable and ambitious climate change agreement for the post-2012

period. The outcome could be in the form of decreased GHG emissions, reduced dependency on fossil fuel, and ensuring that the ecosystem is resilient to climate change. In order for South Africa to make a transition to a low-carbon economy, it is paramount to reduce the reliance of the country on fossil fuel and to adopt other sources of energy, such as nuclear energy, natural gas and renewable energy (Dikgang 2013: 58). These alternative sources of energy will enhance the reduction of the carbon footprint and ensure energy security, which is necessary for economic development.

In 2013, the National Treasury published the Carbon Tax Policy, Act No. 15 of 2019. The primary objective of the policy is to change the current and future behaviour of producers and consumers in consuming carbon-intensive goods and services by reflecting cost in the final cost of the product. The implementation of this policy was set to be 2015 but that did not materialise and it then was postponed to 2016. This was to give other departments time to align their policies with the design of the carbon tax. In implementing this policy, the following tax bases will be applied:

- tax applied directly to measured GHG emissions;
- fossil fuel input tax on coal, crude oil and natural gases based on carbon content; and
- a levy on energy outputs (petrol and diesel).

The policy was then implemented with effect from 01 June 2019 after all departments had taken the opportunity to align their policies with the carbon tax. This policy is aimed at correcting the existing pricing on products that generate anthropogenic GHG emissions (i.e. emissions emanating from human activities), in order to reflect the social costs of such emissions (Twerefou *et al.* 2015: 11954). As a result, the gap in energy pricing of various sources will be closed, encouraging the use of less carbon-intensive technologies and cleaner energy. As indicated before, climate change is a growing problem. Solving it calls for integrating adaptation and mitigation actions into public policies across various sectors (Urwin & Jordan, 2008: 181). Practical ways to integrate climate change into existing and new policy measures ought to be identified.

This study acknowledged that policies alone will not be enough to address the impacts and effects of climate change. The suggested policy formulation is complicated in its design to ensure effective implementation as such policy must integrate with existing

policies in the transport sector because the vertical and horizontal dimensions of environmental policy are challenges in executing public policy. There is a need for other measures based on technology and the will to implement the policies innovatively in all spheres of government. It is for this reason that this study suggests a formulation of a comprehensive climate change policy on road transport that will –

- promote energy-efficient vehicles;
- restructure the pricing of transport to contribute to GHG emissions mitigation;
- protect the road infrastructure by effective law enforcement
- promote road network system efficiency in daily operations; and
- encourage the use of low-carbon fuels.

European Union (EU) members have long integrated climate change into other sectoral policies (EU 2013: Online). This integration was made a priority since 1997 in an effort to reduce GHG emissions.

Integration of climate change mitigation actions into transport policies – specifically in South Africa – is needed to mitigate climate change effectively. This integration is supplementary to the traditional single-purpose climate policies, such as control regulation aimed at decreasing GHG emissions, market-based tools, such as the Kyoto Protocol's Clean Development Mechanism, and voluntary agreements. Patel *et al.* (2003: 53) explain climate policy integration as an integration of other policy sectors into climate change adaption and mitigations. The interface of mitigation actions with transport policies is therefore the desired action for effectively addressing climate change issues. The ability to reconcile climate change interventions with growth plans is critical to the effectiveness of mitigation efforts and actions. Mitigation actions can be integrated within development areas, such as transport and its infrastructure. The integration of climate change adaptation and mitigation actions into other sectoral policies is not new in Europe but relatively new in South Africa.

4.3.7 National Climate Change Response White Paper for South Africa, 2011

The National Climate Change Response White Paper is a comprehensive plan to address both mitigation and adaptation in the short, medium and long term (up to 2050) (see South Africa 2011). The policy has two primary objectives:

- management of the inevitable climate change impacts through interventions that build and maintain social, economic and environmental resilience and emergency response capacity; and
- to contribute fairly to the global effort to stabilise GHG concentrations in the atmosphere.

The climate change adaptation and mitigation strategies are set for the short-, medium- and long-term planning horizons.

The policy highlights a risk-based process to establish and prioritise adaptation strategies and interventions for both the short and the medium term. Mitigations are aimed at reducing GHG emissions for each significant sector, best available mitigation options and a full assessment of the costs and benefits using a carbon budgets approach. The policy also proposes the deployment of a range of economic instruments, including appropriate pricing of carbon and economic incentives, as well as the possible use of emissions offset or emission-reduction trading mechanisms for those relevant sectors where a carbon budget approach has been selected.

South Africa's National Climate Change Response White Paper (South Africa 2011) developed a short-term transport flagship program with the aim of developing a better public transport system. This programme promotes low-carbon mobility in metropolitan municipalities and will establish an efficient vehicles programme that will result in measurable improvements in the average efficiency of the vehicle fleet by 2020. In the medium term, the plan calls for significant up-scaling of energy-efficiency applications in transport; and for promotion of transport-related interventions, such as transport modal shifts and switches to alternative vehicles and lower-carbon fuels.

4.3.8 White Paper on National Transport Policy, 2017

The White Paper on National Transport Policy of 2017 (South Africa 2017) is the primary transport policy document in South Africa and steers all transport legislation and planning (South Africa 2017: 1). The key goal for transport is the smooth and efficient interaction that allows society and the economy to assume their preferred form. This white paper is divided into two key areas – infrastructure, and operations and control. Public transport is encapsulated within the comprehensive area of

operations and control under land passenger transport. The White Paper on National Transport Policy 2017 states that the vision for the South African transport sector is to provide –

> [A system that will] provide safe, reliable, effective, efficient, and fully integrated transport operations and infrastructure which will best meet the needs of freight and passenger customers at improving levels of service and cost in a fashion which supports government strategies for economic and social development whilst being environmentally and economically sustainable (South Africa 2017: 1).

In support of the above vision, the policy objectives are as follows:

- Spatial development principles must support passenger transport policy.
- The principle of devolution of public passenger transport functions to the lowest appropriate level of government.
- Public passenger transport must be provided efficiently so that public resources are used in an optimal manner.
- The application of funds to transport improvements should be self-sustaining and replicable. To encourage this, the users of urban transport facilities should pay for all or most of the costs incurred within the limits of affordability (South Africa 2017: 2).

The White Paper furthermore considers road transport provision as an important element in improving mobility and accessibility. In terms of road infrastructure, the policy provides that there should be efficiency in the provision, maintenance and operation of the main economic road infrastructure network and that attention must be given to the provision and maintenance of the lowest-order roads.

The White Paper on National Transport Policy, 2017 initiates various policy actions aimed at providing urban restructuring and efficient land use–transport interaction, including the following:

- The establishment of structures, which facilitate integrated planning of infrastructure, operations and land use in a coordinated manner.

- Regulation of local land-use growth so that approval of growth is subject to compliance with integrated land-use–transport plans.
- The formulation of land use frameworks, guidelines and policies to channel development, particularly employment-generating activities, into public transport corridors and nodes.
- Giving development priority to infilling, densification, mixed land use and the promotion of development corridors and nodes.
- The containment of urban sprawl and suburbanisation beyond the urban limits.
- Discouraging decentralisation, which disperses employment-generating activities, except in specific cases where it is favourable in terms of decreasing total transport costs and travel times based on an integrated land use plan.

In terms of the White Paper on National Transport Policy, 2017 (South Africa 2017: 5), it is important to establish different modes of transport. The White Paper emphasises that strategic planning should be conducted and should include role players in wider national strategies. The White Paper further highlights the need for integration of transport plans and land use frameworks.

4.4 SUMMARY OF THE CHAPTER

South Africa has embarked on various actions and plans related to climate change and has also developed the Climate Change Response Policy but has no coherent legislation regarding climate change and transport sector. This study proposes that legislation should be in place to regulate the intended actions and plans in order to mitigate climate change effectively. Furthermore, the legislation should regulate human being activities and behaviour since science proved that there is a close link between human activities and the rapid growth of GHG emissions. There is therefore a need for an interface between public policy and climate change – in the context of this study, within the transport sector. This chapter addressed the fourth study objective, which was to determine how climate change is integrated in road transport planning and road transport policy in the City of Tshwane Metropolitan Municipality (CTMM).

From the literature discussed in Chapters 2, 3 and 4, five observations were made. Firstly, it was recognised that climate change has an impact on road infrastructure now than somewhere in the future. Secondly, road transport-related risks hold the potential of severe economic impacts. Thirdly, climate change has the potential to impact road infrastructure negatively. Fourthly, cities are at different points in the development and implementation of management measures. Lastly, implementation of management measures and integrating climate change into transport planning and policies are still challenges.

The South African management of climate change has been channelled on the governance framework. Different policy frameworks were developed to connect transport with development, and development with climate change, and climate change mitigation with the transport sector. However, no consistent framework exists that addresses these three aspects in an integrated manner. Moreover, from the discussion in this chapter, it is clear, that adaptation measures are not a priority within the road transport sector but is considered a secondary measure to mitigation. The next chapter focuses on the research design and methodologies employed in collecting the data for this study.

CHAPTER 5
RESEARCH DESIGN AND METHODOLOGY

5.1 INTRODUCTION

This chapter explains the process that the researcher undertook to collect information and data for this study. Research methodology considers the reasons behind the application of the research procedure of the study and explains why the applied method was considered suitable for the study (Brynard, Hanekom & Brynard, 2014: 38). Methodology explains the research process and the way the solution to the identified problem is found. Hence, Bhattacherjee (2012: 35) calls it “a comprehensive plan” for data collection in an empirical research project. In the current research, the researcher first explained the research design, which was underpinned by a mixed-methods tool. The study employed a concurrent, triangulation, mixed-method tool to generate a vast amount of information and data from various sources (Brybard et al., 2014: 38). In addition, a case study design was used to explore, describe and explain the management of the impacts of climate change in detail. The CTMM, as case study, was used to study the management of climate change impacts on the road transport infrastructure of a municipality in South Africa. A mixed method design was considered the best for this study because the studied phenomena were complex, and a single method would not have produced the desired data.

The objectives of the research are repeated in this chapter to justify the viability of using the selected research method to attain the research goals. As stated in section 1.5 above, the main aim of this study was to investigate management by the CTMM of climate change impacts on its road transport infrastructure. The following objectives were set to achieve this aim:

- to evaluate the impact of climate change on road infrastructure in the CTMM;
- to ascertain the administrative challenges faced by the CTMM in managing the impacts of climate change on road infrastructure;
- to evaluate how the management measures relating to the impacts of climate change on road infrastructure are financed in the CTMM;
- to assess how climate change is mainstreamed in road transport planning and road transport policy in the CTMM; and

- to propose ways by which management measure could minimise the impact of climate change on road transport infrastructure in the CTMM.

In achieving the above-stated objectives, the researcher identified a concurrent, triangulation, mixed-method research approach. This chapter discusses the research approach, case study as a design, the research methodology applied, data analysis and its reliability, validity and ethical consideration issues.

5.2 RESEARCH APPROACH

The study employed a case-study design. According to Bless, Higson-Smith and Sithole (2013: 130), a research design is a research management plan that is employed to guide the researcher in his or her research study. A research design is an overall plan for the research study, which consists of all issues involved in research problem identification, planning and execution of a research study and reporting the results (Punch, 2014: 114). The research design includes the overall approach taken and detailed information about how the study was carried out, with whom and where. The current study attempted to explain, explore, describe, discuss and define climate change, its impacts on road transport infrastructure and management measures such as mitigation and adaptation strategies in a municipal context. Case studies are exploratory and descriptive in nature. According to Kumar (2012: 10), descriptive studies describe the identified research problem, while exploratory studies allow the researcher to explore additional information regarding the same research problem. Exploratory research allows one to understand the studied phenomenon and provides approximate answers to the research questions.

5.2.1 Case study

In the discipline of Public Administration, a case-study design is applied in a real-life set-up and adds to social problems solutions (Thani 2012: 27). Van Thiel (2014: 5) argues that researchers in Public Administration study public sector problems with research methods that are manageable in number, and which provide practical results. A case study involves detailed research of a particular case and involves a single programme or project, individual cases and events with an intention to have a detailed understanding of their distinctiveness. Moreover, a case study is based on a desire to understand the complexity of a phenomenon, pay attention to a particular case, and

keep a practical perspective (Algozzine & Hancock 2011: 12). The CTMM was the case studied for the current research, with special reference to the Department of Roads and Transport and one unit in the Executive Mayor's office, the City Sustainability Unit. With this case study, the researcher examined management by the CTMM of the impacts of climate change on its road transport infrastructure intensively and engaged the findings in a theoretical analysis of the data.

The purpose of this study was to explore and describe the issues of climate change in relation to the road transport infrastructure in the CTMM. This comprised both a descriptive and exploratory study. The study had to answer 'what' and 'how' questions given the persistent reality of climate change and the challenges it poses to the road transport infrastructure. Descriptive research paints a picture of the specific details of situations with the purpose of describing the state of affairs, as it exists (Algozzine & Hancock 2011: 14).

The study investigated the situation in the CTMM in terms of climate change events (see section 2.4), challenges (see section 3.3), status of the road transport infrastructure inventory (see section 2.6) and public policy perspectives (see section 4.3). Moreover, pertinent factors were investigated in detail to arrive at a suitable description of the reality of climate change. The practical relevance of the study may empower novice researchers with a better understanding of the management of climate change impacts on the road transport infrastructure, specifically at local government level.

An exploratory study is important for a persistent phenomenon. Climate change, as a constant threat, had to be studied during exploratory research while the road transport infrastructure was studied according to a descriptive approach. According to Kumar (2012: 11), an exploratory study is conducted to investigate the probabilities of pursuing a research study in order to develop measurement tools and procedures. Climate change continues to occur in South Africa (and around the world), and the CTMM is constantly experiencing climate change events and impacts. Therefore, an exploratory study assisted the researcher to find out more about the persistence of such events by providing further insight about the phenomenon. The findings of this study brought a clearer understanding of climate change and the better way to manage

its impacts on road transport infrastructure as effectively, efficiently and economically as possible.

5.3 RESEARCH METHODS

The choice of the research method to apply is dependent on the aim of the research and the results that the researcher hopes to achieve (Punch 2014: 116). According to Leedy and Ormrod (2014: 96), it is important to verify that the variables to be measured and the manner intended to measure them will answer the research questions before deciding on the methodology to utilise. Wessels, Pauw and Thani (2009: 9) argue that researchers are often inconsiderate in terms of their research context when deciding on a research approach for collecting data. Consequently, the research may not satisfy the epistemic imperative of scientific understanding. It is therefore crucial for researchers to choose the research method that best addresses their research questions and achieves their research goals, as well as to ensure that the methods of collecting data are accurate and reliable. Therefore, given the aim and problem of this research study, the researcher decided to make use of both a qualitative and quantitative approach (also known as the mixed-methods approach) to collect information and empirical data.

This study employed a concurrent, triangulation, mixed method. According to Mertens et al. (2016: Online), the concurrent, triangulation, mixed-method approach refers to collecting quantitative or qualitative data via the traditional approach but with the qualitative strand being added to a quantitative approach, or a quantitative strand being added to qualitative approach. Two relatively independent phases are found in the mixed-method approach: one with qualitative questions, data collection and analysis techniques, and the other with quantitative questions, data collection and analysis techniques (Schoonenboom. & Johnson 2017:112). Neither quantitative nor qualitative methodology dominates the study; equal priority is given to both methods.

The researcher chose to use both quantitative and qualitative research methods for this study because of –

- the possibility to probe into responses and observations as needed
- the opportunity to obtain detailed descriptions and explanations of experiences; and

- gaining perceptions of respondents about road transport infrastructure and climate change policies, mitigation and adaptation strategies.

The combination of the two methods was appropriate for the current study because the subject under investigation has a high level of uncertainty surrounding it.

Quantitative and qualitative techniques complement each other. The study considered the components of qualitative research in the sampling process, data collection and data analysis as a description of the quantified results of quantitative research (Schoonenboom & Johnson 2017: 107). Therefore, combining quantitative and qualitative methods provided a good understanding of the problem studied. In addition, this study sought to generalise the results, as the impacts of climate change on road transport infrastructure are a global concern. Mixed methods could assist in yielding measurable responses from which to draw a conclusion. A mixed-method design also provides a depth and breadth understanding of the complexity of climate change and managing the impacts of the phenomenon (Mertens et al. (2016: Online).

Quantitative and qualitative methodologies offer different views of a situation or phenomenon. When combined, the two approaches are informative (Mertens et al. (2016: Online). Each has its benefits and detriments. In the current study, the quantitative analysis was more efficient than the qualitative one because of the ability of quantitative analysis to generalise broad aspects of climate change and its effects, while the qualitative analysis provides a deep understanding of the mechanisms of the nature and the extent of the road transport infrastructure in the CTMM. Furthermore, employing both the qualitative and quantitative methods in this research assisted in cross-validating responses from these methods, as recommended by Schoonenboom & Johnson (2017: 110).

During the analysis phase, the study mixed both quantitative and qualitative findings. The strength of this method is its ability to collect two types of data simultaneously which allows for perspectives from each as well as provide advantages of both methods. While its weakness is that data need to be transformed to allow integration during the analysis phase, this could lead to issues in resolving discrepancies that occur between different data types (Ingham-Broomfield 2016: 48). The inferences made based on the results of each strand were pulled together to form meta-

inferences at the end of the study. This involves using a qualitative method for exploratory purposes and then a quantitative method with a large sample allows the researcher to generalise results to a population.

5.3.1 Qualitative method

A qualitative method is one in which the researcher develops knowledge claims based on constructivist perspectives (Kumar 2012: 798). It is more about understanding certain aspects of social life, and qualitative methods generate words rather than numbers as data for analysis (Mertens *et al.,* 2016). In this research, the qualitative method was applied to describe the events of climate change and road infrastructure, environmental challenges as well as interventions by the municipality under study. The description includes a context analysis of the legislative framework economic and social status and the management measures used by the CTMM in as far as climate change and its road transport infrastructure issues are concerned.

Qualitative research consists of a wide range of non-numerical data collection and analysis methods and focuses on qualities that are not quantified (Kumar 2012: 799). Qualitative research therefore examines the complex nature of certain phenomena with the intention to describe and understand it from the perception of the respondents (Leedy & Ormond, 2010: 95). Qualitative research allows the researcher to establish the what, how and why of the events under research (Leedy & Ormond 2014: 96). A qualitative research approach was best suited to this study because the research questions (see section 1.4.1) required a detailed understanding of the complex multifaceted planning and integration of climate change into road transport infrastructure planning and public policies regarding climate change and road infrastructure in the CTMM.

Qualitative research embraces triangulation, i.e., the use of more than one method to research a phenomenon. According to Punch (2014: 118), triangulation refers to addressing a problem from various angles to assist in finding an appropriate solution. There are various forms of triangulation, namely –

- methodological triangulation, i.e. triangulation that entails using several methods. methodological triangulation has been found to be useful in providing

clarification of observations, more accurate data, improved validity, and a better understanding of the phenomenon under investigation. (Tracy 2010: 840);

- theory triangulation, i.e., triangulation that uses of several theories or hypotheses. The idea is to investigate a phenomenon from various angles, through various lenses, and with various questions in mind. (Tracy 2010: 838);
- data triangulation i.e., triangulation that uses various methods or data sources to establish a detailed understanding of phenomena (Pelto 2018: 242); and
- interdisciplinary triangulation, i.e., triangulation that which researchers from various disciplines collaborate on a project. (Tobi & Kampen 2018: 1211).

Cottrell and McKenzie (2011: 242) argue that the purpose of triangulation is to attain the same results through various data collection methods but ensuring consistency. Triangulation is based on the basis that one method cannot answer the research question sufficiently; hence, the adoption of various methods is essential (Tobi & Kampen 2018: 1213).

In this study, face-to-face interviews were used to collect data, as recommended by Pelto (2018: 245). The semi-structured questions were prepared to gather qualitative data. These questions were used because they were not restrictive, they had no predetermined answers, and they provided the respondents with an opportunity to share their experiences, ideas and knowledge voluntarily. Moreover, semi-structured questions allowed the researcher to ask probing questions, as described by (Pelto 2018: 240). Qualitative research is often collected in a space where respondents handle or experience the problem under research (Creswell 2014: 185). The current research problem related to the management of the impact of climate change on the road transport infrastructure in the geographical area of responsibility of the CTMM. The respondents were the people managing such impacts and their subordinates. The selected officials at the CTMM were interviewed in their working space during working hours at a convenient time for them, and English was the only language used for all the interviews.

5.3.2 Quantitative method

Quantitative analysis focuses on describing a situation across a broad population and uses post-positivist claims for developing knowledge (Creswell, 2014: 18). The

process involves the collection of data and its analysis in a numeric form (Punch 2014: 116). A quantitative method was used to investigate and record data on road traffic volumes and trends, road infrastructure inventory, mitigation capacity, and demographics. In qualitative research, numbers denote the values of variables, and data are analysed through statistical techniques. Cottrell and McKenzie (2011: 200) contend that quantitative research is used to establish the relationship between measurable variables. This method provides numerical results that can be presented in graphs and tables. Moreover, it assists to answer the questions of 'to what extent?' and 'how many?'. Quantitative method is not useful for gathering in-depth data and information on the context in which the phenomena occurs because its pursuit of concrete, statistical relationships may be constrained, causing researchers to neglect wider themes and relationships (Neumann 2014: 166).

In this study, a structured questionnaire was used with closed-ended questions. Closed-ended questions were preferred because they save time and money as they can be self-administered by the respondents. The questionnaire had standardised answers for all questions to enable comparison of the answers for statistical purposes. The questionnaire was analysed through a statistical procedure. The findings can be generalised to other metropolitan municipalities with similar road transport density as CTMM.

5.3.3 Data collection techniques

Data were collected using the following data collection techniques: a structured questionnaire, face-to-face interviews, personal observations, and public media documentation. The researcher was granted permission to access of data sources ethically from the Research and Development Department of the CTMM (see Annexure B) and the University of South Africa (Unisa). The latter facilitated the research study and also provided the researcher with an ethics clearance certificate (see Annexure A).

→ *Piloting: research questionnaire*

A pilot study was conducted before the survey questionnaire was distributed to the targeted respondents. The pilot study took place within the Department of Transport in the CTMM; however, the units where the respondents were employed were not

established. The department is big with various units; therefore, the chances of distributing the questionnaire to same people twice were zero. The pilot questionnaire was used to establish the amount of time it would take for the respondents to complete the questionnaire, to determine whether the respondents clearly understood all the questions without confusion, and to determine whether useful questions were not omitted. Comments and feedback were used after the questionnaire had been piloted to compile and evaluate the data to revise the questionnaire's objectivity and validity. The shortcomings were found and dealt with before the questionnaire was distributed to the targeted respondents for data collection.

→ *Documentation*

Data were collected through the public media documents to gather information on climate change from a global, African, South African and CTMM perspective and experience. Punch (2014: 158) says documents are rich sources for social science research and can be used in different ways. Yin (2014: 107) adds that documentation is a useful and relevant data collection method for case study research. Documents provide an overview of how an institution portrays itself. For this study, documents used were, inter alia, the annual reports of the CTMM, the CTMM's climate change response strategy, and a CITP (South Africa 2015). However, the results from these documents are not discussed in isolation but are integrated in the discussion of the results of other data collection methods because there was nothing substantial to report but there was enough to complement the results of other methods.

→ *Personal observations*

Field observation often provides data, which surveys are unable to provide. According to Bryman (2008: 257), there are two types of observations, namely structured observation and unstructured observation. Structured observation utilises explicit rules about what to record and to observe and for how long. With structured observation, the researcher is looking for pre-determined events and answers, while, in the case of unstructured observation, the researcher records as much as possible of what he or she sees in order to establish a narrative account of the observed behaviour. The current study applied unstructured personal observation. The researcher observed the behaviour of the CTMM officials who were interviewed. Moreover, the road transport

infrastructure conditions, maintenance and building within the municipality were continuously observed. Additionally, climate change events, such as floods and heat waves, were also observed throughout the study period and in events before embarking on this study.

→ *Semi-structured interviews*

Semi-structured interviews were used to collect data in this study. Neumann (2014: 168) recommends semi-structured interviews because the interviewer is guided by a set of questions and will try to develop rapport with the respondents to yield satisfying data. The advantage of semi-structured interviews is that they give the interviewer an opportunity to probe answers and to build on the responses of the interviewees. Leedy and Ormrod (2010: 159) also state that semi-structured interviews are flexible and likely to provide information that the interviewer had not planned to ask. In the current research, the semi-structured interviews offered the researcher an opportunity to hear the views, beliefs and experiences of the CTMM officials and to ask probing questions to expand their ideas further. The interviews proceeded to gather data related to the main problem, namely that the potential impacts of climate change on the road transport infrastructure are not fully taken into consideration when planning, designing, and constructing the road transport infrastructure of the municipality. The following interview questions were asked:

- What is the role of your department in trying to curb the impacts of climate change on the municipality's road transport infrastructure?

  This question was used as a follow-up to section B of the questionnaire: *impacts of climate change*, which addressed the next research question: "What are the impacts of climate change on road transport infrastructure in the CTMM?" In Chapter 2 above, the impacts of climate change on road transport infrastructure have been described. In section B, the questionnaire therefore focused on identifying the specific impacts of climate change on roads within the CTMM. The above question was asked to gather information on how the CTMM departments curb the identified impacts. The question was constructed in an open-ended manner to prompt passive response of the role if there is any role played in curbing the impacts.

- What are the strategies in place to overcome the identified obstacles?

  This question complemented section C of the questionnaire***:*** *management measures and challenges thereof*. Having identified the impacts and putting the strategies in place to respond to the impacts of climate change on the road transport infrastructure, the municipality is bound to experience some obstacles. This question therefore requested the respondents to indicate any obstacles experienced and the measures in place to address identified challenges. The research question addressed here was: “What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?”

- Where do you get the funds to implement the management measures?

  The question of where the funds came from was posed as an open-ended question, so that respondents could name the stakeholders and role players who finance the key management measures. Moreover, it allowed the respondents to engage further on the challenges regarding finance as a scarce resource; thus, addressing the research question: “How are the management measures of the impacts of climate change on road transport infrastructure financed in the CTMM?” This question further complemented section D of the questionnaire: Mainstreaming climate change into transport planning and policies. The question thus created a deep understanding of how and where the CTMM gets funding. The response to the question resulted in understanding the financial challenges faced by the CTMM. In addition, it assisted in drawing a conclusion on the feasibility to manage the identified impacts of climate change on road transport infrastructure. Moreover, with this question, the issue of political backing was addressed. Although it was not a research question on its own, it comprised aspects of administrative challenges.

Further supplementary questions were added to complement the above main interview questions.

→ *Questionnaire*

Questionnaires were issued to 60 officials within the selected operational units in the CTMM. The questionnaire method employed consisted of a population of interest, a

sample, a construct, and data collection tools utilised to measure the construct in the sample. According to Ingham-Broomfield (2016: 48), the survey method used in a mixed-method approach allows for great depth of enquiry. The survey method is a popular method in social research. According to Bhattacherjee (2012: 73), the survey method has the following strengths:

- It may quantify a number of non-observable data, such as beliefs, evidence, attitudes and preferences of individuals. For example, there are still debates on whether climate change is caused by God or by humans, which are focused on people's beliefs even though evidence prove the opposite. The survey issued thus allowed the researcher to discover evidence, attitudes and desires that are not observable.
- It has the ability to pay special attention to sampling to ensure adequate representation of the research target population.
- Respondents prefer questionnaire surveys because of its convenience and unobtrusive nature.

Questionnaires were given to respondents weeks before the actual interviews. This allowed them time to prepare and answer questions in their own convenient time. The questionnaires furthermore did not attract unnecessary attention, and the respondents could respond without any person realising that they were busy with something else other than their daily duties.

The structure of the questionnaires was the same across all departments. The questionnaire was divided into five sections. It started with the biographic information section, which aimed to determine the number of years the respondents had been working in the specific department as well as the level of qualification. The purpose of determining these two aspects was to establish the level of experience that the respondents had. The assumption was that the longer the period of employment, the better the chances of respondents providing accurate information, as they were thought to be familiar with the subject at hand. Secondly, the impacts of climate change were probed. Section 2.8 of this study discussed the impacts of climate change on road transport infrastructure. Therefore, in order to confirm or contest what literature is saying, the questions under this section were designed to establish regional impacts

of climate change on the road transport infrastructure of CTMM. In addition, the respondents had to provide answers based on their personal experience in the city.

The third section dealt with management of climate change and challenges thereof. This section intended to reveal the management measures in place to address climate change impacts on road transport infrastructure. Over and above this finding, the section sought to provide information about the administrative challenges faced by the CTMM with the intention of recommending possible solutions.

Fourthly, questions were asked about the nature of the financing of climate change-related management measures. Section 3.6 of this study discussed in detail the financing of the management measures of climate change regarding road transport infrastructure, and highlighted the challenges faced in financing the measures. Section D of the questionnaire intended to discover the role players in financing the measures, the challenges in acquiring the funds as well as the extent to which the CTMM financially considers climate change measures as a priority. Moreover, section D in the questionnaire also intended to gather information that had to assist in addressing the following research question “How are the management measures of the impacts of climate change on road infrastructure financed in CTMM?”

Lastly, questions were also asked about integrating climate change into road transport infrastructure planning and policies. Literature indicates that it is essential to integrate climate change into policies and planning (Mashamaite, 2018a: 585). Thus, the questions asked had to determine whether the CTMM is integrating climate change considerations into the planning processes and policies. Sixty questionnaires were issued, eight for the City Sustainability Unit in the Executive Mayor’s office and 52 for various units in the Roads and Transport Department. This number excluded support staff, such as secretaries because the nature of their role in the respective departments was not relevant to this study.

5.3.4 Triangulation

Triangulation implies usage of multiple data collection tools (Tobi & Kampen 2018: 1213). The data collection tools used enabled the researcher to explore, describe and explain the impacts of climate change on the road transport infrastructure of the CTMM and the management of such impacts by the public sector institution in detail. In

addition to the data collection tools employed in this study, the researcher conducted a literature review to understand climate change and its impacts on road transport infrastructure. The global response to the phenomenon was also studied. According to Mertens *et al* (2016: Online), triangulation signifies that dealing with a problem from various angles is useful in successfully finding precise and suitable solutions. The focus of triangulation is not to obtain the same results through various data collection tools but to ensure consistency (Cottrell & McKenzie, 2011: 242). Triangulation is positioned on the fact that a single method may not answer a research question sufficiently and as a result, various tools of data collection and analysis are significant. The framework for the questionnaire and the semi-structured interview questions is summarised in Table 5.1 below. Although the framework informed the design and contents of the questionnaire and interview questions, the responses were not limited and the respondents were encouraged to elaborate on their answers.

Table 5.1: Framework for data gathering

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
QB1 To what extent does your department consider climate change events to be a problem for the City of Tshwane road transport infrastructure sector? (on a scale of 1 to 10) QB2 Which of the following climate change related factors have affected the Municipality's road transport infrastructure? (Tick all that are applicable) B3 Does the Municipality have available information on the following climate change	IB1 What are the persistent impacts of climate change on road transport that you experience in the city? IB2 How often does the Municipality conduct vulnerability assessment of its road transport infrastructure network in terms of climate change? IB3 What are your management	To discover the impact of climate change on road transport infrastructure in the CTMM.	What are the impacts of climate change on road transport infrastructure in the CTMM?	**Chapter 1** •Section 1.2 (Background of the study) •Section 1.3 (Motivation of the study) **Chapter 2** •Section 2.4 conceptualising climate change causes and trends. •Section 2.7 vulnerability of the CTMM road transport infrastructure

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
impacts that have affected road transport infrastructure? QB4 Have the trends observed necessitated management measures from the Municipality? QB5 Which basis of climate change data and information are you using to estimate and establish the nature and extent of management measures for road transport infrastructure in the CTMM? QB6 Does the Municipality have a recent valid and professional vulnerability assessment of its road transport network	measures (e.g. projects and programs) with which to address the impact of climate change on the Municipality's road transport infrastructure?			network to climate change •Section 2.8 the impact of climate change on road transport infrastructure

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
and infrastructure in terms of climate change? QB7 To what extent does the manifestation of climate change affect the lifespan of the Municipality's road transport infrastructure?				
QC1 Are there projects and programmes in your department in place to curb the potential impacts of climate change on CTMM's road transport infrastructure? QC2 How many projects and programmes does your department have that address the impact of climate	IB4 What obstacles have you encountered in implementing the aforementioned management measures identified in B3? IB5 What are the strategies in place to overcome the	To identify the administrative challenges faced by the CTMM in managing the impacts of climate change on road infrastructure.	What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?	**Chapter 2** •Section 2.2.1 Administrative management theory •Section 2.2.2 Problem management theory •Section 2.3.1.2 Organising

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
change on CTMM's road transport infrastructure? QC3 To what extent would you say the response measures of CTMM, in place to curb the potential impact of climate change on its road transport infrastructure, are effective? QC4 Do you think your department in CTMM is well equipped to address challenges posed by climate change on the municipality's road transport infrastructure? QC5 What are the challenges faced by your department in addressing climate change's	aforementioned obstacles identified in IB4? IB6 What resources do you think you lack in trying to curb the climate change impacts on CTMM's road transport infrastructure? IB7 To what extent do you have political backing in all your functions and activities in the Municipality?			•Section 2.3.1.4 Control •Section 2.3.1.5 Staffing •Section 2.3.1.6 Work procedures. **Chapter 3** •Section 3.5 challenges of implementing climate change management measures on road infrastructure

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
impact on CTMM's road transport infrastructure? (Tick all that are applicable) QC6 Does your department in CTMM often communicate, integrate and share climate change information with the other units (e.g. is there synergy)?				
QD1 Where do you get funding for climate change related projects and programmes for CTMM's road transport infrastructure? QD2 What are the main challenges for the	IB8 Where do you get the funds to implement the management measures identified in B4? IB9 How difficult is it to acquire the aforementioned	To establish how the management measures to the impacts of climate change on road infrastructure financed in the CTMM.	How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?	**Chapter 1** •Section 1.2 (Background of the study) •Section 1.3 (Motivation of the study) **Chapter 2**

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
Municipality to mobilise funding? QD3 To what extent would you say climate change related projects are included in CTMM's municipal budget?	funds, and are they usually sufficient?			•Section 2.3.1.3 Financing **Chapter 3** •Section 3.6 Financing municipal response to the impact of climate change on road infrastructure.
QE1 Does CTMM have climate change adaptation plan? QE2 Climate change considerations are integrated in CTMM's Comprehensive Integrated Transport Plan? QE3 Climate change management measures in terms of road transport infrastructure are	IB10 How are the climate change considerations integrated in the road infrastructure policies, planning, building and maintenance? IB11 How do your attempts and interventions to	To discover how climate change is mainstreamed in road transport planning and road transport policy in the CTMM.	How is climate change mainstreamed in the road transport planning and policy in the CTMM?	**Chapter 4** •Section 4.3.5 Tshwane Integrated Environmental Policy (TIEP) (2005) •Section 4.3.6.1 CTMM comprehensive integrated transport plan (2015 to 2019)

SECTION/QUESTION IN QUESTIONNAIRE	INTERVIEW QUESTION	RESEARCH AIM/ OBJECTIVE	RESEARCH QUESTION	SECTION IN LITERATURE REVIEW
embedded within CTMM's existing public policies? QE4 What are the challenges faced by your department in mainstreaming climate change considerations? (tick all that are applicable)	manage climate change compare with those of other metropolitan municipalities in the country?			

Source: Developed by the researcher (2019)

5.4 STUDY AREA, POPULATION AND SAMPLE

The CTMM has 60 roads classified into three categories: national, provincial and municipal roads. Out of the sixty, three are national roads, 13 are provincial and the remaining 44 are municipal roads. Each sphere is responsible for its own roads (DoT, 2014a). The CTMM uses the global circulation models (GCMs) to predict future climatic events. The models have predicted that Tshwane temperatures will increase rapidly, with an increase of up to 2 °C for the period 2015–2035 and between 1 and 3 °C for 2040–6060, lastly, 4 to 7 °C for the period 2080–2100 (CTMM 2015b: 265). The rainfall patterns have also changed in the area. Rainfall anomalies demonstrate a pattern of drying that increases as time passes by. Extreme weather also becomes a concern. The GCMs further predict a drastic increase in the number of very hot days with maximum temperatures over 35 °C in the second half of this century. These predictions may become visible in events that exceed the capacity of the municipality to handle storm-water draining in terms of road transport infrastructure, resulting in, among other, flooding of low-lying areas.

It is worth noting that the CTMM has taken various initiatives in response to climate change, which include but are not limited to aligning its responses with international fellows. The municipality has signed the Compact of Mayors' Declaration in 2014. Moreover, the CTMM is a member of the C40 Cities Climate Leadership Group (C40), an international group of megacities committed to addressing climate change (C40cities nd: Online). As a signatory of the Compact of Mayors' Declaration and a member of C40, the CTMM has the opportunity to be recognised as a leader in local climate change. The city therefore has to develop a climate change response strategy aimed at responding to the findings of both its annual GHG Emissions Inventory and its Climate Change Vulnerability Assessment.

The current study used purposive sampling in order to identify and select respondents dealing with the climate change and road transport infrastructure issues under investigation. In an ideal situation, qualitative research involves a continuous process of collecting data and conceptualising until there are no new data to add to the developing theory. However, due to the scarcity of resources as well as time limitations, it was more practical to sample respondents for qualitative data purposively (see Yin, 2014:106). In purposive sampling, respondents are selected based on their

roles in the municipality as far as climate change and road transport infrastructure are concerned to enable a detailed exploration of the research objectives.

The purpose of using a municipality as a case study was to enrich data by finding out what is happening at grass-roots level in order to establish the best management measures to respond to climate change and try to manage climate change. It should also be highlighted that the municipality is responsible for the majority of road transport infrastructure within the CTMM's geographical area, making it appropriate to use the municipality as a case study. When roads and associated infrastructure are damaged as a result of climate change, it is the responsibility of the municipality to maintain and repair them. The CTMM was chosen as the case study because of its broad authority and the fact that it serves as South Africa's administrative capital, hosting a wide range of political, social, and economic activity. The findings from this city might be applied to any large city with a similar population and density of road transport sector in general.

According to Wessels *et al.* (2009: 11), the number of people interviewed when using a purposive sampling approach is irrelevant, but the criteria used to select them are crucial. For the purpose of this study, only two departments from CTMM were selected for their relevance to the investigation. Purposive sample sizes are often determined based on theoretical saturation; therefore, it is most successful when data review and analysis are done in conjunction with data collection (Wessels *et al.* 2009: 12). The researcher interviewed the participants until saturation had been reached. Intuitively, the expectation was to interview eight participants per department. However, after the fifth person per department, saturation had been reached and the relevant research questions had been answered in full. The departments selected were the City Sustainability Department with eight personnel. The Department of Roads and Transport with 57 personnel, of whom only 52 participated in this study; thus, the total population size of this study was 65 with only 60 as the sample. The interviewees were selected based on their position in their respective departments. People occupying managerial positions were relevant for this study because of the significant role they have to play in managing the impact of climate change on the municipality’s road transport infrastructure. The participants (in groups) in this study, including the site

population, sample size and sampling technique, are summarised in the Table5.2 below:

Table 5.2: Population size and sample

Population name	Population size	Population sample
Department of Roads and Transport	57	52
Executive Mayor (City Sustainability Unit)	8	8
Total	65	60

Source: Developed by the researcher (2019)

5.5 DATA ANALYSIS STRATEGY

When analysing data, one goes through the process of identifying themes and describing what has been found during the investigation. Punch (2014: 122) states that data analysis is at the core of the aim of research as it enables one to give a description of the essential features of a specific experience. Descriptive analysis of data was used to provide preliminary insight into the nature of the responses that had been obtained. A descriptive qualitative data analysis technique was used to describe the environmental challenges of road transport infrastructure, the road transport system, climate change policies, mitigation strategies, implementation challenges, as well as interventions by the CTMM. Creswell (2014: 18) asserts that the mistake most students make is to neglect giving thought to effective analysis of data, in a sense that the way data are analysed will effectively answer the research questions. It was imperative that the data analysis relate the interview questions and answer the problem statement, as well as consider the aim and research objectives of the study. The interviews were thus transcribed in their entirety. The data were analysed in a descriptive manner as follows:

- *familiarisation* by reading field notes, interview transcripts and transcribed audio tapes;
- *inducing themes* by creating themes and categorising the data accordingly. There were no new themes that emerged from the study to categorise data. Data was categorised under themes determined upfront by the researcher.

- *elaboration*, which is about finding meaning on themes, categories and codes, as recommended; and
- *interpretation* by using categories to write interpretations.

Quantitative data from the questionnaires on the other hand were analysed by means of the Statistical Package of Social Sciences (SPSS) program where the responses were calculated.

5.6 DATA QUALITY CRITERIA

Brynard, Hanekom and Brynard (2014: 107) state that the criteria for evaluating quantitative research are validity, reliability and replicability. Data promote the aspect of trustworthiness, and the criteria for evaluating qualitative research are subdivided into transferability, credibility, dependability, conformability and authenticity. Climate change and road transport networks were used as variables in the current analysis. Other climate change researchers (e.g., DiMento & Doughman, 2014; Fatima, et al., 2015) have successfully used the same study designs and methods.Numerous studies have shown the reliability and validity of the concept climate change (see Boyd & Coetzee, 2013; IPCC, 2007; 2011; 2013; Oswald, 2011). The said studies have illustrated the reality of climate change events. Furthermore, the indicators used have illustrated the relationship between climate change and road transport infrastructure. For the collected data to be regarded as valid, it had to provide reliable responses; thus, reliability was a precondition of validity Punch (2014: 122). The study was able to claim reliability and validity since data were collected from people dealing with the issues under investigation on a daily basis.

5.6.1 Validity

According to Bryman (2012: 391), participants' validation is crucial in research because it assists researchers to ensure positive correlation of their findings and the perspectives of research participants. Participants may use participant validity to validate conclusions by correcting, elaborating, or disputing them. It also enables the researcher to elicit additional information and conduct analysis using the transcripts of the interviews if new information or disputes arise during the interviews. (Rossman & Rallis 2012: 65). Validity, according to Leedy and Ormrod (2010: 103), refers to its credibility, precision, and significance rather than the certainty of the topic under

consideration. This suggests that validity is concerned with the research's accuracy rather than its authenticity. As a result, validity indicates the degree to which the test procedure is intended to assess.. Validation is the process of verifying the validity of the results through analysis of other resources (Rossman & Rallis 2012: 65). The researcher used literature sources, research methodologies and data collection techniques to verify the validity of the study.

5.6.2 Reliability

Reliability as explained by various authors (see, for instance, Bless *et al*., 2013: 229) can best be determined in the future as it refers to the accuracy and consistency of the research techniques in attaining the same results when repeated in the same set-up. In essence, reliability means consistency, repeatability and replicability. Reliability also means confirmability because it is expected that the research findings should be the same if another study is conducted with the same research methods (Rossman & Rallis 2012: 65). Different research participants tested with similar research techniques at different times should respond the same each time. Additionally, for the data collected to be considered valid, it must provide reliable responses; thus, reliability is a prerequisite of validity.

5.6.3 Trustworthiness

The degree to which participants and readers view the findings' effects, and whether they find them compelling and serious, is determined by their trustworthiness (Leedy & Ormrod, 2010: 272). This means that the researcher must illustrate the trustworthiness of the research study by putting standards in place to assess such trustworthiness. The readers must be convinced that the study has merit and that the findings are credible and have the potential to be used in future research studies and practices. The standards for judging trustworthiness must include accepted principles of ethics in engaging with participants. Adhering to ethical issues is an acceptable practice (Rossman & Rallis 2012: 65). The current study obtained the ethics clearance certificate from Unisa and participants had to sign a consent form prior to the interviews.

5.6.4 Credibility

According to Du Plooy-Cilliers, Davis and Bezuidenhout (2014: 133), credibility refers to the extent that research claims to be based on evidence. It is the responsibility of the researcher to ensure that the credibility of the study conducted is attained. Credibility also means establishing that the results of the study are believable from the research participants' perspective (Kumar 2014: 219). Punch (2014: 122) argues that credibility brings opportunities for the findings to be acceptable by other research peers as an important destination of research study. Credibility of the study is assessed by the trustworthiness of the research (De Vos, Strydom, Fouche & Delport, 2010: 137). Therefore, the researcher gathered the findings of the current study in a way that will leave no doubt in readers' minds that the findings are believable.

5.6.5 Transferability

Creswell (2014: 218) explains that transferability is achieved when the results of the study can be generalised by demonstrating the process employed for other researchers to understand. In addition, transferability ensures that the study conducted has common ground that is not undermining the social world (De Vos *et al.,* 2010: 137). Research should therefore not be done in isolation but should rather capture the reader's interest and maintain standards of scientific research to ensure that the validity of the results is not questioned. Apart from this, the researcher must make sure that the findings are transferable between the researcher and the participants, respondents or the researched group. The findings of the current study are comprehensive enough to be applied to any municipality with similar road transport infrastructure densities.

5.6.6 Dependability

The dependability of the current study was ensured by describing the research design, methodology, data collection processes, data analysis process and sampling strategy, which will make it easier for the study to be replicated. According to Kumar (2012: 219), dependability requires that the same findings could be used to observe similar things twice. The results of this study are not dubious; they can be replicated at different intervals by other researchers if similar methodologies are employed.

5.6.7 Confirmability

Conformability assists in determining the worth and importance of the data. As a result, the researcher frequently assures the participants that the research could be confirmed by others. According to Kumar (2012: 219), conformability is linked to reliability. The worth of collected data depends on the strength of the study and accessibility of the participants. In the current study, the researcher did not influence the participants or the results of the study. In fact, the researcher was neutral.

5.7 ETHICAL CONSIDERATIONS

According to Leedy and Ormrod (2014: 115), there are numerous terms and phrases that describe the system of ethical considerations that the contemporary research establishment had created in order to protect the rights of research respondents. Any research study requires a set of ethical considerations for the study to be accurate and credible. All the literature sources utilised in terms of this study and cited are acknowledged to avoid plagiarism. These respondents participating in the data and information collection phases were the officials of the CTMM and they were assured that identifying information would not be made available to anyone who is not directly involved in this research. The stricter standard is the principle of anonymity. This meant the respondents remained anonymous throughout the study.

The researcher ensured that no respondent was named, and the questionnaire did not request any personal information besides biographical information that was used for statistical purposes. Furthermore, the respondents' participation was voluntary. The officials were in no way coerced into taking part in this research. Another important aspect related to the notion of voluntary participation was the requirement of informed consent. Prospective research respondents were fully informed about the procedures and they gave their consent to participate. Ethical standards also require that researchers ensure that respondents are not at risk of harm because of their participation, neither physically nor psychologically.

5.8 LIMITATIONS AND DELIMITATIONS OF THE STUDY

There were various inhibiting factors in carrying out this research study. According to Leedy and Ormrod (2014:20), human instruments are as fallible as any other research instrument. The researcher as a human instrument is limited by being human,

mistakes are made, and opportunities are missed. Furthermore, this study was limited to one municipality in South Africa, which was a metropolitan municipality category A in terms of the Local Government: Municipal Structures Act 117 of 1998 as amended (see South Africa 1998). Category B and C municipalities, which are district municipalities, were excluded from this study. This study further focused on the nature and extent of the road transport infrastructure, leaving out all other types of transport, such as aviation, maritime, rail and pipelines.

5.9 SUMMARY OF THE CHAPTER

This chapter presented a discussion of the research design and methodology employed during the current study as well as the nature of the research. Data collected provided empirical evidence of climate change impacts on the road transport infrastructure within the CTMM's geographical area of responsibility. As a result, the researcher gathered information on climate change incidents, road transportation networks, climate change mitigation, adaptation actions, public policies, and climate change-related activity funding. Climate change events are characterised by aides such as flooding, rising temperatures, and erratic precipitation. The next chapter focuses on the presentation, interpretation and analysis of the data collected.

CHAPTER 6
DATA PRESENTATION, ANALYSIS, INTERPRETATION AND FINDINGS

6.1 INTRODUCTION

The previous chapter explained the research design and methodology utilised in the current study. As discussed in Chapter 2, climate change is a growing concern with consequential impacts. The severity of these impacts, as shown in section 2.8, partially depends on the outcomes of global efforts to mitigate GHG emissions and the plans to adapt to climate change. However, developing countries remain the most vulnerable to the impacts of climate change (Hallegate et al., 2012: Online). South African municipalities have a mandate to develop measures to manage the impact of climate change on road infrastructure. Therefore, this study gathered data to analyse and interpret how the CTMM manages the impact of climate change on its road infrastructure.

This chapter presents an interpretation of the analysis of data collected with the purpose of drawing conclusions and addressing the main research question and sub-questions (see section 1.4.1). Data presented in this study established the extent to which the research questions were answered when conducting the study. Analysis of data involves analysing, evaluating and integrating data obtained during the research to generate scientific results (Mertens et al. 2016). Data analysis therefore means evaluating the examined data by explaining and discussing how the study issues should be answered. The data collected for this study showed that, at the time of this research, there were few programmes in place for the CTMM to tackle climate change problems and initiatives to mitigate climate change impacts on road transport infrastructure in its municipal area. Integration of climate change considerations into transport policies, planning and development is necessary to manage the impacts of climate change on road transport infrastructure. However, as far as the researcher could determine, limited studies have so far been conducted on climate change and road transport infrastructure in South Africa (see for instance Winkler 2010; Friedrich & Timol 2011).

In this study, data collected through a questionnaire were analysed through the SPSS Statistics Version 20 software program. Official documents, such as integrated

transport plans and annual reports from the municipality, were consulted in order to attain a reasonable interpretation and analysis of the information collected through questionnaires. Descriptive research was performed on the data collected using questionnaires, and the information gathered was used to formulate graphs showing the data collected for the presentation of results, following in the face-to-face interviews, contextual interpretation of the data obtained was done. The interviewees were assured of privacy and confidentiality. For analysing data, the respondents were therefore numbered from 1–14, and are, for instance, referred to as Respondent 1 or Respondent 9 in the discussion below.

6.2 DATA COLLECTION MEASURES

Mixed-method instruments, namely interviews and questionnaire were used to collect empirical data. A questionnaire was used to collect quantitative data, while the qualitative data were collected using in-depth individual interviews and personal observations. It was necessary to classify the unit of observation for data collection purposes. Therefore, human behaviour and human behaviour items were used as evaluation devices for this analysis, as recommended by Tracy (2010: 841). Human behaviour items provide information, such as reports on road infrastructure maintenance, risk assessment reports, and reported minutes of meetings open to the public within the municipality, while observation units provide monitoring (see Mertens et al., 2016: Online). Human behaviour however involves the views and experiences of local officials. Data collected from these units of observation provided answers to the research questions for this study. The respondents to the questionnaire and the interviewees had the skills and expertise to answer the interview questions. Therefore, the research aim and objectives could be achieved.

The researcher conducted face-to-face interviews with the municipal officials from the Department of Transport and the Executive Mayor's office in the CTMM. In the Executive Mayor's office, only the City Sustainability Unit (CSU) was relevant to this study because of its role in addressing climate change. The Department of Transport is divided into seven divisions, namely Transport Development, Transport Planning, Transport Infrastructure Design and Construction, Tshwane Bus Services, Tshwane Airport Services, Integrated Rapid Public Transport Network, and Licensing Services. Of the seven divisions, only two were relevant to this study, namely the division of

Transport Planning and that of Transport Infrastructure Design and Construction. Therefore, the data were collected from only these two divisions in the department. It should be noted that these divisions have sections within themselves. For instance, the Transport Planning division has three sections: Integrated Transport Planning, Intelligent Transport Systems and Traffic Engineering, and Transport Infrastructure Planning. Of the three sections, only two were relevant for collecting data for this research study, namely Integrated Transport Planning and Transport Infrastructure Planning. The Transport Infrastructure Design and Construction Division also has three sections: Transport Infrastructure Provision, Transport Infrastructure Construction Management, and Stakeholder Management. All sections in this division were relevant to the study because of their role in as far as road infrastructure is concerned. It is worth noting that all these sections have various sub-sections and functional units; thus, the organogram of the Department of Transport in the municipality is a very long chain consisting of posts ranging from two to four in a functional unit.

The total population of the Department of Transport, given the relevance of the population to the study, was 57 and 8 from the City Sustainability Unit from the Executive Mayor's office. Thus, the total population size was 65, and the sample population for the study was 60. Fourteen municipal officials across the relevant divisions, sections, subsections and functional units of the municipality were interviewed face to face, and 60 questionnaires were distributed. Table 6.1 below shows the population size and the sampled size for data collected.

Table 6.1: Population size and sample

Population name	**Population size**	**Population sample**
Department of Roads and Transport	57	52
Executive Mayor's office (City Sustainability Unit)	8	8
Total	**65**	**60**

Source: Researcher's own compilation

In her efforts to comply with research ethics, the researcher explained the purpose of the study and the rights of the respondents before they signed the informed consent forms. The researcher had appointments for individual face-to-face interviews with the respondents at times that suited the respondents. Capturing of detailed field notes took place during the interview process. Figure 6.1 indicates the percentages of respondents from each group.

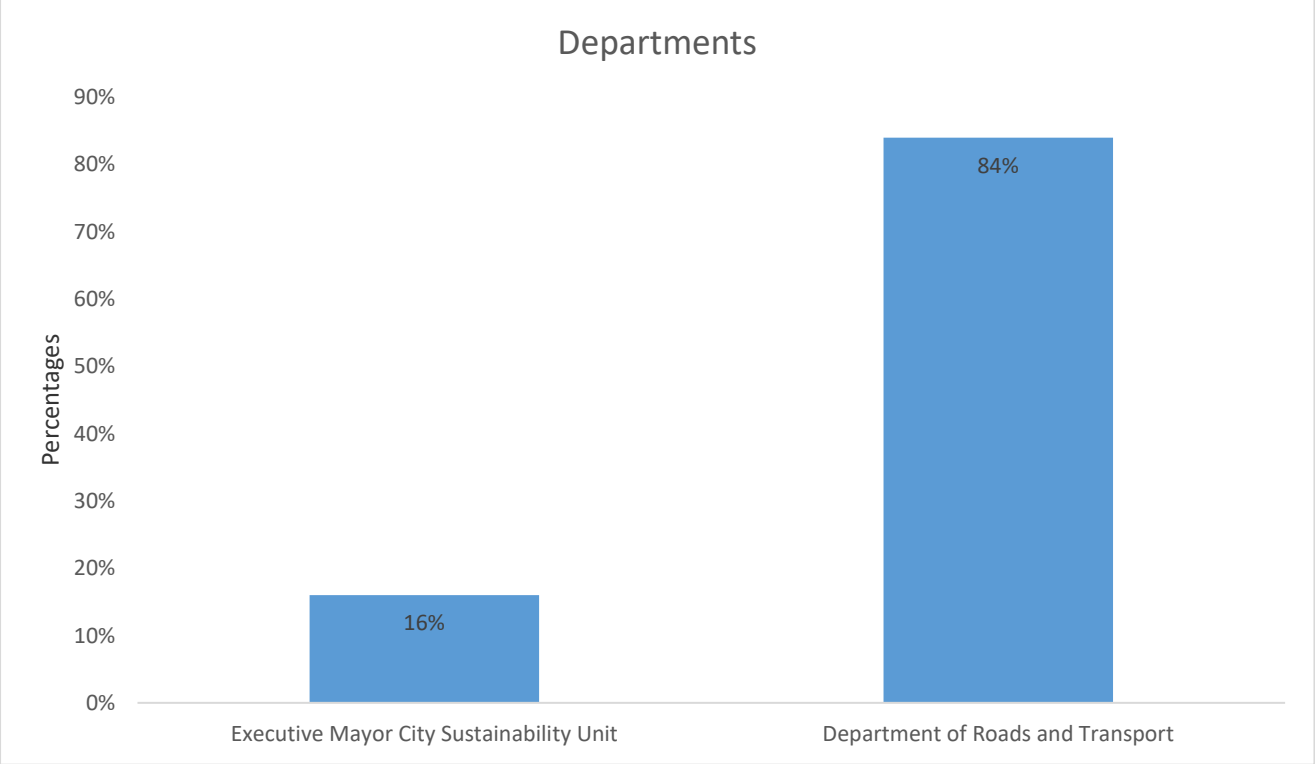

Figure 6.1: Population sample

Source: Researcher's own compilation

Figure 6.1 above illustrates that of the two sampled departments, the Department of Roads and Transport had more participants than the City Sustainability Unit: 15.8% of the respondents were from the City Sustainability Unit, while 84.2% of the respondents were from the CTMM Department of Roads and Transport. The number of units was sampled from the two divisions selected in the Department of Roads and Transport, while the City Sustainability Unit was the only sampled unit from the Office of the Executive Mayor based on its relevance to this study. Figure 6.2 below indicates the level of education of the respondents.

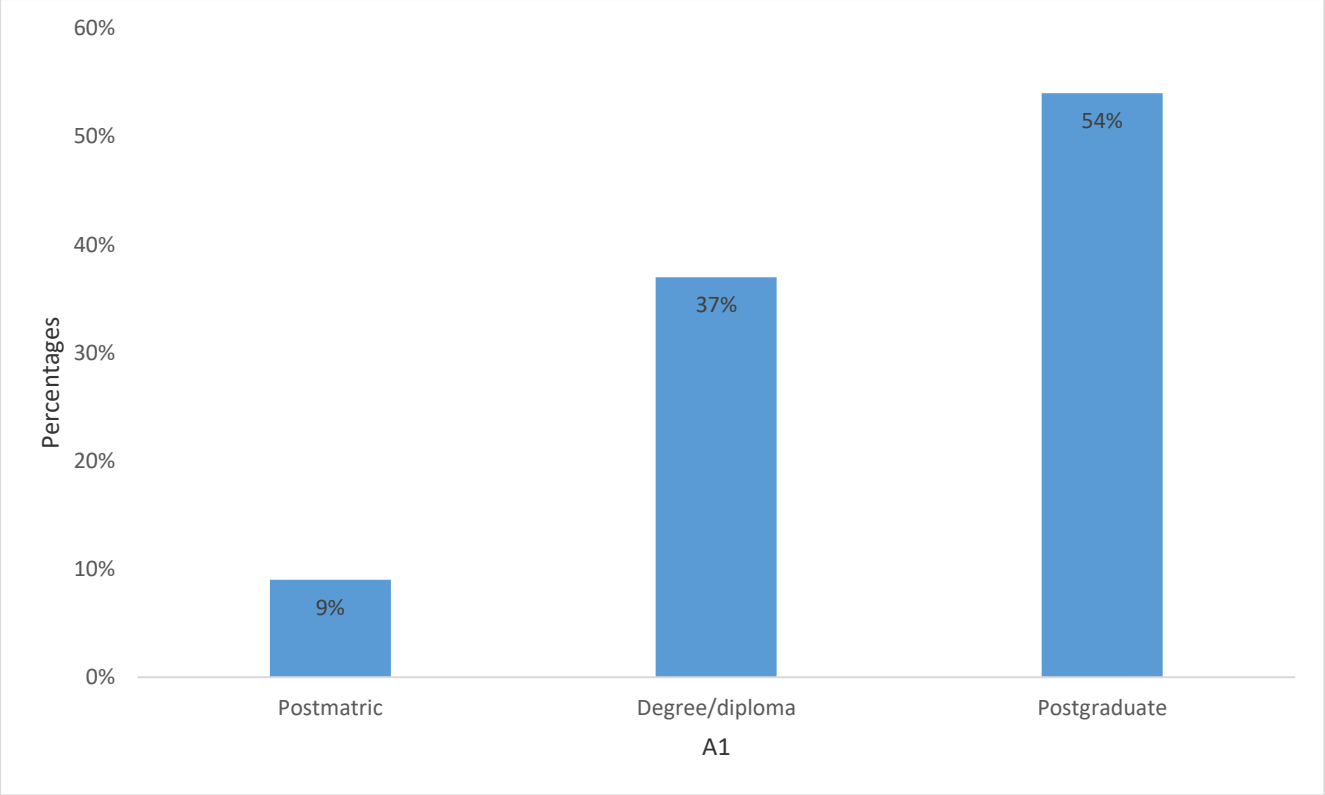

Figure 6.2: Education level

Source: Researcher's own compilation

The level of education of the respondents was important because it is a specialised area. Level of education plays a crucial role since it may determine the level of understanding of the concepts and better chances of the research finding to be reliable. Figure 6.2 illustrates that the majority of the respondents (54%) had a postgraduate qualification, 37% obtained a degree or diploma qualification, and 9% had a post-matric qualification, such as a higher certificate. Nonetheless, this study did not establish the fields of their qualifications, and the presumption was that they came from specific fields but were important to the mandate of the City Sustainability Unit and the Roads and Transport Department. Figure 6.3 indicates the years that the respondents had been employees of the CTMM at the time of this research.

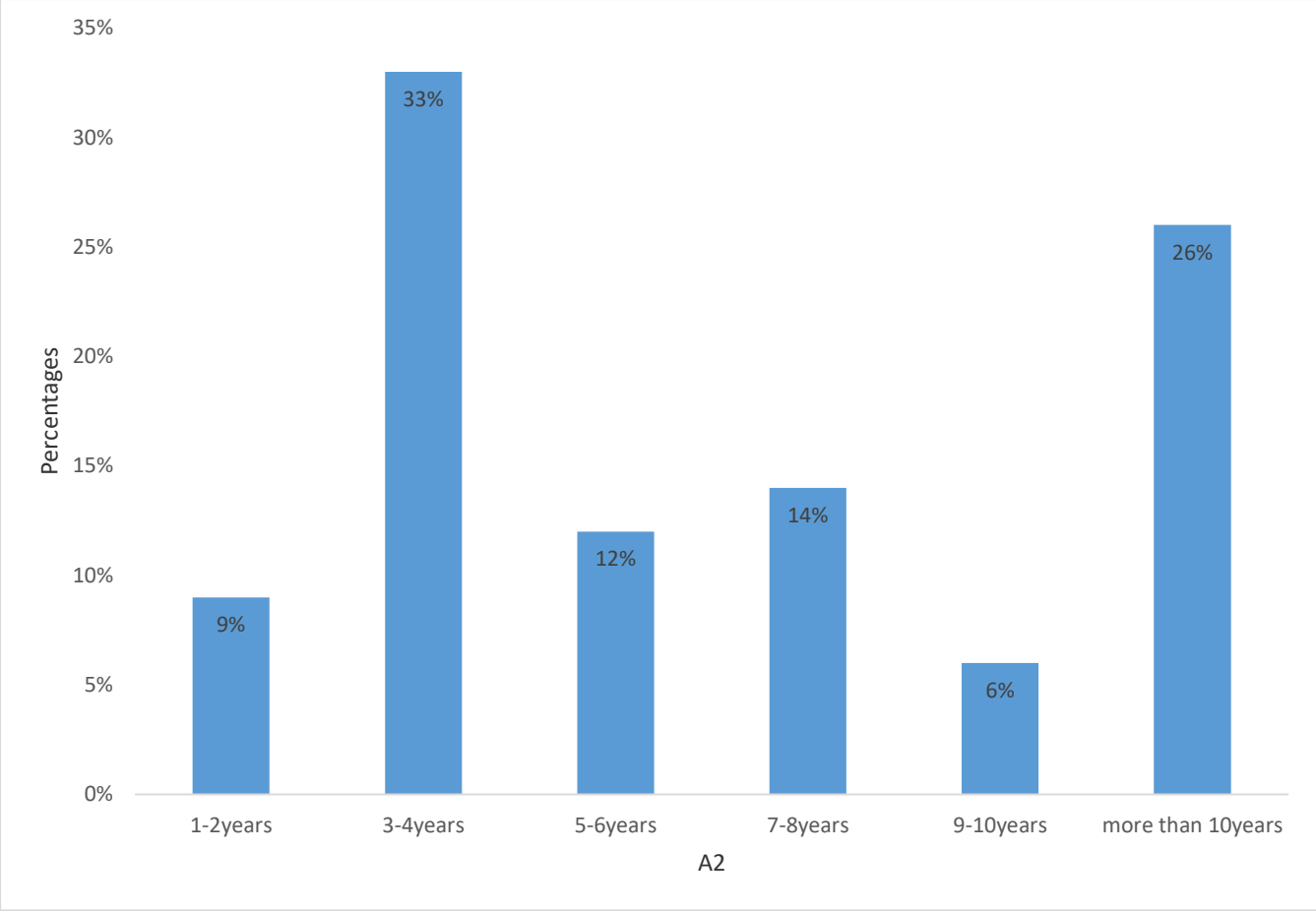

Figure 6.3: Years of employment in the CTMM

Source: Researcher's own compilation (2020)

The purpose of this variable was to probe the period the respondents had been employed in their respective units. This helped to establish whether these individuals had sufficient experience to address challenging issues, such as climate change. Figure 6.3 indicates that the average working period was four years. It should be borne in mind that the City Sustainability Unit is a relatively new unit that was established in 2013; therefore, no respondent in that unit was expected to have more than six years' experience. The researcher observed that some respondents were very confident when answering the interview questions and were elaborating and sharing their personal views on how best to address climate change. From this observation, the researcher concluded that their years of employment gave them good experience, making them reliable sources. However, some respondents still seemed to be uncertain regarding many factors around the management of climate change in the municipality.

6.2.1 Piloting questionnaire

In order to detect and avoid errors in the data collection questionnaire, the researcher conducted a pilot study with a group of officials from the Department of Transport within the CTMM. The questionnaire was administered to ten officials as a pilot group of respondents. Amongst other things, the piloted questionnaire was aimed to establish:

- respondents' understanding of the questions in the questionnaire;
- the time respondents needed to complete the questionnaire; and
- ensuring that useful questions had not been omitted.

All shortcomings observed during the piloting process were identified and addressed before the final questionnaire was constructed and distributed. The pilot process helped to establish whether the questions were relevant to answering the research questions and whether the data gathered would achieve the set objectives.

6.3 RESEARCH QUESTIONS

The interpretation of the analysed data should demonstrate how the analysed data answered the research questions. As indicated in section 5.5, triangulation implies the use of numerous data collection tools. The data collection tools employed enabled the researcher to explore, describe and explain the management of the impacts of climate change on the road transport infrastructure of the CTMM. Therefore, having collected data using mixed methods, the concurrent principle was also applied when analysing the collected data. This study therefore embraced the concept of triangulation. 'Triangulation' means that a single method may not sufficiently answer a research question and, as a result, various tools of data collection and analysis are significant. Merriam and Grenier (2019: 28) assert that the purpose of triangulation is to ensure consistency and not to attain the same results through various data collection tools.

Fourteen officials were interviewed face to face at various times, using a semi-structured interview schedule, and a questionnaire was sent out to 60 respondents. Of the 60 respondents, only 57 replied appropriately and returned the questionnaire. The purpose of using a questionnaire was to gather statistical information that could not be attained through the interviews. Therefore, the data complemented each other and produced empirical evidence that addressed the problem statement. In an effort to

answer the main research question – “How does the City of Tshwane Metropolitan Municipality manage the impacts of climate change on its road infrastructure?” – four sub-questions were used as guidelines to gathering data (see Appendix F: Questionnaire of this study). Section 6.3.1 comprises a presentation, analysis and interpretation of the collected data in line with the research questions.

6.3.1 Impacts of climate change on road infrastructure in the CTMM

Understanding the specific consequences of climate change on road infrastructure that the municipality encounters was critical in determining how the municipality handles the impacts of climate change on its road infrastructure. Literature identified a number of impacts as indicated in 2.8 of this thesis. It was therefore crucial to gather primary data to support what literature is indicating. During the data collection process, the researcher asked the questions as stipulated in Table 6.2. (Interview questions IB1 to IB3 and questions in the questionnaire QB1 to QB7).

Table 6.2: Framework for data analysis

RESEARCH QUESTION	INTERVIEW QUESTIONS	QUESTIONS IN QUESTIONNAIRE
What are the impacts of climate change on road infrastructure in the CTMM?	IB1 What are the persistent impacts of climate change on road transport that you experience in the city? IB2 How often does the Municipality conduct vulnerability assessment of its roads transport infrastructure network in terms of climate change? IB3 What are your management measures (e.g. projects and programs) with which to address the impact of climate change on the Municipality's road transport infrastructure?	QB1 To what extent does your department consider climate change events to be a problem for the City of Tshwane road transport infrastructure sector? (on a scale of 1 to 10) QB2 Which of the following climate change related factors have affected the Municipality's road transport infrastructure? (Tick all that are applicable) QB3 Does the Municipality have available information on the following climate change impacts that have affected roads transport infrastructure? QB4 Have the trends observed necessitated management measures from the Municipality? QB5 Which basis of climate change data and information are you using to estimate and establish the nature and extent of management measures for road transport infrastructure in the CTMM? QB6 Does the Municipality have a recent valid and professional vulnerability assessment of its roads transport network and infrastructure in terms of climate change? QB7 To what extent does the manifestation of climate change affect the lifespan of the Municipality's roads transport infrastructure?

Source: Researcher's own compilation

IB1 What are the persistent impacts of climate change on road transport that you experience in the city?

The purpose of this question was to gather information from the respondents on what they thought to be the persistent impact of climate change on road infrastructure within the municipal jurisdiction areas. All the respondents mentioned flooding as one of the notifiable changes. This could be due to poorly maintained storm-water culverts, low-water bridges and shoulders of roads and the apparent lack of reaction by the municipality to the filling of potholes in tarred roads, as well as the inconsistent operation of traffic lights. Others mentioned wind, precipitation, storms, sinkholes and temperatures. These six items were the only impacts identified by the respondents, although none of the respondents mentioned all of them, and one mentioned three or four of the six. Below is what some of the respondents had to say:

> **Respondent 1:** *Floods, we do not experience a lot of change in as far as temperatures are concerned. However, floods have been experienced number of times in and around the city. You see, flooding is the city's worst nightmare because not only roads infrastructure is affected, people in informal settlements are also affected, and some of these places are in […] sinkholes areas, and the food security. Of recent, I read a study on food security and climate change, that study shows that we are in trouble.*
>
> **Respondent 2:** *Climate change directly affects road infrastructure in various ways. High temperatures cause roads to develop cracks quickly after their construction. While, higher temperatures reduce the life of asphalt road surfaces.*
>
> **Respondent 3:** *At the moment what we physical can feel over and above the high temperatures, which has the impact on our roads for example if you have a tarred road you have to do maintenance more often, due to high temperatures. Is mostly storm-water sewage, we got flooding, overflowing bridges, and we have a high number of low water bridges like in Sosha … and people can't to travel long distance, those in informal settlements are affected in the worst possible way.*
>
> **Respondent 4:** *Potholes after heavy rains, and soil erosion on the sides of the tar roads, making it unsafe to get off the road in many instances. Some low-lying bridges also get flooded, making it unsafe to use, especially in low-lying areas. Road signals (traffic lights) always get dysfunctional during rainy weather conditions. Sinkholes on road infrastructure are also common in Tshwane.*

As mentioned in section 6.2 above, the researcher used both human behaviour and products of human behaviour as units of observations to collect data. The researcher observed that the respondents were concerned about the impacts of climate change, not only on road infrastructure, but also on human settlements and food security. Climate change would have an effect on humans, according to the IPCC (2014), particularly in Africa. That is why climate change must be taken seriously in Africa as a whole. It was also noted from the climate response strategy of the municipality that various sectors were listed as vulnerable to climate change, such as flood-prone human settlement area, agro-ecosystems that provide food protection, and human health. Moreover, the strategy indicates that the impacts of climate change threaten the municipal response priority to promote clean mobility.

IB2 How often does the CTMM conduct vulnerability assessment of its road transport infrastructure network in terms of climate change?

Climate change as a growing concern has to be approached in three principle elements: vulnerability, impacts and mitigation capacity (Mehrotra et al., 2011: 8). 'Vulnerability' refers to the physical elements and socio-economic conditions that determine the responsiveness to changes in climate. The purpose of this question was to determine whether the municipality has a tool that informs its vulnerability to climate change and provides a projection of the impacts to which the road transport infrastructure is vulnerable; thus, identifying the impacts to which the road infrastructure is more vulnerable. Moreover, the vulnerability assessment could inform the municipality whether it has the management capability, ability and capacity to respond to climate change and manage the impacts of it. From the responses, it was found that the municipality does not necessarily have an assessment plan, particularly for road transport infrastructure, but it has a plan that encompasses all aspects related to service delivery of the municipality. Very limited information is however provided in the plan about transport. Figure 6.8 illustrates that 65% of the respondents indicated that, at the time of the research, there was no vulnerability assessment. The researcher observed that some of the respondents were not aware of the existence of the vulnerability assessment because it was not part of their primary functions and responsibilities to develop the assessment. Respondent 4 remarked:

> *There is a dedicated section in the department dealing with road infrastructure assets management, which is responsible for maintenance of road infrastructure, both on reactive and planned basis*.

It was to an extent worrisome that the officials that were tasked with the responsibility of providing road transport services were not aware of these vulnerabilities. However, some were aware of the current vulnerability assessment. Respondent 2 said:

> *We do have a vulnerability assessment.*

The researcher interjected here by asking, "[o]n road infrastructure and road networks?"

> **Respondent 2 replied:** *[O]n roads, no on roads we don't have, the existing one is a general one. You know, focusing on service delivery in general, am not sure what it says about roads. I have not really checked it.*

The researcher read the vulnerability assessment document and saw that indeed the assessment of the vulnerability of the road transport infrastructure is not sufficiently conducted. There is only a long paragraph available in the document addressing issues of transport at large.

IB3 What are your management measures (e.g. projects and programmes) with which to address the impact of climate change on the CTMM road transport infrastructure?

This question was asked with an understanding that the municipality will develop management measures that are meant to address the climate change impacts that are experienced most in the city. This had to assist the researcher to understand climate change impact management measures implemented by the CTMM. As stated in section 3.4.1 of this thesis, the municipality is increasingly improving its climate change management initiatives by resolute projects and programmes that emphasise GHG mitigation and climate change adaptation, such as the BRT buses using CNG to lower GHG emissions. The respondents acknowledged that mitigation is their key focal area. The current management measures reflected in section 3.4.1 above shows the impact of climate change on road infrastructure in the municipality. However, it was essential to get primary data on the management measures to understand the status

quo of the measures in the municipality. The initiatives that the respondents shared were related to compressed natural gas (CNG), bus rapid transit (BRT), electric vehicles (EV) and non-motorised transport (NMT). These initiatives were developed over time for different purposes and are at various stages of implementation. Below is what some of the respondents had to say:

> **Respondent 7:** *EVs, the city purchased 10 EVs and were a pilot to test that it is possible because we have a huge fleet management in the city. To change the way, we do thing why not go electric vehicle route? And, as unit to support this initiative we suggested that we go the solar filling stations. We have one in Centurion and one in the Metro police. So, the idea is also to upscale those and encourage the community to buy EVs and now they will have infrastructure available to charge their cars.*
>
> **Respondent 5:** *Ours is to maintain storm water and bridges, like I said there are projects in the municipality, but they are not directly implemented from our section. I know of the BRT and NMT that are prioritised in the city.*
>
> **Respondent 9:** *EVs, first it was the CNG. Thirty per cent of the Areyeng BRT buses and also slowly but surely the Tshwane buses will also use the CNG. Though is not enough because it cuts down ± 30% of the emission. And the rate we going is almost BAU, we need to do something drastic. That is where electric vehicles come in. The biggest problem there is costs. It can be done in South Africa Cape Town is already doing that rolling out the electric buses. You cannot discount the cost, for buses is 8 years financing span then you can buy a new one, the legislations outline so. The cost is high; however, the maintenance of the bus is cheaper. If we look at rail, their life span using electricity is 50–60 years. It is expensive to get it in place, but in the long run it is cheaper to maintain.*

Figure 6.4 below shows the degree to which the respondents perceived climate change as a problem within the CTMM.

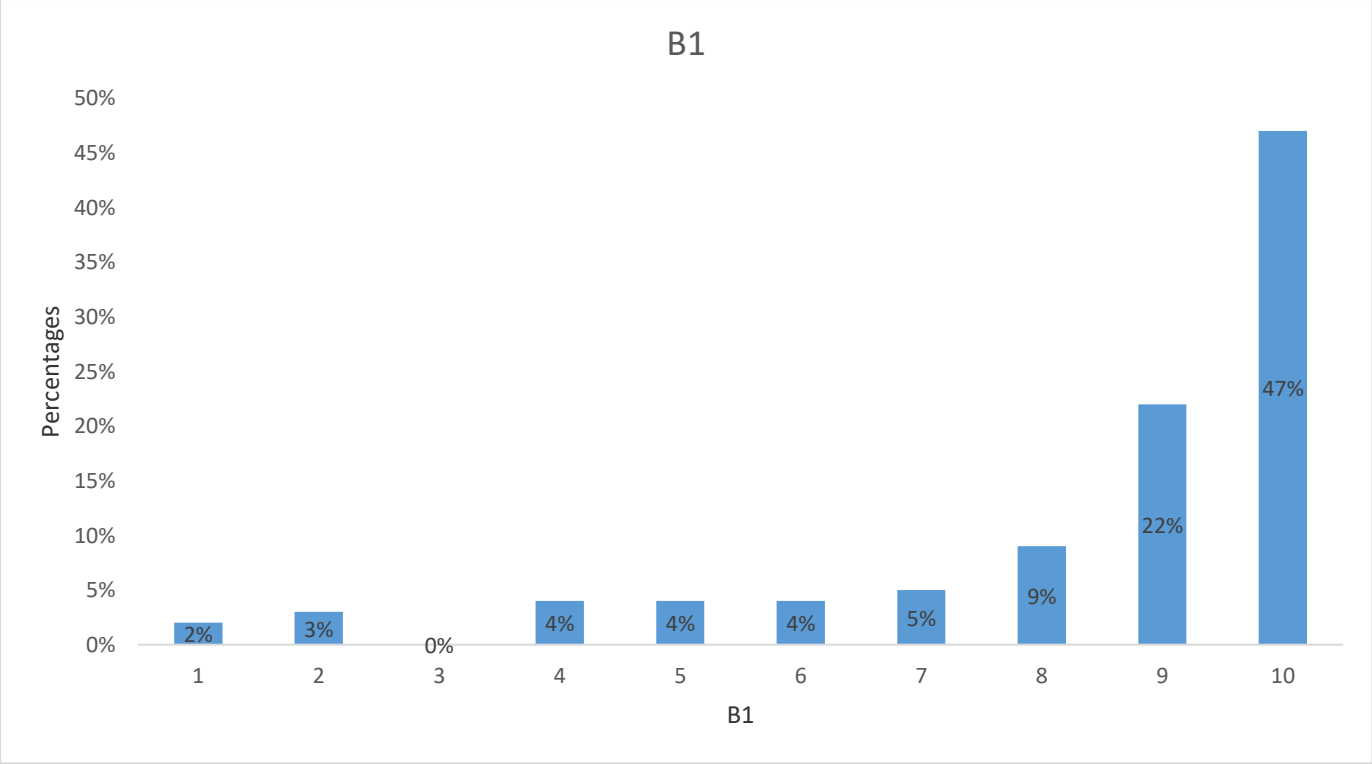

Figure 6.4: QB1 Extent to which climate change events are considered a problem

Source: Researcher's own compilation

The researcher included this question in order to assess the extent to which the officials believed that the CTMM considered climate change a problem. Figure 6.4 indicates that over 80% of the respondents selected above 5, which shows that they considered climate change a problem. According to Brown (2018), climate change is not just a problem, but rather a collective problem that requires collective action to address it. Communities in the municipal geographical area of responsibility should have people working together to address climate change through various initiatives, such as local education initiatives and fundraising campaigns, according to Allen et al. (2018: 47) climate change is a global problem affecting road transport networks, among other problems. In addition, concerns – such as GHG emissions – emanate from the road transport industry, making a major contribution to climate change. Scientists have predicted that in the next 30 years, GHG emissions will grow rapidly (Brown, 2018). Reducing such emissions will therefore become a challenge for all governments. Figure 6.5 below illustrates the climate change factors affecting the municipal road transport infrastructure.

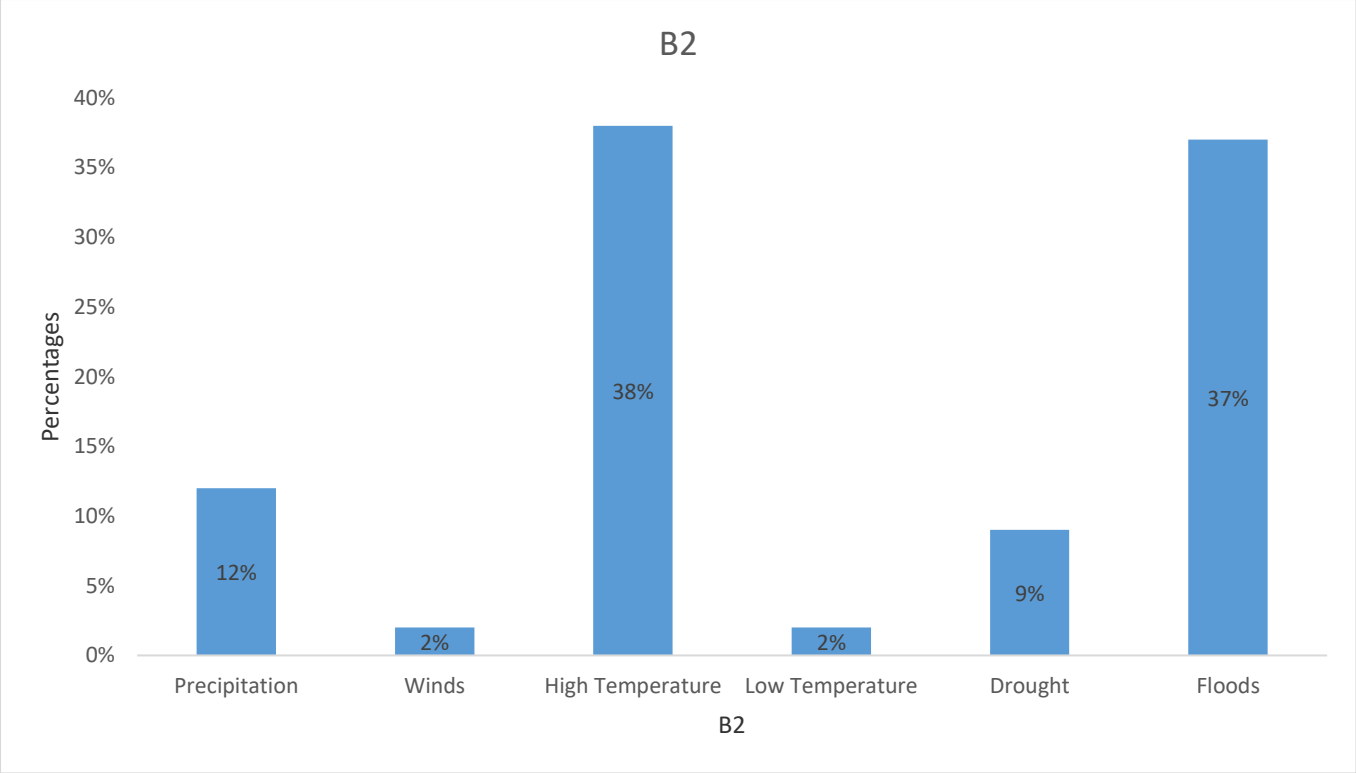

Figure 6.5: QB2 Climate change factors affecting the municipal road transport infrastructure

Source: Researcher's own compilation

Climate change is a problem with significant effects. The researcher considered it important to assess factors influencing the road transport network of the CTMM in order to determine the implications of the factors. The top three factors were high temperatures (reported by 37% of the respondents), floods (by 38%) and precipitation (by 12%) respectively. Scientists project that, in the coming decades, temperature trends will exacerbate in various cities (Moretti & Loprencipe, 2018: 3) and this will result in greater vulnerability of common road surfaces and worsen the general public welfare. In recent years, the CTMM had experienced quite a number of flooding incidents (CTMM 2018: Online). The floods were due to extreme heat waves and a lack of public road infrastructure maintenance, as some of the interviewees have suggested. High precipitation, although a low percentage selected it as one of the factors affecting the road infrastructure in the CTMM, has the potential to allow new roads to develop potholes easily and deepen existing potholes fast. Figure 6.6 below shows the availability of information on climate change impacts that affect road transport infrastructure.

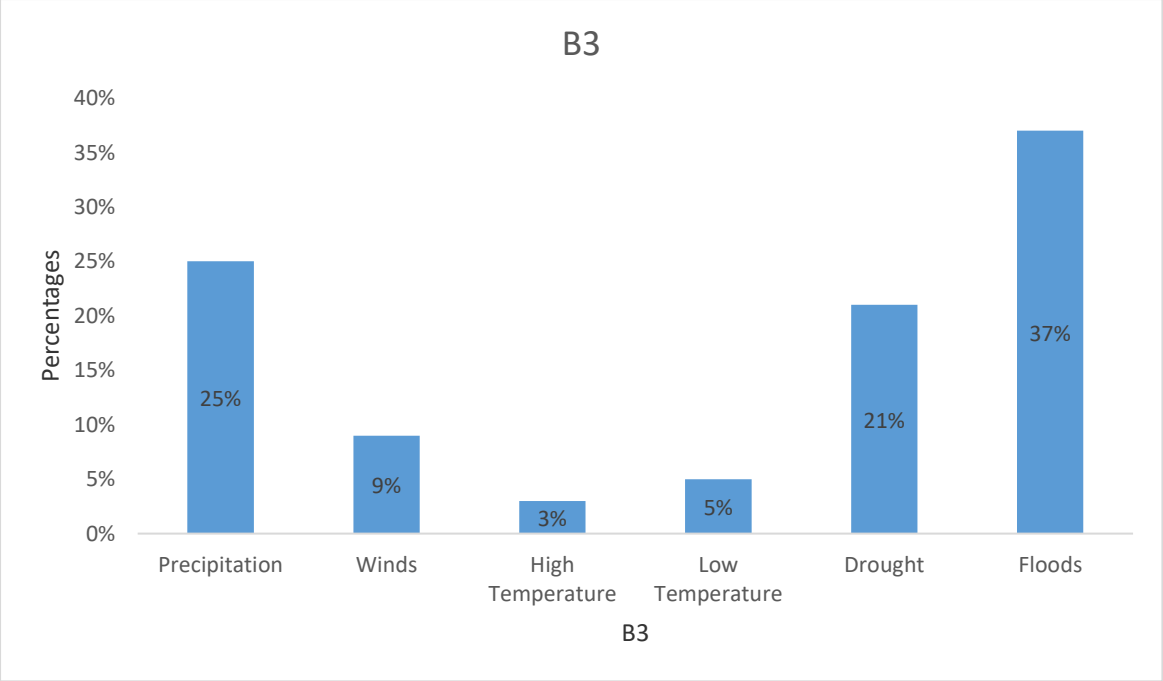

Figure 6.6: QB3 Availability of information on climate change impacts that affect road transport infrastructure

Source: Researcher's own compilation

In order to address climate change as effectively and efficiently as possible, it was necessary to have information on its impacts readily available. The purpose of including this question was to establish whether information on the identified factors was available or not. Figure 6.6 above indicates that 37% of respondents stated that information on floods was available at the time, 25% said there was information on precipitation available, and 21% agreed that information on droughts was available. These percentages are worrisome because they do not present a conclusive picture of what is available and what is not. The percentages fluctuate and differ vastly across the factors, implying that some respondents knew about certain factors and others had no information regarding the factors. However, this could be expected given the organogram and structure of the CTMM. The Department of Roads and Transport in the CTMM is divided into seven divisions with a number of sections and subsections as well as units under the subsections. As a result, one unit may not have much information on the aspect of climate change although it affects the entire department. Figure 6.4 below indicates whether climate change necessitates the need for management measures in the municipality.

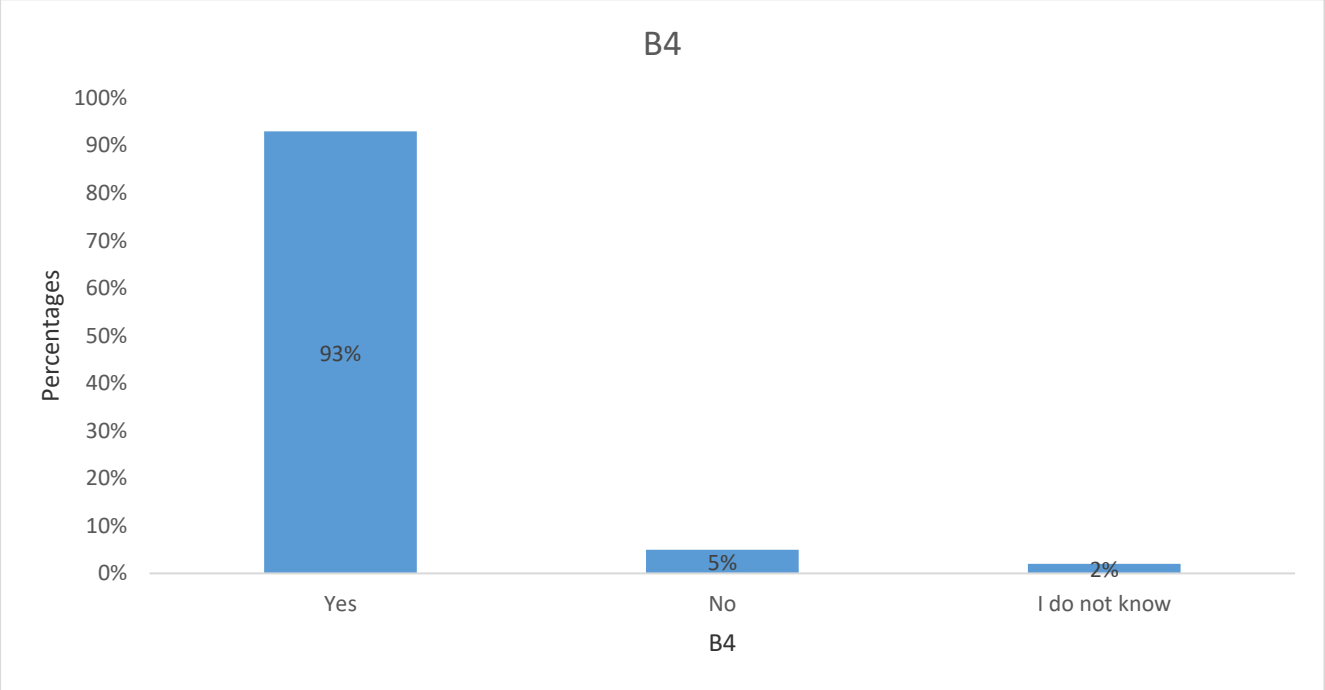

Figure 6.7: QB4 Climate change necessitates the need for management measures in the CTMM

Source: Researcher's own compilation

Climate change is a global issue with considerable challenges. The researcher wanted to determine whether, with global awareness of climate change as a concern, the CTMM had experienced climate change impacts that required the municipality to respond. Figure 6.7 above shows that 5% of respondents stated that climate change did not necessitate the need for management measures, 2% did not know whether climate change necessitated the need for management measures, while 93% of the respondents stated that climate change did necessitate the need for management measures. The 1992 UNFCCC, the 1997 Kyoto Protocol to the UNFCCC and the Paris Agreement agreed at COP21 to include some general provisions on the cross-border impacts of climate response measures (Bacchus 2019: 4). It is therefore important to have reaction mechanisms in place to handle climate change impacts. The current study therefore calls for management measures because such measures are meant to manage the impact of climate change. Figure 6.8 below indicates in percentages the data and information used to estimate the nature and extent of management measures for road transport infrastructure.

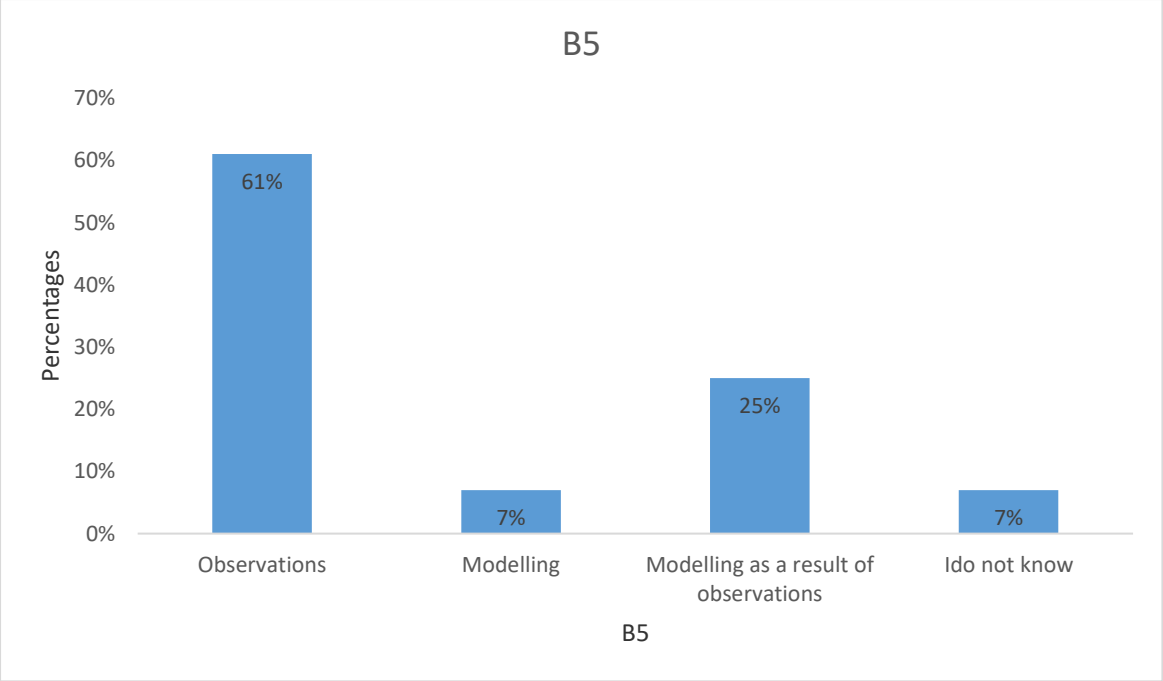

Figure 6.8: QB5 Data and information used to estimate the nature and extent of management measures for road transport infrastructure

Source: Researcher's own compilation

In order to manage the impact of climate change on road infrastructure in the CTMM, data and information on the events of climate change should be gathered. Figure 6.8 above illustrates that 61% of the respondents indicated that information was gathered through observations, while 25% stated that a model was created after observation. Through the interviews and reading of municipal documents, the researcher found that there were models in place to establish management measures. However, these models were not used when addressing climate change within the road transport sector. They were rather used by other departments dealing with energy (i.e. electricity). Figure 6.9 below illustrates the availability of vulnerability assessment in the CTMM.

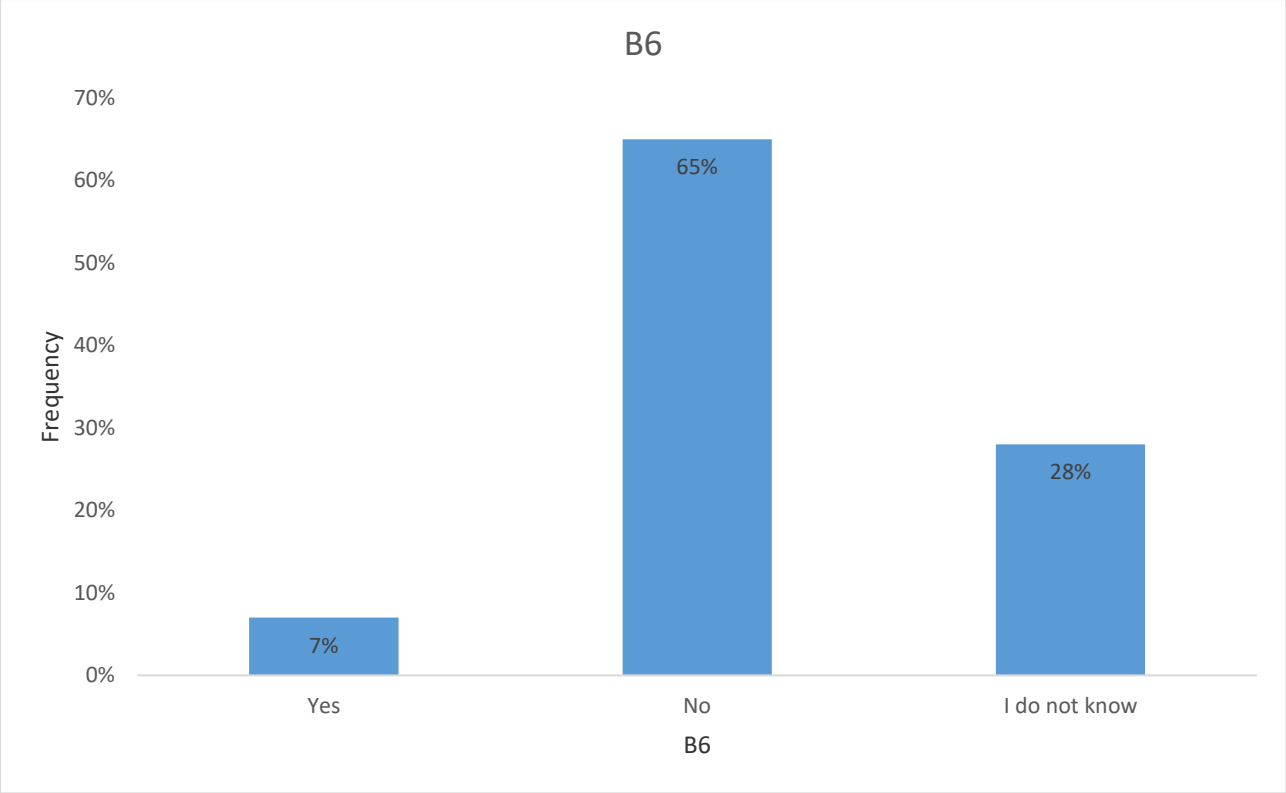

Figure 6.9: QB6 Availability of vulnerability assessment

Source: Researcher's own compilation

Vulnerability assessment is a tool used to measure potential harm using information about climate impacts (Enei 2011: 15). It entails an assessment of the regional ability to adapt. The assessment of vulnerability to climate change is a pivotal instrument for an adaptation move (Enei 2011: 15). Figure 6.9 indicates that the majority of the respondents (65%) stated that, at the time, the CTMM did not have a vulnerability assessment, while 7% of the respondents claimed that the municipality had a vulnerability assessment. During the interviews, the researcher established that there was indeed a vulnerability assessment in place in the municipality at the time. However, the vulnerability assessment was not specifically for road transport alone. The researcher further found that the focus on the transport sector at large in the vulnerability assessment was minimal. This could explain why the majority of the respondents believed that there was no vulnerability assessment, because they never had to use it in their unit, as their core business and focus were not catered for in the vulnerability assessment. Figure 6.10 below, demonstrates on a scale of 0–10, the extent to which manifestations of climate change affect the lifespan of the municipal road transport infrastructure.

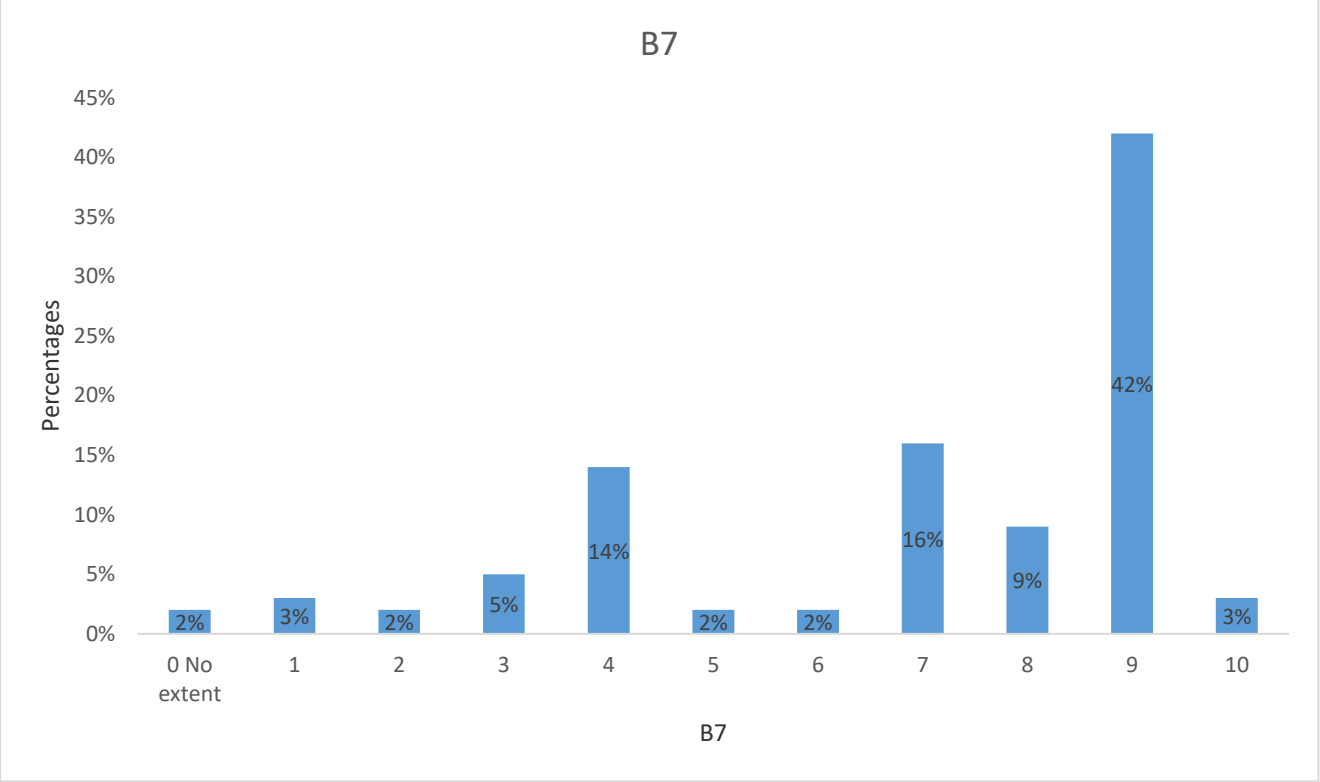

Figure 6.10: QB7 Extent to which manifestations of climate change affect road transport infrastructure

Source: Researcher's own compilation

Several climate change literature stresses the need to assess the impacts on road transport infrastructure (see, for instance, Anyala 2011; Fatima 2015; Twerefou 2015). The common finding in the literature was that climate change is a threat to the road transport infrastructure (Chinowsky, Schweiker, Strzepek & Strzepek, 2015: 53). While the reason for considering climate change impacts on road infrastructure is obvious, the measurement of these outcomes in terms of costs and a period scale gets less consideration. From the respondents' perceptions, climate change manifestation largely affects the lifespan of the road infrastructure of the CTMM. Over 70% of the respondents attested to this. Figure 6.9 proves the researcher's observation was right when she noted that most respondents confirmed that the road infrastructure was affected by climate change. In addition, some expressed little faith that the municipality would effectively address the challenges of climate change within the road transport infrastructure.

6.3.1.1 Overview of main findings

The responses to section B of the questionnaire and some face-to-face interview questions aimed to answer the research question: “What are the impacts of climate change on road infrastructure in the CTMM?” Some responses are summarised below:

- Of all climate change factors known to have an impact on road infrastructure, floods, high temperatures and precipitations are the three that mainly affect CTMM.
- The CTMM did have a vulnerability assessment, but the road infrastructure and city road network was not sufficiently covered in the assessment. Moreover, most respondents were not familiar with the vulnerability assessment, let alone knowing how often the assessment is conducted.
- There are four management measures in place to mitigate the impact of climate change on road infrastructure, i.e. BRT, CNG, NMT and EVs. These initiatives were not all as effective as anticipated, they encountered various challenges that hindered the potential to attain the desired outcomes.
- The CTMM did not have data and information readily available on climate change impacts that affect road transport infrastructure. Thus, the municipality addressed climate change impacts as they arose.

Hambly et al. (2013: 613–629) conducted a comprehensive study during which they developed a general framework for the consideration of climate change impacts on transport. The authors specify climate conditions and hazards that make up the environment within which infrastructure is built, maintained and utilised. They further argue that the climate-related setting would change with environmental change, influencing the recurrence, length and severity of the impacts. These impacts may have an effect on road transport infrastructure, activity, and interest. Therefore, the authors regard it as essential to address climate-change impacts to curb its influence. Due to the need to curb the impacts, governments across the globe develop management measures, such as projects and programmes aimed at addressing climate change impacts on road transport and infrastructure. Nevertheless, during the time spent actualising the management measures, there are challenges. The next

research question therefore tried to establish the administrative challenges that the CTMM was experiencing at the time while executing its management measures.

6.3.2 What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?

Climate change is one of the most pressing challenges facing policymakers around the world, posing substantial and significant challenges to sustainable growth. Therefore, managing the impacts of climate change effectively and sustainably is a key objective for governments (South Africa 2011: 2). Different variables present challenges in the implementation of the management measures, factors such as capacity, political will, social acceptance of the initiatives and funding. In an attempt to respond to the second research question of this study, four questions were asked during interviews and five in the questionnaire, as demonstrated in Table 6.3 below.

Table 6.3: Framework for data analysis

RESEARCH QUESTION	INTERVIEW QUESTIONS	QUESTIONS IN QUESTIONNAIRE
What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?	IB4 What obstacles have you encountered in implementing the aforementioned management measures identified in B3? IB5 What are the strategies in place to overcome the aforementioned obstacles identified in B4? IB6 What resources do you think you lack in trying to curb the climate change impacts on CTMM's road transport infrastructure?	QC1 Are there projects and programmes in your department in place to curb the potential impacts of climate change on CTMM's roads transport infrastructure? QC2 How many projects and programmes does your department have that address the impact of climate change on CTMM's roads transport infrastructure? QC3 To what extent would you say the response measures of CTMM, in place to curb the potential impact of climate change on its roads transport infrastructure, are effective? QC4 Do you think your department in CTMM is well equipped to address challenges posed by climate change on the municipality's roads transport infrastructure?

RESEARCH QUESTION	INTERVIEW QUESTIONS	QUESTIONS IN QUESTIONNAIRE
	IB7 To what extent do you have political backing in all your functions and activities in the Municipality?	QC5 What are the challenges faced by your department in addressing climate change's impact on CTMM's roads transport infrastructure? (Tick all that are applicable) QC6 Does your department in CTMM often communicate, integrate and share climate change information with the other units (e.g. is there synergy)?

Source: Researcher's own compilation

IB4 What obstacles have you encountered in implementing the aforementioned management measures identified in IB3?

Inasmuch as climate change is a challenge on its own to governments, addressing its impacts on road infrastructure poses more challenges. However, the current study was especially interested in administrative challenges as they are key to Public Administration as a management discipline. It should also be noted that only management measures in terms of administrative problems reported by the respondents are discussed and evaluated in this thesis. The researcher admits that the respondents may not have mentioned other administrative issues. As a result, such issues were not addressed in this study, but should be discussed in the future research. The respondents mentioned the following as existing management measures at the time of this research: the CNG, BRT, EVs and NMT.

The respondents suggested that considerable difficulties were encountered when implementing management steps. City Sustainability Unit (CSU) respondents stated that one of their key challenges was the non-cooperation of their counterparts from other municipal departments. The CSU is a support unit by nature; it cannot operate on its own. Its sole purpose is to support other departments on issues of climate change. Therefore, it is essential for other departments to cooperate. The researcher observed a level of demoralisation on the faces and in the body language of the respondents from this unit when they spoke about a lack of cooperation. This is what the respondents had to say in this regard:

> **Respondent 6:** *We've been trying to make sure that the departments are running without us having to tell them that this is what you need to do. But, even after five years, we still need to push and remind people please do away with business as usual. Do things in sustainable manner, so there is still a need to change the mind-set and have buy-ins from other departments.*

> **Respondent 8:** *The challenges are many but manageable since we have a very close working relationship with other stakeholders. Now, when we speak of roads, we … we now need to focus on the Department of Transport, we work closely with those guys there, we plan our projects together and we advise them on the best approach in executing the project and taking into account the issues of climate change but now, the challenges are from the external people. You know, our communities, taxi industry.*

The taxi drivers are not considerate of the law. Look, when we implement the BRT … it was very clear that those buses will have their own designated lanes and traffic light, but I can promise you taxi drivers are using those lanes and disregarding the normal traffic lights and that's very dangerous and can cause accidents … but those guys do not care.

However, one CSU respondent praised the CSU's working relationship with other departments and their cooperation. The researcher came to the conclusion that the respondent was treated differently than his co-workers, most likely because of his seniority in the unit. He was not involved in project execution because of his position in the unit, but rather in planning, briefing, and reporting phases. The respondents from the Department of Transport also mentioned the issue of cooperation from other units and colleagues as a challenge. Others mentioned that they work well together as a department, but the City Sustainability Unit imposes projects on them without understanding the nature of their work as road infrastructure service providers and the challenges they face, while others indicated that there is a good working relationship.

Respondent 14: *The City Sustainability Unit is not old and it is a political office, they do projects to please the mayor and not aware of our workloads […] they are very demanding.*

The researcher noticed that some respondents had little interest in the CSU and, in fact, regarded CSU as 'new kids on the block' who thought they knew everything. Other Department of Transportation respondents expressed frustration and dismissiveness of the CSU. Furthermore, the researcher noticed that this resentment was not personal, but rather that the respondents were not happy with the change that this unit was bringing in the way they should approach their mandate. At the time of this study, the CSU was prioritising the impacts of climate change and therefore, they argued that the operations in the departments should not be 'business as usual'. This caused discomfort among some of their colleagues.

Respondent 10: *Climate change cannot be addressed in isolation; all affected areas need to work together. Energy and us are the main culprits for emissions. We constantly work with the department of energy, disaster management section and the City Sustainability Unit. When a road is hit by floods, they will come to us as planning guys to unpack the causes and plan going forward.*

> **Respondent 13:** *We work very close with the City Sustainability Unit, which is a political baby. The challenge is we work with politicians who work on a five-year plan, but we are busy with 20–30 years plan that we have to break in chunks. What we need to do in their first five years and convince the politicians that the projects need to be done and if we don't do it we fall behind so this unit is important for such administration.*

The respondents indicated that the barriers to enforcing the NMT included, but were not limited to, obstructions such as spatial planning, which is a private vehicle located within urban areas. In addition, there is recognition for pedestrians and cyclists. Respondents further indicated that, in general, the public see walking and cycling as methods of transport for poor people. Additionally, individuals using the NMT are not safe. Cyclists and pedestrians are defenceless against crime, for example, theft. In addition, the NMT clients are more inclined to mishaps than vehicle clients (IPCC, 2014). In their own words, respondents from both units had the following to say:

> **Respondent 2:** *In South Africa, NMT is considered to be for the poor, the expectation from people is the minute one bag a job should buy a car. You know. And, if you buy a car and not use it as frequent … rumours will begin that you do not afford the car. Societal pressure …*

The respondent was laughing while talking. However, the interviewer observed that the laughter was not necessarily because the interviewee found the situation funny. Rather, the respondent was disturbed by the mentality that the public has about NMT and how much this perspective affects the decisions of other people – even those considered 'educated'. The respondent further gave an example and said:

> *[I]imagine me walking to the office from my apartment wearing my suit, even if it is from the BRT bus stop. My colleagues expect me to park my car next to the office building.*

One of the concerns raised by all respondents was the issue of policies and legislation guiding NMT planning. It was indicated that, at the time, there were regulatory and institutional systems that promoted and encouraged NMT and which ensured the inclusion of NMT in the planning processes. These systems, however, were not sufficiently efficient due to a variety of factors, including a lack of appropriate and long-term funding for designing and promoting NMT.

Respondent 4: *The existing frameworks and policies provide adequate guiding principles; however, it is evident that physical manifestation of the principles contained in the policies are lacking.*

Respondent 12: *NMT infrastructure is not up to standard in most areas within the city, let alone townships under the municipality. There are no pedestrian sidewalks that are supposed to serve the large number of pedestrians. The only provisions that are available in most streets are pedestrian crossings that also needs to be repainted and a few bus shelters constructed. Another challenge is some pedestrians are school kids who most are too young to understand and follow the pedestrian crossing lines and rules.*

Respondent 1: *[A] lack of maintenance, the parks in the townships, the streets so much needs to be done in promoting the use of NMT; it is not safe even.*

The researcher observed that most respondents were not keen on NMT and had little faith in the effective implementation of it. The respondents raised a number of issues, including safety of NMT users, stigma attached to poverty and classification of NMT users. It was remarked during the interviews that NMT was classified as a mode of transport for the poor people. To avoid being classified as 'poor', most people were therefore not open to use NMT. The City of Tshwane Comprehensive Integrated Transport Plan (2015) indicates a significant awareness of the need to promote and accommodate NMT in current and future plans. This includes the planning and executing of operations and NMT infrastructure.

For cycling and walking, NMT requires uncommonly allocated regions and routes. There isn't enough land available to meet this demand. Finally, providing secure and efficient NMT and its excellent base is expensive from a financial perspective. The cost of NMT includes the construction and maintenance of bike and pedestrian paths, as well as open mindfulness battles. The successful implementation of NMT depends on a number of factors, such as culture, political commitment, public awareness and policy efforts. In addition, Koetse and Rietveld (2009: 217) argue that geographical and climate aspects are also factors affecting the effectiveness of the implementation of the NMT. The Victoria Transport Policy Institute (2010) claims that, if successful policies are enforced, 5–10% of vehicle trips will be replaced by NMT.

The second management measure identified in IB3 is the BRT. The BRT is a specialised bus system aimed at providing a quality rapid mass transport system. However, in pursuit of this aim, the system encountered numerous challenges in the CTMM. The respondents indicated that the system did not have support from the road public transport industry. Public transport operators, such as minibus taxi owners and bus companies, did not support the project because it was seen as competitive and they feared losing commuters. The BRT has dedicated lanes, which the minibus taxis are not allowed to use. This has led to inefficient transport in affected areas since the minibus taxis caused traffic congestion because of fewer lanes available than before. As a result, commuters were delayed. This is what some respondents said:

> **Respondent 11:** *BRT is a good initiative, only if people used it. Right now most of the time the buses are empty, is like people do not know about them.*

> **Respondent 5:** *The BRT is not receiving support and other public transport like taxis, private buses feel like municipality is a competitor, and they are not in support of the transit, in fact, they boycott the system by forcefully using their designated lanes and traffic lights.*

Another challenge that most respondents agreed on was that BRT has a challenge of attracting users, especially private vehicle users, since the buses are predominantly operating in cities and do not reach most nearby areas. Additionally, the respondents indicated that the BRT was an expensive project to maintain. Moreover, developing a financial model for future maintenance of the system was a challenge. This is what some had to say:

> **Respondent 14:** *BRT is expensive to implement, the BRT in the city is known as 'Areyeng'. The challenge now is the public who is not attracted. Most people prefer using the private vehicles to the buses, this may be because these buses are not accessibly in the townships yet, but the rollout is still taking place. The municipality is trying to reach the townships as well.*

> **Respondent 11:** *Financing the BRT is expensive. We should remember that these buses do not use the fuel combustion engines, but the natural gases ones. The BRT buses are expensive to purchase, however, in the long run it could be cheaper and moreover they are environment friendly, they do not pollute like your normal petrol or diesel engines.*

> **Respondent 3:** *You see, if people were using these buses the municipality would recover some money and but more buses and safe the environment. Second issue is lack of regulation; you should check these buses around school out time in the afternoon. School kids use the buses because of free Wi-Fi and they manage to ride on and off bus stops without paying. One thing I noticed is because there are no bus conductors, the passengers cheated their way in, one paid ticket will tag for five or more learners, so the bus is full but not every passenger has paid and that is like running at a loss for municipality.*

> **Respondent 6:** *The BRT is not a success, literature shows that there is no successful BRT anywhere in the world where the BRT corridors is more than 22 km and we are running 35 km and means we need so many buses. Promote public transport so that private doesn't become more effective anymore.*

Another obstacle is that the spatial density of human settlements is limited to realistically foresee a zero or near-zero private transportation system based on service levels. The lack of law enforcement agents to regulate existing regulations and bylaws to allow unregulated public transport providers to keep their costs low, through sub-standard vehicles and speeding. This further exacerbates the inability for a formal system to compete with an informal system. The respondents have indicated that CNG is now the preferred fuel for reducing emissions. CNG is classified as an alternative fuel (Kalinichenko, Havrysh & Atamanyuk 2019: 3). However, the respondents indicated that the costs of implementing CNG is a challenge as indicated below:

> **Respondent 1:** *The big challenge that we face is acquiring the CNG engine vehicles because they are expensive due to the on-board fuel storage as well as the modification of the vehicle engines. Moreover, the engines and vehicles are limitedly available. Over and above refuelling is not only available in selected areas, the City of Tshwane is still busy with infrastructure constructions for the refuelling.*

Municipalities have to make difficult decisions to find a balance between competing interests of the communities with limited resources and funding. Climate-resilient road programmes and projects aim to address the impact of climate change and provide safe road transport for the community. However, public funds alone are not adequate to achieve this aim. Furthermore, the respondents were frustrated by the lack of political will to address the challenges faced in implementing projects and programmes. The respondents further indicated that other challenges included:

- high transaction costs related to purchase the buses
- competitiveness of the BRT to other modes of transport;
- costs of reduction of emissions
- availability of investment capital to purchase more buses and maintain them; and
- little progress in technological development in the CTMM.

The researcher noted that not much was said about electric vehicles, except the fact that the municipality intends to change its fleet of vehicles to electric vehicles. However, of the few respondents who spoke about electric vehicles, none showed enthusiasm. In fact, they demonstrated a lack of faith in the project. One even said the following:

> **Respondent 11:** *These EVs are expensive to buy and we still lack infrastructure for recharging, but then the municipality is trying. However, so far the municipality has only 10 EVs. From what I heard is these EVs are low-cost maintenance, but high purchase, so money to buy them is currently a problem.*
>
> **Respondent 8:** *Finance, money is the problem. There is so much that the municipality needs to do in terms of delivering the service and communities demanding equal services not equity. Secondly, political issues, now there is a new mayor, the plans are short-term and they keep on changing at strategic meetings and before you realise the mayor's term of office is expired.*
>
> **Respondent 13:** *The challenge is poor interaction, with the national government at least. The National Council for Climate Change has invited some of the local governments to sessions but what is really going on is not so much a discussion as the Land and Tourism Department provide information and reviews on its own projects.*

The researcher observed that most of the respondents from the Department of Transport had concerns around the Executive Mayor's Office and term of office and the lack of political will. They indicated that, at the time of this research, some projects had been left incomplete or were delayed due to the political game played out between political parties. The mayoral office is a term-based office and this has a negative impact on long-term planning. Funding of these projects was among the challenges faced in implementing the management measures, although some indicated that money was not an issue. Respondents argued that there are means and ways to get

funding. The only challenge is the process and procedure of acquiring the funds. Overcoming these challenges to implementation requires policy intervention and incentives. Most importantly, municipal spending patterns should be adjusted to accommodate the climate change mitigation strategies.

IB5 What are the strategies in place to overcome the aforementioned obstacles identified in IB4?

Faced with problems of air pollution and traffic congestion, the CTMM is one of the municipalities in South Africa that has introduced a number of initiatives, such as BRT, CNG and NMT projects in an effort to curb GHG emissions caused by the transport sector. These initiatives are aimed at curbing the growth of motor vehicle dependence and related emissions. Many challenges were indicated by respondents in this regard. However, the same cannot be said about the strategies in place to address the identified challenges. The researcher observed that most respondents felt it is not their responsibility to have solutions to the problems, but rather the responsibility of top management and political leaders. Respondent 12 said the following:

> **Respondent 12:** *My work is to research the problem and someone else will do the planning while others will implement the plan.*

According to the above quote, if the preparation fails, the individual doing the initial research is unconcerned since the implementer is the one who fails to implement or encounters difficulties. As a result, whoever faces the obstacles assumes sole responsibility. However, the very same person facing the challenge can blame the person who did the initial research or the planning for poor research and planning; hence, most respondents felt that the responsibility was therefore that of management. Moreover, they indicated that the municipality relied on the performance management system to encourage people, as well as units in general, to perform their task satisfactory. The appraisal of work performance should be a motivating aspect to do well in executing the mandate. The respondents stated the following:

> **Respondent 9:** *Performance management system, we put the strategies in the KPIs [Key Performance Indicators], then people will be forced to change the mind-set because they would not want to lose money.*

> **Respondent 5:** *The climate action planning, our green economic strategy has as per sector, we have aspirations and there are steps as to what each department has to do. However, this has been there for four years now, but it has not happened. Now we came up with climate change strategy to bringing it into a plan. In every sector, highlighting the things that need to be done. And they need to be in KPI, performance management.*

> **Respondent 12:** *I doubt they are any. I mean in order to get funding the municipality needs to have proper convincing project spelled out to the T to explain what to be done, where, when and why, then money can be borrowed or moved from intended expenses, so money issue is big*.

The CTMM aligns its climate change response with international peers under the leadership of its Executive Mayor, having signed the Compact of Mayors' Declaration in 2014 (now recognised as the Covenant of Mayors for Climate and Energy and being a member of the C40 Cities Climate Leadership Group (C40), an international group of megacities dedicated to fighting climate change. The C40 movement supports cities and their mayors to collaborate actively, share expertise, and accelerate positive, measurable and sustainable climate change action.

> **Respondent 7:** *The municipality is a member of C40; we have an opportunity to be recognised as a leader in local climate change. Therefore, we develop a climate change response strategy aimed at responding to the findings of both its annual Greenhouse Gas (GHG) Emissions Inventory carbon footprint and its Climate Change Vulnerability Assessment.*

Climate change makes cities uninhabitable globally (South African Cities Network 2016: Online). The CTMM, as a metropolitan municipality, has differing perspectives on the goal of reducing GHG emissions, climate adaptation funds, and renewable energy investments. Political leaders and government officials at managerial level need to make changes on the ground to mitigate the impact of climate change and deliver basic services at the same time.

IB6 What resources do you think you lack in trying to curb the climate change impacts on CTMM's road transport infrastructure?

In addressing the impacts of climate change on road infrastructure, the CTMM will require various resources, such as finance and personnel. Therefore, the researcher had to investigate which resources the CTMM was lacking at the time. During the interview, the researcher observed the consistency of respondents in the need for education and awareness of the impacts of climate change on road infrastructure as well as the human contribution to climate change. Most respondents indicated that there is a need to raise awareness and education, not among for the public, but among municipal officials as well. This is what some of the respondents had to say:

> **Respondent 5:** *Expert personnel, financial backup and education. Not all officials in the municipality understand climate change and disaster management. Just because an event took place and the section or does not have money to address it, that does not make it a disaster. The event needs to be analysed in detail before it can be declared a disaster, and then a decision can be taken whether a local disaster is or other spheres should intervene and assist with managing the disaster.*

> **Respondents 3:** *In the unit, we lack capacity; we are a unit of nine people with three directorates, mitigation, adaptation and financing mechanisms and partnership. Three directors, there is a need for deputies and functional head, but we do not have. Human capital we are struggling, resources budgeting, and they are declining. The city now has competitive responsibilities that sometimes we are told we come up with fancy staff that we can't afford while we have bigger issues on the ground. But, those bigger issues can be solved in a more investable and sustainable way but that understanding is not there yet. Therefore, education is needed.*

> **Respondents 2:** *We are eight or nine in our unit and only three engineers, two of us retiring soon and we have not passed the intellect to anyone. I have been asking that they bring people I can train, but that doesn't happen.*

Insufficient or improper resources compromise the quality of service delivery. The researcher learnt that, in the CTMM, some of the events that were ultimately associated with climate change were exacerbated by a lack of service delivery, such as no maintenance of storm-water drainage canals. In the past, this lack of

maintenance has resulted in events of flooding, as waste blocked the culverts next to the roads and storm-water drainage systems. Respondent 10 contended:

> **Respondents 10:** *Our drainage system is not well built to accommodate the level of flooding we have experience in the last few years. However, the other issue that we have noticed and busy addressing is poor maintenance of the existing drainages, yes, we acknowledge that our drainages are not enough but the ones we have are not properly maintained and when it heavily rains the waste in the drainages block the water flow and result in flooding events. For instance, in the Centurion side the drainage systems are not well built hence that area experience a lot of flooding during rainy seasons. Moreover, there was an incident of a bed mattress blocking the storm water drain. So, the public also use this sites as dumping area, the municipality can come and clean today, tomorrow they dump waste a day later in rain so ja … that's some of our challenges and lack of resources such as enough personnel to do the cleaning across the municipality's jurisdiction.*

One respondent indicated that personnel shortage is amongst the resources that are lacking, and this affects service delivery and implementation of management measures negatively. The respondent argued that, due to the lack of personnel as a resource, they are unable to assess the effectiveness of their initiatives through monitoring and evaluation. Therefore, the respondent suggested that more personnel should be employed and a monitoring and evaluation unit be established to evaluate the success, failure and progress of the initiatives. However, the researcher observed that the City of Tshwane Climate Response Strategy (CTMM 2017: 40) indicates that, in as far as monitoring and evaluation are concerned, the City Sustainability Unit has to estimate the emission reduction potential of various projects and should advise on how to improve the emission reductions, retaining the oversight position.

IB7 To what extent do you have political backing in all your functions and activities in the municipality?

As climate change becomes more serious and obvious, politicians must be supportive, decisive and comprehensive regarding action plans for climate change (Bacchus, 2019:4). The amount of GHG emissions has increased, bringing humanity closer to the dangerous levels of global warming that were anticipated (Bacchus, 2019:4). This is not to say that there has not been progress. Most respondents have indicated that

there was no sufficient support from politicians. They demonstrated their frustration about ‘political will’ stating that some of the initiatives need political drive, but they lack that. The respondents also indicated that the political office period has a negative influence on their initiatives because every politician wants things done his or her way, and they are only in office for five years while some projects are anticipated to run beyond the above-mentioned political duration. This is what some respondents had to say:

> **Respondent 1:** *There is no political backing, none whatsoever. The Executive Mayor just issues instructions to his people and next thing we need to get things done, it gets hectic at time.*
>
> **Respondent 6:** *You see the problem is these politicians are in office for a short term and we plan for long term so we do not get support in fact we get frustrated at times because every Executive Mayor come with his plans and goals. We must make those plans reality. Before we know it, five years is gone.*
>
> **Respondent 5:** *We used to have the support, honestly, the backing was there especially when this unit was established. I started with the unit, but now … things are different. The enthusiasm is no longer there; when it’s time for election everything else stops the focus is on canvasing.*

However, just a few believed that the political backing was there and the former Executive Mayor invested his interest in building a green economy for the CTMM.

> **Respondent 4:** *Executive Mayor Ramokgopa has been hands on and supportive of every initiative we came up with. We hope that our new Executive Mayor will be just as supportive.*

Climate change in the city is caused by human actions within the city; therefore, the governors of the city are in a better position to address it – and that means by-laws offer the best way forward. In 2015, political leaders from various countries visited Paris to agree on a response to climate change. The outcome of the visit was an international treaty called the Paris Agreement (see McLusky & Sessa, 2015: 5).

Climate change poses a political dilemma, where politicians need to choose between lowering the GHG emissions and providing basic services with scarce resources. This dilemma could result in subordinates feeling there is no support for their initiatives

because the politicians may want to provide a specific basic service over an initiative to curb the impact of climate change. Figure 6.11 below indicates whether there are projects and programmes in place to curb the potential impacts of climate change.

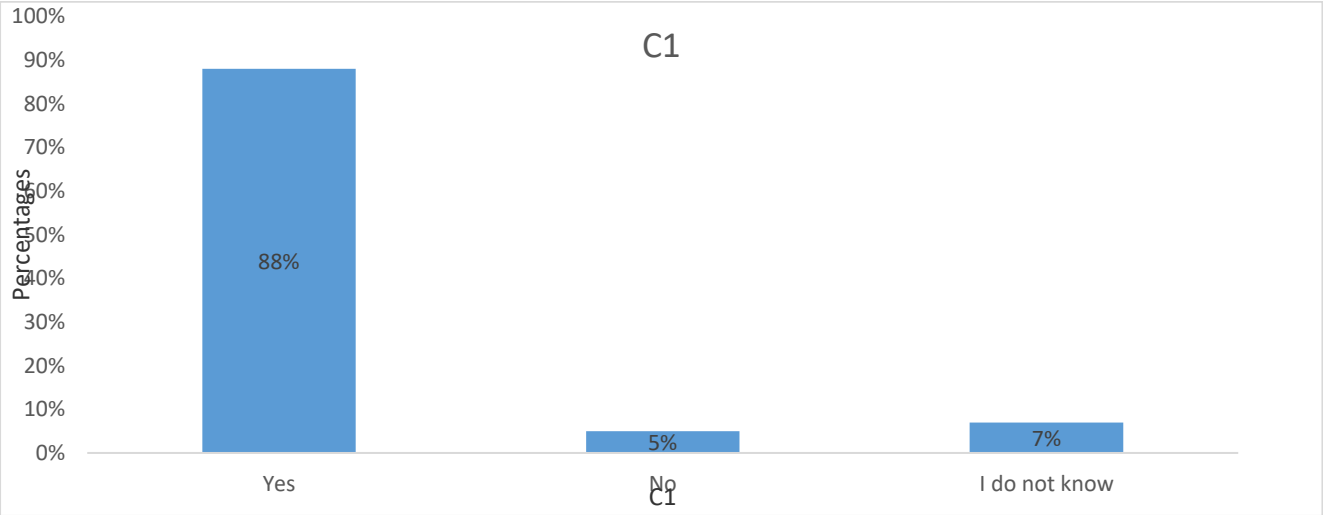

Figure 6.11: QC1 Are there projects and programmes in place to curb the potential impacts of climate change?

Source: Researcher's own compilation

Figure 6.11 above shows that the majority of the respondents were aware of the projects in place within the CTMM that were meant to address climate change. Over 80% of the respondents stated that there were projects in place. However, there was a group of 12% who claimed not to know about the projects. The presumption was that these respondents were aware of the programs in progress, but they may not have understood that they were climate change management projects. Perhaps the respondents linked the projects with just public transport initiatives rather than mitigation measures. Figure 6.12 below indicates the number of projects and programmes in place at the time of this research to address the impact of climate change.

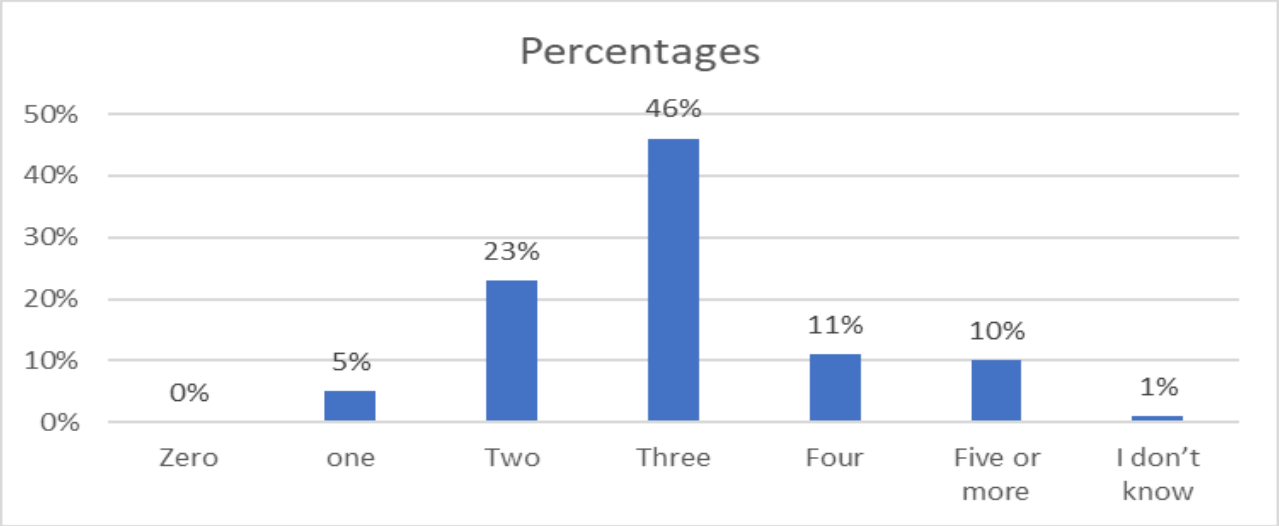

Figure 6.12: QC2 Number of projects and programmes in place to address the impact of climate change

Source: Researcher's own compilation

From the interviews, it was established that, at the time of this research, the CTMM had four active projects in place to address climate change. Figure 6.12 above indicates that 46% of the respondents stated that the municipality had three active projects at the time. It might have been that some respondents did not consider the CNG an isolated project, but one with the BRT. Figure 6.13 below illustrates the extent to which the response measures curbed the potential impact of climate change on its road transport infrastructure.

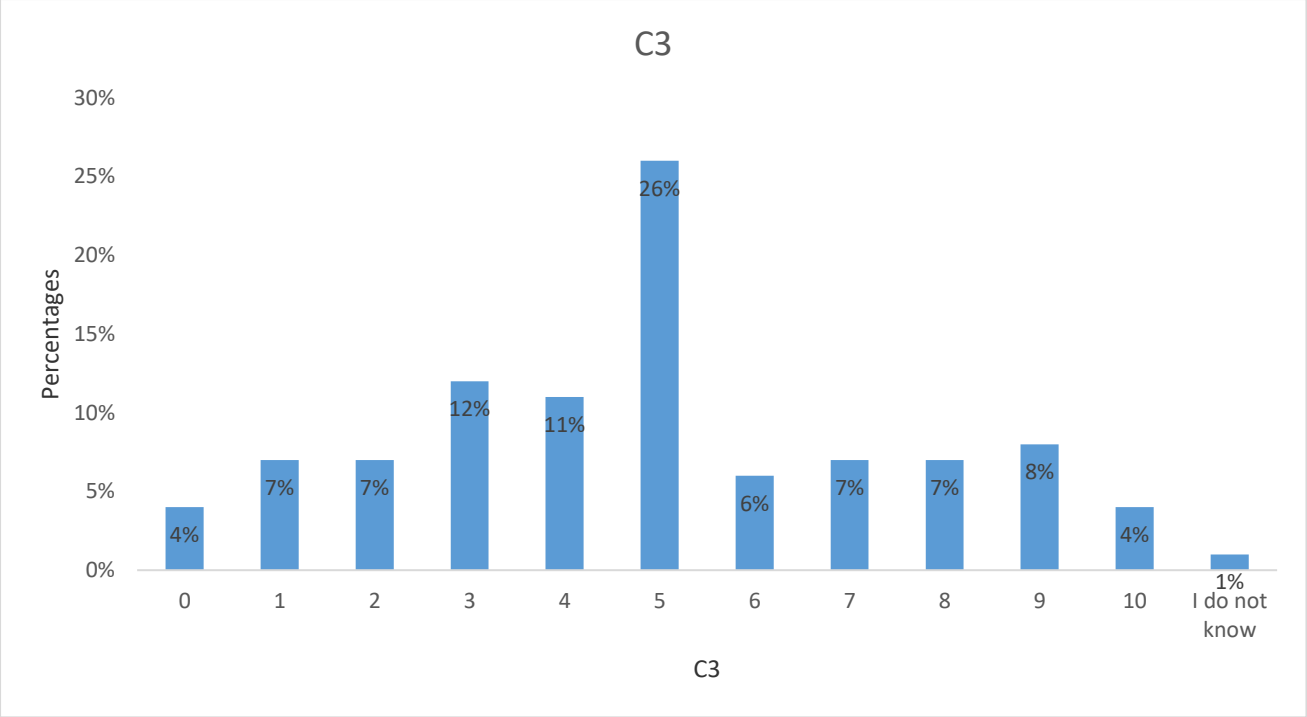

Figure 6.13: QC3 Extent to which response measures curbed the potential impact of climate change on road transport infrastructure

Source: Researcher's own compilation

During the interviews, the researcher observed that some respondents were not convinced of the effectiveness of the projects in place. Figure 6.13 above indicates that over 65% thought that response measures in place curbed the impact of climate change on road transport infrastructure to a low extent (from 5 downwards). Figure 6.13 below indicates the extent to which the departments were equipped to address challenges posed by climate change on the municipal road transport infrastructure.

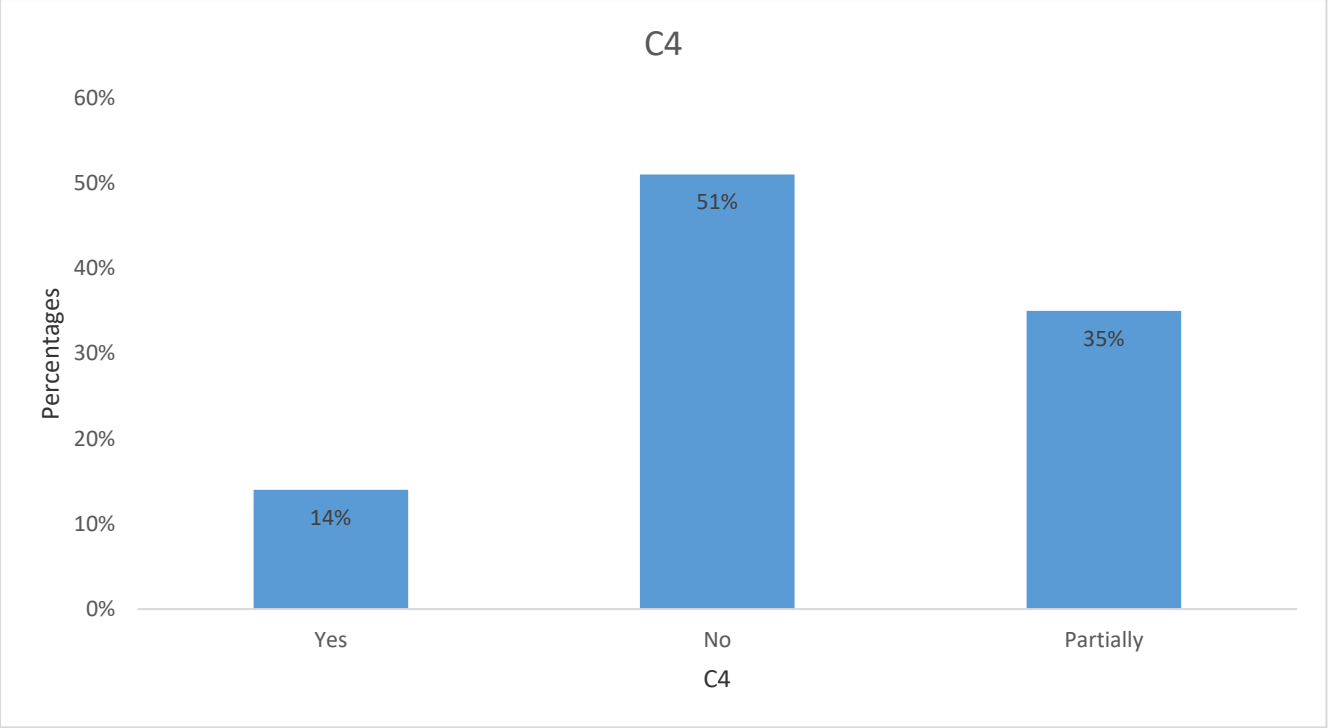

Figure 6.14: QC4 Departments equipped to address challenges posed by climate change on the municipal road transport infrastructure

Source: Researcher's own compilation

In addressing climate change, resources are required. Figure 6.14 shows that only 14% of the respondents indicated that they were equipped with all the necessary resources required to address climate change impacts on road transport infrastructure in the CTMM. It was observed during the interviews that the respondents felt that the resources in place were not sufficient, as most respondents indicated a lack of finance, expertise and political support. Figure 6.15 below presents the challenges faced in addressing the impact of climate change impact on the CTMM road transport infrastructure.

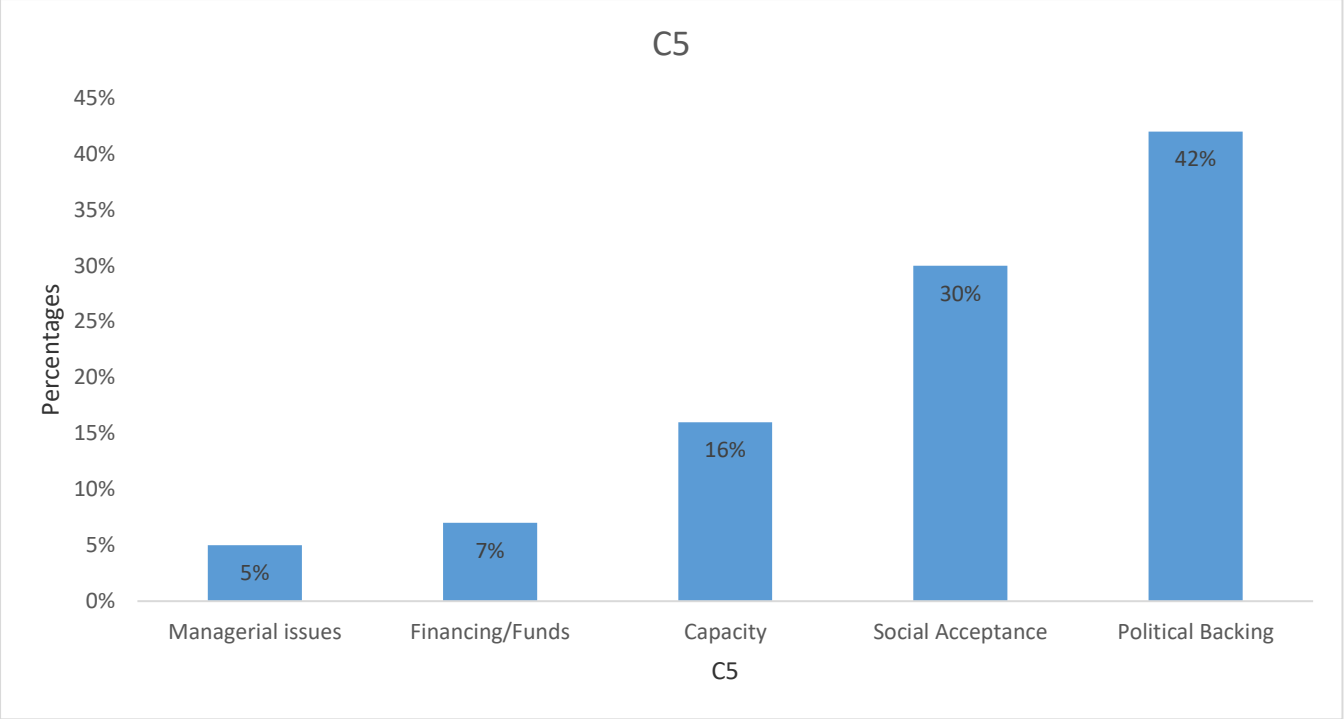

Figure 6.15: QC5 Challenges faced in addressing the impact of climate change on the CTMM road transport infrastructure

Source: Researcher's own compilation

Figure 6.15 above illustrates graphically what has been said during the interviews, namely that there was a lack of political support. Of the respondents, 42% believed that there was no backing from the political office. A second challenge was social acceptance. It was raised during the interviews that there was a lack of social acceptance of the initiatives. In the City of Tshwane, for example, neither Areyeng nor the NMT are socially embraced and supported by all. Figure 6.16 below presents answers to the question regarding communication, integration and sharing of information on climate change with other units within the municipal departments.

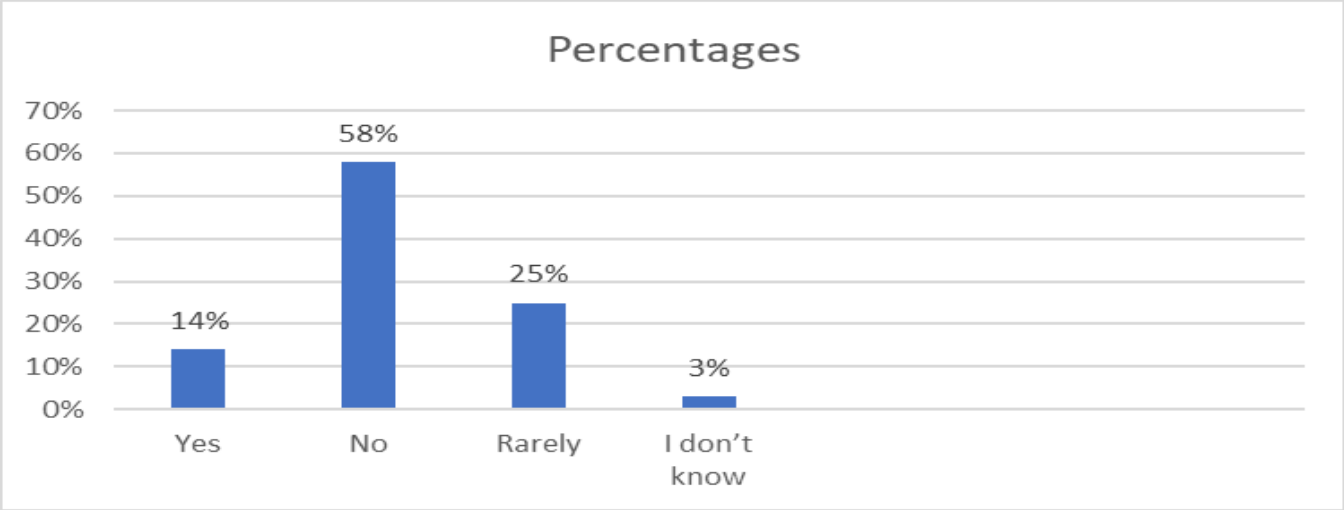

Figure 6.16: QC6 Communication, integrating and sharing climate change information with other units

Source: Researcher's own compilation

Synergy, in this case, offers the units and departments an opportunity to achieve a greater level of success in managing the impacts of climate change than one unit would on its own. Coordination, communication and integration of resources would therefore generate better results in addition to curbing the GHG emissions and promoting a green economy. However, the graph above (Figure 6.16) indicates that there was not sufficient synergy between the two departments. Moreover, there was a lack of synergy between the units in the same department.

6.3.2.1 Overview of main findings

The responses to section C of the questionnaire, as well as some responses to face-to-face interviews, were aimed at answering the research question.: "What are the administrative challenges of managing the impacts of climate on road infrastructure in the CTMM?" are indicated below.

Four management measures were identified, namely NMT, BRT, CNG and EVs. All these initiatives experience vast challenges and are at different levels of establishment and implementation.

- A lack of political backing is a major challenge in the municipality, followed by a lack of expertise on climate change issues. Additionally, social acceptance and financing are also making it difficult to implement the management initiatives. Other challenges include capacity and managerial issues.

- A lack of maintenance of road infrastructure exacerbates the impact of climate change, while a lack of synergy between departments delays the implementation process.
- A lack of law enforcement and legislation poses additional administrative challenges.
- There is a lack of education and awareness amongst the CTMM officials and the public at large.
- There is a lack of monitoring and evaluation of management measures implemented. However, the general feeling from the respondents was that the current management measures in place were not effective in curbing the impact of climate change on road transport infrastructure.

6.3.3 How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?

A transition from an energy-intensive economy to a green economy requires capital investment, in addition to the resources needed by municipalities to provide the services required to achieve development objectives. During the interviews, two questions were asked in an effort to answer the funding aspect on the research question in the questionnaire as shown in Table 6.4.

Table 6.4: Framework for data analysis

RESEARCH QUESTION	INTERVIEW QUESTIONS	QUESTIONS IN QUESTIONNAIRE
How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?	IB8 Where do you get the funds to implement the management measures identified in B4? IB9 How difficult is it to acquire the aforementioned funds, and are they usually sufficient?	QD1 Where do you get funding for climate change related projects and programmes for CTMM's roads transport infrastructure? QD2 What are the main challenges for the Municipality to mobilise funding? QD3 To what extent would you say climate change related projects are included in CTMM's municipal budget?

Source: Researcher's own compilation

IB8 Where do you get the funds to implement the management measures identified in IB4?

Tackling climate change has become a priority for municipalities in South Africa. According to the South African Local Government Association [SALGA] (2018: 12), municipalities have started sourcing funding for the remarkable capital investment and were engaged in testing various inventive funding models. During the interviews, the researcher found that the respondents were confident that funding is not a problem; the problem was rather the management and accessibility of the funds. Respondents indicated that there were bilateral organisations that were willing to provide funds as long as the project was viable.

> **Respondent 14:** *The projects are financed from various sectors, private investors, bilateral organisations, and some from our very own municipal revenue*.
>
> **Respondent 8:** *Money is there, trust me there is money. The problem is it is not easily accessible for us to use and the procedure to access the money is long and tedious. The procurement unit requires so much admin and takes time to acquire or purchase material.*
>
> **Respondent 10:** *Financing the inevitable damage caused by climate change represents an additional financial burden on the municipality, costing tens of billions of rands a year, so you can imagine that getting such funds is not an easy task for a municipality. We do have private investors but getting the private investors on board is a heavy task, they do not just come as investors and offer money. We must go out approach potential investors with projects plan.*

Failure to access funding for climate-related projects could therefore be the death knell for attempts to deal with the impacts of climate change. Various tools can encourage national governments to increase their revenues. There is a financial opportunity to alter behaviours that are contributing to climate change. Usage fees and dedicated taxes, such as a carbon tax (City of Cape Town 2014: 15). Such methods are influenced by the 'polluter pays' principle states that those who cause pollution should pay for the costs of managing it in order to avoid harm to human health or the environment. (City of Cape Town 2014: 13). In addition to the financial mechanisms available, a multitude of agencies for development cooperation, bilateral and

multilateral financial institutions provided funding for climate action in developing countries as initiated by the UNFCCC.

IB9 How difficult is it to acquire the aforementioned funds, and are they usually sufficient?

In 2010, when the Green Climate Fund (GCF) was introduced at COP16, the aim was to offer direct access to finance for developing countries to protect themselves against climate change (Havenga & Pienaar 2012: 8). However, the majority of developing and at-risk countries now argue that they lack the means to directly access these funds. The respondents of the CTMM indicated that accessing the funds was challenging at first, but once they had a C40 advisor in the CTMM, this was no longer challenging. Some of the respondents indicated that it would forever be difficult to access funds not only for climate change, but also for all other services due to economic conditions.

> **Respondent 11:** *It's a paradox, funding for projects is not as easy, people see the outcome not the hassle we go through to get the money.*

Financial instruments and funding in South Africa consist of loans (85%), grants (5 to 10%), and technical assistance (5%) (Integrated Report Committee of South Africa 2018: Online). This funding focuses on energy conservation and renewable energy programmes with limited resources for natural resource management, climate change and other green technology presentations. Figure 6.17 below reflects the funding sources for initiatives and services related to climate change within the CTMM.

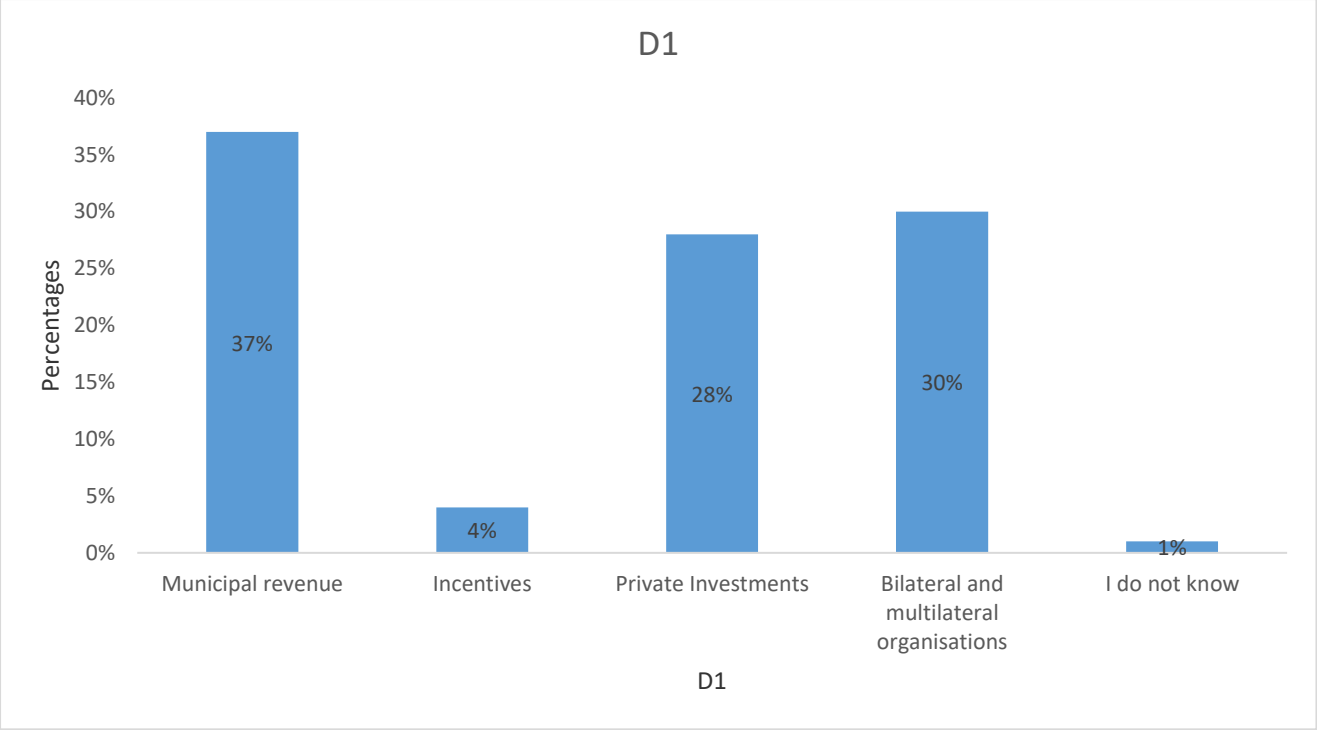

Figure 6.17: QD1 Funds for climate change-related projects and programmes
Source: Researcher's own compilation

Figure 6.17 indicates that the bulk of the funds used for the programs came from municipal revenues, with 37% and 30% coming from bilateral and multilateral organizations, respectively. It was interesting to learn that the CTMM had private investors as indicated by 28% of the respondents. Figure 6.18 below presents the challenges of mobilising funding for climate change-related projects and programmes in the CTMM.

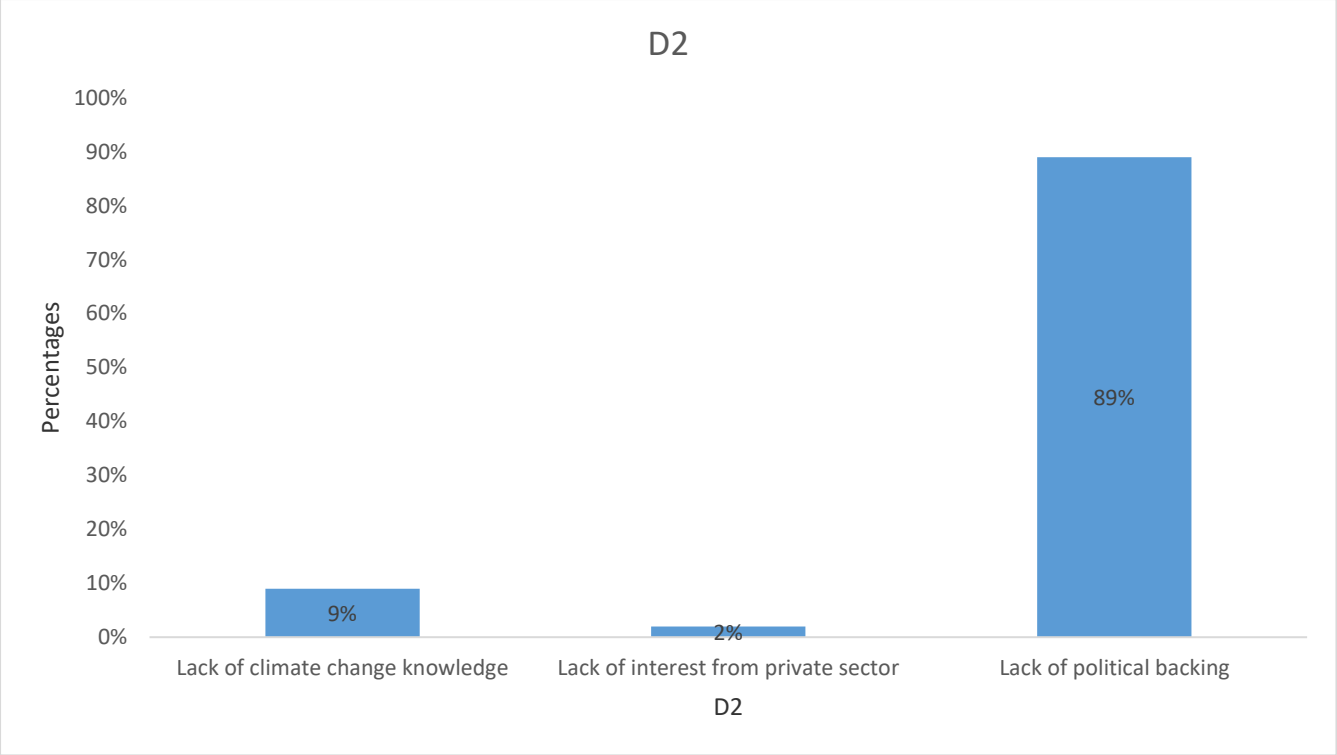

Figure 6.18: QD2 Challenges related to mobilising funding

Source: Researcher's own compilation

The municipality's lack of political support is clearly a source of concern and an impediment. Only 2% of respondents say there is a lack of private sector interest, while 89 percent say there is a lack of governmental support and 9% say there is a lack of climate change awareness. Figure 6.19 below illustrates the extent of inclusion of climate change-related projects in the municipal budget on a scale of 0–10, where 0 = to no extent and 10 = to a large extent.

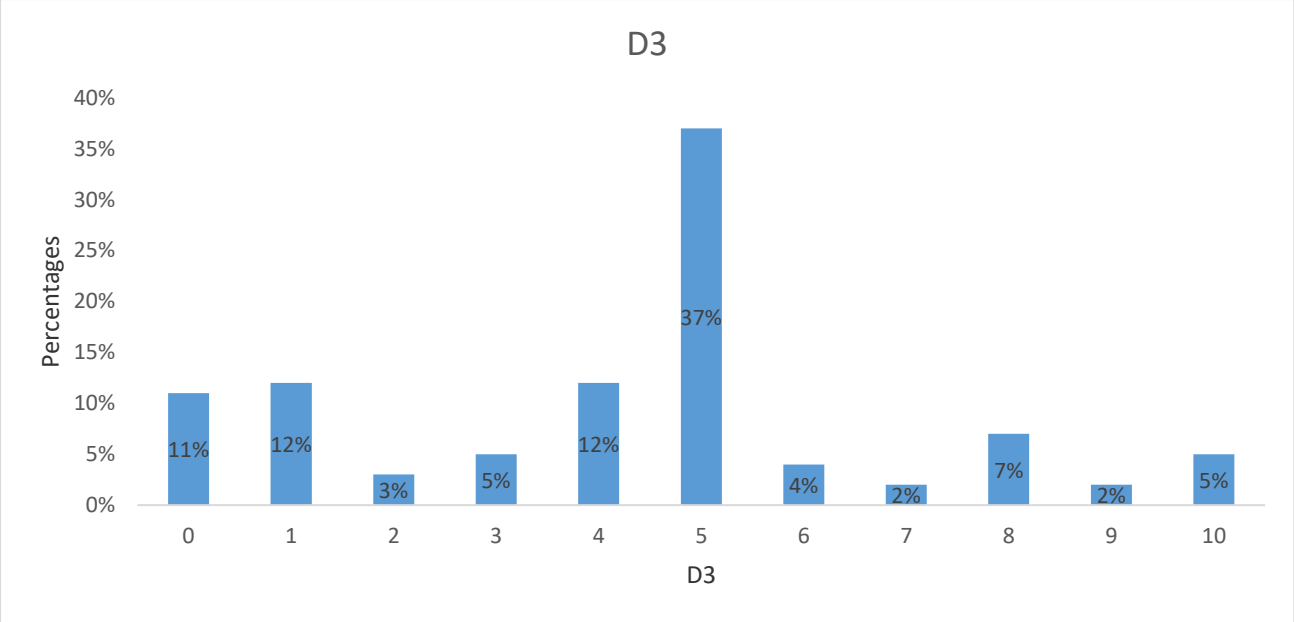

Figure 6.19: QD3 Extent of inclusion of climate change-related projects in the municipal budget

Source: Researcher's own compilation

In addressing climate change, finance was a key aspect; thus, the lack of it may have created numerous challenges. Figure 6.19 above indicates that more than 75% of respondents believed that the inclusion of climate change-related projects in the municipal budget was minimal. One way of including climate change issues into the budgetary process is to contribute discretionary resources (i.e., the limited amount of uncommitted money available to a government) to specific new climate change measures.

6.3.3.1 Overview of main findings

The responses to section D of the questionnaire and during the face-to-face interviews aimed to respond to the research question: "How are the management measures of the impacts of climate change on road infrastructure financed in the CTMM?" The summary of the findings are as follows:

- There are funds available from various sources, but management of those funds is ineffective.
- Procedures in place make it difficult to access the available funds.

- There is red tape in acquiring the required resources for climate change-related projects.
- Political backing is a major challenge in mobilising the funds.

6.3.4 Integration of climate change into the road transport planning and policy in the CTMM

Integration involves incorporation of climate change considerations into transport planning, such as the Integrated Transport Plan and policies. For this study, 'integration' referred to the process of revising and expanding existing transport plans and policies to include mitigation of GHG emissions and adaptation to climate change to ensure the long-term viability and sustainability of the transport sector.

The researcher observed the confidence that the respondents had in addressing the issues around integration. They were convinced of what needs to be done, although others were just as sure of what needs to be done, but demonstrated a side of disappointment of what was done as opposed to what could be done. Integrating climate change into transport planning could assist, for example, with mitigating GHG emissions by reducing travel distance and congestion of vehicles. Two questions were asked in the interview and four in the questionnaire as shown in Table 6.5 in an effort to answer the last research question on the issues of integrating climate change into transport planning and policies.

Table 6.5: Framework for data analysis

RESEARCH QUESTION	INTERVIEW QUESTIONS	QUESTIONS IN QUESTIONNAIRE
How is climate change mainstreamed in the road transport planning and policy in the CTMM?	IB10 How are the climate change considerations integrated in the roads infrastructure policies, planning, building and maintenance? IB11 How do your attempts and interventions to manage climate change compare with those of other metropolitan municipalities in the country?	QE1 Does CTMM have climate change adaptation plan? QE2 Climate change considerations are integrated in CTMM's Comprehensive Integrated Transport Plan? QE3 Climate change management measures in terms of roads transport infrastructure are embedded within CTMM's existing public policies? QE4 What are the challenges faced by your department in mainstreaming climate change considerations? (tick all that are applicable)

Source: Researcher's own compilation

IB10 How are the climate change considerations integrated in the road infrastructure policies, planning, building and maintenance?

The planning process should integrate all modes of transport and improve integration of transport planning with land use (Mashamaite, 2018a: 586). The transport sector will have a range of benefits in addressing climate change impact by integrating it into the planning process, such as improved air quality, increased road safety, reduced traffic noise and other social and economic benefits. The CTMM has a specific unit for transport planning and the researcher had an opportunity to speak to some of the officials in the unit. The respondents indicated that they do have a comprehensive plan that integrates transport modes and considers climate change considerations. However, they cannot confidently state that their comprehensive plan is being implemented.

> **Respondent 14:** *We have a comprehensive plan … is a thick book, our very own bible … but now the challenge is implementing that plan. One of our challenges is in the municipality our tasks are separated. We have us as a unit planning, and we plan for what has been researched by someone else and then another unit must implement while they do not control the funds within the unit … they have to apply for money in our finance unit so on and so on. Now, the challenge is red tape! Ja [yes] … and often you find someone not helping because of personal vendetta, delaying the process forgetting that we are here to deliver services to the public, a person just delays you deliberately.*

> **Respondent 7:** *When we do our planning we consider everything that may affect our transport system, climate change included. Our Comprehensive Integrated Transport Plan is exactly that comprehensive and one of the best in the country if not just the best plan. We do not take climate change for granted, we understand the seriousness of climate change and the potential it has to destroy the sector if not catered in the planning. Remember, our plan is for five years, so every five years we review our plan. During the review and planning process, we consider what took place in the last term, you know … in terms of damages, challenges, and many other and plan well. Our plan is always better than the last one.*

> **Respondent 13:** *Our ITP has dedicated the whole chapter on transport, addressing issues of sustainable transport and going green in transport as well as the transport demand projections.*

The researcher observed that the respondents were confident that their transport plan was comprehensive, although some were not as confident about the implementation of the plan. **Respondent 5** indicated that it was all good in writing, but not much was being implemented. When asked to elaborate on what was well planned and not carried out so well, the answer was:

> *Look at the city. Is there any integration of transport modes? Do we have infrastructure for NMT? Big trucks driving in and out of the city damaging the roads and the maintenance people … there is so much that is not right. Have you noticed how congested the city is during peak hours? We have traffic lights every street, which is not necessary but delays traffic flow, then there are BRT buses driving around the city empty, where is the integration, our public transport! With our public transport there is no law enforcement and the taxi operators are ungovernable and that makes it hard to enforce anything we have planned.*

When it comes to integration of climate change, consideration into policies and maintenance, not much has been found. The respondents from the maintenance unit were not necessarily the ones doing the maintenance labour, therefore, they indicated that they did have projects of cleaning and maintaining the city and they were confident that the people who were doing the job were doing it explicitly as they are happy with what they see when they walk around the city. One of the respondents indicated that when they did maintenance, climate change was considered minimal, but when it came to waste management, they had a sustainable waste management process and procedure.

> **Respondent 9: "***When it comes to waste, for example, we have shown that we can handle waste in a sustainable manner by demonstrating a material recovery facility, but our broader waste management is not competitively motivating."*

IB11 How do your attempts and interventions to manage climate change compare with those of other metropolitan municipalities in the country?

Metropolitan municipalities are critical places for evaluating potential impacts and possible management measures. They are major contributors to the GDP despite their high concentration of economic activity and the number of human beings being employed, but they inevitably do so in ways that lead to high GHG emissions. SA municipalities have embarked on various measures in an effort to combat climate

change. This question was presented to check if CTMM does a benchmarking exercise with other metropolitan municipal projects in order to keep up with the competition. CTMM was discovered to be up to date with what others were doing and to be performing admirably. In fact, the CTMM was amongst the top performing municipalities in the country. This is supported by Mashamaite (2018a: 588) when reporting that the CTMM, CoJ Metropolitan Municipality and the CoCT Metropolitan Municipality had the most initiatives aimed at addressing climate change at the time. The respondents profoundly said:

> **Respondent 4:** *The municipality recognises climate change as a major challenge facing today's world affecting all aspects of human life from economic, social and environmental angles. That is why as a city we aim to be exemplary African municipality, leading the change towards resilience to the impact of climate change, while systematically reducing the contribution of the city to the global warming.*

> **Respondent 8:** *We are doing relatively ok; of course, we can still do better. The City of Cape Town is by far doing better than all cities with the BRT … so there is no one municipality that is doing marvellous with all interventions in the country.*

> **Respondent 5:** *Well … I would say City of Cape Town looking at the BRT and the infrastructure for the NMT.*

The researcher observed that the respondents were confident that their municipality was not at the bottom of the ladder in addressing climate change, but they were envious of the CoCT Metropolitan Municipality. One even indicated that there was a high probability of political backing in the CoCT Metropolitan Municipality:

> **Respondent 14:** *You can tell by the level of competence that there is political will.*

This demonstrates the degree to which officials believed political support is crucial to achieving the goals of most of the interventions. They argued that the funds could be easily accessible if there were political support and all bureaucracy were cut. Figure 6.20 shows the officials' responses in terms of availability of a climate change adaptation plan.

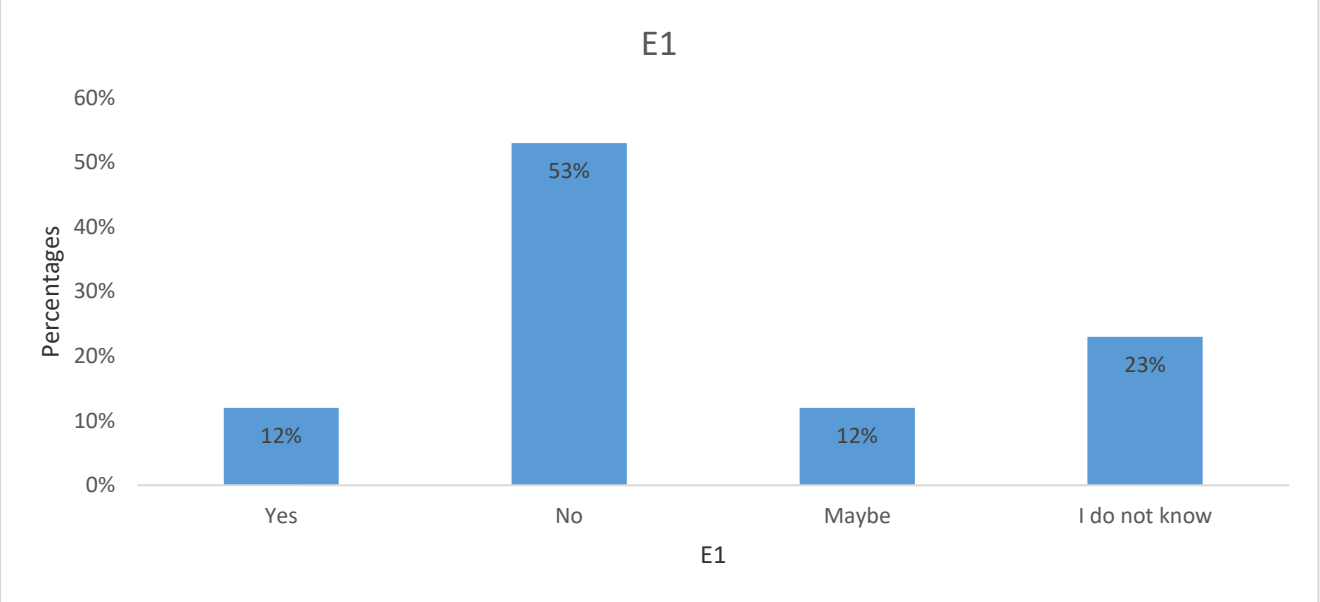

Figure 6.20: QE1 Availability of climate change adaptation plan

Source: Researcher's own compilation

Adaptation to climate change offers South Africa an opportunity to transform the economy, strengthen the social and spatial fabric, and build a climate resilient society (DEA, 2014). Given the national importance of the adaptation plan, the researcher wanted to find out if the municipality had an adaptation plan in place. Figure 6.20 indicates that 53% of the respondents indicated that the municipality did not have the plan, 12% was not sure whether there was such a plan or not while the other 12% indicated that there was and more than 20% did not know about the existence or non-existence of the plan. During the interviews, the researcher found that the municipality was busy with the establishment of the adaptation plan. At the time, the plan had already been drafted, but had not yet been approved. Therefore, only few officials were aware of it because of their line of duty and others were not aware since they were not involved in the establishment of the plan. Figure 6.21 below demonstrates the integration of climate change considerations in the CTMM Comprehensive Integrated Transport Plan.

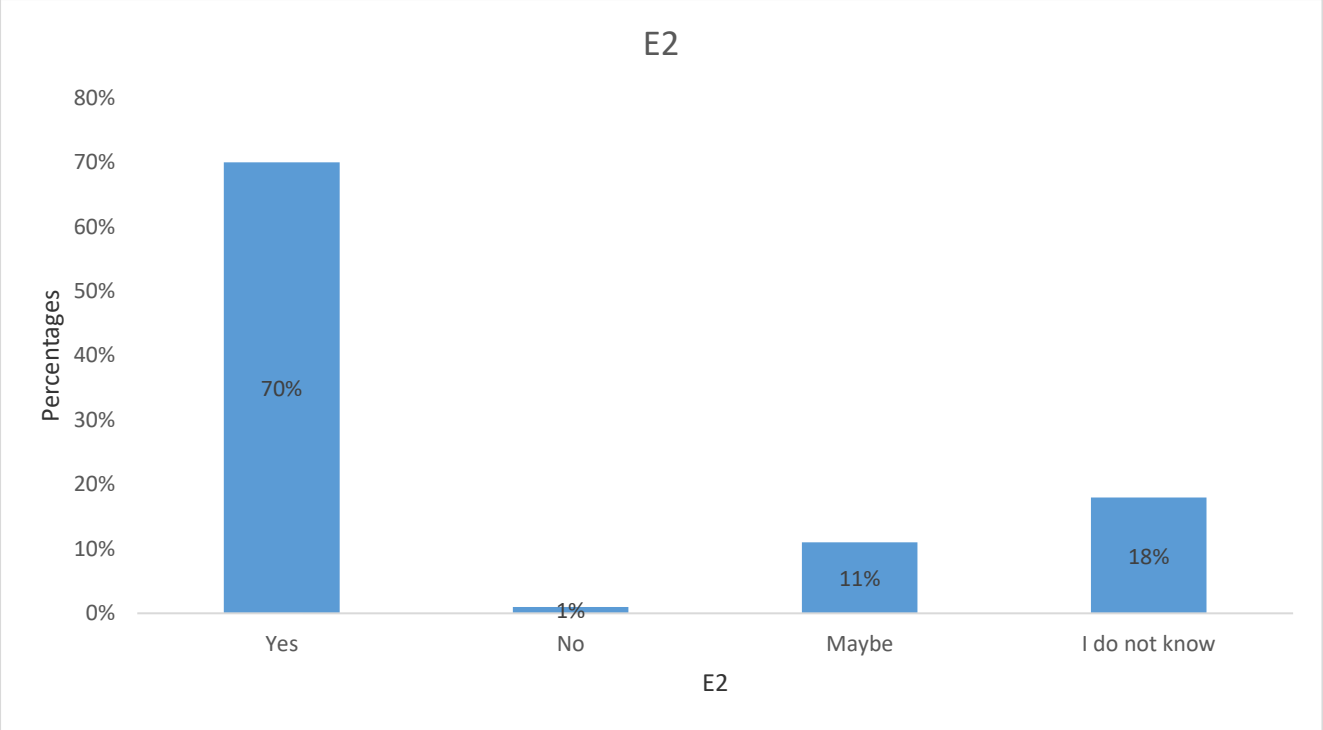

Figure 6.21: QE2 Integration of climate change considerations in the CTMM Comprehensive Integrated Transport Plan

Source: Researcher's own compilation

According to Lebel *et al*. (2012: 5), integration means the inclusion of adaptation to climate change into development planning. Thus, in this thesis, 'integration' means revising and expanding existing transport plans to include climate change considerations to ensure long-term viability and sustainability of the road transport infrastructure. Figure 6.21 shows that 70% of the respondents indicated that climate change considerations were integrated into the municipal integrated transport plan. The researcher observed the CTMM Comprehensive Integrated Transport Plan (CITP 2015–2020) (CTMM 2015b), and found that indeed the climate change considerations were taken into account when planning for transport at large in the municipality. Figure 6.22 below shows the inclusion of climate change management measures in existing public policies.

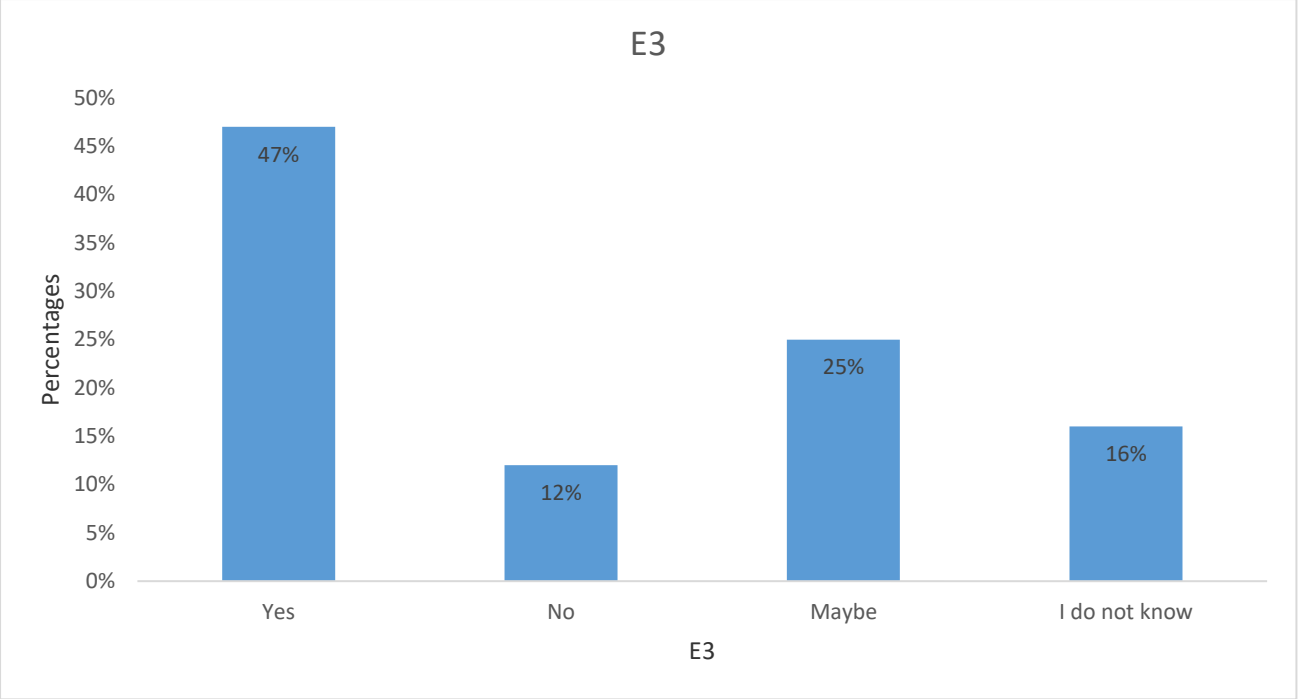

Figure 6.22: QE3 Inclusion of climate change management measures into existing public policies

Source: Researcher's own compilation

Figure 6.22 illustrates that 47% of the respondents indicated that climate change management measures were included in the existing public policies. The researcher accessed a few policies and could not find the inclusion of the management measures in the policies. Instead, the researcher found that there was a lack of policies around the issue of climate change and transport at large, and no coherent legislation in place. Figure 6.23 below presents the challenges of integrating climate change considerations.

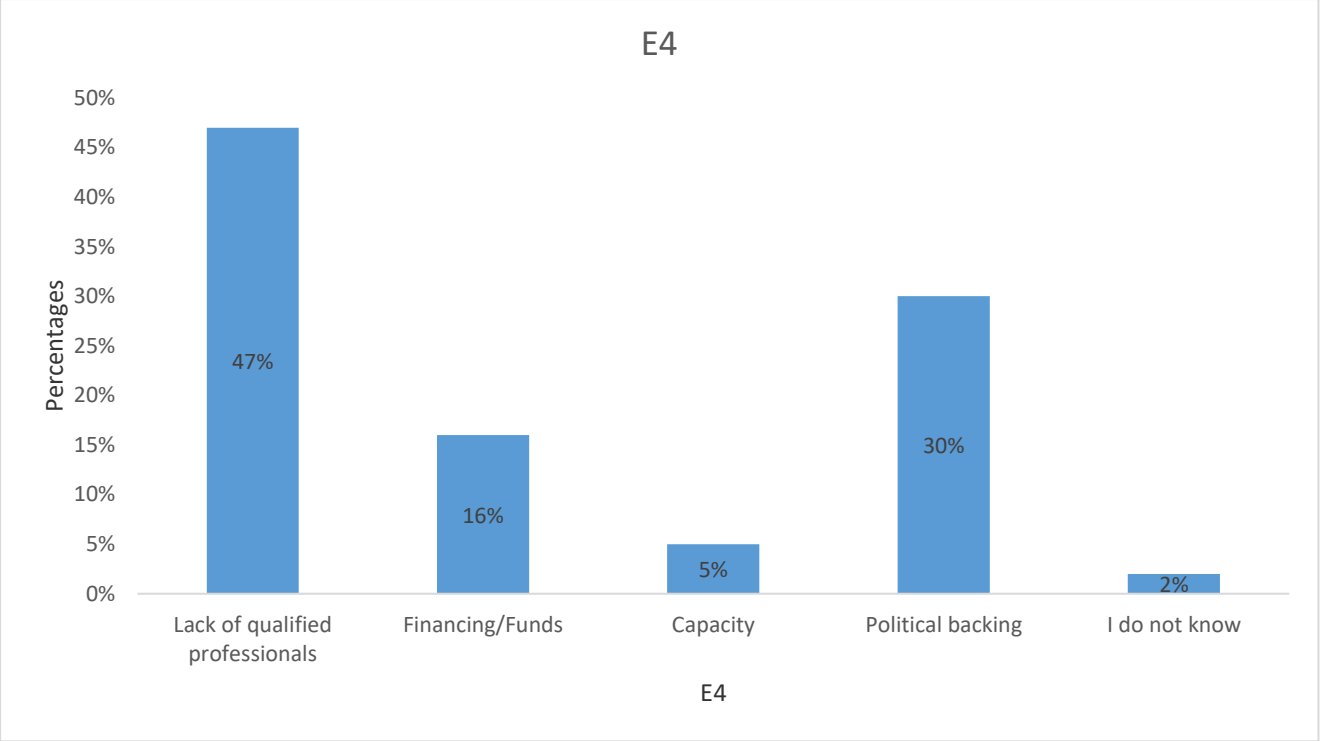

Figure 6.23: QE4 Challenges of integrating climate change considerations
Source: Researcher's own compilation

In spite of the municipality including climate change in its CITP, challenges were encountered in doing so. The challenges were the absence of qualified professionals, of political support and of funding and capacity, and these challenges hindered efficient inclusion.

6.3.4.1 Overview of main findings

The responses to section E of the questionnaire and to some face-to-face interview questions aimed to respond to the research question: "How is climate change mainstreamed in the road transport planning and policy in the CTMM?" The answers are presented below.

- The CTMM does not have an approved transport adaptation plan yet.
- Climate change considerations are integrated into the transport planning of the CTMM. However, the researcher observed that the implementation of the plan was not effective.

- A lack of qualified professionals, of political backing and of funds are major challenges faced by the municipality in integrating climate change into transport planning.

6.4 SUMMARY OF THE CHAPTER

Various aspects seemed to influence the ability of the municipality to respond positively to the impacts of climate change. It was reported that the devastating effects of high temperatures, winds, precipitation and floods, directly or indirectly affected the CTMM road infrastructure and network. However, it was clear from the discussions during the interviews that the CTMM was playing a pivotal role in setting and influencing the direction of the national policy agenda on climate change. In addition, CTMM contributions were appreciated and the CTMM is a member of the C40 with the ability to launch projects. The management measures reflect a sincere commitment to prioritising climate change mitigation and adaptation in the light of socio-economic growth in South Africa. Commendable as these management measures might be, the CTMM also faces significant challenges, especially with regard to the financial resources needed to ensure that climate management measures were not merely specified policy goals but represented a collection of concrete acts by the municipality.

The next chapter will provide the conclusions and recommendations for this study.

CHAPTER 7
RESEARCH RECOMMENDATIONS AND CONCLUSION

7.1 INTRODUCTION

This study was aimed at investigating management by the CTMM of the impact of climate change on road transport infrastructure. The objectives set for achieving the aim included establishing in the CTMM the effect of climate change on its road transport infrastructure. Following the identification of the administrative challenges facing the CTMM in addressing the effects of climate change on road transport infrastructure, the researcher will show –

- how initiatives to reduce the impact of climate change on road transport infrastructure are funded by the CTMM; and
- how climate change is incorporated into the road transport strategy and planning of the CTMM.

Different research designs and methodologies have been employed to direct the process of making this study a success.

This study collected data using three distinct methods of data collection, namely questionnaire, interview schedule and observations by the researcher. This was done at the CTMM to generate different views, understandings, and perspectives on its road transport infrastructure. The researcher will also make recommendations to the CTMM, which could help them to address those impacts. Furthermore, data were analysed in the form of description, classification and relationships of different variables under investigation. The Statistical Package for the Social Sciences (SPSS) was used to generate statistical variations in the form of percentages and frequencies, while Microsoft Excel was employed for graph creation.

There were five major observations made from the findings in Chapter six:

- there was recognition that the impact of climate change on road transport infrastructure is now not somewhere in the future;
- road transport-related risks have the potential for severe economic impacts;
- climate change has the potential to affect the road transport infrastructure negatively;

- at the time of the research, the CTMM was establishing and implementing its management steps at different points; and
- implementation of management measures and integration of climate change into transport planning and policies were still a challenge.

In section 2.2 of this thesis, it was clearly stipulated that this study was underpinned by two theories, namely the administrative management theory and the problem management theory. The administrative management theory tries to find a logical way of organising an entire institution. The theory typically calls for a formalised administrative structure, consistent division of labour and delegation of power and authority to managers relative to their mandates (Fayol 1949: 45). As indicated in section 2.2.1, there are generally 14 principles of administrative management theory established by Fayol (1949), but for the purpose of this thesis, only the 12 listed below were applicable and relevant. However, this does not suggest that the remaining two (stability of tenure of personnel, and remuneration of personnel) are less important. They just did not contribute to attainment of the current set research objectives.

- **Division of work:** This principle is the same as Adam Smith's division of labour.
- **Authority:** By virtue of his position, the is able to give orders.
- **Discipline:** Employees must obey and respect the rules and regulations that govern the institution.
- **Unity of command:** Every employee should receive instruction or direction from his or her superior.
- **Unity of direction:** Each group of the institution should be directed by one manager using one plan.
- **Subordination of individual interests to the general interest:** Management must see that the aims of the businesses are always supreme.
- **Centralisation:** The process of transforming the assignment of decision-making power to a higher level of an organisational hierarchy should be accompanied by centralisation of the power.
- **Scalar chain:** The line of authority from top management to the lower ranks represents the hierarchy or scalar chain. The scalar chain is a formal line of authority that runs in a straight line from highest to lowest level. This chain

defines the path that the information will take to reach the desired location or individual.

- **Order:** People and materials should be in the right place at the right time.
- **Equity:** A combination of kindness and justice requirements when operating an organisation.
- **Initiative:** Allowing all personnel to show their initiative in some way is a source of stretch for the institution.
- ***Esprit de corps*:** Promoting team spirit will build unity and harmony within the institution.

The second theory, the problem management theory, was applied in an effort to find a solution to a complex global issue known as climate change. As indicated by Pine (n.d.), the steps below make for a successful problem management process:

1. identify ALL the issues involved in climate change;
2. understand everyone's interests;
3. list all the possible solutions (options);
4. evaluate the options;
5. select an option or options;
6. document the agreement(s); and
7. agree on contingencies, monitoring and evaluation.

The seven steps mentioned above are guidelines that can be followed when solving a problem. There is no question about the existence of climate change, but there is consensus that climate change is a problem that governments need to address. This study argued that the above steps would lead to an effective solution to the climate change issue by balancing the impacts of climate change in the CTMM network of road transport. The study identified unique impacts due to climate change that affect the CTMM road transport infrastructure.

The first step is to identify all issues involving climate change, the impacts and effects of climate change as well as the climate change events. Identifying such will assist in following all other steps because all issues would be known as well as the challenges that they may pose. The second step above refers to considering the interests of everyone when resolving the defined issues. Within the context of this study, ‘everybody’ referred to the users and providers of the road transport infrastructure in

the CTMM, as well as the funders. The third step in solving problems relates to climate change in the CTMM entails identifying potential solutions to the problem; thus, researching and brainstorming the potential management measures aimed at addressing climate change problems.

The fourth step above mentions assessing possible solutions by determining the possible input and desired output. For example, evaluation of a future project and its ability to resolve climate change issues, as well as the costs associated with project execution. The fifth step refers to designing management measures. The sixth step points to the creation of the contract agreement to coordinate the selected management measures and their implementation. The final step comprises the monitoring and assessment, a critical step, which question IB6 probed. During the interviews, the respondents suggested that, at the time, the CTMM still lacked this latter step.

The steps discussed above are important in solving a problem. The researcher however noted that the steps did not involve the implementation process. The researcher established that the implementation of management measures tends to be a challenge in the CTMM. This study has found that climate change issues are identified, solutions found, and agreement documents drawn up in terms of management measures, but the management measures were not effectively implemented in the CTMM. This study therefore includes a range of recommendations for managing the impacts of climate change on road transport infrastructure. The recommendations extend to any other municipality, which might face similar challenges to the CTMM.

7.2 RECOMMENDATIONS

Driven by the detailed review of the literature, a comprehensive examination was undertaken of the data gathered in the CTMM and the findings as described in the section 7.1 above. The researcher therefore makes the following recommendations.

7.2.1 Objective 1: To evaluate the impact of climate change on road infrastructure in the CTMM

The first objective of this study was to evaluate the impact of climate change on road infrastructure in the CTMM (see section 1.5). Every day, human beings are confronted with situations that are contrary to them, comprising obstacles that must be overcome in order to fulfil their goals. In order to deal with these situations, it is vital to employ thinking processes that enable the generation of knowledge required for successful obstacle removal. As a result, evaluating the magnitude of the impact is critical. The Problem Management theory was applicable in the evaluation of the impact, first, because it has been established that climate change is a problem that has a potential to disrupt humans. Secondly, in as much as climate change is a problem, its impacts are manageable. According to Mayer (1990: 285), problem management can be described as a summary of cognitive processes aimed at changing a given state to a final state where the solution mechanism is not clear. The conditions for managing the impact of climate change on road infrastructure and climate change cause are the basic knowledge of the problem. There are barriers in the way of the goal that must be overcome (e.g., the lack of political will, finance and expertise).

This study discovered that the impacts of climate change on road transport infrastructure of the CTMM are temperature, floods and precipitation. High temperatures cause the softening and expansion of road surfaces. Temperature fluctuations also cause rutting and potholes, particularly in high-traffic areas and can put stress on the joints of bridges. In addition, heat waves limit construction activities while heavy rains lead to flooding, which interrupts traffic, delays construction activities, and washes out the soil and culverts supporting highways, tunnels and bridges. Therefore, this study recommends that, in order to manage the impacts of climate change, these conditions must be taken into account in the design of road transport infrastructure, such as the design of the sub-surface and foundation, material choice and drainage capacity. The following questions need to be asked because of the uncertainties concerning the effects of climate change:

- Will the drainage capacity be adequate to deal with unexpected precipitation increases?

- Which infrastructure is potentially at risk for critical roads?
- As extremely hot temperatures and heat waves are becoming increasingly common, which new road infrastructure materials might be needed?

Consideration of climate events is essential for the proper design and maintenance of roads and road surfaces. The frequency of regular maintenance must be increased to safeguard roads against excessive heat and heavy rainfall. Regular clearance of drains and weeds, regular inspection of expansion joints, bearings, foundations and steel bridge construction and installation of additional warning boards and road signs are necessary to protect roads from certain impacts associated with high temperatures.

Managing impacts of climate change requires the authorities to consider planning frameworks that will integrate vulnerability assessment of climate change. One of the management steps include designing alternative plans for adaptation and mitigation to combat climate change. Management measures include a response about changes in the design and materials of road transport infrastructure. To sustain expected network efficiency, successful management strategies include an evaluation of the inventory of vulnerable road transport infrastructure. In designing the inventory, it would be appropriate to create a risk-based approach and consider the following:

- where and when possible impacts might occur;
- whether organisational improvements and maintenance practices are required; and
- whether vulnerable infrastructure relocation is required.

Hence, it is important to evaluate the adaptation measures to understand the positive trade-offs and cost implications of the construction of road networks. Given the importance of components of road transport infrastructure and the potential for other benefits, such as congestion relief, and the elimination of bottlenecks on the evacuation route, it is important to assess investment priorities when planning management activities.

7.2.2 Objective 2: To ascertain the administrative challenges faced by the CTMM in managing the impacts of climate change on road infrastructure

As indicated in section 6.3.3 above, the municipality has initiatives aimed at addressing climate change issues within the road transport sector. The identified initiatives are in different phases of implementation because of various reasons, including administrative challenges, such as securing managerial issues and political backing. In addressing the findings, the principles of administrative management theory applicable are the following:

- Centralisation: This will enhance the support of politicians for the municipal initiative implementation. The process of transformation should be assigned to politicians and they need to be hands-on and should be held liable for non-delivery of services. The Individual Performance Management System (IMPS) should be applicable and effective to the politicians and office bearers not as just a system in place, but rather as a monitoring tool used by management to ensure performance in executing the mandates (Fatemi & Behmanesh 2012: 44). For instance, their performance should be assessed on the progress of initiative implementation (i.e., implementation of projects such as BRT).
- Subordination of individual interests to the general interest: It is crucial for management to understand that the aim of the CTMM is supreme. The goal of the CTMM from the point of view of this study is to resolve climate change issues with a view to protecting the health of communities and the road transport infrastructure.
- Unity of command: Municipal officials should get commands from their superior. Politicians should therefore be the leaders in addressing the climate change issues. Politicians include, but are not limited to, the municipal mayor and the councillors.
- *Esprit de corps*: Synergy is essential in promoting unity and harmony. The current study found that there is little synergy between units in the Department of Transport and the City Sustainability Unit of the CTMM as indicated in section 6.3.2.1 above.

The second objective of this study was to identify the administrative challenges faced by the CTMM in managing the impacts of climate change on its road transport infrastructure. A number of administrative issues have been identified, such as social acceptance, political support and managerial issues. The researcher therefore suggests that climate change impacts should be addressed in the context of local government to reduce these impacts on road transport infrastructure.

As indicated in section 3.1.1 above, the BRT public transport system – known as Areyeng (‘Let us go’) – is one of the management measures in place in the CTMM. The researcher recommends revision of and a different implementation of the BRT system. The decision to embark on a brand-new BRT network was not a success. This was confirmed by respondents from the CTMM during the interviews (see Question IB4 in Chapter 6). The best solution will be to split the public transport system into stages, motivate and restructure existing public transport providers, improve and enhance current network efficiencies, and reinforce existing infrastructures.

Another management measure relates to NMT. Some of the most theoretical benefits of NMT are its global environmental effects. Despite its considerable accumulated benefits, the environmental significance of NMT is rarely taken into consideration when evaluating local transport projects. NMT should be considered when upgrading the road transport network. Areas designated for cyclists and pedestrians should be safe. In addition, the municipality should enter into agreements with security companies to ensure protection for NMT users. Education and awareness programmes should be created and efficiently enforced to combat the negative stigma of NMT use as found during the interviews of the respondents of this study in the CTMM (see Chapter 6, question IB4).

Because of the unpredictable nature of climate change, it is difficult (but not impossible) to plan and build road transport infrastructure, which can withstand climate change impacts. This is due to multiple factors, such as the lack of available data on the various climate change hazards, such as floods and heat waves, especially for the road transport sector and their economic effects. However, there is uncertainty in the available data. For example, climate change intensity, the magnitude of climate change impacts and the reliability of future forecasts of climate vary. Historical data may not be fully accurate in forecasting the potential effects of climate change, and

the impacts are likely to change over time. The construction of more efficient road networks to handle climate change incidents would also be costly and more difficult to introduce, taking into account budget constraints. Such issues affect how the CTMM approaches climate change and accommodates it within government programmes, such as public transport.

In addressing the climate change problem, organisational units of the CTMM have to work together and establish solutions. For example, the CSU and the Department of Roads and Transport need to tackle the problem together in reacting to the effect of climate change on road transport infrastructure. While the various units all have individual and specific mandates, the effects of climate change compel the units to work together to resolve it. Although the literature explicitly differentiates between climate change mitigation and adaptation, reacting to the dynamic challenges of climate change in cities does not always lend itself to different categorisations in terms of mitigation or adaptation. Comprehensive and integrated solutions, including strategies for mitigation and adaptation, and the synergies between them, are required to tackle this challenge in full. Mitigation and adaptation actions can offer incentives for cities to recognise and benefit from co-benefits. Improvements in energy efficiency in buildings, for example, can both minimise GHG emissions and improve resilience in the face of more severe weather.

7.2.3 Objective 3: To evaluate how the management measures relating to the impacts of climate change on road infrastructure are financed in the CTMM

In an attempt to achieve this objective, the following three of the 14 principles of administrative management theory were applied:

- Order: people and materials should be in the right place at the right time. Addressing climate change requires various resources, such as human and financial resources. Putting finances and procedures in order will assist in curbing the red tape, which respondents indicated was amongst their challenges.
- Unity of direction: management is crucial and has to be effective in executing the mandate. Moreover, it is essential for the effective implementation of the

management measures that the direction of orders and procedures be clear and not contradictory. During the respondents' interviews (see section 6.2.3.1), it was established that a lack of synergy also contributes to misalignment of projects in place. The projects will not align because of various directives from line managers, and this will result in poor implementation and unattainable aims.

- The scalar chain requires hierarchy. If the institutional chain is transparent to lower ranks, chances of proper chain follow are high. This will assist in project implementation, as well as monitoring and evaluation as everyone will know what the project and the obstacles in place are in the scalar chain.

The third objective of this study was to establish how the management measures in terms of the impacts of climate change on road transport infrastructure are financed in the CTMM. It was established that, at the time, the financing of management measures came from municipal revenues, bilateral and multilateral organisations and private investments. However, according to participants, at the time of this study, the CTMM was encountering numerous challenges in securing and accessing the funds. Nevertheless, concentrating exclusively on how money should be committed to new adaptation or mitigation programmes does not tackle the problem of reducing policies with adverse impacts on climate change results (e.g., subsidies for fossil fuel). This study recommends that responding to climate change require not only more committed expenditure on climate change initiatives, but also a structural shift through policy over time in the overall structure of expenditure to such an extent that spending that exacerbates climate change can be minimised and future synergies maximised.

The South African Cities Network (2016) suggests that municipal grants and taxes are outweighed by urban infrastructure needs, leaving municipalities with borrowing funds one of the few options. Unfortunately, the World Bank estimated that, at the time, 500 cities in developing countries were considered creditworthy enough to have access to global financial markets (UNEP, 2016: Online). The World Business Council for Sustainable Development and the Twenty High-Level Committee on Infrastructure Provision support the involvement of the private sector in infrastructure projects (WHO, 2018: Online). The presence of the private sector would facilitate the transfer of the

expertise to the public sector. Moreover, the private sector has more sophisticated technological tools that can be useful in public projects.

To find a balance between competing community interests with limited resources and funding, municipalities have to make difficult decisions. Nevertheless, the lack of political will to overcome the problems facing the implementation of projects and programmes is a concern on its own. Other challenges are high transaction costs of procuring new buses, competition between the BRT and other public transport modes, pollution mitigation costs, investment capital supply and little progress in technological growth. Surmounting these implementation problems require policy action and incentives. Most notably, the patterns of public spending should be changed to match the mitigation strategies.

At the time of this research, the SA government has not yet set up a comprehensive national climate finance system. The Department of Environmental Affairs with the aid of the Development Bank of South Africa (DBSA) and the National Treasury have been working on creating such a scheme (DEA 2014). Government has acknowledged the need to raise funds at the sphere of local government and has committed funds to mitigate and adapt to climate change According to the DEA (2014), South Africa continues to support the Africa Group and BRICS (Brazil, Russia, India, China and South Africa) agenda, emphasising that reducing the national GHG emissions remains conditional on adequate financial, technical and technological assistance from developed economies.

7.2.4 Objective 4: To assess how climate change is mainstreamed in road transport planning and road transport policy in the CTMM

In an attempt to realise the fourth objective the following two principles of the administrative management theory were applied:

- Initiative: allowing all personnel to show their initiative in some way is a source of stretch for the organisation. Municipal officials are also local residents, and therefore they are at the root of the issue. They are also consumers of the system, and are affected by climate change; therefore, they are not just suppliers of the programmes. These officials therefore have the potential to

offer the best solutions if given an opportunity. Moreover, they can provide better monitoring and evaluation as the users of the measures, such as BRT.

- Authority: top management will give the authority to incorporate climate change into transport planning and policies to middle management and to public planners and policymakers.

The fourth objective of this research study was to determine how climate change is integrated into road transport planning and road transport policy in the CTMM. It was found that the CTMM was integrating climate change in their planning by taking into account the climate change issues in their Comprehensive Integrated Transport Plan (see section 4.3.5.1). There are inadequacies in the inclusion of climate change in the transport planning cycle. This study therefore recommends that preparation and up-skilling programmes for planning and integration in the municipality should be provided to officials, which will build the capacity of the departments. Furthermore, to manage climate change effectively, there should be greater convergence of climate change policies with other sectoral policies at all spheres of government. Of utmost importance is the fact that municipal officials and politicians must have a crystal-clear understanding of the effects of and responses to climate change. Above all, it is important to conduct a study of vulnerability for road networks and infrastructure. This will help municipal and transport planners to prepare effective mitigation measures needed to manage the extent of the climate change impact on road transport and road infrastructure.

This study suggests that all spheres of government should work closely together and encourages innovation at lower spheres of government to manage the impact of climate change on road transport infrastructure. Furthermore, a hybrid model enhances the accomplishment of essential tasks of bringing democracy and liberation on the issue of climate change. Climate change can be addressed adequately if all spheres of government work collectively in taking action and formulating policies. National policies could be enablers of local actions on climate change mitigation. The national government can take the lead in designing policies (i.e. a South African carbon tax policy). However, when it comes to public policy implementation, the national government should devolve the authority and make available financial resources to local government in order to enable local government to take effective

and efficient actions. When designing the policy, the national government should enable all other spheres of government to integrate climate change into their development strategies.

Finally, the researcher suggests that further research be conducted on climate change adaptation within the CTMM because most of the interventions found during the data collection were simply mitigation measures. In addition, government policies during the COVID-19 pandemic in 2020 had significantly altered energy consumption trends across the globe. Most international borders were closed, and people were confined to their homes, reducing migration and shifting habits of consumption. Thus, adaptation plans should integrate the probability of future pandemics that may affect road transport positively and negatively.

7.3 CONCLUSION

Combating climate change is a difficult topic because of the uncertainties of when, how fast and how serious the impacts would be. This study underlined the need to integrate climate change as a key component in planning processes by road authorities. The CTMM should follow an appropriate theoretical approach in designing management strategies to identify and appreciate the potential impact of climate change. In addition. CTMM needs to identify its climate change commitments and responsibilities through its road network and transport system. The impact of climate change has a strong influence on the specifications of the road network design. For example, the heightened temperatures and flooding affect pavements, roads and bridges. In these situations, clear management approaches are required to prepare communities for operational improvements or infrastructure designs to mitigate climate change events. Significant costs are related to these undertakings, and careful consideration should be given to the trade-off between improving infrastructure to develop efficient road infrastructure and the costs involved. The current study identified, amongst others, the need to –

- raise awareness of the impact of climate change among stakeholders;
- review established road design standards and building practices that consider possible impacts;
- introduce guidance on climate change impact assessment; and

- create organisational units to enforce adaptation and mitigation strategies and strengthen collaboration among various stakeholders to develop resilient road infrastructure.

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APPENDICES

APPENDIX A: Ethics clearance approval

UNISA university of south africa

DEPARTMENT: PUBLIC ADMINISTRATION AND MANAGEMENT
RESEARCH ETHICS REVIEW COMMITTEE

Date: 31 May 2018

Ref #: PAM/2018/012 (Mashamaite)
Name of applicant: Ms MM Mashamaite
Student#: 44401442

Dear Ms Mashamaite

Decision: Ethics Clearance Approval 31 May 2018 to 1 June 2021

Name: Ms MM Mashamaite, student#: 44401442, mashamm@unisa.ac.za, tel: 060 503-2798

[Supervisor: Prof EJ Nealer, tel: *012 429-3341,* Nealeej1@unisa.ac.za*]*

Research project 'The City of Tshwane Metropolitan Municipality's Response to Climate Change Impacts on Roads Infrastructure' **Qualification:** PhD (Public Administration)

Thank you for the application for **research ethics clearance** by the Department: Public Administration and Management: Research Ethics Review Committee, for the above mentioned research. Ethics approval is granted for the period **31 May 2018 to 1 June 2021**. If necessary to complete the research, you may apply for an **extension** of the period.

The decision will be tabled at the next College RERC meeting for notification/ratification.

For full approval: The application was **expedited and reviewed** in compliance with the *Unisa Policy on Research Ethics* and the *Standard Operating Procedure on Research Ethics Risk Assessment* by the RERC on 30 May 2018.

The proposed research may now commence with the proviso that:

1) The researcher will ensure that the research project adheres to the values and principles expressed in the Unisa Policy on Research Ethics.
2) Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to this Ethics Review Committee.
3) The researcher will conduct the study according to the methods and procedures set out in the approved application.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Open Rubric

4) Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.

5) The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study, among others, the **Protection of Personal Information Act** 4/2013; **Children's Act** 38/2005 and **National Health Act** 61/2003.

6) Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.

7) Field work activities **may not** continue after the expiry date given. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Kind regards

Ms C Alers
Chairperson:
Research Ethics Review Committee
alersc@unisa.ac.za

pp **Prof MT Mogale**
Executive Dean: CEMS

Open Rubric

APPENDIX **B: Permission letter from the City of Tshwane Metropolitan Municipality**

CITY OF TSHWANE
IGNITING EXCELLENCE

City Strategy and Organizational Performance

Room CSP22 | Ground Floor, West Wing, Block D | Tshwane House | 320 Madiba Street | Pretoria | 0002
PO Box 440 | Pretoria | 0001
Tel: 012 358 7423
Email: NosiphoH@tshwane.gov.za | www.tshwane.gov.za | www.facebook.com/CityOf Tshwane

My ref: **Research Permission/ Mashamaite**
Contact person: **Pearl Maponya**
Section/Unit: **Knowledge Management**

Tel: 012 358 4559
Email: PearlMap3@tshwane.gov.za
Date 28 February 2018

Mrs Maijane Martha Mashamaite
6539 Mmaba Str
Birch acres
Kempton Park
1618

Dear Mrs Mashamaite,

RE: THE CITY OF TSHWANE METROPOLITAN MUNICIPALITY'S RESPONSE TO CLIMATE CHANGE IMPACTS ON ROADS INFRASTRUCTURE

Permission is hereby granted to Mrs Mashamaite, a Doctor of PhD in Public Administration at UNISA candidate, to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that your study seeks to investigate how the CTMM (City of Tshwane Metropolitan Municipality curbs the impact of climate change on road infrastructure and to further review the international best practices on road infrastructure adaptation strategies to climate change in order to develop a Climate Change Adaptation Framework for Road Infrastructure to enhance the adaptation strategies for CTMM. The City of Tshwane further notes that all ethical aspects of the research will be covered within the provisions of UNISA Research Ethics Policy. You will be required to sign a confidentiality agreement form with the City of Tshwane prior to conducting research.

Relevant information required for the purpose of the research project will be made available upon request. The City of Tshwane is not liable to cover the costs of the research. Upon completion of the research study, it would be appreciated that the findings in the form of a report and or presentation be shared with the City of Tshwane.

Yours faithfully,

PEARL MAPONYA (Ms.)
ACTING DIVISIONAL HEAD: INNOVATION AND KNOWLEDGE MANAGEMENT DIVISION

APPENDIX C: Participant information letter

TITLE:

MANAGEMENT OF CLIMATE CHANGE IMPACTS ON ROAD INFRASTRUCTURE: A CASE OF CITY OF TSHWANE METROPOLITAN MUNICIPALITY

Dear Prospective Participant

My name is Maijane Martha Mashamaite and I am doing research with Eric Nealer, a professor in the Department of Public Administration and Management towards a PhD in Public Administration at the University of South Africa. We have funding from National Institute of Human Social Science (NIHSS-SAHUDA) for conducting the study. We are inviting you to participate in a study entitled management of climate change impacts on roads infrastructure: a case of City of Tshwane Metropolitan Municipality.

I am conducting this research to find out what are the impacts of climate change on the road infrastructure in the City of Tshwane Metropolitan Municipality and how does the municipality manage to those impacts in as far as policy is concerned.

WHY AM I BEING INVITED TO PARTICIPATE?

You are invited to participate in this study because of your position in the municipality. Your role in the municipality is of relevance to this study. Your contact details were obtained from your institution's Research and Development unit. Personnel in three units (City sustainability, Utility and Road transport) were purposively selected to participate in this study.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

Describe the participant's actual role in the study. The study involves *structured questionnaire and semi-structured interviews*. The questionnaire is designed in a way that you select answers from provided options. While interviews you are expected to answer as honest and to the best of your knowledge. The questionnaire will take not more than 30 minutes to complete, while the interview will take 30 minutes. Therefore, I hereby request a maximum of one hour of your time.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. However, it will not be possible to withdraw once you have submitted the questionnaire and done the interview.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Your participation will assist the researcher to answer the identified research question and enhance the City of Tshwane Metropolitan Municipality's management measures of climate change impacts on roads infrastructure.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There will be no consequence, risk or harm for you if you take part in this study. The interview and questionnaire will be done in your work place, therefore, there will be no risk than the everyday norm.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

You have the right to insist that your name will not be recorder anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research *[this measure refers to confidentiality]* OR your name will not be recorded anywhere and no one will be able to connect you to the answers you give *[this measure refers to anonymity]*. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings *[this measure refers to confidentiality].*

If relevant, identify who will have access to the data *[transcriber/external coder]* and how these individuals will maintain confidentiality *[e.g. by signing a confidentiality agreement.* Your answers may be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder, and members of the Research Ethics Review Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records. A report of the study may be submitted for publication, but you will not be identifiable in such a report.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet in my house for future research or academic purposes; electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Hard copies will be shredded and/or electronic copies will be permanently deleted from the hard drive of the computer through the use of a relevant software programme.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

There will be no gifts, incentive or payment given to you for participating in this study, neither will you incur any financial cost.

HAS THE STUDY RECEIVED ETHICS APPROVAL

This study has received written approval from the Research Ethics Review Committee (ERC) of the College of Economics and Management Science ERC, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Maijane Mashamaite on 012 429 4280/6595 or email at mashamm@unisa.ac.za. The findings are accessible for 12 months. Should you have concerns about the way in which the research has been conducted, you may contact the supervisor Prof EJ Nealer on 012 429 3341/6595 or email at nealeej1@unisa.ac.za. Alternatively, contact the research ethics chairperson of the CEMS ERC , Dr C. Alers 0n 012 429 6286/6595 or emal at alersc@unisa.ac.za.

Thank you for taking time to read this information sheet and for participating in this study.

Regards

……..

APPENDIX D: Informed consent form

CONSENT TO PARTICIPATE IN THIS STUDY

I, …….. (participant name & surname), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

- I have read and understood the study as explained in the information sheet.
- I have had sufficient opportunity to ask questions and prepared to participate in the study.
- I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.
- I am aware that the findings of this study will be anonymously processed into a dissertation.
- I agree to be interviewed.

Participant's name and surname	**Date**	**Signature**
Researcher's name and surname	**Date**	**Signature**
Witness name and surname	**Date**	**Signature**

APPENDIX E: Lists of interview questions

GENERAL RULES

1. This data collection is based on research about the management measures of the climate change impact on roads transport infrastructure of the City of Tshwane Metropolitan Municipality
2. You have been invited to participate in this data collection phase because of your extensive experience about the topic under study.
3. You are kindly requested to complete the questionnaire and answer the interview questions as honestly and completely as possible.
4. The data collection questionnaire and interview will take a maximum of 30 minutes to complete.
5. Participation is anonymous: You are not requested to disclose your identity. Your privacy will be respected.
6. No one will be able to connect you to the answers you give.
7. The data and information collected from you will be treated with strict confidentiality and used for research purposes only.
8. You have the right to withdraw your participation at any time. Hence, your participation is regarded as voluntarily.
9. You will not receive any payment or reward, financial or otherwise, and the participation in the data collection part of the study will not incur undue costs for you.
10. The collected data and information will be stored in a locked cupboard and the captured data stored in a computer will be protected by the use of a password.
11. The collected data and information will be destroyed when it is no longer of functional value (presumably after five years).
12. A copy of the finally printed and bound thesis will be available in the library at the Muckleneuk Ridge Campus of the University of South Africa (Unisa), Pretoria.

Please tick the following box if you consent to participate:

☐ I hereby consent and understand that my participation is voluntary and anonymous and that the data and information will be kept strictly confidential.

PLEASE INDICATE (tick) YOUR department

City Sustainability Unit	
Department of Roads and transport	

SECTION A: BIOGRAPHICAL DETAILS

Please answer all the questions by marking your choice with a cross (x) or adding your answer in the space provided.

A1 Highest qualification

1	Matric	
2	Post Matric Technical Qualification	
3	Degree / Diploma	
4	Post Graduate Qualification	
5	Other (name qualification)	

A2 How long have you been working in the department?

1	Less than 1 year	
2	1-2 years	
3	3-4 years	
4	5-6 years	
5	7-8 years	
6	9-10 years	
7	More than 10 years	

A3 What is your current job title and role in the department?

_____

SECTION B: Management measures in the CTMM

B1 What are the persistent impacts of climate change on road transport that you experience in the city?

B2 How often does the Municipality conduct vulnerability assessment of its roads transport infrastructure network in terms of climate change?

B3 What are your management measures (e.g. projects and programs) with which to address the impact of climate change on the Municipality's road transport infrastructure?

B4 What obstacles have you encountered in implementing the aforementioned management measures identified in B3?

B5 What are the strategies in place to overcome the aforementioned obstacles identified in B4?

B6 What resources do you think you lack in trying to curb the climate change impacts on CTMM's road transport infrastructure?

B7 To what extent do you have political backing in all your functions and activities in the Municipality?

B8 Where do you get the funds to implement the management measures identified in B4?

B9 How difficult is it to acquire the aforementioned funds, and are they usually sufficient?

B10 How are the climate change considerations integrated in the roads infrastructure policies, planning, building and maintenance?

B11 How do your attempts and interventions to manage climate change compare with those of other metropolitan municipalities in the country?

Thank you for your participation and invaluable contribution.

APPENDIX F: Questionnaire

UNIVERSITY OF SOUTH AFRICA
DEPARTMENT OF PUBLIC ADMINISTRATION AND MANAGEMENT

FIELD OF STUDY
PhD: PUBLIC ADMINISTRATION

QUESTIONNAIRE FOR RESEARCH TITLE
Management of climate change impact on roads infrastructure: a case of City of Tshwane Metropolitan Municipality

PERSONAL DETAILS

SURNAME: Mashamaite

NAMES: Maijane Martha

CONTACT DETAILS
TELEPHONE NUMBER: 012 429 4280
CELL. NUMBER: 060 503 2798
E-MAIL ADDRESSES
mashamm@unisa.ac.za

PROMOTOR
PROF EJ Nealer
CO-PROMOTOR
DR C Alers

I am a student of University of South Africa in the Department of Public Administration and Management and as a part my studies towards a PhD in Public Administration, I am required to submit a thesis in fulfillment of the degree. The research is conducted under the supervision of Professor EJ Nealer from the Department of Public Administration and Management, University of South Africa.

My research interest is to analyse and address the management measures in place to curb the impact of climate change on the roads transport infrastructure of a municipality. The study objectives entail the following:

- To discover the impact of climate change on the roads transport infrastructure in the CTMM.
- To identify the administrative challenges faced by the CTMM in managing the impacts of climate change on its road transport infrastructure.

- To establish how the management measures to the impacts of climate change on the road transport infrastructure are financed in the CTMM.
- To discover how climate change is mainstreamed in road transport infrastructure planning and public policy in the CTMM.
- To recommend ways that management measure could minimise the impact of climate change on roads transport infrastructure in the CTMM.

This study has been designed, reviewed and undertaken with a view of investigating the management of the impact of climate change on roads transport infrastructure with the intention to establish ways that management measures could minimise the identified impacts in the City of Tshwane Metropolitan Municipality.

With regard to ethical issues guiding the study, the researcher pledges strict adherence to ethical conduct as it applies to academic research projects in higher educational institutions in South Africa. It means the following:

- The participation is anonymous and respondents are not required to disclose their identity.
- The information collected from the respondents will be used for the research purpose only.
- Respondents have the right to participate and withdraw their participation in the data collection phase of the study at any time.

GUIDELINES TO PARTICIPANTS

There is no RIGHT or WRONG answers and your honest, anonymous opinion will be appreciated. We are NOT asking about anything that you or any other academic personnel have done—we merely are seeking your PERSONAL PERCEPTION:

- Please read the questions and or statements carefully before indicating your choice in the appropriate block.
- Please indicate only ONE choice per question/statement by marking the relevant box with an X.
- This is an anonymous questionnaire. Please do NOT write your name or Personnel/Student number anywhere on the questionnaire.
- Please do not complete anything in the GREY boxes as they are for office use only.
- After completion of the questionnaire, please place the questionnaire in the box in the secretary's office or wait for the researcher/research assistant to collect the questionnaire.

INSTRUCTIONS TO COMPLETE THIS QUESTIONNAIRE

Do not write your name, surname or any other personal details or numbers on this questionnaire.

The questionnaire will not take longer than 30 minutes to complete.

Please tick the following box if you consent to participate:

	I hereby consent and understand that my participation is voluntary and anonymous and that the data and or information will be kept strictly confidential.

PLEASE INDICATE (tick) YOUR Department

City Sustainability department	
Department of Roads and transport	

SECTION A: BIOGRAPHICAL DETAILS

Please answer all the questions by marking your choice with a cross (x) or adding your answer in the space provided.

A1 Highest qualification

1	Matric	
2	Post Matric Technical Qualification	
3	Degree / Diploma	
4	Post Graduate Qualification	
5	Other (name qualification)	

A2 How long have you been working in the department?

1	Less than 1 year	
2	1-2 years	
3	3-4 years	
4	5-6 years	
5	7-8 years	
6	9-10 years	
7	More than 10 years	

A3 What is your current job title and role in the department?

_____

_____

_____

SECTION B: IMPACTS OF CLIMATE CHANGE

B1 To what extent does your department consider climate change events to be a problem for the City of Tshwane roads transport infrastructure sector? (on a scale of 1 to 10)

0 (no extent)	1	2	3	4	5	6	7	8	9	10 (to large extent)	I do not know

B2 Which of the following climate change related factors have affected the Municipality's road transport infrastructure? (Tick all that are applicable)

1	Precipitation	
2	Winds	
3	High temperatures	
4	Low temperatures	
5	Drought	
6	Floods	

B3 Does the Municipality have available information on the following climate change impacts that have affected roads transport infrastructure?

Impacts		Yes	No	Not sure
1	Precipitation			
1	Precipitation			
2	Winds			
3	High temperatures			
4	Low temperatures			
5	Drought			
6	Floods			

B4 Have the trends observed necessitated response measures from the Municipality?

1	Yes	
2	No	
3	I do not know	

B5 Which basis of climate change data and information are you using to estimate and establish the nature and extent of response measures for road transport infrastructure in the CTMM?

1	Observations	
2	Modelling	
3	Modelling as a result observation	
4	I do not know	

B6 Does the Municipality have a recent valid and professional vulnerability assessment of its roads transport network and infrastructure in terms of climate change?

1	Yes	
2	No	
3	I do not know	

B7 To what extent does the manifestation of climate change affect the lifespan of the Municipality's roads transport infrastructure?

0 (no extent)	1	2	3	4	5	6	7	8	9	10 (to large extent)	I do not know

SECTION C: MANAGEMENT MEASURES AND CHALLENGES OF IMPLEMENTING THE MEASURES

C1 Are there projects and programmes in your department in place to curb the potential impacts of climate change on CTMM's roads transport infrastructure?

1	Yes	
2	No	
3	I do not know	

C2 How many projects and programmes does your department have that address the impact of climate change on CTMM's roads transport infrastructure?

1	Zero	
2	One	
3	Two	
4	Three	
5	Four	
6	Five and more	
7	I do not know	

C3 To what extent would you say the response measures of CTMM, in place to curb the potential impact of climate change on its roads transport infrastructure, are effective?

0 (no extent)	1	2	3	4	5	6	7	8	9	10 (to large extent)	I do not know

C4 Do you think your department in CTMM is well equipped to address challenges posed by climate change on the municipality's roads transport infrastructure?

1	Yes	
2	No	
3	Partially	
4	I do not know	

C5 What are the challenges faced by your department in addressing climate change's impact on CTMM's roads transport infrastructure? (Tick all that are applicable)

1	Managerial issues	
2	Financing/Funds	
3	Capacity	
4	Social acceptance of projects and programmes	
5	Political backing	
6	Any other: specify	

C6 Does your department in CTMM often communicate, integrate and share climate change information with the other units (e.g. is there synergy)?

1	Yes	
2	No	

3	Rarely	
4	I do not know	

SECTION D: FINANCING CLIMATE CHANGE MANAGEMENT MEASURES

D1 Where do you get funding for climate change related projects and programmes for CTMM's roads transport infrastructure?

1	Municipal collected revenue	
2	Incentives	
3	Private investments	
4	Bilateral and multilateral organisations	
5	I do not know	
6	Any other: Specify	

D2 What are the main challenges for the Municipality to mobilise funding?

1	Lack of climate finance knowledge	
2	Lack of interest from private sector	
3	Lack of political backing	
4	I do not know	
4	Any other: Specify	

D3 To what extent would you say climate change related projects are included in CTMM's municipal budget?

0 (no extent)	1	2	3	4	5	6	7	8	9	10 (to large extent)	I do not know

SECTION E: MAINSTREAMING CLIMATE CHANGE INTO ROAD TRANSPORT INFRASTRUCTURE PLANNING AND PUBLIC POLICIES

E1 Does CTMM have climate change adaptation plan?

1	Yes	
2	No	
3	Maybe	
4	I do not know	

E2 Climate change considerations are integrated in CTMM's Comprehensive Integrated Transport Plan?

1	Yes	
2	No	
3	Maybe	
4	I do not know	

E3 Climate change management measures in terms of roads transport infrastructure are embedded within CTMM's existing public policies?

1	Yes	
2	No	
3	Maybe	
4	I do not know	

E4 What are the challenges faced by your department in mainstreaming climate change considerations? (tick all that are applicable)

1	Lack of qualified professionals to do the planning/mainstreaming	
2	Financing/Funds	
3	Capacity	
4	Political backing	
5	I do not know	
5	Any other: (specify)	

Thanking you in advance for your participation and invaluable contribution.

APPENDIX G: Research study photographs

Figure G.1: Flooded road in Centurion

Source: Researcher's photo (2018)

Figure 7.2: Traffic lights partially submerged in floods

Source: Researcher's photo (2018)

Figure 7.3: Centurion CBD flooded

Source: Researcher's photo (2018)