A framework for sustainable road freight decarbonisation in South Africa

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DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent where explicitly stated otherwise), that reproduction and publication thereof by Stellenbosch University will not infringe any third party's rights and that I have not previously, in its entirety or in part, submitted it in order to obtain any other qualification.

Date: December 2019

DEDICATION

I dedicate this dissertation to my husband and best friend, Dewald. Your kind soul, patience and brilliant mind will always inspire me to greatness.

ABSTRACT

Local and international governments are becoming more aware of carbon emission outputs and the damage that these emissions are inflicting on the environment. The definite impact that carbon emissions have on global warming has received public and media attention, which has placed high carbon-intensive companies and products under surveillance. Following electricity, road freight in South Africa is the second-biggest generator of carbon emissions. Thus, this research problem identified the need to decrease South Africa’s road freight emissions through the use of a road freight decarbonisation framework. The research problem entailed applying a framework to South Africa and expanding the structure to include the unique challenges in the South African road freight industry.

A mixed methods research design was conducted to include both qualitative and quantitative data for the road freight industry in South Africa. The first objective of the research was to establish which road freight decarbonisation strategy, framework, system or tool would suit South Africa that also provides a holistic approach to decarbonising road freight activities. A literature review and criteria analysis concluded that the McKinnon road freight decarbonisation framework would be best suited to adapt and expand within the South African context. The literature review was followed by qualitative and quantitative data gathering to establish how industry professionals perceived the McKinnon framework, and to determine what further inputs into the framework could be provided. The data gathering consisted of personal interviews with industry professionals and data questionnaires that were sent out to working professionals in the road freight industry. After South African challenges were established and added to the chosen framework, the South African challenges for road freight carbon emission were quantified, through data questionnaires, to determine what total impact these challenges have on total road freight emissions and to quantify the carbon variables on a national basis. The outcome of the research provided the first South African decarbonisation framework, which highlights the road freight challenges South African companies are facing daily. The study identifies what the current main road freight carbon-intensive challenges are in South Africa, so that South Africa can focus on these costly and highly intensive emission influences and be aware that the problems are not isolated events, but can affect all road freight companies in South Africa.

Keywords: Road freight, decarbonisation, carbon emissions, challenges

UITTREKSEL

Plaaslike en internationale regerings is besig om meer bewus te raak van koolstofemissie-vrystellings en die skade wat hierdie vrystellings aan die omgewing aanrig. Die definitiewe impak wat koolstofemissievrystellings het, ten opsigte van globale aardsverwarming, het aandag gekry van beide die publiek en media, wat hoë emissievrystellings maatskappye en produkte onder die soeklig geplaas het. Naas elektrisiteitsopwekking, is padvragvervoer die tweede hoogste genereerder van koolstofemissies. Dus het hierdie navorsingsprobleem die nodigheid om Suid Afrika se padvervoeremissies te verminder deur gebruik te maak van ‘n koolstofverminderingsraamwerk vir padvrag, uitgewys. Die navorsingsprobleem het ingesluit die toepassing van ‘n raamwerk op Suid Afrika en om dit verder te ontwikkel sodat die raamwerk die unieke uitdagings in die Suid Afrikaanse padvrag industrie kan inlsuit.

‘n Gemengde navorsingsontwerp is gebruik om beide kwalitatiewe en kwantitatiewe data vir Suid Afrikaanse padvrag in te sluit. Die eerste doel van die navorsing was om vas te stel watter padvrag koolstofverminderingstrategieë, raamwerke, sisteme of hulpmiddels die beste sal pas in die Suid Afrikaanse padvrag omgewing, wat ook ‘n holistiese benadering tot koolstofvermindering tot alle padvrag aktiwiteite sal bring. Nadat die literatuur studie voltooi is en kriteria toepassing uitgevoer is, was McKinnon se Padvrag Koolstofvermindering Raamwerk gekies. Die literatuur studie is gevolg deur die kwalitatiewe en kwantitatiewe data insameling met die doel om te bevestig wat professionele industrie gerigte individue se opmerkings was van die McKinnon raamwerk. Die doel was ook om vas te vas te stel watter verdere fasette by die raamwerk gevoeg kan word. Die data navorsing het ingesluit die uitvoer van persoonlike onderhoude met professionele padvrag individue, asook data vraelyste wat uitgestuur was. Nadat die Suid Afrikaanse uitdagings vasgestel was, was hierdie uitdagings bygevoeg by die McKinnon raamwerk en die uitdagings is numeriese waardes gegee deur die data vraelyste wat uitgestuur was. Die kwantifisering is gedoen om die impak te verstaan wat hierdie beperkinge het op die totale padvrag koolstofemissies in Suid Afrika.

Die gevolgtrekking van die navorsing was dat die eerste Suid Afrikaanse koolstofverminderings raamwerk vir padvrag ontwikkel is, wat aandui met watter uitdagings Suid Afrikaanse besighede elke dag te doen het. Die navorsing identifiseer vir die industrie watter hoof koolstof-intensiewe uitdagings in Suid Afrika is sodat bestuurders kan fokus op hierdie beperkinge weens die hoë kostes en omdat die beperkinge ook hoogs koolstofintensief is. Die navorsing lig ook verder uit

dat hierdie uitdagings nie ge-isoleerd tot ‘n maatskappy is nie en dat dit heel moontlik is dat baie besighede ook geaffekteer word deur hierdie selfde beperkinge.

Sleutelwoorde: Padvervoer, koolstofvermindering, koolstofemissies, beperkinge

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LIST OF ACRONYMS/ABBREVIATIONS

1/kWh	1 per kilowatt
1/m	1 per metre
ANOVA	Appropriate Analysis of Variance
CFP	Corporate Financial Performance
CO_2	Carbon Dioxide
CSIR	Council for Scientific and Industrial Research
CSR	Corporate Social Responsibility
CSP	Corporate Social Performance
DDPP	Deep Decarbonisation Pathways Project
DEA	Department of Environmental Affairs
DEFRA	Department for Environment, Food and Rural Affairs
ETS	Emissions Trading System
EU	European Union
FDM	Freight Demand Model
FMCG	Fast-Moving Consumer Goods
g/kWh	Grams per kilowatt
GDP	Gross Domestic Product
GHG	Greenhouse Gas(es)
Gt	Gigatonnes
$GtCO_2eq$	Gigatonnes per Carbon Dioxide Equivalent
GTT	Green Truck Toolkit
HC	Hydrocarbon
IRI	International Roughness Index
Km(s)	Kilometre(s)
LCA	Life Cycle Analysis
LS	Least Square
LSD	Least Significant Difference
NASA	National Aeronautics and Space Administration
NaTis	National Traffic Information System
NFFM	National Freight Flow Model

NO_x	Nitrogen Oxide
PM	Particulate Matter
PN	Particulate Number
OECD	Organisation for Economic Co-operation and Development
PwC	Price Waterhouse Coopers
RFA	Road Freight Association
RTMS	Road Transport Management System
SABS	South African Bureau of Standards
SANEDI	South African National Energy Development Institute
SANRAL	South African National Roads Agency Limited
SANS	South African National Standards
SARS	South African Revenue Services
SFST(s)	Strategies, Frameworks, Systems and Tools
StatsSA	Statistics South Africa
SVOC	Standard Vehicle Operating Costs
TDM	Transport Demand Management
TIMBER	Technology, Infrastructure, Market, Behaviour, Energy and Regulation
UN	United Nations
WEF	World Economic Forum
WWF	World Wildlife Fund

CHAPTER 1 INTRODUCTION

1.1 A BRIEF GLOBAL OVERVIEW

Since 1960, the global population has grown by 4.5 billion, with 7.53 billion humans populating the earth in 2017 (World Bank Group, 2017). Although population growth can have positive impacts, such as economies of scale, an increased workforce and specialisation, the negative effect is the increased pressure population growth places on the earth's natural resources (Easterlin, 1967). In the last 50 years, humans have consumed more resources than all of humanity together before this period (Australian Academy of Science, 2015). With the exponential growth of the world's population and consumption, the condition of the environment is beginning to change (WWF, 2016). As the population keeps growing, humanity is using up more resources than the planet can sustain, and the earth will not be able to continue to support the demands for future generations (WWF, 2014).

Population growth has led to increased urbanisation with over half of the global population now living in cities (World Economic Forum, 2014). While urbanisation can lead to better living conditions, it can also result in infrastructure challenges, such as housing, electricity and increased transportation (World Economic Forum, 2014). Urbanisation has brought about traffic congestion, which is reported as a common hurdle to overcome, together with an increase in freight traffic (Bretzke, 2013). Demands and expectations of freight transport are changing as the world is becoming more dedicated to consumerism. Globalisation has ensured customers receive goods and services faster, cheaper and more reliably (Coronado, 2015). The increase in demand and, thus, supply for transport and freight has resulted in more significant amounts of harmful gases being emitted into the atmosphere, such as greenhouse gases. Greenhouse gases include carbon dioxide, methane gas, nitrous oxide and fluorinated gases (Environmental Protection Agency, 2017).

Carbon dioxide (CO_2) is the primary gas responsible for greenhouse gases (GHG) (Environmental Protection Agency, 2016a). By producing more CO_2 emissions than what the earth can absorb, the natural balance of the earth's atmosphere is being distressed, warming the earth's surface and the lower atmosphere (Environmental Protection Agency, 2016b). Global temperatures will continue to rise for decades to come, due to greenhouse gases emitted by human activities (NASA, 2015a).

1.2 A SOUTH AFRICAN PERSPECTIVE

South Africa's population has increased from 51 770 560 people in 2011 to 55 653 654 in 2016 (StatsSA, 2016). South Africa has been described as a high-energy and electricity-intensive economy with 62% of South Africa's electricity generated from coal and 23% from petrochemical industries, such as Sasol (Republic of South Africa: Department of Energy, 2017).

Eskom, South Africa's electricity generator, is ranked as the world's seventh-largest electricity generator (Eskom, 2017). Having one of the world's largest mineral deposits, the exploration of these minerals is also an energy-intensive activity. While coal deposits currently provide cheap and reliable energy, the source will soon be seen as a point of judgement in South Africa's interest in the global reduction of carbon emissions (National Development Plan 2030, 2012).

The European Commission reported total annual CO_2 emissions in South Africa for the year 2015 at 417 160 kilotonnes (European Commission, 2016). The World Wildlife Fund (WWF) South Africa reported, in 2016, that the total transport sector (freight and passenger) contributed 47 600 kilotonnes of total CO_2 emissions (Cohen & Mason-Jones, 2016) by quoting data from the year 2010, provided by the South African Greenhouse Gas (GHG) Inventory Report (Department of Environmental Affairs (DEA), 2014). From the GHG Inventory Report, road transport (freight and passenger) was reported at 43 440 kilotonnes, with rail transport responsible for only 497 kilotonnes (excluding passenger and electricity generation from rail) for 2010, which is shown in Figure 1.1. Smaller modes of transportation, such as pipelines, are also represented in the report and contribute a negligible amount.

Total road transport emissions from the years 2000 to 2010 showed a steady increase as can be seen in Figure 1.2, highlighting the need to decarbonise and reduce carbon emissions from road transport, together with limiting the rise in this trend. Total CO_2 emissions for transportation increased by 3% per year for the 10-year data provided.

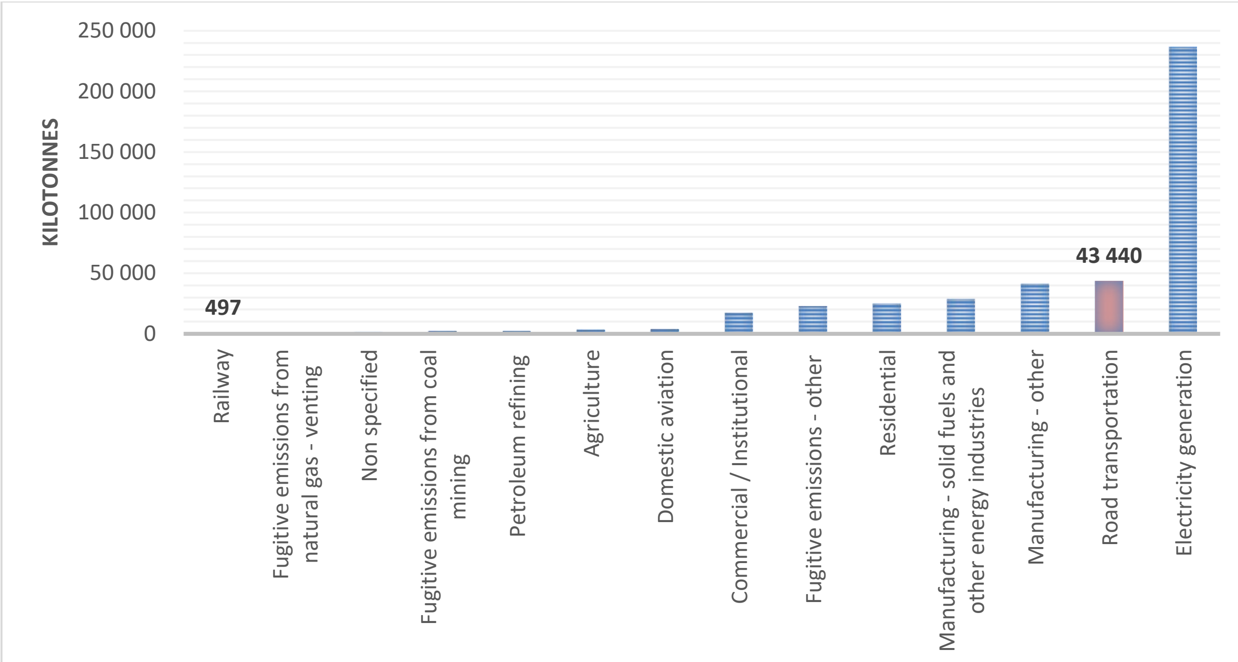

Figure 1.1 Total CO_2 Kilotonnes for South Africa

Source: Figure developed by the author, data gathered from DEA, 2014

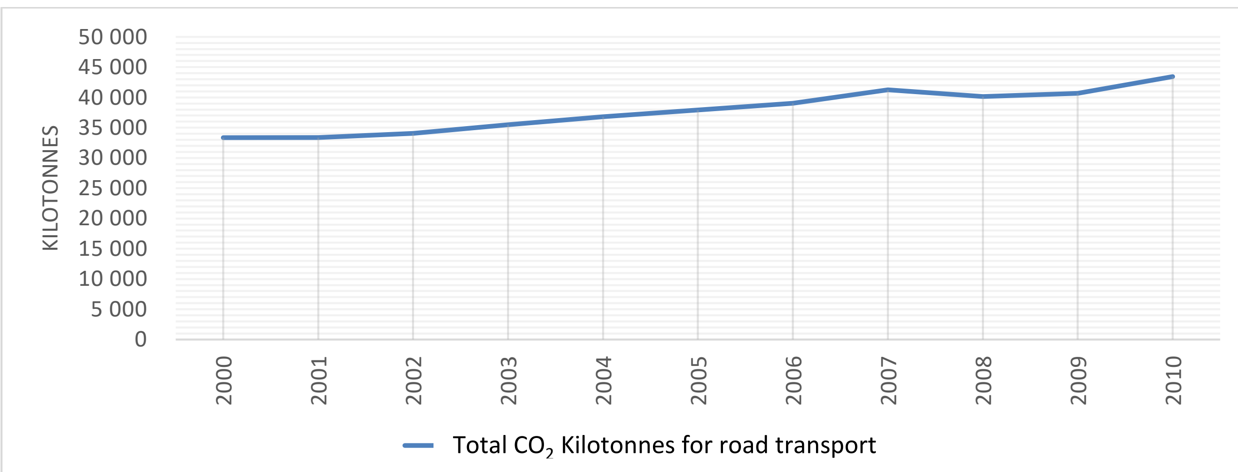

Figure 1.2 Road Transport Emissions - 10-year period

Source: Figure developed by the author, data gathered from DEA, 2014

Swarts, King, Simpson, Havenga and Goedhals-Gerber reported, in 2012, that total road freight emissions in 2010 equated to 16 411 000 million tonnes of CO_2. The CO_2 emissions were calculated by the total estimated diesel usage for all vehicles in the Freight Demand Model (FDM) in 2010 and multiplying this by the carbon output per litre of diesel, which is 2 688.9 grams of CO_2 per litre diesel used (Swarts *et al.*, 2012). Should the same methodology as what Swarts *et al.* (2012) used in the 2012 report be applied to the latest data from the FDM in 2015 (most recent version), the total road freight emissions would be estimated at approximately 16 800 000 million tonnes of CO_2. The FDM is discussed in Chapter 2 and calculations from the FDM are provided in Chapter 6.

South Africa also faces development challenges in terms of national poverty levels, the high unemployment rate and inequality (Magara, 2015). For South Africa to become a low-carbon economy, certain trade-offs must be made. Guideline principles for the transition to becoming a low-carbon economy are provided in South Africa's National Development Plan 2030. The principles are summarised in Table 1.1. With poor planning for development and social vulnerability, the capacity to respond to climate change has been compromised for South Africa (National Development Plan 2030, 2013).

In addition to the National Development Plan of 2030, South Africa is also part of the Deep Decarbonisation Pathways Project (DDPP), which sets out to provide research aiding in lowering carbon emissions and becoming a low-carbon economy. Research from the DDPP shows that South Africa has high emissions per capita and also emits high units of emissions per GDP. This presents difficulty in presenting possible emission reduction scenarios for South Africa due to the high degree of energy intensity in the economy with persistent high levels of inequality, poverty and unemployment (Altieri, Trollip, Caetano, Hughes, Merven & Winkler, 2015). The poverty gap is estimated at 19.6% (the percentage of national income at which it is estimated will bring one up to the poverty line). Social grants are estimated to reach 16 million South Africans, with an unemployment rate of almost 40% (Altieri *et al*., 2015).The South African government recognises that South Africa faces difficulty in switching over to a lower-carbon economy in the National Development Plan. South Africa is also vulnerable to climate change, which will directly affect South Africa's health, water availability and food production (Altieri *et al*., 2015).

South Africa's primary focus to address climate change and its consequences will be to ensure that all sectors of society are resilient to the impact of climate change. This will involve placing focus on the areas that will be most negatively impacted by climate changes.

Table 1.1 National Development Plan 2030 guideline principles to a low-carbon economy

Principle	Description
Just, ethical and sustainable	Recognise the aspirations of South Africa as a developing country and remain mindful of its unique history.
Global solidarity	Justly balancing national interests with collective action in relation to environmental risks and existential threats.
Ecosystems protection	Acknowledge that human well-being is dependent on the health of the planet.
Full cost accounting	Internalise both environmental and social costs in planning and investment decisions, recognising that the need to secure environmental assets may be weighed against the social benefits accrued from their use.
Strategic planning	Follow a systematic approach that is responsive to emerging risk and opportunity, and that identifies and manages trade-offs.
Transformative	Address the structural and systemic flaws of the economy and society with the strength of leadership, boldness, visionary thinking and innovative planning.
Managed transition	Build on existing processes and capacities to enable society to change in a structured and phased manner.
Opportunity-focused	Look for synergies between sustainability, growth, competitiveness and employment creation, for South Africa to attain equality and prosperity.
Effective participation of social partners	Be aware of mutual responsibilities, engage on differences, seek consensus and expect compromise through social dialogue.
Balance evidence collection with immediate action	Recognise the necessary tools needed for informed action.
Sound policymaking	Develop a coherent and aligned policy that provides predictable signals, while being simple, feasible and effective.
Least regret	Invest early in cost-effective low-carbon technologies, to reduce emissions and position South Africa to compete in a carbon-constrained world.
A regional approach	Develop partnerships with neighbours in the region to promote mutually beneficial collaboration on mitigation and adaptation.
Accountability and transparency	Lead and manage, as well as monitor, verify and report on the transition.

Source: Adapted from National Development Plan 2030, 2013

1.2.1 South Africa’s transport challenge

1.2.1.1 *Road Freight*

South Africa faces a challenge with the high volume of transportation taking place via the road corridors. South Africa’s road network is a freight-intensive network with 75.86% of freight being transported by road (only 10.41% via rail, Figure 1.3) on a proclaimed network that is approximately 618 081 kilometres in extent (another 131 919 kilometres are unclaimed roads). Of the 618 081 kilometres, 459 957 are non-urban roads, which brings the total urban roads to only 25.58% (SANRAL, 2019).

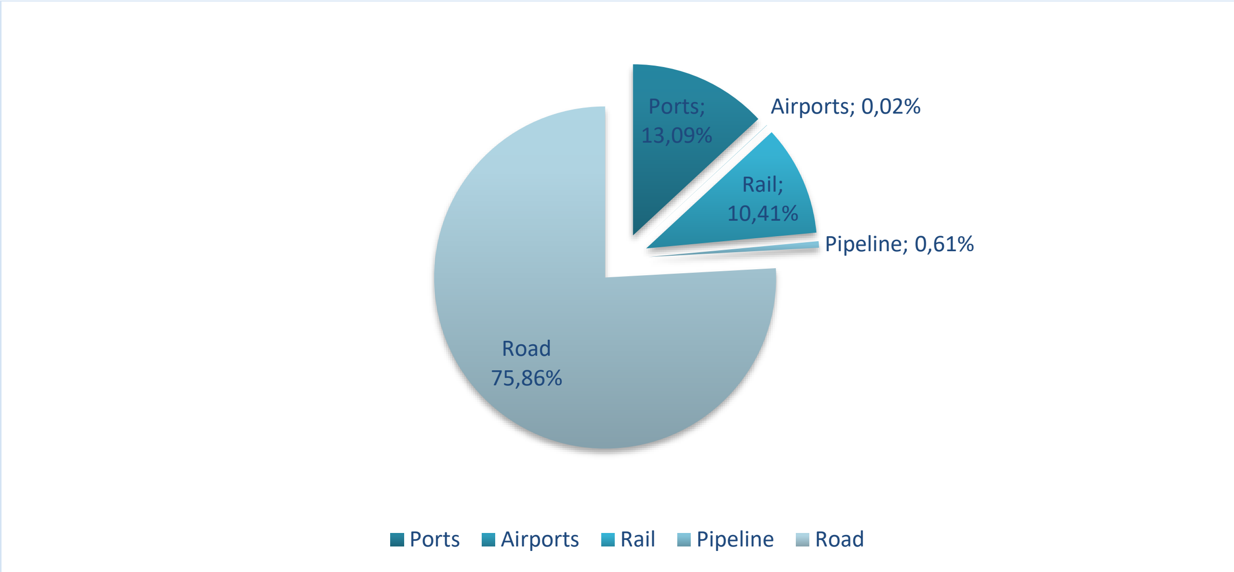

Figure 1.3 South Africa's freight node usage

Source: Adapted from National Transport Masterplan 2050 Chapter 7, 2011

The road networks are used at a high intensity in comparison to rail freight, overloading the road network to move high volumes of freight. This overloading contributes to crashes, road infrastructure damage, congestion and pollution (South African Department of Transport, 2013). The road freight traffic is projected to increase even further by 2050 to 1 million freight vehicles on the road with the Gauteng corridors taking most of the increase, due to the economic activities surrounding this hub. Other corridors that will have significant increases will be the N1 to N11 (population and industrial growth), the N2 (mineral and timber traffic from Mpumalanga to Richards Bay) and increased traffic in Lephalale, due to the power generation and mining industries in this area (National Transport Masterplan 2050 Chapter 7, 2011). Figure 1.4 represents the national roads that are the most freight-intensive, showing the forecasted freight movement of vehicles per annum by 2050. Figure 1.4 also depicts the volume of freight movements and the heavy traffic on national roads.

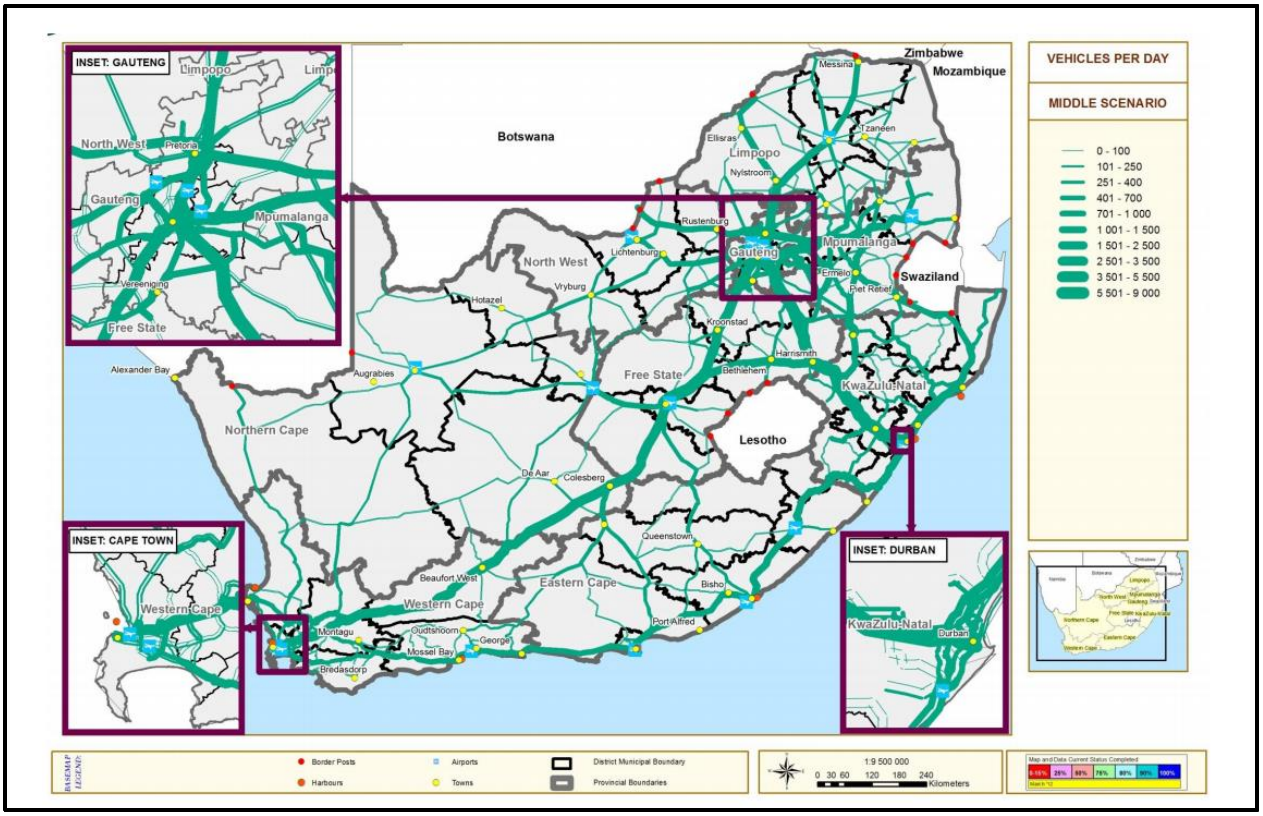

Figure 1.4 Forecasted national road freight per annum by 2050

Source: National Transport Masterplan 2050 Chapter 7, 2011

Given that 98% of the transport sector's energy is derived from petroleum liquids, a high volume of energy is being consumed, which is contributing to the carbon emissions being emitted into the atmosphere. The prediction is that, by 2050, the transport industry will grow in energy consumption, a problematic occurrence, due to oil supply, which will become constrained in the next twenty years (National Transport Masterplan 2050 Chapter 7, 2011). BP (2016) estimated that world total oil production is also only enough to last for another 50 years. South Africa will need to incorporate alternative fuelling and movement solutions to prevent the vulnerability of future oil shocks (Vanderschuren & Jobanputra, 2008). With the high volumes of freight being transported on South African roads, it is prudent to capture the current state of freight movements in South Africa.

Transport planning for road freight in South Africa must be taken into account for future sustainable development. South Africa has, historically, separated transport planning and settlement planning, thus creating large developments outside urban areas that increase travelling distances (Vanderschuren & Galaria, 2003). This increases the need for long distance road freight travelling as well.

Another concern is South Africa's rising cost in logistics. South Africa's relative demand towards fuel is, on average, higher in comparison to other countries with a lower output of tonnes per kilometre given the extensive road freight transport network (Havenga, Simpson, De Bod & Viljoen, 2014). This decreases South Africa's competiveness towards other sub-Saharan African countries (Havenga *et al*., 2014).

1.2.1.2 *Rail freight*

Rail freight in South Africa is perceived to be unreliable (Marsay, 2015) with a network consisting of 30 400 kilometres of track and 20 953 route kilometres (Transnet, 2017). This is considerably less than the road freight network, and it can, thus, be understood why rail has a low rate of accessibility for the loading of goods. Rail's inability to respond quickly to shifts in demand is seen as a challenge, together with the multimodal planning that is needed for rail usage to be executed efficiently (Havenga, 2012). Havenga and Simpson (2016) argue that should 'rail friendly' freight be moved away from road freight and shifted to rail, a total of 7.5% of freight could be moved to rail, amounting to 64 metric tonnes in 2013. The financial impact this possible shift from road freight to rail freight may have is a decrease from 44 cents per tonne-km to 36 cents per tonne-km (Havenga & Simpson, 2016:327). Rail freight transport is estimated to be four times more energy efficient than road freight transport (Havenga & Simpson, 2014).

To decrease the freight burden on the road, freight can be moved onto rail. Havenga, Simpson, Fourie and de Bod (2011) made an assumption that unitisable (goods that can be placed on a pallet) commodities that are being moved over a distance of more than 500 km can be moved to rail and can be defined as 'rail-friendly. Furthermore, to be classified as rail friendly, these freight flows must be between dense origin to destination points and the tonnes being moved must be more than 100 000 tonnes. These movements would be equal to the movement of one commodity train per week (Havenga *et al*., 2011). Havenga and Simpson (2016:325) stated that, given an analysis of the FDM, a significant driver to South Africa's high logistics costs is the long-distance and high-density freight movements on corridor routes (Havenga & Simpson, 2016:325).

The implementation of future technologies must also be taken into account when evaluating South Africa's rail freight system and the fast response in lead times for high-speed Maglev freight trains has been met with positive responses from China (Wang & Cripps, 2019). Other technologies, such as Hyperloops, a Tesla and SpaceX invention (SpaceX, 2013) have been met with similar optimism from various countries, but would require extensive engineering and large capital investments to realise within South Africa. Hyperloop technologies are still in the development stages and it will require some further research before this option becomes a reality (Schulze, 2018). CO_2 emissions from Maglev trains have been recorded as a fifth compared to normal road passenger transportation due to its lower use of energy (Wee, Brink & Nijland, 2003).

As both these technologies are not available in South Africa, and would require a large change in the operating nature of South Africa's current rail infrastructure, together with a large amount of investment, these future technologies fall outside the scope of this dissertation and was not included as an immediate feasible solution for South Africa.

1.3 RESEARCH PROBLEM AND RATIONALE

Many supply chain strategies, today, are based on quick and frequent transportation delivery systems with a strong dependence on oil (Vanderschuren, Lane & Korver, 2010:826). These include just-in-time deliveries and transport that is readily available for these frequent deliveries (Simchi-Levi, 2012). In 2012, transport accounted for 25% of the world's use of primary energy and, according to the "*BP Statistical Review 2016*", the world has enough oil left for an estimated 50 years (Inderwildi & King, 2012; DiLallo, 2014). The extraction and use of fossil fuels are now becoming one of the critical drivers for air pollution, public health issues and the depletion of forests and freshwater resources (Currás, 2014). Most scientists today agree that the leading cause of global warming is the human expansion of the 'greenhouse effect' (NASA, 2015b). Greenhouse gases can affect season shifts, climbing temperatures, longer heat waves, rising sea levels and erosion (NASA, 2015a; The Nature Conservancy, 2015).

It is estimated that road transport accounts for 74% of total transport CO_2 emissions and 25% of world energy-related CO_2 emissions (Kahn-Ribeiro, Kobayashi, Beuthe, Gasca, Greene, Lee, Muromachi, Newton, Plotkin, Sperling, Wit & Zhou, 2007). There are road freight emission reduction systems, frameworks, strategies and tools available for countries outside of South Africa, but limited decarbonising or carbon reduction systems, frameworks, strategies and tools based on South African road freight infrastructure, could be found during the research. The research problem can thus be stipulated as:

- **GHG constitute a significant contributor to climate change, negatively impacting the global impetus towards sustainable development. CO_2 is the primary gas responsible for GHG. Globally, the road freight sector accounts for about one-third of transport's final energy demand and transport-related GHG emissions. Several developed countries have ratified agreements and/or policies to decarbonise the road freight sector. However, no established framework currently exists in South Africa to facilitate the transition to a low-carbon freight**

sector. Therefore, this research develops a road freight decarbonisation framework for South Africa by adapting an existing road freight decarbonisation framework to South Africa's unique road freight criteria.

1.4 RESEARCH AIMS AND OBJECTIVES

The aim of this dissertation is to firstly develop a road freight decarbonisation Strategy, Framework, System or Tool (SFST) for South African road freight companies to enable these companies to lower road freight carbon emissions in South Africa. Secondly, to quantify the SFST with national data to identify how much specific road freight activities contribute to total road freight carbon emissions. To accomplish the research aim, the objectives included:

- Investigate global road freight decarbonisation SFSTs;
- Choose an SFST that can be easily adapted to the fit the South African road freight environment and that can incorporate the added South African road freight challenges;
- Discuss the chosen SFST to establish how the SFST will fit into the South African environment;
- Identify and address any South African gaps and opportunities that may exist in the chosen SFST and expand the chosen SFST to include the gaps and opportunities;
- Include the gaps and opportunities identified in a newly developed SFST for South Africa;
- Calculate the carbon emission reduction potential of the identified gaps and opportunities identified by using data gathered from questionnaires and the South African Freight Demand Model;
- Test the chosen SFST on a South African company to validate the newly developed SFST.

1.5 RESEARCH QUESTIONS

Section 1.5 outlines the main research question, as well as the sub-questions that were investigated. The dissertation focused on these questions.

1.5.1 Main research question

Which existing road freight decarbonisation SFST can be customised for the South African environment to facilitate the transition to a low-carbon road freight sector?

1.5.2 Sub-questions

The sub-questions were divided into different sections that were focused on during the dissertation. To answer the main research question, various sub-questions needed to be investigated and answered. Table 1.2 summarises these sub-questions.

Table 1.2 List of various sub-questions for the dissertation

	Sub-questions	Research objective	Discussed in
1.	**What types of SFSTs for decarbonisation are available?**	Investigating global road freight decarbonisation SFSTs.	Chapter 4
2.	**Which SFST will be best suited for South Africa?**	Choosing an SFST that will be easily adaptable to the South African environment, which can also incorporate the added South African road freight challenges.	Chapter 4
3.	**What gaps and opportunities exist within the chosen SFST?**	Identify and address any gaps and opportunities that may exist to expand the chosen SFST.	Chapter 6
4.	**What factors can be added to the newly developed SFST?**	Develop the SFST further to fit road freight for South Africa.	Chapter 6
5.	**Can the South African decarbonisation SFST be quantified?**	Calculate the carbon emission reduction potential by using data gathered from data questionnaires and the South African Freight Demand Model.	Chapter 6&7
6.	**What are the possible benefits companies can achieve with the South African-focused SFST?**	Test the chosen SFST on a South African company to validate the newly developed SFST.	Chapter 8

1.6 LAYOUT OF CONTENTS

Chapter 2 is dedicated to the research methodology and design.

Chapter 3 is set out to explain research concepts of supply chain, supply chain sustainability and external factors that may influence the number of carbon emissions in road freight transport. It forms part of the first section of the literature review.

Chapter 4 is dedicated to the second part of the literature review. The chapter highlights the importance and relevance of the research from various sources about road freight decarbonisation.

Chapter 5 provides the full explanation and discussion of McKinnon's road freight decarbonisation framework and presents the third and final section of the literature review.

Chapter 6 analyses the data that was gathered during fieldwork for the dissertation. The chapter includes results received from various interviews and questionnaires. The chapter deals with the data gathered when McKinnon's framework was applied to South Africa. Gaps are identified that are specific to South Africa. The chapter includes the new challenges and influences that need to be included in the new framework.

Chapter 7 provides a further interpretation of the data provided in Chapter 6 and calculates the possible reductions in carbon emissions by introducing synergy calculations.

Chapter 8 presents a case study where the South African road freight decarbonisation framework was used as a guideline for a company and presents the findings.

Chapter 9 is the conclusions and recommendations of this dissertation. Further research areas for South Africa are discussed, and the contribution to knowledge is highlighted.

CHAPTER 2 RESEARCH APPROACH

Chapter 2 describes how the research was undertaken and discusses the methods used to gather primary and secondary data.

2.1 RESEARCH METHODOLOGY AND DESIGN

Both qualitative and quantitative data were gathered for the research study. Thus, a mixed method research design was used. The nature of the research was exploratory with the research being divided into two main stages. The first stage consisted of a literature review in the form of secondary data to identify existing road freight decarbonisation SFSTs, available literature and practices on supply chain sustainability and factors influencing carbons emissions within road freight. The methodology included four key elements that developed the structure of the research, which was supported by literature by Walker, James & Brewer (2017).

- Confirmation;
- Elimination with replication;
- Extension and
- Application

The confirmation during the literature review ensured an understanding and verification of sustainability and carbon emission influences that may increase carbon emissions within road freight. Elimination took place by means of investigating road freight decarbonisation SFSTs and developing criteria to assist with eliminating SFSTs that did not adhere to the criteria. In addition to elimination, the chosen SFST was also supported by replication studies specifically on carbon emission influences and sustainable practices during the literature review in Chapter 3. Elimination was thus assisted by the confirmation of literature review that established what carbon emission factors contribute to road freight carbon emissions.

Extension was applied on the chosen SFST by means of expanding the chosen SFST with literature review confirmation and qualitative data gathered from interviews and questionnaires. Finally, application from the expanded SFST was ensured by a small case study that was conducted to establish the preliminary feasibility of implementing the developed SFST within a South African environment.

The literature review served as a criteria development strategy to establish what criteria the chosen SFST must meet to be adapted for South Africa. Criteria for the chosen SFST will incorporate:

- Identifying the adaptability of the SFST to the South African road freight environment;

- Identifying further development opportunities;
- The feasibility of implementation;
- The research that has been done on the SFST.

After the literature review was completed, and a road freight decarbonisation framework was chosen by meeting the set criteria, the second stage began. The second stage entailed understanding the current views of sustainability and the gaps and opportunities that exist in the road freight decarbonisation framework and populating the framework with data gathered through interviews and questionnaires. This was done by collecting qualitative and quantitative data from questionnaires and interviews. Finally, the total potential carbon reductions for South African road freight were calculated from data gathered through data questionnaires. The final framework was tested on one company to establish the potential reduction of carbon emissions by using the newly developed framework. Figure 2.1 provides a breakdown of quantitative and qualitative data gathered throughout the research process.

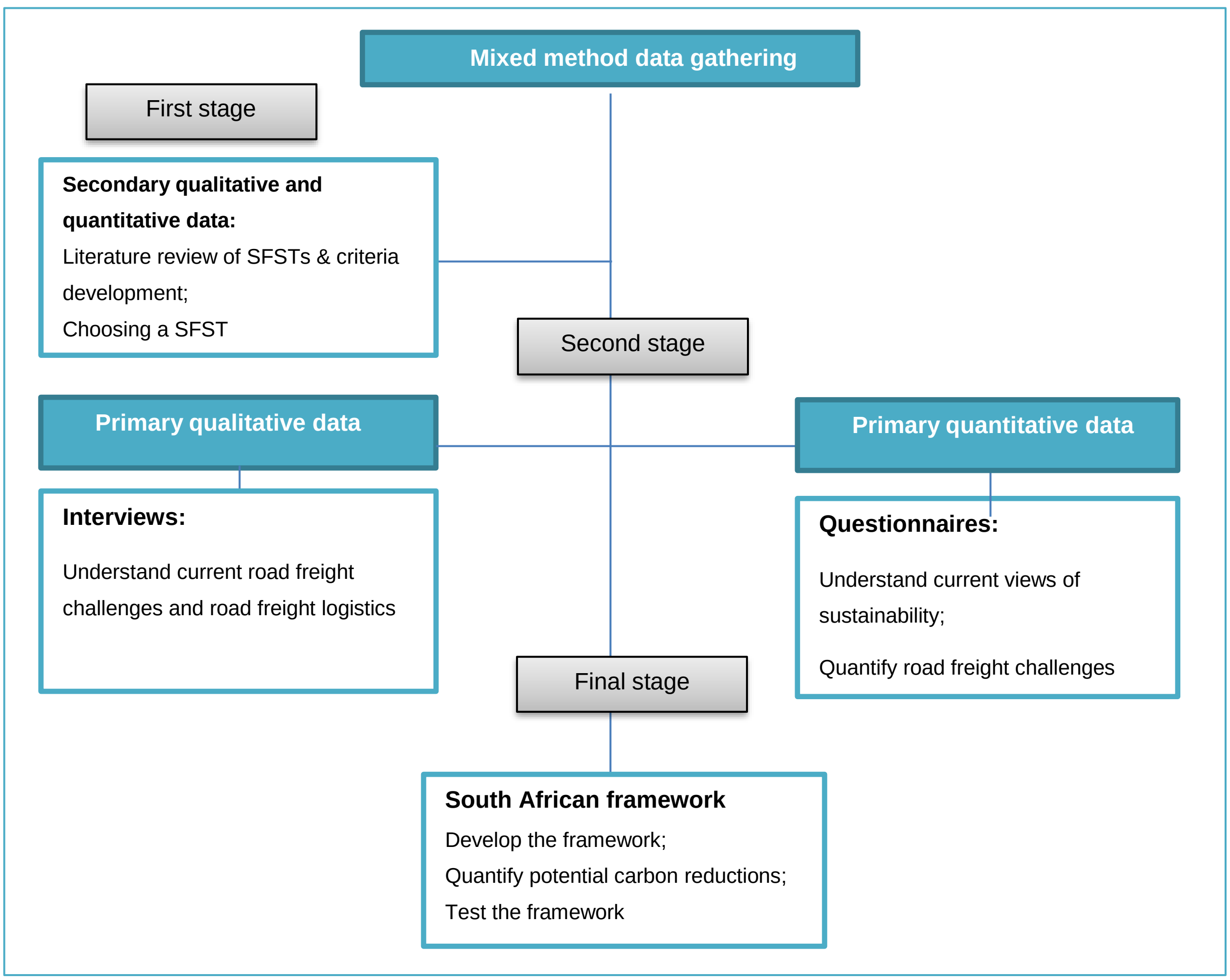

Figure 2.1 Data gathering process

2.2 CRITERIA DEVELOPMENT

It was essential for the research to develop the criteria that must be met by the SFST before beginning with the quantitative and qualitative data gathering. The criteria would narrow the scope of the dissertation to focus only on carbon emission reduction that can be used for road freight transport, and to allow an understanding of the shortcomings of decarbonisation in South Africa. With the application of the criteria, it was possible to design interview and questionnaire questions with more precision to focus on asking the relevant questions needed to design and populate a decarbonisation SFST for South Africa.

1. **Identifying adaptability and a holistic view of the SFST to the South African environment**

The SFST must be adaptable to the South African environment, as the majority of freight is being transported by road. Thus, the SFST must have the ability to be used for road freight decarbonisation.

2. **Identifying further development opportunities**

The SFST must be able to be developed further within the South African context, given the gaps and opportunities identified during the literature review.

3. **The feasibility of implementation**

The implementation of the SFST must be feasible within a South African context given South Africa's road freight infrastructure. Criteria for the feasibility of implementation include:

- The technology required to implement;
- Funding required to implement;
- The simplicity of implementation;
- Internal or external resources required to implement;
- Limit the risk to the company to implement;
- Implementation within a feasible short period.

These criteria will ensure that companies can implement the SFST with little financial investment and also ensure that all companies, irrespective of the size of its turnover, can make use of the SFST.

4. **The research done on the SFST**

An SFST must be chosen based on previous research done on the SFST. There must be evidence that the SFST is effective in reducing carbon emissions from road freight.

2.3 SECONDARY QUALITATIVE DATA

The literature review was conducted as preliminary research to understand road freight decarbonisation, as well as what sustainability entails and the need for a sustainable supply chain. This was the first step taken before primary data was collected, which was an essential step towards building knowledge to undertake the future required steps in the research.

Road freight decarbonisation SFSTs were investigated in the research and the most holistic SFST, which incorporated all road freight activities, processes and decision-making factors contributing to road freight emissions, was chosen to be applied and further developed in the South African context.

The literature review highlighted the shortcomings of currently available information on South African decarbonisation in the road freight industry. These shortcomings allowed for an SFST to be chosen that best suited South Africa’s needs and included a holistic view of logistical activities. Furthermore, the literature review established the confirmation of current factors that may increase carbon emissions.

2.4 A THREE-STEP PRIMARY DATA GATHERING PROCESS

The literature review and criteria analysis were followed by three phases of data gathering. The initial data requirements were to establish what the current view of road freight sustainability was in South Africa, what the participants taking part in the data gathering knew of sustainable practices, if sustainable practices were being implemented and to find out what the challenges are in the road freight environment. This was expressed through primary qualitative and quantitative data. The first phase was represented by questionnaires, which were followed by a round of interviews (the second phase) to gather qualitative data. The interviews were to establish the views represented in the first phase (questionnaires) and to show the participants the chosen SFST to engage in further discussions. The third and final data-gathering technique was also conducted in the form of questionnaires. The third phase of data-gathering questionnaires was more focused upon the population of the South African-developed SFST and to quantify the South African carbon emissions for road freight challenges and influences.

2.4.1 Primary qualitative and quantitative data: Phase one

After the completion of the literature review, the first step of gathering primary qualitative and quantitative data was initiated. The first phase of primary data gathering consisted of sending out questionnaires to working logistics professionals who are familiar with current road freight challenges and engage with road freight daily. The method used for choosing participants for the questionnaires was judgement sampling, as this allowed participants to be chosen on predetermined criteria (Deming, 1990:31). The criteria on which the participants were chosen, involved contacting professionals currently working in the operational environment of road freight activities and would have an insight into the current logistical practices. This ensured knowledge of what the current state of road freight challenges are, to warrant a holistic view on the logistical supply chain challenges in South Africa and what solutions can be proposed to these. Participants were thus selected, based on the following criteria:

- Must currently work with road freight, i.e. have the same or similar position as Logistics or Freight Manager/Director, Controller or Scheduler;
- Can be in a lower, middle or higher management position;
- Must at least have more than one year of work experience in the logistics or road freight industry.

Questionnaires were set up in a Microsoft Word document (Appendix B), and the document was sent out to 120 judgement sampling participants to complete. Participants' contact details were gathered through social media (LinkedIn) and company websites. All questionnaires were sent via electronic mail (email) over a two-month period. The response rate to the questionnaires was 17%. Thus, twenty completed questionnaires (n = 20) were returned. Questionnaires were summarised in a Microsoft Excel document. This allowed data patterns to be visually represented and created ease of access to summarise all the answers to the questionnaire in one document. Through the analysis process of the questionnaire answers, it was possible to derive what the current views are, trends in these views and what challenges are currently experienced in the South African logistical context. In addition, the conclusions from the summary and data analysis allowed the second phase of interview questions to be set up to focus more specifically on the data trends, such as similar challenges in road freight activities. It was now also possible to ask the interview participants to elaborate on logistical challenges, why these challenges are occurring, investigate possible solutions to the challenges and how these challenges may have an effect on road freight emissions.

2.4.2 Primary qualitative data: Phase two

After the data analysis of the first phase of data gathering, the interview process began. A summary of the interview questions can be seen in Appendix C. Interviews took place over a period of twelve months. The reason for the prolonged time for the interviews were time constraints from participants taking part in the interviews. Interviews were scheduled to take one hour, but many participants found it challenging to take time off during working hours to take part in a data-gathering process that would not yield any direct benefits for the participant or their company given that the SFST still needed to be developed. There was also some reluctance from participants to take part in an interview due to the participants being unwilling to share company and possibly competitive advantage insights. Participants for the interviews were again chosen by judgement sampling based on the criteria of the first phase of questionnaires. In addition to the criteria, four aspects for participant selection were also taken into account:

1. Credibility;
2. Transferability;
3. Dependability;
4. Conformability.

Credibility was ensured by only selecting participants from active road freight companies or participants that have a comprehensive history of working within the road freight industry. All interview participants also agreed to be available for follow-up questions. Transferability was ensured through thick description, by participants engaging in in-depth descriptions of behaviour, experiences and the context of responses. Dependability and conformability were achieved by keeping records of all interviews, dates, times and place where the interviews took place. All participants were asked the same interview questions to be consistent with information requests during the interviews. Data interpretations were all summarised in Microsoft Excel to keep a record of all participant answers and to analyse the answers of participants to identify similar themes, which occurred during the interview process.

Participants from the first phase of questionnaires were asked if a personal or telephonic interview could be granted, and an additional 50 more participants were contacted through LinkedIn and email to participate in interviews. A total of 170 participants were requested for a personal interview with a positive response rate of 12%, which resulted in an interview. Thus, 20 participants (n = 20) were interviewed, expanding over a twelve month period.

The interviews were divided into two sections of questions. The first section of questions focused on the logistical activities of the participant's company. Participants had to describe, in detail, the activities in the company in order to make a delivery to a client possible. Further questions elaborating on delivery challenges were asked and documented. The primary reason for documenting logistical challenges was to establish the impact these challenges may have on the carbon emission outsets. As interviews (and phase one questionnaires) were conducted after the literature review was completed, it was possible to ask more in-depth questions regarding logistical challenges in the company, which may have an impact on increasing carbon emissions. After the first section of questions was completed, the second section was discussed. Participants were asked what could be added to the SFST to make the SFST more specifically focused on the South African environment, and thus, a more in-depth discussion of South African challenges was initiated. Topics such as strikes, road infrastructure, legislation compliance and culture were discussed.

After completion of the interviews, the qualitative data was processed, and the expansion of the SFST began. The SFST took into account the results from the questionnaires and the interviews. It included the newly discovered themes and road freight challenges that were mentioned most frequently by all the participants and the themes and influences that caused the most disruptions in deliveries, which also had a possible impact on carbon emissions. After the development of the SFST, phase three of the data gathering was initiated.

2.4.3 Primary qualitative and quantitative data: Phase three

The third phase of the data gathering process was to populate the South African decarbonisation SFST with the relevant South African road freight data. The reasons for the population of the SFST were threefold. Firstly, to comprehend how much freight is being moved on the road network by the participants and the impact all these freight activities have on road freight carbon emissions in South Africa. Secondly, to quantify what amount of carbon emissions are being emitted as a result of the carbon emission influences and challenges, which were identified during the first and second phase of data gathering. The data gathered also confirmed the results of studies on how these identified carbon influences and challenges are experienced in South Africa and that these influences and challenges are representative of what is happening operationally in the road freight industry. Thirdly, to calculate the carbon emission reduction potential and carbon spend for South Africa from the new carbon emission influences, to indicate by how much road freight emissions can be reduced, should these influences and challenges be limited or reduced. This threefold population and calculations entailed gathering quantitative data from data questionnaires that were sent out to logistics professionals in the road freight industry.

2.4.3.1 *Population and sample size calculation*

To send out the questionnaires that were required for the data population of the adapted SFST, it was deemed appropriate for the study to contact all registered road freight companies in South Africa to obtain the required road freight data. From the total population, a sample size estimation was calculated to represent the total population.

To gather the contact details of all road freight companies, requests for road freight company details (company name, contact details and company fleet size) were sent out to the South African Revenue Services (SARS), the National Administration Traffic Information System (NaTIS), the Road Freight Association (RFA) and Statistics South Africa (StatsSA). Requests consisted of phone calls and emails directly to all four possible data providers. Follow-up phone calls and emails were sent weekly. After three months of data requests, the RFA sent a list of all registered road freight companies in South Africa, with contact details. No data with company fleet sizes could be obtained from the RFA.

The list from the RFA consisted of 2992 registered road freight companies with 4250 accompanying email addresses, which were used to send out the questionnaires (Hadzhiyski, 2019). To calculate the sample size, three sets of criteria had to be met to determine what the appropriate sample size should be, namely the sampling error, the level of confidence and the estimate proportion of the population (Israel, 1992:1). The sampling error refers to the value of what the true reflection of the population might be. For example, should the sampling error be 10%, the results of an answer can either be 10% more or 10% less than what the actual result reflected.

The confidence level refers to whether, should the study be repeated, the results of the study would be the same as in the first study (given the same sampling error). For the purpose of this study, a 95% level of confidence was used (Z), as used frequently in statistics (Bartlett, Kotrlik & Higgins, 2001). A sampling error of 10% was accepted for this study. The sample size calculation used in this study was chosen from the methodology of Keller (2008:407) to estimate some unknown proportion (p) in the data. The estimate of the proportion can be written as p̂ and the error percentage (10%) is indicated as Cp. In other words, $[p\text{-}Cp,\ p+Cp]$ will constitute a 95% confidence interval for the unknown proportion p. The sample size needed for a 10% error percentage (Cp) with a 95% level of confidence (Z), was computed as:

$$n_o = \frac{Z^2\,\hat{p}\,(1-\hat{p})}{(Cp)^2}$$

$$n_o = \frac{(1.96)^2\,(0.5)(1-(0.5))}{(0.10)^2}$$

$$n_o = 97$$

The standard deviation for $\hat{p}(1-\hat{p})$ varies very little for different p values and the proportion p that is needed to be estimated can simply be chosen as $\hat{p} = 0.5$.

Where:

n = sample size

Z = the percentile of the 95% confidence equals 1.96 (Fisher, 1925)

$\hat{p}$ = the estimated proportion of the population

cp = the sampling error

With the results from the equation, the estimated sample size to represent the road freight population, for the purpose of this research, was identified as 97 road freight companies. Through the data requested from StatsSA, StatsSA provided a stratification table of road freight companies (Table 2.1) (de Beer, 2019). To ensure that a representative sample of the population was obtained through sampling, Table 2.1 was used as guidance in the sampling stratification for this research. No responses were received from SARS or NaTIS.

Table 2.1 Road freight company stratifications by StatsSA

Number of companies	Total number of trucks	Turnover - R million
23	23	400
163	860	6 310
235	5 666	18 970
88	21 698	36 541
509	**28 247**	**62 221**

Source: de Beer, 2019

The stratification table provided by StatsSA provides the total number of companies (509) who responded the 2016 StatsSA transport and storage industry report. StatSA divided these companies based on the number of companies that responded, the number of trucks these companies have and company turnover. The stratification table does not solely stratify based on revenue.

With the help of the table provided from StatsSA, it was derived that from the total of 509 sampled road freight companies, the companies can be further categorised into the sizes of small, medium and large according to the number trucks in operation within each of the companies. This was done by dividing the number of trucks by the number of companies. Table 2.2 shows the results from this calculation. Table 2.3 categorised the company sizes further by grouping the smaller companies (those with an average of one truck and five trucks) together into one group of companies that have 1-10 trucks in operation. This was done to simplify the stratification by increasing the grouping of smaller companies to include companies that have more than one truck in operation, but less than ten. The next company size category, medium, includes companies with an average number of trucks ranging from 11-200 trucks, and companies with more than 200 were categorised as “large”. Table 2.2 was used as guidance to derive the company size profiles in Table 2.3.

Table 2.2 Average number of trucks per company

Number of enterprises	Number of trucks	Average number of trucks per company	Company size
23	23	1	Small
163	860	5	Small
235	5 666	24	Medium
88	21 698	246	Large

Table 2.3 Stratification used for the road freight sample

Company size according to trucks in operation	Number of trucks per company	Number of companies	Percentage of companies represented in the StatsSA sample
Small	1 - 10	186	36.5%
Medium	11 - 200	235	46.2%
Large	200 +	88	17.3%

2.4.3.2 *Questionnaire*

The questionnaire to obtain road freight data was sent out in four separate stages. The first three stages were conducted before any responses were received from the RFA or StatsSA. The first stage involved contacting potential participants directly through email addresses that were gathered from websites belonging to road freight companies or companies who participate in road freight activities. Judgement sampling was used for the first three stages on the criteria that:

- The participant must represent a company who primarily or secondarily participates in road freight activities. For primary, that the company’s leading source of income is from the movement of freight for contracted companies or secondarily, that the company makes use of its own fleet to move freight within the company, to clients or makes use of a service provider that moves the company’s freight.

The first stage resulted in poor results, with 130 companies contacted with a response rate of 12% (fifteen responses). The second stage was initiated after the first stage resulted in a low response rate. The second stage consisted of potential participants being contacted directly through LinkedIn, rather than an email sent to a generic company email address. Through the second stage, 344 potential participants were contacted, with monthly reminders sent, and a response rate of 6% (twenty responses) was recorded. The third stage was to set up an electronic questionnaire for participants to complete through the use of CheckBox Survey. The questionnaire was sent out by the Road Transport Forum through the weekly email distribution to their members for two months; no responses were received from the third stage. This brought the total contacted potential participants, from stage one and two to 474 with a total response rate of 7% or 35 individuals, representing 35 companies.

The fourth stage involved sending out the electronic CheckBox Survey questionnaire to the total South African population of registered road freight companies through the contact details obtained by the RFA. A bulk email was sent out to 4250 participants through CheckBox Survey, representing 2992 road freight companies. Road freight companies represented in the 2992 were categorised into seven groups:

1. Abnormal loading of large freight;
2. Bulk carriers;
3. Couriers;
4. Food and beverage carriers;
5. Fuel carriers;
6. Refrigeration;
7. Retail and FMCG.

Bi-weekly reminders were sent to potential participants over a period of two months. Figure 2.2 summarises the number of responses received from each email prompt, where ‘Week 1’ refers to the first time the questionnaire was sent out to potential participants and ‘Week 7’ refers to the week in which the final reminder to participate in the research was sent out. The total response rate from the fourth stage thus was 3%, a total of 97 companies. This brought the total sample gathered to 132 companies, 4% of the total registered road freight companies in South Africa. Table 2.4 represents the total sample gathered from stages one to four, stratified into the categories of small, medium and large. Small companies are represented by 25% in the sample, medium companies by 62% and large companies by 13%. When comparing the results against the StatsSA sample, Figure 2.3 was developed to compare the difference in company representation from both the StatsSA sample and the research sample.

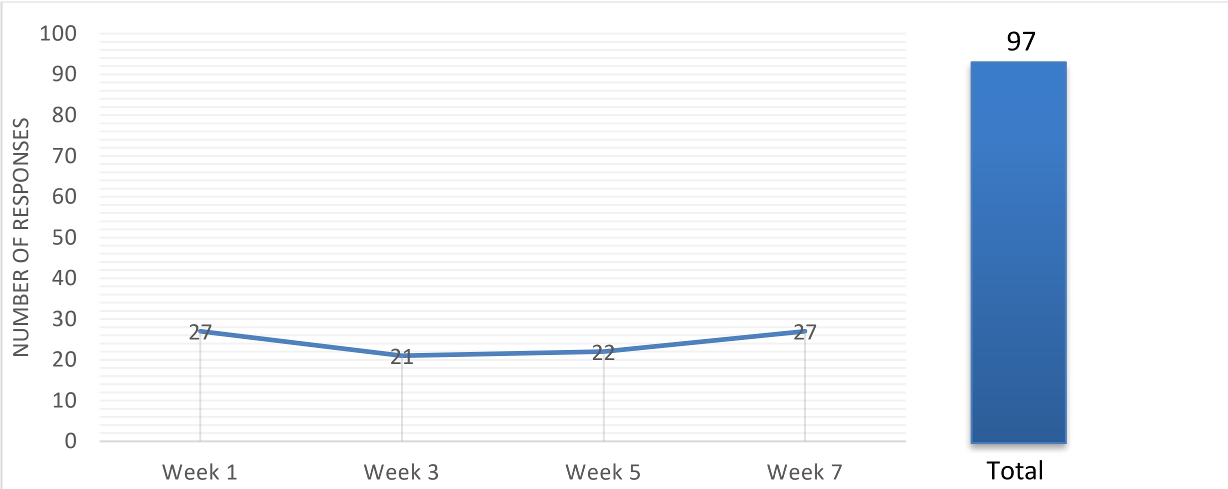

Figure 2.2 Total responses received from the fourth attempt

Table 2.4 Total research sample

Company size according to trucks in operation	Number of trucks per company	Number of companies in the research sample	Percentage of companies represented in the research sample
Small	1 - 10	33	25%
Medium	11 - 200	82	62%
Large	200 +	17	13%

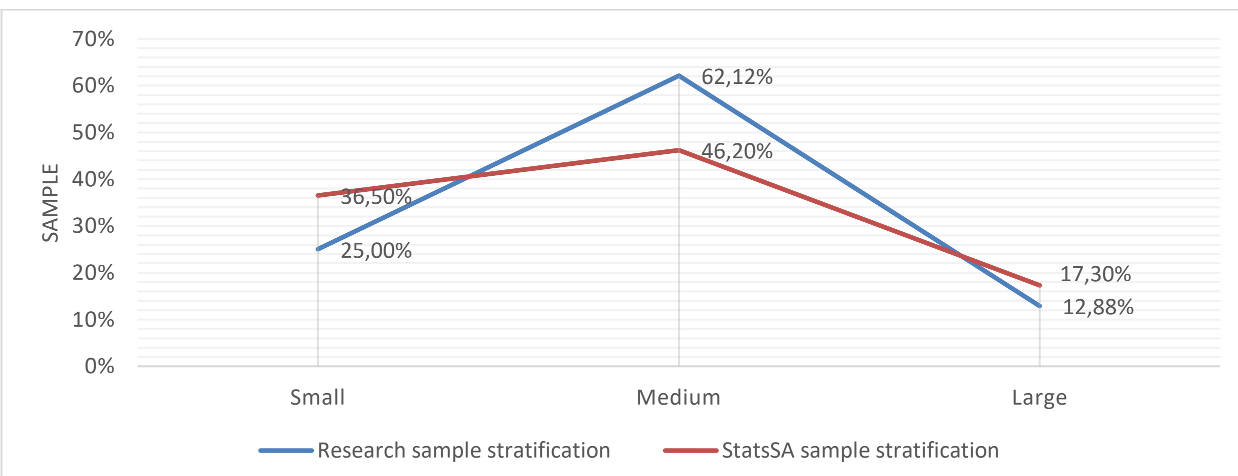

Figure 2.3 Comparing the StatsSA and research sample stratification

Table 2.5 represents all the stages in the questionnaire data gathering process, which sampling technique was used, the targeted companies, the method used to gather the data, the number of responses in each phase and the total response rate in each phase.

Table 2.5 Summary of response results from the questionnaire

Phase	Sampling technique	Companies targeted	Method	Total companies contacted	Total companies responded	Response rate
One	Judgement	Primary and secondary road freight activity	Email	130	15	12%
Two	Judgement	Primary and secondary road freight activity	Email, LinkedIn private messaging	344	20	6%
Three	Judgement	Primary and secondary road freight activity	CheckBox Survey through the Road Transport Forum	Road Transport Forum weekly email	0	0%
Four	Total population contacted with stratification of all phases to ensure population representativeness.	Primary and secondary road freight activity	CheckBox Survey to all registered road freight companies	2992	97	3%

Throughout the data gathering stages, there were no companies that were duplicated in stages one to four. However, should a company have provided data more than once in the different phases, only the first response would have been included in the study.

2.5 VALIDITY AND DATA ACCURACY

To confirm the results obtained for data validity and accuracy, triangulation was done. Triangulation involves comparing data from more than one source, to compare the data and results on the same subject matter with each other to confirm that the data is valid and accurate (Rothbauer, 2008). In the case of this research, triangulation was done by comparing the results obtained from the third phase data questionnaires with the available data from the Freight Demand Model (FDM). The literature review in Section 3.7, discusses the FDM, and the triangulation results are discussed in Chapter 6.

As with the interview process, credibility, transferability, dependability and conformability ensured that data gathered from the data questionnaires were valid. Questionnaires were only sent out to road freight transportation companies to ensure the credibility of the data. Detailed analysis is provided in Chapter 6 to ensure that the data gathering process is transferable and Appendix D provides the data questionnaire that was used to gather the data. To ensure dependability and conformability, all data gathered was stored in Microsoft Excel in addition to providing detailed extraction of the electronic questionnaires date and time of responses.

In instances where comparable data from the FDM was available, the same method of calculation was used for the FDM data as what was used from the data that was gathered from the questionnaires to ensure calculation consistency. This included calculating weighted averages for variables such as kilometres travelled, load utilisations, handling factors etc. (Chapter 6). By comparing the data gathered from the FDM and from the data questionnaires, it was possible to depict if there were differences from the FDM and the data questionnaires. Where differences occurred, interviews were conducted with the FDM's Data Analyst at Stellenbosch University to understand these variances. It was concluded that the variances depicted between the FDM and the data questionnaires resulted in some assumption calculations made in the FDM, such as the empty loading percentage, which is not data that is readily available in FDM. Unique variables that were identified in this study will not always match those of the FDM. However, where data assumption calculations were not made, comparative figures indicated that there were no significant differences between the data from the FDM and the data questionnaires.

2.6 DATA TOOLS AND ANALYSIS

All data gathered from the first, second and third phases of primary data gathering were summarised in Microsoft Excel to simplify the method of theme analysis for the first and second phases and mean calculation with weighted averages for the third phase. Further descriptive statistics and inferential statistics were done in STATISTICA 13 (TIBCO Software Inc., 2017), a data software system, to calculate summary statistics that described the variables gathered in the third phase.

The distribution of variables was represented in histograms and/or frequency tables with means and mediums used to measure the central location for ordinal and continuous responses. Standard deviations and quartiles were used as indicators of spread for the data. To analyse the relationships between continuous response variables and nominal input variables, appropriate analysis of variance (ANOVA) was used. For responses where ordinal response variables or non-normal data were compared versus a nominal input variable, non-parametric ANOVA methods were used. After the ANOVA analysis, the data was confirmed with the Kruskal-Wallis test, in case the residuals were not normally distributed. A p-value of $p < 0.05$ represented a statistical significance or validity in hypothesis testing that a correlation exists, or does not exist, between variables in the data.

2.7 LIMITATIONS OF THE STUDY

It was observed, during interviews and the final third phase data questionnaires, that companies are reluctant to share data, and this delayed the research timelines. Where companies and individuals declined to take part in the research, the reasons included a loss of competitive market advantages, sharing internal knowledge and sensitive data and time constraints to filling in the questionnaire or being available for interviews.

Updated research data for South Africa's carbon emissions was minimal, with some of the road freight carbon emissions and total emissions for South Africa being outdated. This made it difficult to calculate the reduction potential of carbon emissions. Although the data on carbon emissions for South Africa may not be up to date, the reduction potential of carbon emissions is still relevant. Where data was not available, estimated assumptions had to be made given global or industry standards.

Triangulation of the data was done between the data captured during the research and the FDM. However, the FDM does not include all the researched road freight challenges. Therefore, only a limited amount of data could be used for triangulation. For the purpose of this dissertation, the following assumption was made for the data calculations:

- Due to the complexity of establishing precisely how much carbon emissions can be saved by reducing road freight kilometres, due to various fluctuating variables, it was assumed that the reduction in kilometres would have the same linear decrease to the reduction of carbon emissions and vice versa.

When companies were approached to test the South African road freight decarbonisation SFST, only one company agreed to test the SFST. Due to the nature of the SFST that would entail operational activities to be changed, companies were not willing to accept the risk, should there be any unforeseeable negative impacts by implementing the SFST.

CHAPTER 3 BACKGROUND AND TERMINOLOGY

This chapter is dedicated to explaining the terminology and concepts of the supply chain, sustainability and external factors, which may also influence the number of carbon emissions released in road freight transport.

3.1 SUSTAINABILITY

Every second on earth, a person dies of hunger. In August 2018, the total number of people who had died of starvation since the beginning of 2018 reached over 21 million (The World Counts, 2018). Rain forests are being destroyed, hundreds of animals or species are being driven to extinction, and millions of tonnes of toxins are being released into the environment (Hartmann 2004:2; Anderson, 2012; Alcoforado, 2015). According to the WWF, the earth needs the equivalent of 1.5 planets to sustain the demands humans are currently placing on the environment (WWF, 2014a). The world is making excessive demands on the planet, and the earth's eco-system is suffering as a result. By the year 2050, 2.4 billion people will be added to the world's population. This population will need food, water and energy (WWF, 2014a).

There are marine crises such as cod stock in the North Atlantic having declined from an estimated 264 000 tonnes in 1970 to under 60 000 in 1995. The world's forests have decreased by 12% in 32 years, and humans are dumping toxic radioactive waste into the oceans (Townsend & Burke, 2002). The world needs to start making better choices and select sustainable practices that will help the planet for generations to come. There is a 'One Planet Perspective' that needs to be adopted by companies and people. Figure 3.1 represents the 'One Planet Perspective' developed by the WWF (WWF, 2014a). It is essential to start preserving the natural capital, apply resource governance and redirect the financial flows to produce and consume the earth's resources more wisely. With more sensible and conscious consumption of the resources, it will be possible to maintain ecosystem integrity, conserve the biodiversity and secure water, food and energy for the population (WWF, 2014a).

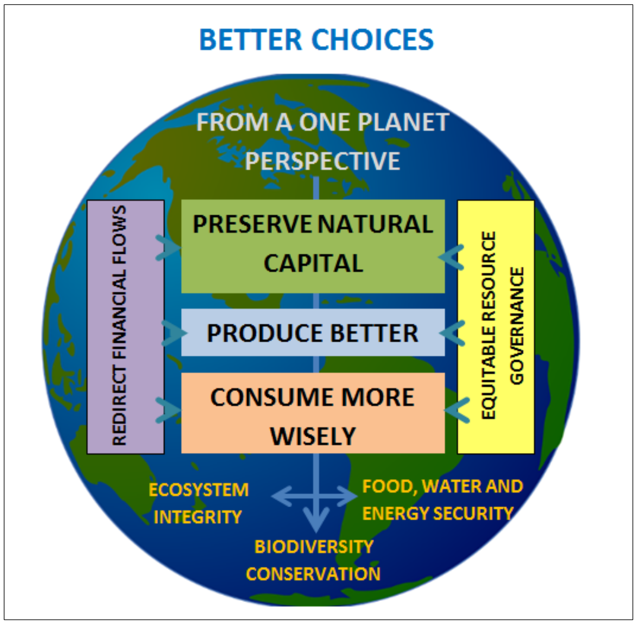

Figure 3.1 WWF's one planet perspective

Source: WWF, 2014a

Focus must be placed on sustainable developments to support and conserve the planet with the increasing population and the demands that coincide with this growth. Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission, 1987:44). Companies are now, more than ever, under pressure to reduce the environmental impact of logistics operations. Operations include moving goods, warehousing and materials handling (McKinnon, Browne, Piecyk & Whiteing, 2015:3). As stated by Kenneth Boulding, a famous British economist in 1966, "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist" (Boulding, 1966).

The Environmental Protection Agency (EPA) states that sustainability can be based on one principle, i.e. that the survival and well-being of humans depends either directly or indirectly on the natural environment. This statement stems from the first world climate conference, which was held in 1979 in Geneva. The conference recognised that the survival of humanity would require humans to live in harmony with nature. By doing this, the world will be able to support both present and future generations (Environmental Protection Agency, 2016a). The United Nations (UN) has highlighted seventeen development goals that will help the planet and its people reach sustainability. Of these seventeen goals, a few might affect the supply chain more than others. Goal nine has a target to develop a quality, reliable, sustainable and resilient infrastructure. This includes road infrastructure. Goal twelve focuses on responsible consumption and production, placing emphasis on water, energy and food to minimise wastage.

The importance of sustainability on a global level can be seen in the goals that the UN has set. The Paris Agreement, which directly links to goal thirteen on climate change, was held on 12 December 2015 to take action to limit the rise of global temperatures to below two degrees Celsius. To date, 194 countries have signed the Paris Agreement with 122 countries having already submitted the plans for Ratification, Acceptance and Approval. South Africa signed the agreement on 22 April 2016 and Ratification, Acceptance and Approval plans were submitted on 1 November 2016. All seventeen goals can be seen in Appendix A.

One driving force of change is the need for sustainable supply chain improvement. With the indications that the world is moving away from an abundance of cheap energy, supply chains will need to adapt to alternative human resources, raw materials and fuelling solutions (Beamon, 2008:7). With fossil fuels providing the bulk of energy inputs to the modern day supply chain, this finite resource is nearing world peak production. There is, thus, a new and increased demand for companies to source renewable (and non-renewable) sources of energy (Beamon, 2008:7). The future supply chain will have to start focusing on more sustainable and renewable sources of energy.

There is a range of published evidence of what global warming is doing to the planet, the net damage and the cost. This is likely to increase significantly over time (Intergovernmental Panel on Climate Change, 2015). NASA and governments have decided that this is a concern of great importance, and there are already serious steps being taken to reduce carbon emissions and the results of climate change. Sweden, Scotland and Australia have already implemented policies to reduce carbon emissions (Vidal, 2006; Nichols, 2015; DecarboniseSA, 2015). South Africa implemented the first phase of Carbon Tax legislation on 1 June 2019. Phase one will be until 30 December 2022, with the second phase coming in play from 2023 to 2030 (Swart, 2019). The tax effectively has two objectives to reach. These are to manage climate change and its impacts effectively and to make a contribution to the global efforts to stabilise greenhouse gases, which are the leading cause of climate change (Hemraj, 2016). The phase-in will assist companies transitioning to adopt cleaner and more efficient technologies and behaviour (The Carbon Report, 2015; Hemraj, 2016). The marginal tax rate will be fully taxable at R120 per ton CO_2 equivalent. CO_2 equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential (OECD, 2013). CO_2 equivalent is a standard use of measure used to convert various different types of global warming gasses into the same amount of equivalent units of CO_2 (The Guardian, 2019). All carbon taxes will be implemented by SARS (Hemraj, 2016).

In 2018, South Africa completed the construction on four of the six power generating units on the Medupi power plant, producing tonnes of carbon emissions yearly and quoted as "the most expensive power plant in the world" (Terra Firma Academy, 2015; Greyling, 2018). South Africa has continuously missed the global decarbonisation target set by the United Nations needed to limit world global warming (PwC, 2014). It is estimated that logistics accounts for around 5.5% of global greenhouse gases. This can mostly be divided between logistical buildings and freight transport (McKinnon, 2010:1).

In 2006, Sweden announced that the country would be the world's first economy to be practically oil free. Sweden will attempt to replace all fossil fuels with renewable sources to stifle climate change and to be independent of the growing oil scarcity by 2020 (Vidal, 2006). Scotland also followed suit by setting a policy to decarbonise the nation's electricity generation by 2030 (Nichols, 2015). Globally, countries are beginning to switch over to sustainable and environmentally friendly means of transportation and energy.

The South African National Energy Development Institute (SANEDI) stated that a national programme would be critical to making contributions to the reduction of energy consumption and carbon emissions. Global energy demands are on the increase, and natural resources are depleting. For economic development and global welfare, sustainable energy and the impact of fossil-based fuels on the environment, SANEDI was established to conduct research and apply energy research, development, demonstration and deployment (SANEDI, 2013).

The year 2016 in total, was recorded as the hottest overall year the planet has seen in 136 years (NASA, 2016a). To date, global temperatures have risen, to cause nine of the ten warmest recorded months in history, all occurring after the year 2000. The Arctic summer sea ice is decreasing by 13.4% per decade, resulting in land ice decreasing by 281 gigatonnes per year and sea levels rising by 3.4 millimetres per year (NASA, 2016b). The future effect of climate change on the planet will be increased temperatures, seasonal changes, droughts and heatwaves, more intense and stronger hurricanes and the Arctic becoming virtually ice-free (NASA, 2016c). According to NASA (2013), the rise in CO_2 emissions has a direct relationship to the amount of fossil fuel burned. As seen in Figure 3.2, there has been a substantial increase in CO_2 levels for the past sixteen years.

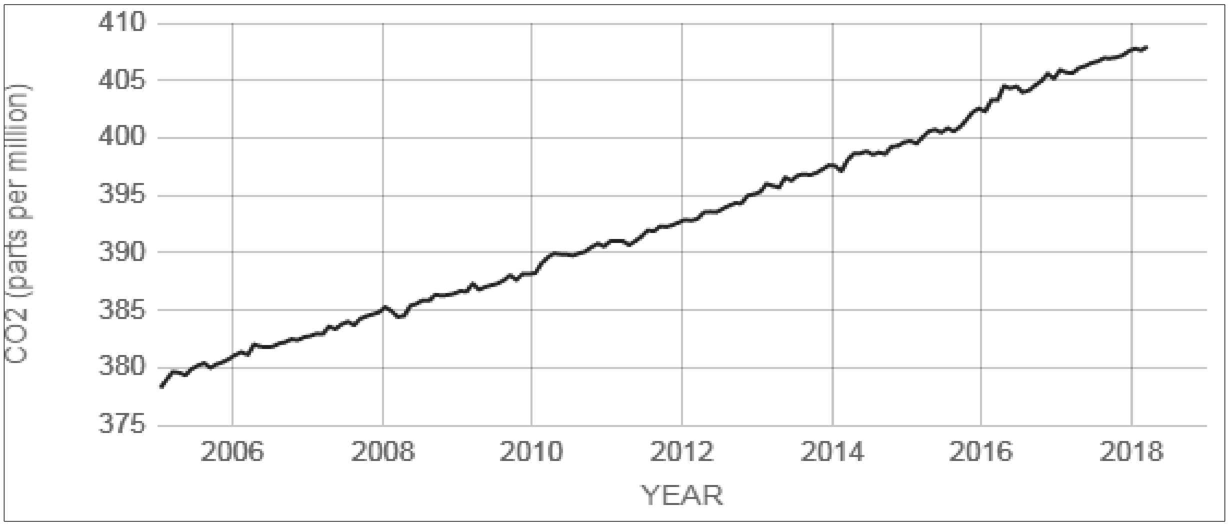

Figure 3.2 Atmospheric CO_2 levels - parts per million

Source: Adapted from NASA, 2018

Climate change mitigation would be promoted by reducing the heat-trapping greenhouse gases in the atmosphere. Reducing the gases would require reducing the source of the gas emissions (NASA, 2016d). One such source is the transport sector. The transport sector produced 7.0 gigatonnes of CO_2 equivalent ($GtCO_2eq$) and was responsible for 23% of the total energy-related CO_2 emissions in 2010 (Sims, Schaeffer, Creutzig, Cruz-Núñez, D'Agosto, Dimitriu, Figueroa Meza, Fulton, Kobayashi, Lah, McKinnon, Newman, Ouyang, Schauer, Sperling & Tiwari, 2014).

3.2 SUPPLY CHAIN MANAGEMENT

To understand supply chain management, one must also be able to explain what a supply chain is. A supply chain, as defined by Chopra and Meindl (2003), "consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves". A supply chain, thus, includes the point of origin to the point of consumption. The supply chain integrates the flow of products, information and financials. Figure 2.1 is a simple representation of the supply chain and how all the nodes are linked within the chain. Products, services, information and finances extend and cross boundaries throughout the supply chain. Products and services are a two-way flow showing the importance of reverse systems to be in place for both suppliers and customers. Sharing information on a timeous manner is essential for suppliers and their customers to make accurate decisions on the information, which is provided.

Lastly, finances (or cash) are critical to ensuring a healthy cash-to-cash or order-to-cash cycle (Langley, Coyle, Gibson, Novack & Bardi, 2009:70).

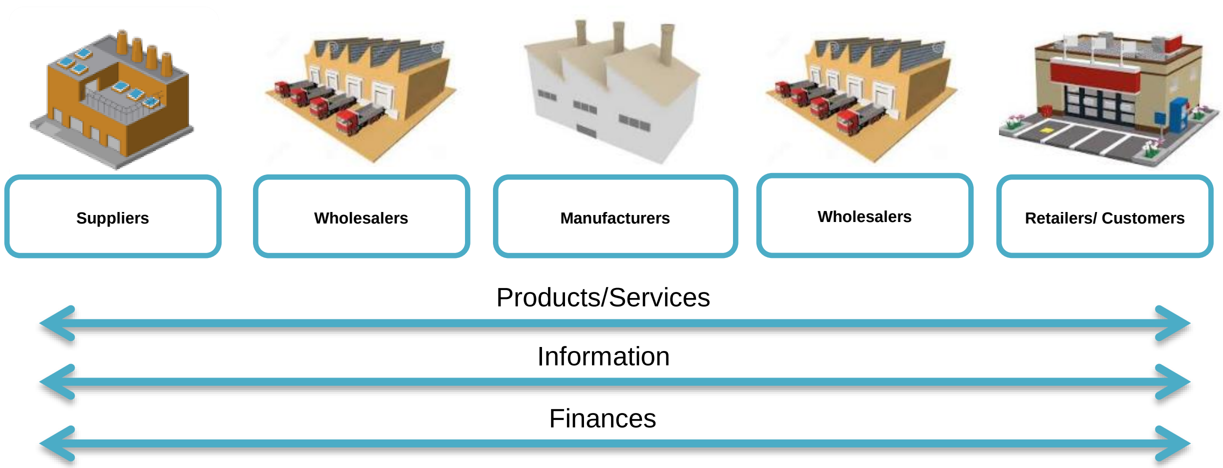

Figure 3.3 A simple representation of the supply chain

Source: Adapted from Langley *et al*., 2009:70

Globalisation and population growth have played a significant role in the growing supply chain management environment. The trend of globalisation has led to an increased number of companies being involved in activities, such as importing and exporting, ensuring customers receive goods and services faster, cheaper and more reliably (Coronado, 2015). The results have been supply chains becoming more agile, responsive and competitive to differentiate themselves from others (Temple, 2013). Globalisation has called for supply chain management to be more coordinated between all the supply chain nodes. As stated by Hugos (2011:40), supply chain management is the "coordination of production, inventory, location, and transportation among the participants in a supply chain, to achieve the best mix of responsiveness and efficiency for the market being served".

During the course of supply chain evolvement, numerous definitions of what supply chain management is, have become available. The APICS dictionary (Blackstone, 2013) defines supply chain management as "the design, planning, execution, control and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply chains with demand, and measuring performance globally" and Handfield (2011) states that supply chain management is based on two core ideas: products reaching its end users with a cumulative effort from numerous organisations, and supply chains not looking beyond the companies' own scope. Supply chains have now started to actively manage the activities within the supply chain to achieve a sustainable competitive advantage to maximise customer value (Handfield, 2011). Further definitions of supply chain management also include "a set of approaches utilised to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimise system-wide costs, while satisfying service level requirements" (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008).

3.3 SUPPLY CHAIN SUSTAINABILITY

Companies today are realising the importance of sustainability and the immediate actions that need to be taken in terms of how resources are used. For the long term, sustainability is essential for a company's success, profitability and economy (Ansari & Qureshi, 2015:24). Sustainability must now be an integrated part of a company's supply chain incorporating sustainability in all its existing supply chain practices (Ansari & Qureshi, 2015:24). There are crucial differences in how traditional supply chains were managed compared with how a new sustainable supply chain is managed. Traditional supply chains only focus on the elements connecting the point of origin to the point of consumption and not all the environmental and economic issues these connections might have caused (Ansari & Qureshi, 2015:24). The boundaries and extensions of the channels in the supply chain resemble the traditional structure of the channel elements involved, such as distribution and marketing. The elements prior to the point of origin were rarely given attention, nor were the elements prior to consumption (Svensson, 2007:212). Figure 3.4 shows the different approaches between traditional supply chain management and sustainable supply chain management. As seen in Figure 3.4, recycling before the point of origin and the after the point of consumption was not given the proper attention. Some of the key differences between traditional supply chain management and sustainable supply chain management are provided in Table 3.1.

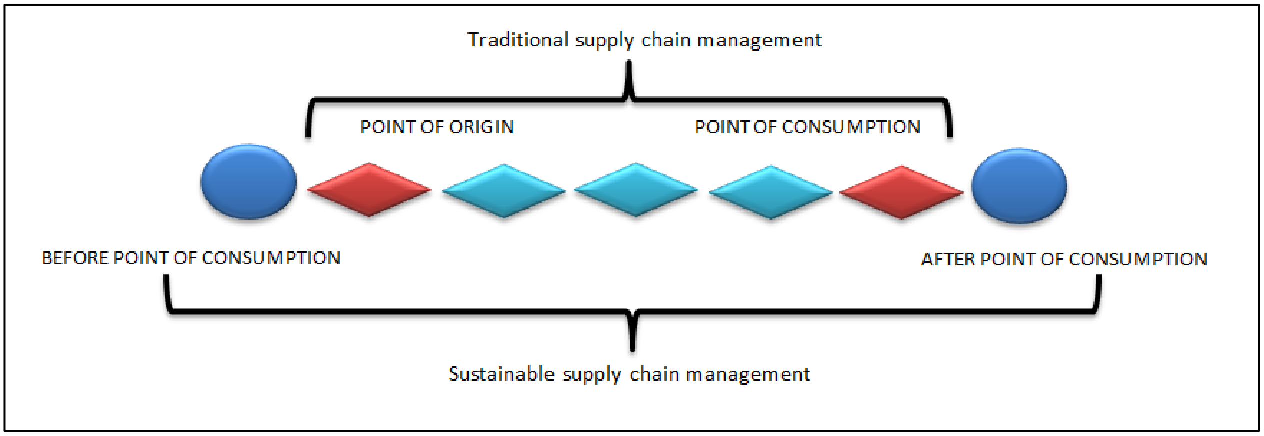

Figure 3.4 Traditional supply chain management vs sustainable supply chain management

Source: Adapted from Svensson, 2007

Table 3.1 Differences between traditional and sustainable supply chain management

Differences between traditional supply chain management and sustainable supply chain management	
TRADITIONAL	**SUSTAINABLE**
The focus is placed on the elements connecting the point of origin and the point of consumption.	Social and environmental issues are considered in the supply chain.
Company and consumer purchases do not consider any environmental issues.	Purchasing strategies include green purchasing strategies and environmental purchasing.
Environmental significance and protection are not given in any marketing strategies for the product or service.	The product or service is given green and/or environmental marketing and marketing management.
ISO certification is not an integral part.	Includes ISO-14000 certification.
Supply chain does not include reverse logistics as an integral part.	Supply chain does include reverse logistics as an integrated part.
Waste reduction during manufacturing is not given.	Reducing waste during production is emphasised upon.

Source: Adapted from Ansari & Qureshi, 2015:30

The importance and reasoning behind supply chain sustainability for companies are not purely for environmental protection. Possibly the primary reason behind supply chain sustainability is ensuring compliance and adherence to laws and regulations. This compliance and adherence are also supported by international principles for sustainable business conduct (United Nations, 2010). Companies are starting to become more sustainable, not only because society expects this, but also because there are business benefits to becoming more sustainable (United Nations, 2010). A regulation, such as ISO 14000 (which is a family of standards) is an example of new international environmental responsibilities. ISO 14000 provides management tools for companies to manage environmental aspects and to access environmental performance. These tools include reducing the use of raw materials and resources, reducing energy consumption, improvements on process efficiencies, reduced waste generation and disposal costs, and utilisation of recoverable resources (ISO, 2010).

Failure of climate change mitigation and adaption was highlighted as the number one global impact risk in the annual 2016 Global Risk Report by the World Economic Forum (WEF, 2016). This risk rated higher than weapons of mass destruction, and it is the first time this risk climbed to the number one spot. Climate change is also rated in the ten most-changed risks when comparing 2015 to 2016 (WEF, 2016). Figure 3.5 represents all the top global risks as defined by the WEF (2016). Risks are rated on the impact and highest likelihood of the risk being realised.

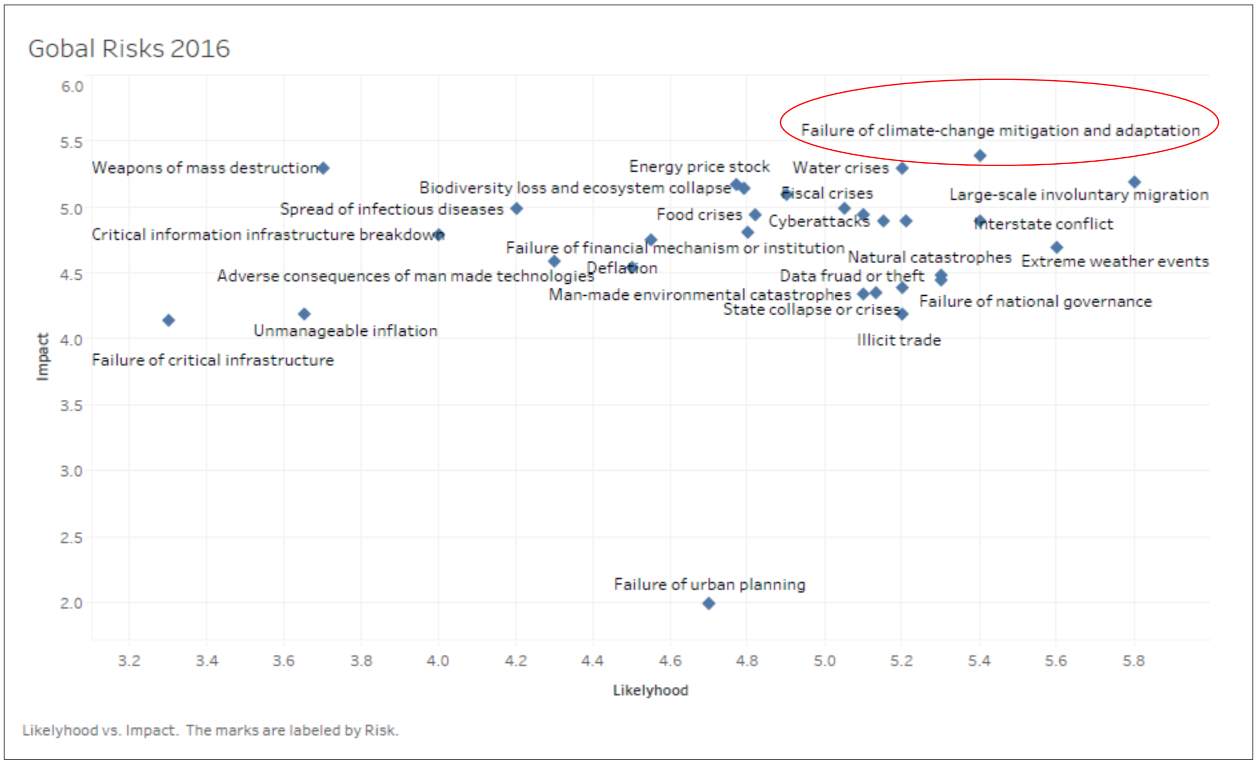

Figure 3.5 The global risk landscape 2016

Source: Adapted from World Economic Forum, 2016

The adoption of the Paris Agreement was a historic turning point for countries agreeing to make climate change a priority and to actively provide and implement plans to fight the battle against increasing global temperatures. One of the commitments in the agreement is to start decarbonising portfolios, the issuing of green bonds or to start supporting more robust carbon-pricing initiatives. To decarbonise, as defined by the Oxford Living Dictionary (2017) is to "reduce the number of gaseous carbon compounds released in or as a result of (an environment or process)". The implementation of decarbonisation can range from industrial processes such as manufacturing, the energy sector and transportation. For the purpose of this dissertation, the focus is placed on road freight decarbonisation.

Road freight decarbonisation can include methods such as shifting from a high intensive fossil-fuel base to a lower carbon renewable based fuel mix or by lowering energy usage by placing more focus on energy output efficiency (PwC, 2012; United Nations Environment Program, 2015; Mulder, 2013:16-17; Kannan, Diabat, Alrefaei, Govindan & Yong, 2012:58). Detailed methods of decarbonisation are discussed in Chapter 3.

3.4 CORPORATE SOCIAL RESPONSIBILITY AND THE PILLARS OF SUSTAINABILITY

Companies are now more than ever aware of the choices made about products, which can have substantial environmental and social implications (Sarkis, 2001:667). Corporate social responsibility (CSR) is a tool used for enhancing companies' reputations and also to create goodwill among customers (Chernev & Blair, 2015). Studies show that chief financial officers believe CSR can create value by improving a company's overall reputation (McKinsey & Company, 2009a) and even have an impact on employee attitudes and perceptions of how people outside the company are treated (Glavas & Kelley, 2014:2). CSR has a positive relationship with employee performance, commitment, the attractiveness of future employees and organisational citizenship behaviour (Glavas & Kelly, 2014:2). McKinsey & Company (2009b) believes partnering may help companies overcome hurdles associated with CSR; strengthening a business while contributing to society at the same time.

Partnering between society and business, as seen in Figure 3.6, has the highest benefits to both parties involved. The benefits decrease as businesses step into the propaganda section, not delivering what was promised, and philanthropy tends to benefit one party more than the other. Many companies still see CSR as 'pet projects' that need to happen and only reflect what the senior executives see as relevant. These types of projects have little benefits to the company or society. Propaganda and philanthropy are used to create good reputations for companies, but these types of activities can generate low benefits that are often only one-sided. The best opportunity to create the most value for both society and business is to create a partnership with companies who have mutual benefits with long-term strategic goals that are in line with the companies' overall goals. A good example of such a partnership is Unilever's partnership in India with local rural villages. These villages are sometimes difficult and costly to reach. Unilever appointed women entrepreneurs in local villages to help sell products and make them more accessible to the locals, while also engaging and encouraging women to build self-esteem and independence (McKinsey & Company, 2009b). In this aspect, Unilever made use of the local culture to improve upon their business strategy, together with anchoring their relationships with the residents and customers. This links to Hawks' pillars of sustainability. The sustainability pillars are widely known as the three pillars of sustainability, which are social, environmental and economic. As Scott-Cato (2009:36) explains in *Green Economics,* the pillars were traditionally seen to interact, but are not interdependent. Figure 3.7 represents the traditional view of the three pillars of sustainability with all pillars contributing an equal weight and importance. The pillars are drawn in equal size and equal importance. Scott-Cato (2009:37) states that in the *Green Economics* paradigm, the economy operates within the social relationships and that society is embedded within the natural world. Thus, each of the pillars is embedded within the others, as seen in Figure 3.8. The economy carries more influence in reality, such as decision-making, with the society bearing the costs and the environment paying the most substantial price (Scott-Cate, 2009).

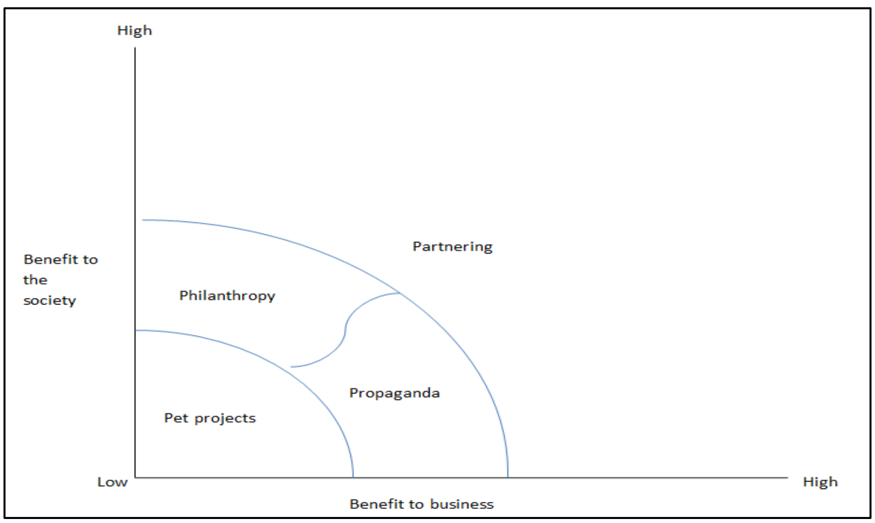

Figure 3.6 Mapping partnering for corporate social responsibility

Source: Adapted from McKinsey & Company, 2009b

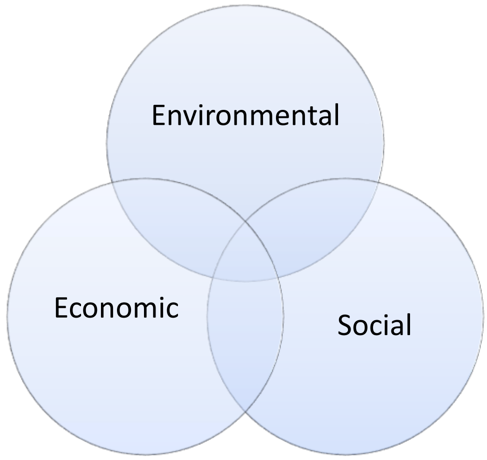

Figure 3.7 Traditional view of the three pillars of sustainably

Source: Adapted from Green Art Lab Alliance, 2016

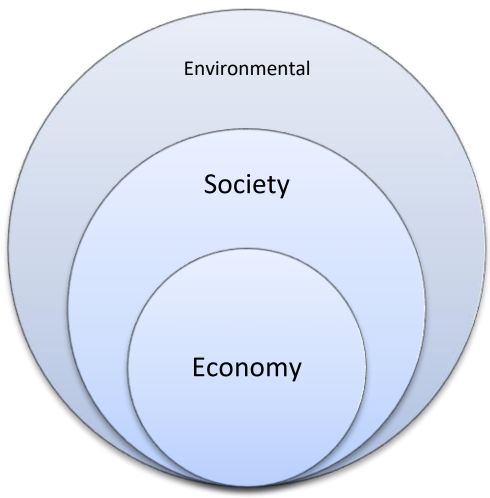

Figure 3.8 Green Economics paradigm of sustainability

Source: Adapted from Scott-Cato, 2009:37

Hawks (2001) argued that there is also a fourth pillar of sustainability, which plays a crucial role in society and decision-making. The fourth pillar is culture. According to Hawks (2001), the value basis on which a society is built is expressed in its culture. The fourth pillar is essential to building a healthy and sustainable society. The importance of this is understood by Unilever's example of making use of local culture to expand their business, as well as helping the locals by empowering local entrepreneurs. Hawks (2001) states that in order for public planning, environmental responsibility and economic viability to be successful, the methodology of culture should be included. Figure 3.9 represents Hawks' four pillars of sustainability, the fourth pillar, culture, encircling all the other traditional pillars. Apart from CSR, it is compulsory for listed companies in South Africa to report upon corporate governance. The following section provides an overview of corporate governance in South Africa.

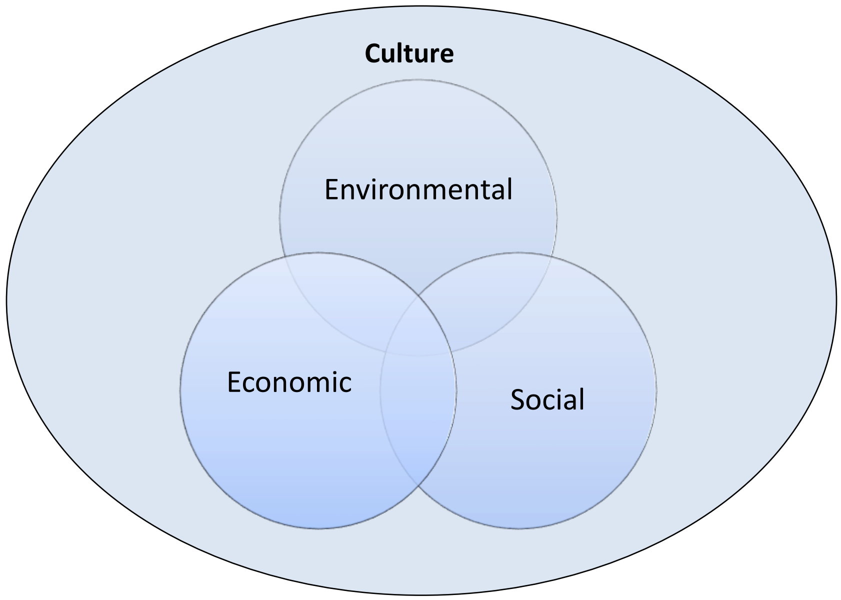

Figure 3.9 Hawks' four pillars of sustainability

Source: Adapted from Green Art Lab Alliance, 2016

3.5 THE FINANCIAL IMPACT OF CORPORATE SOCIAL RESPONSIBILITY

CSR and the financial impact (positive or negative) it may have on a company has long been a debate (RobecoSAM, 2014; Lu, Chau, Wang & Pan, 2014). RobecoSAM, a sustainable investment firm in Switzerland, explains in a white paper research “Alpha from Sustainability” that there is a positive relationship between corporate sustainability and financial performance (as measured in stock turns) (RobecoSAM, 2014). RobecoSAM argues that companies who introduce long-term sustainable opportunities and risk as part of their long-term strategy will benefit from the effective management of these risks, such as climate change, resource scarcity and demographic changes. These companies become leaders in sustainability and are more likely to prosper over a longer term than companies that forsake sustainability.

Lu *et al*. (2014) conducted a study on a decade’s worth of empirical relationship studies between CSR and corporate financial performance (CFP). The authors found that, while many of the research studies show a positive relationship, the results remain inconclusive regarding a relationship between CSR and CFP. This conclusion from the authors is based on the variety of results of the empirical studies, which varied from positive to negative and neutral. Thus, no consistent result could be found from all the studies (Lu *et al*., 2014). Nollet, Filis and Metrokosas (2016) found that there are no significant linear trends between CSR and corporate social performance (CSP). The study used two accounting measures (return on capital and return on assets) and one market-based measure (excess stock returns) as performance indicators. The study mentions, however, that there is a relationship between CSR and CSP, thus implying in the study that CFP is only positive after a certain threshold of long-term investment has taken place on CSR to improve corporate social performance. A conclusion was also derived that effective CSR can attract investors and stakeholders to a company, but in order to serve investors and stakeholders, long-term planning and resources should be dedicated to CSR (Nollet *et al*., 2016).

Rodriguez-Fernandez (2015) found positive results in the study of corporate social responsibility and financial performance. The study included 107 Spanish companies listed on the Madrid Stock Exchange and investigated the bidirectional relationship between CSR and CFP. Results showed a positive bidirectional relationship between CSR and CFP and those companies that increased CSR expenditure displayed improved financial results (Rodriguez-Fernandez, 2015).

It may seem that, across all studies done on the relationship of CSR and CFP, that a positive result can be achieved if companies place enough emphasis and invest sufficiently on CSR. CSR makes a company more desirable for investment opportunities and creates positive social value for customers.

3.6 FACTORS INFLUENCING ROAD FREIGHT EMISSIONS

Carbon emissions can either decrease or increase given certain externalities. Section 3.6 provides an overview of these external factors and how the factors have a relationship with carbon emissions.

3.6.1 The TIMBER framework

The TIMBER framework consists of six external factors that may contribute to logistics carbon emissions. The six factors are technology, infrastructure, market, behaviour, energy and regulation (Havenga, Goedhals-Gerber, Freiboth, Simpson & de Bod, 2015). New technologies, such as low-carbon technologies for trucks, can decrease carbon emissions. Further technology developments also include adopting automatic transmission and installing anti-idling devices (McKinnon, 2015c).

Infrastructure can also play a key role in carbon emissions. Depending on the volumes being moved, choosing what mode of transportation will be used is the first step, as waterways and pipelines are more carbon-friendly modes of transportation. Congestion can also increase carbon emissions, and route planning can be implemented to choose routes with less congestion. Warehouse locations also play a role because warehouses located far away from the direct demands, lead to more time travelled between warehouses and customers. Remote locations also lead to excessive refuelling (McKinnon, 2015c).

Market opportunities exist in the form of collaboration with transport companies. An increase in vertical and horizontal agreements can result in less empty-running trucks and inefficient loading of trucks. The increase in rail competitiveness can decrease the use of road transportation, which, in turn, will lower the carbon emissions from the road freight transport sector. Behavioural adjustments can be made by training drivers on eco-friendly driving methods and by incorporating technological advances by way of vehicle control devices. Energy consumption can be decreased by the use of biofuels, electric vehicles and the use of fuel additives. The role of regulation can speed up the process of industries switching to lower-carbon technologies at a faster rate. Increasing industrial standards to adopt and manage the truck size and weight limits will, in turn, enforce more regulations to follow and force companies to adapt from current to a future state of lower carbon emissions (McKinnon, 2015c).

3.6.2 Hijacking

Data shows that truck hijacking in South Africa displayed a steady linear increase from the year 2013 onwards. In recent years, 2015 saw a high number of truck hijacking incidents, namely 1 279 reported incidents. The year 2016 saw a slight decline and had a total of 1 184 incidents. However, 2009 ranked highest with a total of 1 437 reported incidents (CrimeStats SA, 2018). Figure 3.10 represents the data from Crime Statistics SA in which the linear increase of truck hijacking can be seen.

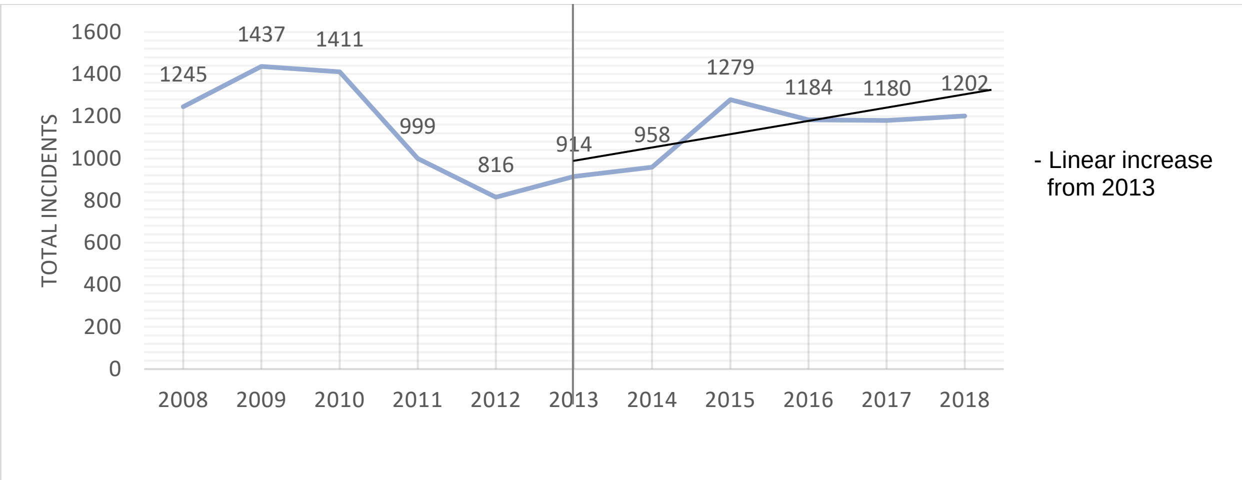

Figure 3.10 The number of truck hijacking incidents in South Africa

Source: Adapted from CrimeStats SA, 2018

The most popular trucks being targeted are those carrying freight such as fuel, cigarettes, electronic goods and food (Venter, 2014). A 3-axle truck carrying cigarettes can be worth roughly R20 million, says Slabbert (2014). Rautenbach (2016) reported that truck hijacking has contributed to an R3 billion loss in the South African economy. On top of the value lost on stolen goods, companies also have to replace the stolen goods (De Klerk, 2015). This inevitably means that companies need to replace customers' orders (redistribute the orders again), which leads to unplanned trips, more carbon emissions and costs the company did not plan for. Hijacking can also lead to an intense emotional memory and can influence an individual's thought pattern and actions (Lamia, 2012).

3.6.3 Strikes

During a South African strike in 2012, gunshots were directed at trucks delivering sugar. Farmers delivering the sugar had to reroute trucks or stopped delivering goods altogether for fear of safety (Möller, 2012). Strikes in South Africa have a tendency to turn violent, hindering standard route planning and deliveries. During a transport strike, in 2012, working truck drivers were assaulted. A 10-tonne truck was stoned in Boksburg and police had to escort the truck back to its depot. Numerous trucks were also set alight in 2012 (Figure 3.11), resulting in road closures (News24, 2012). In 2018, 54 people were arrested due to violent protests at the Mooi River toll plaza in KZN, where 35 trucks were damaged, looted or set alight. The protest actions led to the closure of the N3 for 24 hours (Wicks, 2018). Strike actions result in more futile trips, which increase the number of carbon emissions on road freight.

Figure 3.11 Truck set alight in the 2012 transport strike

Source: News24, 2012

3.6.4 Theft

Cargo theft also poses a risk in South Africa. While a truck might be hijacked and cleared of all goods, smaller thefts, such as looting also remain a problem. Looting can occur when a truck is stationary for too long, making a looting opportunity possible. An example of an incident that was reported in terms of looting was Coca-Cola in 2017 when a stationary truck was looted of its soft drinks cargo. The incident took place in Butterworth, Eastern Cape. Coca-Cola trucks have open side panels, which makes looting easy. While the truck was stuck in congestion, pedestrians cut the straps of the cases and began looting the truck (News24, 2017). A similar incident occurred near Glenvista in Johannesburg in December 2016. The looted truck had broken down on the N12 (The Citizen, 2016). In November 2018, a stationary RTT Logistics truck, trapped under a low-hanging bridge in Boksburg, was looted of its cargo (Rood, 2019). Another incident occurred in October 2018, where a SAB truck was looted in a Port Elizabeth township while the truck was busy off-loading beer to a client (Unknown, 2019). All of these incidents may indicate a trend in South Africa where stationary trucks in possible unsafe areas, may be looted.

3.6.5 Delivery challenges

Supply chain uncertainty can reduce the reliability of delivery schedules, which may have a knock-on effect further down the supply chain. Delays at delivery and collection points, truck breakdowns and congestion can lead to missed delivery times (slot times) and longer travelling distances, impacting the overall performance of the transport operations (Sanchez-Rodrigues, Potter, Naim, McKinnon & Darby, 2010). Slot times are the specific time slots allocated to a truck for a delivery to take place. Trucks are allocated a particular delivery timeslot during which goods must be delivered. In the South African road freight industry, it is common for businesses to use the term 'slot time' rather than delivery time or time slot. This is to prevent bottlenecks at the offloading site and ensures efficient planning for the offloading of the goods. Sanchez-Rodrigues, Potter and Naim (2007) identified four challenges in the UK supply chain that hinder the sustainability of the transport sector.

Delays, delivery challenges, coordination as well as demand, and inventory management were the main themes identified during a focus group study with UK practitioners and policymakers. Delays were caused by congestion, supply disruptions and operational problems with loading and unloading. Delivery challenges occurred due to delivery curfews, restricted delivery windows and limited storage capacities. Should a delivery challenge occur, instances may take place where the truck would need to deliver the same goods to the same destination at a different time. Volatile customer demand, incorrect demand forecasting, the lack of information sharing and poor inventory policies lead to demand and inventory management challenges and also result in poor logistical execution. Lastly, the coordination of transport flexibility, the disconnect of poor communication between sales and logistics and the lack of carrier-customer integration resulted in logistical expectations that could not be met (Sanchez-Rodrigues *et al.,* 2007). These four challenges can lead to unnecessary trips, which could have been prevented.

3.6.6 Driver behaviour and vehicle energy efficiency

Research, such as Scania's eco-driving programme (FleetCarma, 2014), has shown a strong relationship between fuel efficiency, vehicle efficiency and driver behaviour. Scania's programme focuses on more rollout, less harsh braking, less idling, less hard accelerations, less high revolutions per minute, and more use of cruise control. This has resulted in a saving of between 10% to 30% on fuel consumption, which can be directly linked to driving behaviour. MasterDrive South Africa has also reported savings of almost 15% (Kimberley, 2018) when focusing on driver behaviour in the MasterDrive programme, with a similar focus being placed on the same aspects as in the Scania eco-driving programme. FleetCarma, a clean-tech company based in Canada, provided a detailed analysis of how fuel consumption can decrease when the correct measures are taken to improve driver behaviour. Some of the results shared by the company are how hard acceleration and braking can affect the fuel efficiency of a vehicle. Figure 3.12 highlights the fact that as hard acceleration and hard braking increase towards 50%, fuel efficiency decreases. This is also seen by the linear decrease line in both of the graphs.

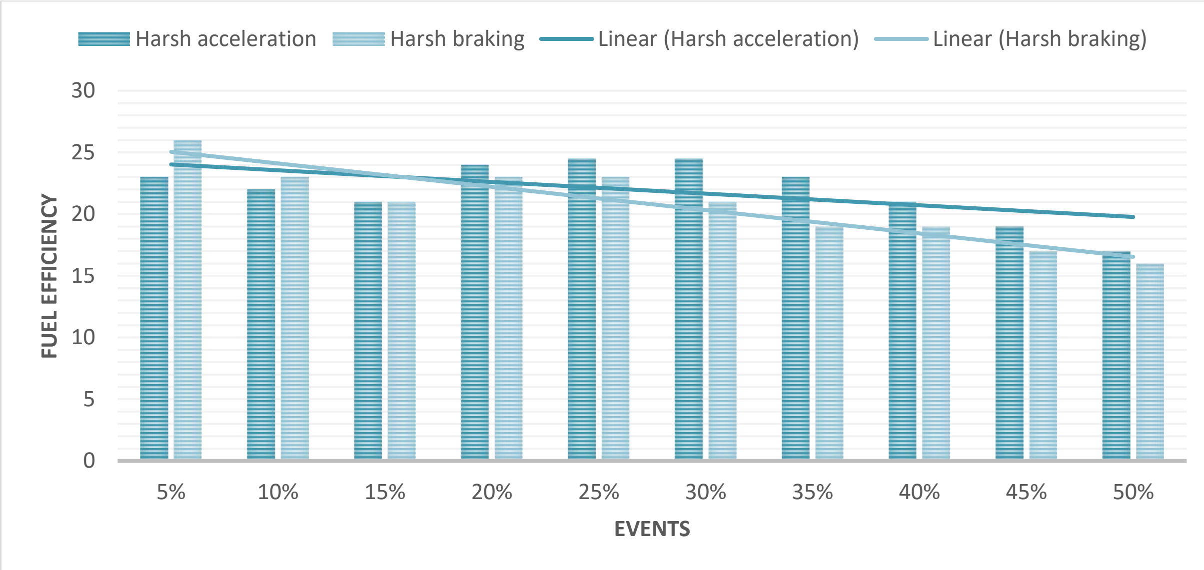

Figure 3.12 Harsh braking and hard acceleration on fuel efficiency

Source: Adapted from FleetCarma, 2014

It can be concluded from these references that driver behaviour affects the fuel efficiency of a vehicle, thus also impacting the number of carbon emissions released. Another impact on fuel efficiency is the amount of fuel used by the vehicle per kilometre travelled. With new vehicle technologies emerging, companies are focusing on manufacturing vehicles with increased fuel efficiency and lowered carbon emission outputs. An example of this is the various upgrades of the Euro Emission Regulation to which heavy-duty trucks are being manufactured. A summary of the various Euro Emission Regulation standards for heavy-duty trucks can be seen in Table 3.2 where it can be observed how carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_x), particulate matter (PM) and smoke standards decreased with new standards being introduced. Particulate number (PN) has only been introduced since Euro VI and this focused on the actual particulates of emissions in real-time driving as opposed to PM, which is the calculated mixture of solid particles and liquid droplets emitted into the air (Environmental Protection Agency, 2016c; Kirchner, Gallus, Börensen & Vogt, 2013).

Table 3.2 Summary of Euro truck standards

Stage	Date	CO	HC	NO_x	PM	PN	Smoke
		g/kWh				*1/kWh*	*1/m*
Euro I	1992, ≤ 85 kW	4.5	1.1	8.0	0.612		
	1992, > 85 kW	4.5	1.1	8.0	0.36		
Euro II	1996.10	4.0	1.1	7.0	0.25		
	1998.10	4.0	1.1	7.0	0.15		
Euro III	*1999.10 EEV only*	*1.5*	*0.25*	*2.0*	*0.02*		*0.15*
	2000.10	2.1	0.66	5.0	0.10[a]		0.8
Euro IV	2005.10	1.5	0.46	3.5	0.02		0.5
Euro V	2008.10	1.5	0.46	2.0	0.02		0.5
Euro VI	2013.01	1.5	0.13	0.40	0.01	8.0×10^{11}	

Source: Adapted from the European Union Law, 2007

In addition to the Euro Emission Regulation standards, many more technologies have joined the fight against excessive fuel consumption that leads to more carbon emissions. Other initiatives also include cylinder deactivation, which can increase fuel efficiency by 5% and allows specific cylinders to be turned off when not in use. The use of turbochargers can increase the power of an engine, allowing smaller engines to be installed without sacrificing performance. Fuel efficiency can increase by up to 8%, and valve timing and lift technologies can increase the engine efficiency by improving and optimising the flow of air and fuel at various engine speeds. The latter can increase fuel efficiency by 3% to 4% (National Research Council, 2015).

It is then concluded that the more efficiently the driver of a truck behaves, and the more fuel-efficient the vehicle itself is (fewer litres used per kilometre travelled), fewer carbon emissions will be emitted as less fuel will be used that is contributing to the carbon outputs of the vehicle. For the purpose of this dissertation, the average energy efficiency of 5% is used for calculations in mechanical efficiency and a driver behaviour efficiency of 15% is used.

3.6.7 Road infrastructure

Research has shown that the amount of emissions being released by road freight has a strong relationship to road infrastructure (European asphalt pavement association, European concrete paving association & Forum of European National Highway Research Laboratories, 2016). Better maintained road infrastructure leads to more efficient performance of vehicles with regards to CO_2 emissions. Research conducted by three European pavement industries argues that road pavement directly influences increases in vehicle fuel consumption (Chatti & Zaabar, 2012), energy losses in the suspension systems and loss of contact between the tyre and pavement through uneven roads.

Emissions can be reduced through road maintenance strategies. Deterioration of pavement also leads to increased journey time, congestion and crashes (Setyawana, Kusdiantorob & Syafi'i, 2015:425). Setyawana *et al*. (2015:429) found a very high coefficient of correlation between declined vehicle speeds (as a result of poor road conditions) and increased emissions being released as a result of these slower speeds. It was estimated in the study that the average emissions increased by 2.49% on poor road conditions. According to the South African National Roads Agency Limited (SANRAL) 2014 report, South Africa has a total road network of approximately 750 000 km; this includes the 130 000 of unclaimed roads. Of this, 158 000 km are surfaced and 592 000 km are gravel roads. Only 38% of South-Africa's surfaced road are classified as good, while 36% are fair and 26% are classified as poor. Gravel roads show a staggering 67% in poor conditions, with only 8% classified as good (SANRAL, 2014) (see Figures 3.13 - 3.14).

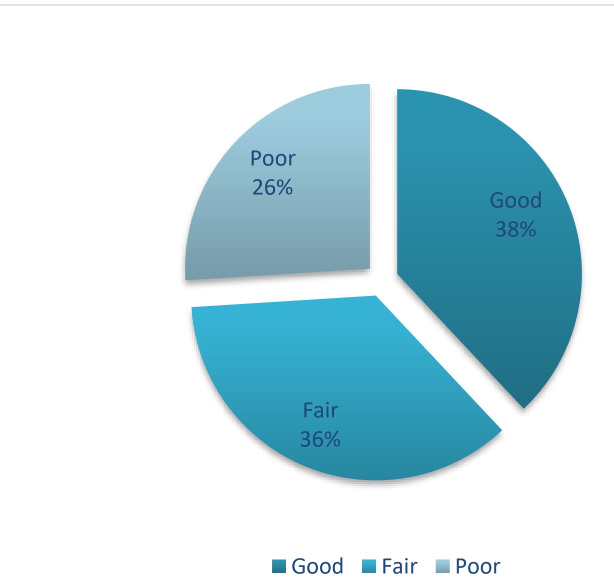

Figure 3.13 Surfaced roads in South Africa
Source: Adapted from SANRAL, 2014

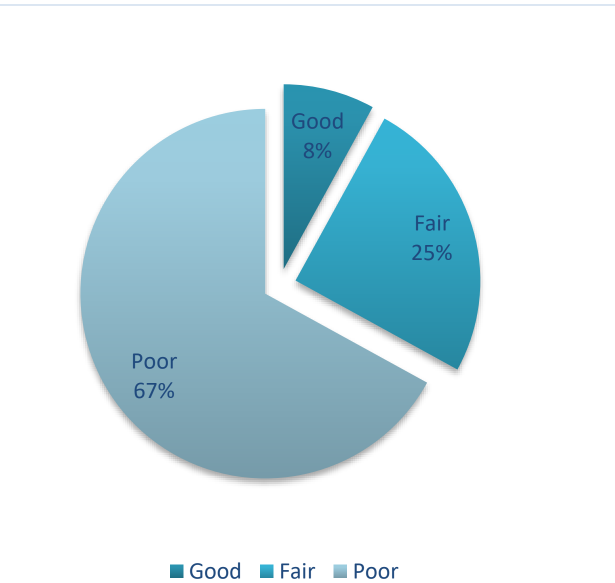

Figure 3.14 Gravel roads in South Africa
Source: Adapted from SANRAL, 2014

The condition of the roads also has a financial impact on the maintenance cost of the vehicles. Roads in poor condition claim a higher cost per kilometre than well-maintained roads. This leads to an increase in the standard vehicle operation costs (SVOC) as claimed by the Council for Scientific and Industrial Research (CSIR) (2015). Table 3.3 was compiled by the CSIR to highlight the difference in SVOC when different road networks are being used with deteriorated roads having as high as a 15% increase in SVOC when travelling along these routes.

Table 3.3 SVOC for different routes

Network Condition Scenario	Percentage increase in SVOC compared to the perfect road network	Estimated increase in annual heavy vehicle operating costs
Ideal	2%	R3 billion
National	5%	R0.8 billion
Provincial	9%	R12.2 billion
Deteriorated	15%	R22.5 billion

Source: Adapted from Roux, Sallie, Nordengen, Ras & de Franca, 2004

The South African road network can be further broken down into three movement type segments of corridor, metropolitan and rural (Havenga *et al*., 2016). The freight transport that uses these divisions makes use of public infrastructure. The definitions of the three types of movements can be seen in Table 3.4. As per the Logistics Barometer of 2015, corridor movements are still the main movement type when it comes to general freight systems of road transportation, as seen in Figure 3.15. The explanation of the movement types can be seen in Table 3.4.

Table 3.4 Three different types of freight movement in South Africa

Movement type	Description
Corridor	▪ Occur along with a defined geographical route, typically between major metropolitan areas and ports. ▪ Variable in length depending on their specifically identified Origin/Destination points. ▪ Examples: Cape Town to Gauteng and Durban to Gauteng corridors.
Rural	▪ Characterised by dispersion of Origin/Destination points. ▪ Generally movements of agricultural or other primary products direct to ports or urban hubs where goods may be processed or transferred to other modes or into corridor routes.
Metropolitan	▪ Movements that occur within metropolitan areas. ▪ Generally either the first or last component of more extended movement, or movements between independent origin and destination points within metropolitan areas (from the warehouse to a retailer).

Source: Adapted from Republic of South Africa: Department of Environmental Affairs, 2014

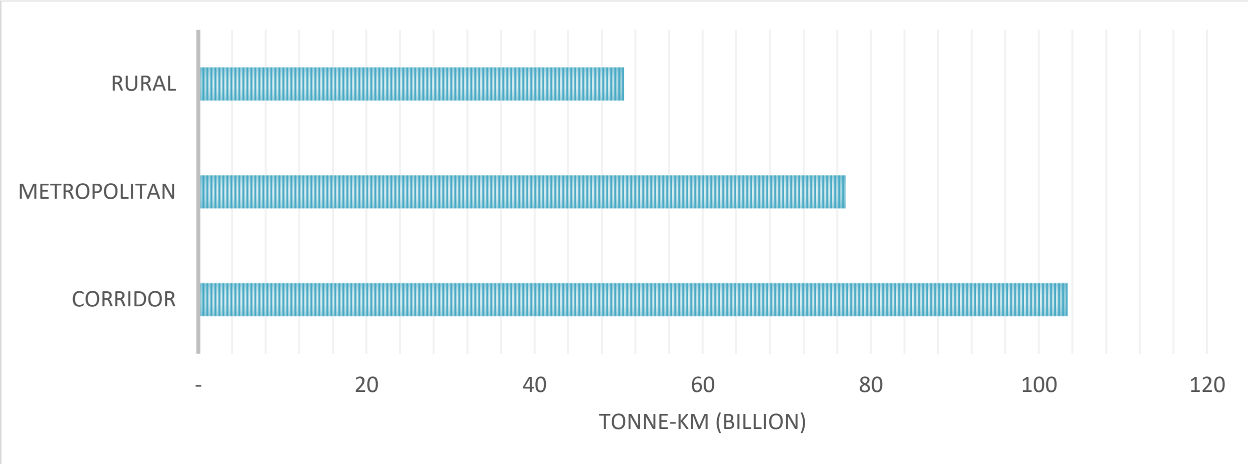

Figure 3.15 Freight system split of road transportation

Source: Adapted from Havenga *et al*., 2016

In addition to the different road infrastructures, each of the different infrastructure types also have different carbon intensities. The CSIR conducted research to indicate the environmental impact that South Africa's different road infrastructures have on carbon emissions and how road roughness increases the carbon emissions as the kilometres per hour increases on the road when measured against the International Roughness Index (IRI) (Mashoko, Bean & Steyn, 2014). It can be concluded when examining Table 3.5 that the carbon emissions output increases as speed increases.

Table 3.5 IRI and carbon emissions for different road conditions

	Weighted IRI (m/km)	GHG Emissions (kg/km)			
		60 km/h	80 km/h	100 km/h	120 km/h
Very good	1	0.68	0.94	1.28	1.76
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: Adapted from Mashoko *et al*., 2014

With the difference in road infrastructure and the concern South Africa faces with the increasing trends in road freight usage, which will go hand-in-hand with economic growth, the sustainability of the supply chain must be investigated. Supply chain sustainability is addressed in Section 3.14.

3.7 THE FREIGHT DEMAND MODEL

To understand what the total annual road freight kilometres travelled are in South Africa, data from the South African FDM was used for the purpose of this research. The FDM estimates freight flows from areas in South Africa by using a gravity modelling approach. Every five years, the FDM provides a 30-year forecast for three types of scenarios: low, likely and high growth scenarios (Havenga, 2007). The FDM data includes data monitoring from 22 corridors with cargo types from these corridors divided into nine types of cargo, named in Table 3.6.

Table 3.6 Types of cargo data included in the FDM

Types of cargo included in the FDM		
Roll-on/roll-off	Open skip bulk	Light break-bulk
Refrigerated	Mining dry bulk	Heavy break-bulk
Palletised	Liquid bulk	Agricultural dry bulk

Source: Adapted from Havenga, Le Roux & Simpson, 2017

In addition to total road freight kilometres, the following data was also provided by the FDM for this dissertation:

- Average handling factor of goods;
- Average length of a haul (trip);
- Average load on a truck in tonnes;
- Percentage of empty loading of trucks.

3.8 INTERRELATIONSHIPS AND SYNERGY WITHIN THE SUPPLY CHAIN

An interrelationship in supply chain can be defined as the way in which supply chain processes are connected, interact and affect one another" (Lui, 2012). Synergy is defined as "the concept that the value and performance of two or more parts combined will be greater than the sum of the separate individual parts" (Hattangadi, 2017).

Both of these concepts can play an essential role in the supply chain. Synergy in the supply chain typically involves activities to achieve cost synergy between supply chain processes such as procurement, manufacturing, distribution and service offerings. By achieving synergy within the supply chain structure and between business partners, mutually beneficial cost savings can be achieved (PwC, 2016). Synergy can be achieved by investigating the supply chain processes and reaching agreements between business partners that would be more mutually beneficial for all parties involved than separating activities and embarking on a solo journey (PwC, 2016). Thus, the cumulative effect of synergy will have a more significant positive impact on the entire business than only focussing on improving individual components.

The interrelationships managed to achieve synergy may play a pivotal role to attain mutual goals and objectives. The synergy between processes can have a direct interrelationship with one another, where one process may directly affect another (Grandval & Vergnaud, 2006). It was observed by Moktadir, Ali, Rajesh and Paul (2018) that the interrelationships between supply chain barriers in the Indian leather industry can be modelled and documented to promote collaboration between supply chain partners to promote better decision making that would be mutually beneficial for the supply chain and the environment.

Through supply chain coordination, emission reduction can be achieved by the improving the interrelationships between certain road freight factors such as road conditions, driving behaviour and vehicle conditions (Demir, Bektaş & Laporte, 2014). Numerous emission reduction models that promote supply chain coordination and interrelationships between factors to decrease carbon emissions are available (Boulter, McCrae & Barlow, 2007; Smit, Smokers & Rabé, 2007; de Haan & Keller, 2000), but no research could be found that quantifies and discusses the possible synergistic decrease of carbon emissions on a total road freight decarbonisation framework when focussing on road freight factors and challenges within the framework.

The available emission models typically place focus on a small number of factors that can contribute to the decrease of carbon emissions when these factors are improved (Zissis, Saharidis, Aktas & Ioannou, 2018). These individual factors include vehicle efficiency, road conditions, average speeds, traffic congestion, driving cycles and vehicle types (Zissis *et al*., 2018). While the emission models demonstrate the carbon reduction potential of individual factors, the models do not discuss the possible synergy reduction of carbon emission when all factors are used simultaneously for carbon emission reduction. Carbon spend for specific road freight activities in South Africa could also not be found during research.

3.9 CONCLUSION

The theme of carbon emissions and the effect the emissions are having on the planet cannot be ignored. NASA (2018) indicated the rising levels of CO_2 emissions (Figure 3.2), emphasising how climate changes are a concerning subject matter. The transport sector is an industry that has one of the largest impacts on the number of emissions being released into the atmosphere. There are SFSTs available that can be applied to reduce the CO_2 burden on the economy as well as the transport sector. While there are other modes that are less carbon-intensive to transport goods, South Africa has a large road freight-based intensity with corridors having hefty flows of traffic on a daily basis. Rail is not a reliable alternative in South Africa at the moment, and companies will rely on road transportation for now and the near future.

Companies can no longer continue using fossil fuels, which are becoming scarce, are affected by fluctuating oil prices and result in endangering the environment by emitting harmful carbon emissions. Companies are facing a revolution in how goods are being transported and will have to become responsible for preserving the planet. Decarbonisation will become prominent in all future road freight transport.

CHAPTER 4 DECARBONISATION STRATEGIES, FRAMEWORKS, SYSTEMS AND TOOLS

This chapter focuses on literature relating to road freight decarbonisation SFSTs. Criteria from Section 2.2 were used to choose the SFST that was developed further for South Africa.

4.1 ROAD FREIGHT DECARBONISATION

In 2010, over 53% of the primary global oil consumption was used to meet 94% of the total transport energy demand. The greenhouse gases from the transport sector have more than doubled since 1970, and the prediction is that the gigatonne CO_2 equivalent per year will rise to 12 gigatonnes by 2050 (Sims *et al*., 2014). In the freight movement sector, road is by far the most carbon-intensive mode of transport given the intensity of use. The trend shows that the increasing carbon intensity of road transport and road greenhouse gases outweighs all the other sectors such as pipeline, rail and aviation.

4.2 THE WORLD ECONOMIC FORUM'S SUPPLY CHAIN DECARBONISATION FRAMEWORK

The World Economic Forum (WEF) published a report in 2009 (Doherty & Hoyle, 2009), highlighting recommendations for three sectors, namely, logistics and transport providers, shippers, and buyers and policymakers, to decrease carbon emissions. The WEF report includes a ranking scale that further introduces 13 recommendations that would provide the highest potential opportunities to decrease carbon emissions and provides a brief summary of how each of the recommendations can be achieved. Table 4.1 provides a summary of these recommendations per sector and Table 4.2 is a summary of the 13 recommendations. Table 4.2 summarises the possible total global decrease in carbon emissions in metric tonnes should an opportunity be implemented by all parties. A feasibility score was also allocated to each of the opportunities based on criteria such as implementation barriers. The feasibility score was derived from workshops with organisational professionals.

The report also discusses the context of decarbonisation and outlines the objectives to quantify the carbon emissions for each of the sectors. Data and analysis were done with the aid of available sources such as the Organisation for Economic Co-operation and Development (OECD), the Intergovernmental Panel on Climate Change (IPCC), government statistics organisations and GHG Protocol emissions. The report shares data that road freight is the most intensive of all logistics activities, with rail freight having the least carbon emissions.

Table 4.1 Opportunities and recommendations to reduce carbon emissions per sector

Sector	Recommendations
Logistics and transport providers	- Adopt new technologies industry-wide. - Improve training and communication industry-wide. - Switch modes where possible. - Develop recycling offerings. - Develop home delivery offerings. - Promote carbon offsetting of shipments.
Shippers and Buyers	- Understand and reduce the carbon impact of manufacturing through alternative sourcing. - Plan to allow slower and better-optimised transport. - Reduce packaging materials. - Work on product carbon labelling, standards, auditing tools, and use. - Increase shared loading.
Policy Makers	- Reflect the cost of carbon in energy tariffs. - Support carbon measurement and labelling standards. - Build open carbon trading systems. - Invest in infrastructure and flow management. - Facilitate recycling along the supply chain. - Encourage retrofitting of buildings to better environmental levels.

Source: Adapted from Doherty & Hoyle, 2009

Table 4.2 WEF 13 recommendations to decrease carbon emissions

Decarbonisation Opportunity	Description	Potential abatement Mt CO_2 emissions	Assessed Index off feasibility
Clean vehicle technologies	Introduce clean and environmentally efficient technologies	175	0.8
Despeeding the supply chain	Decrease transport speed and increase load fill	171	0.8
Enabling low-carbon sourcing: Agriculture	Optimise the location of agriculture	178	0.6
Optimised networks	Improve network planning through transformation projects	124	0.8
Energy efficient buildings	Minimise emissions from operating activities	93	0.9
Packaging design initiatives	Reduce weight and volume of packaging	132	0.7
Enabling low-carbon sourcing: Manufacturing	Optimise manufacturing location	152	0.6
Training and communication	Provide training to road transport contractors and building operator	117	0.8

Source: Doherty & Hoyle, 2009

Table 4.2 (continued) WEF 13 recommendations to decrease carbon emissions

Decarbonisation Opportunity	Description	Potential abatement Mt CO_2 emissions	Assessed Index off feasibility
Modal switches	Transfer freight from the air and long-haul road freight to ocean, road and rail freight	115	0.7
Reverse logistics / Recycling	Improve the percentage of total supply chain waste that is recycled	84	0.6
Nearshoring	Transfer long-haul air and ocean freight to road and rail freight	5	0.7
Increased home delivery	Rely on alternate transport services to deliver goods home	17	0.5
Reducing congestion	Introduce traffic management techniques	26	0.3

Source: Doherty & Hoyle, 2009

From Table 4.2, it is thus derived that the opportunity that will have the most substantial impact on carbon reductions together with the highest score of feasibility would be to focus on cleaner vehicle technology. The opportunity with the lowest score of carbon reduction potential and feasibility is linked to reducing traffic congestion.

4.2.1 Adaptability

The WEF provides guidelines that are similar to other carbon reduction SFSTs such as adapting to new technology, training and the switching of transport modes. The guidelines are, however, generic and can thus be modified to fit any country given the availability of opportunities that fall within the scope of the 13 recommendations.

4.2.2 Development opportunity

The guidelines can be further developed to fit into the South African road freight industry as the guidelines are not holistic in nature and external factors influencing carbon emissions can be developed. The framework provides a global overview that can be adapted to the South African environment.

4.2.3 Feasibility

The scope to implement such a broad set of guidelines will entail a large amount of research for each of the opportunities to be South African road freight specific. Focussing on the road freight sector, the broad guidelines do not provide enough detailed information for quick implementation. Thus, the feasibility of implementation might have a range of timelines for implementation. Opportunities that focus on road freight and have a high impact of carbon reductions and feasibility of implementation simultaneously were clean vehicle technologies, despeeding the supply chain and enabling low-carbon sourcing for agriculture. Although the framework provides a good guideline for decarbonisation in the supply chain, the framework does lack some detail in a holistic approach to emphasise the carbon reduction potential of road freight. The framework would deem fit as a guideline to compare with similar SFSTs, but, the WEF supply chain decarbonisation framework provides a total overarching view of supply chain decarbonisation with not enough focus on road freight activities to adapt within the South African environment for a holistic road freight decarbonisation framework.

4.2.4 Evidence of results

The carbon reduction potential derived for the WEF framework included data from, as quoted, “major logistics and transport firms”. Each analysis phase for the 13 opportunities are discussed, and the key findings are presented in the framework. The reduction potentials shared include tried and tested methods and deliver good insight to what implementation of each of the opportunities can hold for a company. It can thus be concluded that the WEF framework shows promising results for the top-rated opportunities, should companies wish to implement it.

4.3 DEEP DECARBONISATION PATHWAYS PROJECT

Countries who take part in the Deep Decarbonisation Pathways Project (DDPP) are Canada, the United States, Brazil, Mexico, South Africa, France, the United Kingdom, Germany, Italy, Russia, China, Japan, India, Indonesia and Australia. The DDPP was initiated by the Sustainable Development Solutions Network (a United Nations initiative) and the Institute for Sustainable Development and International Relations (a non-profit policy research institute based in Paris). DDPP is a global research initiative on how countries can transform into a low-carbon economy, its primary focus being to limit global warming to the agreed upon less than 2 ºC for this century (refer to the Paris Agreement). The DDPP has three pillars of sustainability, which are energy efficiency and conservation, decarbonising electricity and fuels, and switching energy end-users to lower-carbon, and eventually zero-carbon energy carriers (e.g. electricity, hydrogen and biofuels) (Ribera & Sachs, 2015).

The South African DDPP focuses on the national current and forecasted circumstances that will influence decarbonisation, such as high levels of poverty resulting in structural, social and economic concerns (with a focus on unemployment and inequality) and the unskilled workforce. The report talks to the high energy-intensive economy with its resulting emissions. Four objectives for DDPP are outlined:

1. Characterising the socio-economic context and identifying and providing quantitative descriptions of two likely socio-economic futures for South Africa;
2. Within the socio-economic futures, identifying measures needed for South Africa to achieve deep decarbonisation of the energy system by 2050;
3. For South Africa to simultaneously achieve multiple climate and development objectives, including providing quantitative descriptors of the economic, energy system and emissions pathways, the report defines the suite of technologies, efficiency improvements, socio-economic structural changes, and policies;
4. While maintaining a South African resident-centred, development-first approach, demonstrating that the country can contribute to the 2 ºC global target set by the Paris Agreement.

For the energy and economy sectors, the report predicts that decarbonisation can be achieved by increased demand and supply of technology efficiencies by switching end-use fuel and the increase of renewable energy production, such as wind and solar electricity generation. Energy generation from coal is predicted to decrease. It is further predicted that the use of renewable energy production will motivate other sectors to follow suit to switch over to electricity as a low-carbon energy source (Ribera & Sachs, 2015).

Passenger transport is said to gain efficiency due to modal shifts and vehicle efficiency improvements with electric vehicles becoming an opportunity in 2030 with the decarbonisation of the energy sector. Freight transport is said to be demand-driven by the predicted sectoral GDP growth, which is associated with transport needs.

4.3.1 Adaptability

The report discusses future scenarios for South Africa provided there are improvements made to drive activities that will have a positive effect on South Africa's social and economic concerns. The report is written explicitly for South Africa and addresses what carbon reduction potential there is for carbon reduction in the three pillars of DDPP.

4.3.2 Development opportunity

The report can be further developed to provide an in-depth structure for companies on how to achieve the decarbonisation methods discussed. The report provides an overview of all the opportunities available in the carbon-intensive sectors, and more detailed guidelines can be beneficial for companies who are in the first phases of decarbonisation and are yet to implement strategies on how to achieve carbon reductions.

4.3.3 Feasibility

For the decrease in carbon emissions to be realised given the predicted outcomes in the report, it is stated that there must be political involvement to push the social and economic status of the country. Without governmental involvement to drive carbon reduction policies, companies may struggle to decarbonise. Timelines of implementation for decarbonisation through the identified opportunities in the DDPP are extensive, ranging from 2 to over 30 years and funding would be required to implement options such as an electric truck fleet.

4.3.4 Evidence of results

The results of the report are driven by the e-SAGE model, which is a dynamic recursive computable general equilibrium model developed by the United Nations University's World Institute for Development Economics Research. The results are thus forecasted, given the two sets of possible outcomes when a set of variables is submitted into the model. In the DDPP, the South African Social Accounting Matrix was used for the data input. This matrix represents a set of accounts for all of South Africa's productive sectors, commodities, market factors, enterprises and household data versus global data (Ribera & Sachs, 2015).

4.4 EUROPEAN COMMISSION: LOW-EMISSION MOBILITY

Focusing solely on transportation, the European Commission has developed a strategy for low-emission mobility. The main elements of the strategy are to increase the efficiency of the transport system, to speed up the deployment of low emission alternative energy for transport and to move towards zero-emission vehicles. To increase efficiency, the strategy proposed to make use of more digital technologies, pricing strategies and to encourage the use of lower carbon-intensive transport modes (EU Commission on Climate Action, 2017).

The main focus of this strategy will be on technology. To increase the efficiency of the transport system, the strategy will propose digitalisation such as door-to-door mobility together with integrated logistics. Price signals will reward or penalise lower or higher carbon outputs, while modal shifts will ensure less carbon-intensive modes of transportation will be used. Overall, this is said to increase transport efficiency.

Alternative energy solutions rely on incentives for faster innovation and infrastructure developments can lead to alternative fuelling solutions, such as biofuels and electric vehicles. The linking of alternative solutions can decrease communication barriers. Lastly, the strategy focuses on emissions testing and standards to ensure accurate low-emission vehicle measurement. A set of emission standards will ensure compliance of vehicle emissions and consumer vehicle labelling and public procurement rules can support low- and zero-emission vehicles.

4.4.1 Adaptability

The strategy is very generic and can be adapted to any country willing to follow the strategy as a guideline to methods of decreasing carbon emissions. However, the development opportunity must be considered to decide what opportunities lie within this strategy for South Africa.

4.4.2 Development opportunity

The strategy focuses on using technology to decrease carbon emissions. Opportunities exist to expand the strategy to include other methods of carbon reduction, such as driver training or optimised vehicle routing. Further research opportunities, therefore exist within the strategy.

4.4.3 Feasibility

For the purpose of this dissertation, it is not feasible to solely focus on the future deployment of technology to decrease carbon emissions when there is a range of research available to expand on decarbonisation opportunities. Readers must also consider the feasibility of implementing some of the recommendations in a South African context given the technology, financial and governmental aid that would be needed on influences such as pricing signals, incentive schemes and consumer information. There are, however, recommendations made that companies can implement such as the use of digitalisation and making use of rail. The timeline of implementation would be challenging to estimate as the majority of the strategy would require political involvement.

4.4.4 Evidence of results

Discussions on the possible results from implementing this strategy were limited as the strategy has yet to be fully implemented. There is research data available on strategies that recommend similar methods of reducing carbon emissions, such as the WEF 13 opportunities, and these research results can be referred to as guidance on possible results for implementing similar strategies.

4.5 MOBILITY MANAGEMENT

Litman (2015) believes the answer to the reduction of transport emissions and energy use is through mobility management. Mobility management or transport demand management (strategies that result in the more efficient use of transportation) can provide benefits such as consumer cost savings, increased traffic safety, improved mobility for non-drivers and improved fitness and health. Litman (2015) argues that analyses often ignore the costs involved in increased fuel efficiencies or alternative fuel substitutes. The options to switch to more fuel-efficient vehicles or fuel substitutes can often result in the 'rebound' effect. This term refers to when the consumption is increased as a result of increased efficiencies and reduced consumer costs. Traffic rebound can result in more vehicles on the road, because road improvements led to more traffic being able to travel on the improved roads (Victoria Transport Policy Institute, 2017).

The Victoria Transport Policy Institute developed steps to implement transportation demand management. The implementation of transport demand management (TDM) can lower transport emissions and energy use. The steps can be seen in Figure 4.1.

Policy and Planning Reforms

(more funding for alternative modes, increased support for TDM programmes, changes in land-use planning practices)

Changes Travel Options and Incentives

(improved walking and cycling conditions, improved ridesharing and public transit services, more compact and mixed land-use development, increased road and parking fees, reduced transit fares)

Travel Changes

(shifts in travel time, route, mode, destination and frequency

Outcomes

(reduced traffic congestion, road and parking facility cost savings, crash reductions, energy conservation, pollution emission reduction, improved mobility for non-driver)

Figure 4.1 The steps to implement transport demand management

Source: Adapted from Victoria Transport Policy Institute, 2014

In addition to the steps to implement transportation demand management, emission reduction strategies are also provided by the Institute. These include improved transport options, efficient incentives and land-use management. The strategies are summarised in Table 4.3.

Table 4.3 Transport management strategies

Improved transport options	Efficient incentives	Land-use management
Transit improvements	Congestion pricing	Smart growth policies
Walking and cycling improvements	Distance-based fees	Transit-oriented development
Rideshare programmes	Commuter financial incentives	Location-efficient development
Car-sharing	Parking pricing	Parking management
Telework and flexitime	Parking regulations	Car-free planning
Taxi service improvements	Fuel tax increases	Traffic calming
	Transit encouragement	

Source: Adapted from Litman, 2015

4.5.1 Adaptability

Mobility management places focus on passenger transportation, but can be adapted to the road freight industry by similar methods such as switching to fuel-efficient modes of freight movement (rail or pipeline) and improved route planning. The adaptation of mobility management to fit the South African freight industry can incorporate specific challenges such as route planning according to the road infrastructure or sharing loading space within a freight truck. Thus, further investigation into mobility management for road freight can be researched.

4.5.2 Development opportunity

The adaptation of mobility management can be further developed to incorporate more freight-specific activities, but opportunities may be limited due to the scope of mobility management focusing on transportation demand. For a holistic SFST, a broader scope must be investigated to expand the application of mobility management to other freight activities.

4.5.3 Feasibility

The implementation of mobility management will not be immediate as detailed schemes, policies or facilities will take time to develop, test and implement. The adaptation for mobility management from passenger transport to road freight may include long research timelines and feasibility studies. Both internal and external resources may have to be allocated to research mobility management, and the cost of implementing may be very high, given the current road freight challenges in South Africa. There are limited opportunities available for South African companies to implement transportation demand management as other methods of transportation are scarce (Nordengen, 2013). With South Africa’s high level of poverty (National Development Plan 2030, 2013), it is also not feasible to increase transport prices to market more ‘healthy’ ways of travelling, such as proposed by Litman (2015), due to the intermodal challenges faced with road freight intensity.

4.5.4 Evidence of results

Shareen and Lipman (2007) reported a range of possible carbon reduction potential from implementing mobility management. It was reported that Stockholm’s carbon emissions are set to be reduced by 15 tonnes per year by 2050 by implementing a carpooling scheme and 600 tonnes per year for the implementation of park-and-ride facilities between the years 2030 and 2050. Further research can be done on how to adapt these to road freight and what carbon reduction potential this might have for road freight emissions.

4.6 THE WWF TRANSPORTATION STRATEGIES

WWF Canada (2012) believes transport emissions can be reduced by following three main strategies. These are: avoid, reduce and replace. The strategies focus solely on light-duty vehicles as this sector accounts for 65% of the Canadian transport emissions. The three strategies are summarised in Table 4.4. The WWF's strategy to reduce carbon emissions from transportation has also been referenced in South Africa with the South African strategy being reducing, shift and improve (Lewis, Cohen & Rambaran, 2014). These strategies are summarised in Table 4.5.

Table 4.4 WWF Canada's three strategies to lower transport emissions

Strategy	Summary
Avoid	▪ Dense urban design and land-use planning to support public transit. ▪ Facilitating modal shift to active transportation. ▪ Increasing fuel taxes, increasing road taxes and parking costs. ▪ Facilitating teleconferencing and working from home.
Reduce	▪ Improving fuel-efficiency standards, supporting and facilitating carpooling. ▪ Facilitating modal shift to public transit. ▪ Switching to cleaner fuels (biodiesel, ethanol, and propane). ▪ Supporting vehicle retirement programmes that support low-emission transportation replacements. ▪ Promoting driver education programmes.
Replace	▪ Supporting zero-tailpipe emissions engines powered by renewable energy.

Source: Adapted from WWF Canada, 2012

Table 4.5 WWF South Africa's three strategies to lower transport emissions

Strategy	Summary
Reduce	▪ To reduce the need to move people and goods. This includes shortening the length of demand and supply and localising production.
Shift	▪ Shifting the demand for private transportation to public transportation.
Improve	▪ To improve the fuel efficiency of vehicles and incorporate renewable energy.

Source: Adapted from Lewis *et al*., 2014

The WWF in South Africa identified long term mitigation scenarios together with a potential mitigation analysis on opportunities to decrease greenhouse gases. By making a particular set of assumptions such as rail freight increasing to 71% usage in 2030 and 68% usage in 2050, the increased usage of energy-efficient vehicles and uptake in biofuels and hybrid vehicles, the following were identified that can lead to a decrease in greenhouse gas emissions from transportation (Lewis *et al*., 2014):

- Passenger modal shifts to more rail usage;
- Vehicle occupancy increasing;
- Increase the number of hybrid vehicles on the road;
- Introduce electric vehicles;
- Vehicle efficiency;
- Increase in privately owned diesel cars that emit fewer carbon emissions than petrol;
- The use of biofuels.

Mitigation opportunities and measures based on the three strategies to reduce road freight emissions are provided by WWF South Africa and are also provided and summarised in Table 4.6.

Table 4.6 WWF mitigation opportunities for decreased greenhouse gas emissions

Opportunity	Measure
Avoid or reduce freight activity	- Sustainable consumption of goods - Increasing the proportion of goods sourced locally and seasonally - Reducing and improving packaging - Optimising logistics
Shift to lower carbon modes of freight transport	- Improving rail infrastructure, availability of rolling stock, the reliability of service and cost competitiveness - Improving infrastructure and operation for intermodal links
Improved efficiency of freight transport: operational measures	- Intelligent routing and scheduling
Improved efficiency of freight transport: technology measures	- Reducing driving resistance: aerodynamic drag and rolling resistance - Changes to vehicle design - Increasing engine efficiency - Waste heat recovery - Changing transmission systems - Hybrid and electric vehicles - Improving driving efficiency - Conversion of diesel rail to electric rail - Regenerative braking on trains
Improve GHG emissions efficiency of freight transport: alternative fuels	- Biofuels - Compressed natural gas and liquefied petroleum gas - Hydrogen - Reducing the carbon intensity of the electricity grid mix

Source: Lewis *et al*., 2014

4.6.1 Adaptability

The WWF South Africa strategies and mitigation plans are written for South Africa with it being possible to investigate all mentioned opportunities further in South Africa for more detailed analysis and execution timelines.

4.6.2 Development opportunity

The WWF mitigations and opportunities are robust and comprise of a wide variety of carbon reduction measures that companies can implement to decrease carbon emissions from road freight transport. The measurements are focused on road freight and provide a good guideline on how to achieve carbon reductions.

4.6.3 Feasibility

The measurements can possibly be described as having a range of feasibility of implementation from the possibility to implement immediately and with little cost (optimising routing and scheduling) to longer-term implementation with a higher associated cost (improving aerodynamic designs and switching over to rail). Companies can possibly choose to allocate internal resources to investigate opportunities, as well as external resources on aspects such as improving logistical performance. The South African WWF's approaches to reduce, shift and improve require long-term behaviour change, and it would take an extended time for implementation to begin.

4.6.4 Evidence of results

The WWF South Africa do not mention specific carbon reduction results in South Africa from implementing the suggested opportunities and measurements, but international data on the proposed measurements would be available on how each of the measurements can contribute to the reduction of carbon emissions, such as in the case of the WEF framework.

4.7 INTERNATIONAL TRANSPORT FORUM

The International Transport Forum conducted a study on the opportunities available to reduce transport greenhouse gas emissions. Five key strategies were investigated, which are fuels, vehicle efficiency, traffic management, demand management policies and modal shift. A summary of the outcome from the five strategies can be seen in Table 4.7

The report highlights important transport challenges such as transport being a significant contributor to carbon emissions, the dependency on fossil fuels and transport's vulnerability to climate change where significant investments and adaptions will be needed to mitigate risks (International Transport Forum, 2010). Furthermore, the report stresses that for transport to achieve carbon reduction effectively, national transport policies must be adapted to provide the same in-depth concerns that are given on policies such as transportation safety.

Table 4.7 The International Transport Forum's five strategies to lower transport emissions

Strategy	Outcome
Fuel	There is limited fuel decarbonisation potential in the short term though this will change, and more alternative fuel sources will come on line as oil prices rise.
Vehicle efficiency	Improving traditional internal combustion engine vehicle fuel economy is a key low-cost transport GHG reduction strategy. There is a clear opportunity to improve new car fuel economy 30% or more by 2020 and 50% by 2030 at low costs taking into account lifetime fuel savings.
Traffic management	Better traffic and congestion management can reduce CO_2 emissions from road transport. This can be done by enlarging the traffic capacity and managing existing capacities better.
Demand management	Improving the efficiency of vehicles and traffic will not be sufficient to reach ambitious CO_2 reduction objectives from transport. Demand will have to be better managed in the future to reduce growth in CO_2-intensive travel. Demand management, however, will deliver smaller and smaller relative gains in GHG emissions reduction as vehicle efficiency improves throughout the fleet.
Modal shift	Improving the quality and coverage of public transport and improving cycling and walking opportunities helps to reduce CO_2 emissions in some cities depending on local and national circumstances.

Source: Adapted from the International Transport Forum, 2010

4.7.1 Adaptability

The strategies highlight specific opportunities for transportation, which can be used for both passenger and road freight.

4.7.2 Development opportunity

Each of the strategies can be given a South African perspective as to how these can be achieved within the South African environment. Research opportunities will include investigating each of the strategies to conclude what is currently available in South Africa and how these strategies can be evolved into governmental and company policies.

4.7.3 Feasibility

The timelines to implement the strategies will need to be evaluated as there are certain aspects to the strategies that can be relatively quickly implemented (improved vehicle technology and efficiency), while others such as demand management may have a longer timeline involved. The financial implications must also be considered as although strategies may be quickly implemented, it might not be viable for a company to replace a whole fleet with fuel-efficient trucks in a short period of time.

4.7.4 Evidence of results

The report does not focus on results from implementing the strategies, but rather how each of the strategies can have an impact on lowering carbon emissions. Infrastructure and economic factors are discussed to provide contextual information on how the strategies would be implemented.

4.8 MCKINNON'S ROAD FREIGHT DECARBONISATION FRAMEWORK

The framework places comprehensive focus on road freight logistics and revolves around road freight decarbonisation by targeting parameters such as transport intensity, freight modal split, vehicle utilisation, empty running, energy efficiency and the carbon intensity of the energy source. The McKinnon framework is summarised in Table 4.8, with the total framework provided in Figure 4.2. The decarbonisation of road freight can be targeted by crucial parameters, defined by McKinnon (2010) as transport intensity, freight modal split, vehicle utilisation, energy efficiency and the carbon intensity of the energy source. The intensity of freight transport is mostly due to the broader sourcing of supplies and the centralisation of economic activities (McKinnon, 2010:2). Sourcing from international suppliers, which already increases the long haul distances, will be challenging to reverse, but companies are already starting to near-shore some of their production (SupplyChainBrain, 2015). Companies still find it challenging to move back to local sourcing or decentralised systems due to cost trade-offs not being realised (McKinnon, 2010). Carbon tax laws may force companies to near-shore some of their activities to save costs. A further option to reduce the carbon intensity of freight transport is shifting to a lower carbon-intensive mode of transport.

The carbon intensity of a transportation mode is expressed in the volume of carbon emissions produced per tonne-km. The biggest stumbling block for South Africa is the limitation of the various modes of transportation. South Africa does not have low-cost inland waterways and rail transport is unreliable. Thus, road transport must be used. To lessen the degree of carbon emissions for transportation, various options are available. These are: switching to more carbon 'friendly' modes of transportation, which are not so carbon intensive, increasing current vehicle utilisation and raising the energy efficiency of freight transport operations.

Switching to more carbon-friendly modes of transportation includes rail, pipelines and water transportation, but the trade-off with these types of transportation modes may be lower flexibility, accessibility and slower transit times (McKinnon, 2010:4). Vehicle utilisation requires improving the way the vehicles are loaded by increasing the capacity of loading. Increasing the loading capacity can reduce the CO_2 emissions being emitted per tonne-kilometre (tonne-km). It is essential to take into account the challenges that may dampen vehicle capacities. These are government regulations, infrastructure, market conditions and equipment. One of the challenges companies must also take into account for vehicle utilisation are the relationships between the different company functional groups. These functional groups, such as packaging, warehousing, procurement, sales, and inventory management all have different perspectives and policies that may constrain vehicle utilisation. Policies such as just-in-time, frequent ordering systems for inventory reduction, or improving customer satisfaction all have a direct influence in the vehicle utilisation capacities. Vehicles are making frequent deliveries with low capacities being utilised, which increases the CO_2 emissions per tonne-km (McKinnon, 2010:4). Recent studies also show that online consumer shopping can have a significant impact on the reduction of carbon emissions (Edwards & McKinnon, 2009).

Improving CO_2 emissions can also be done by raising the energy efficiency of vehicles. New technologies in vehicles reduce the CO_2 emissions being emitted (McKinnon, 2010:5). Low-carbon vehicle projects are becoming more prominent in government and company policies. The United Kingdom has implemented a low-carbon vehicles innovation platform focused on reducing carbon emissions, accelerating the introduction of low-carbon vehicle technologies and helping improve the demand for low-carbon vehicles (United Kingdom Government, 2009).

Table 4.8 McKinnon's parameters for road freight decarbonisation

Decarbonisation factors	Summary
Transport intensity	The ration between generated GDP and tonne-km.
Freight modal split	How freight is split into different types of modes: road, rail, air or waterways.
Vehicle utilisation	Vehicles are not fully utilised during loading.
Empty running	How many tips in kilometres are trucks running empty and not being utilised.
Energy efficiency	How much energy is consumed while moving freight? This is measured in the distance travelled versus the energy consumed to travel that distance.
Carbon intensity	This is the amount of CO_2 that is being emitted per unit of energy consumed.

Source: Adapted from McKinnon & Piecyk, 2010

4.8.1 Adaptability

The framework provides a simplistic representation of how each freight activity within road freight can contribute to carbon emissions. The framework can possibly be adapted not only for South Africa, but also globally, given the detailed description of relationships between freight activities.

4.8.2 Development opportunity

McKinnon provides a holistic view of road freight activity aggregates and how key freight parameters have a relationship to the aggregates. The parameters can be further investigated within South Africa to establish how these parameters can compare to freight activities within a South African context and what additional opportunities exist for new aggregates or parameters to be included in the framework.

4.8.3 Feasibility

It appears that the framework would be relatively simple to follow to reduce carbon emissions and that little external resources with high financial investments would be required. The timelines involved would possibly range from short- medium- to long-term, depending on how many adaptations a company would need to make should any of the aggregates or parameters be implemented.

4.8.4 Evidence of results

Extensive research material is available from McKinnon on various topics such as road freight decarbonisation as well as decarbonising logistics, which have not been covered in the literature review due to the scope of the dissertation focusing on road freight.

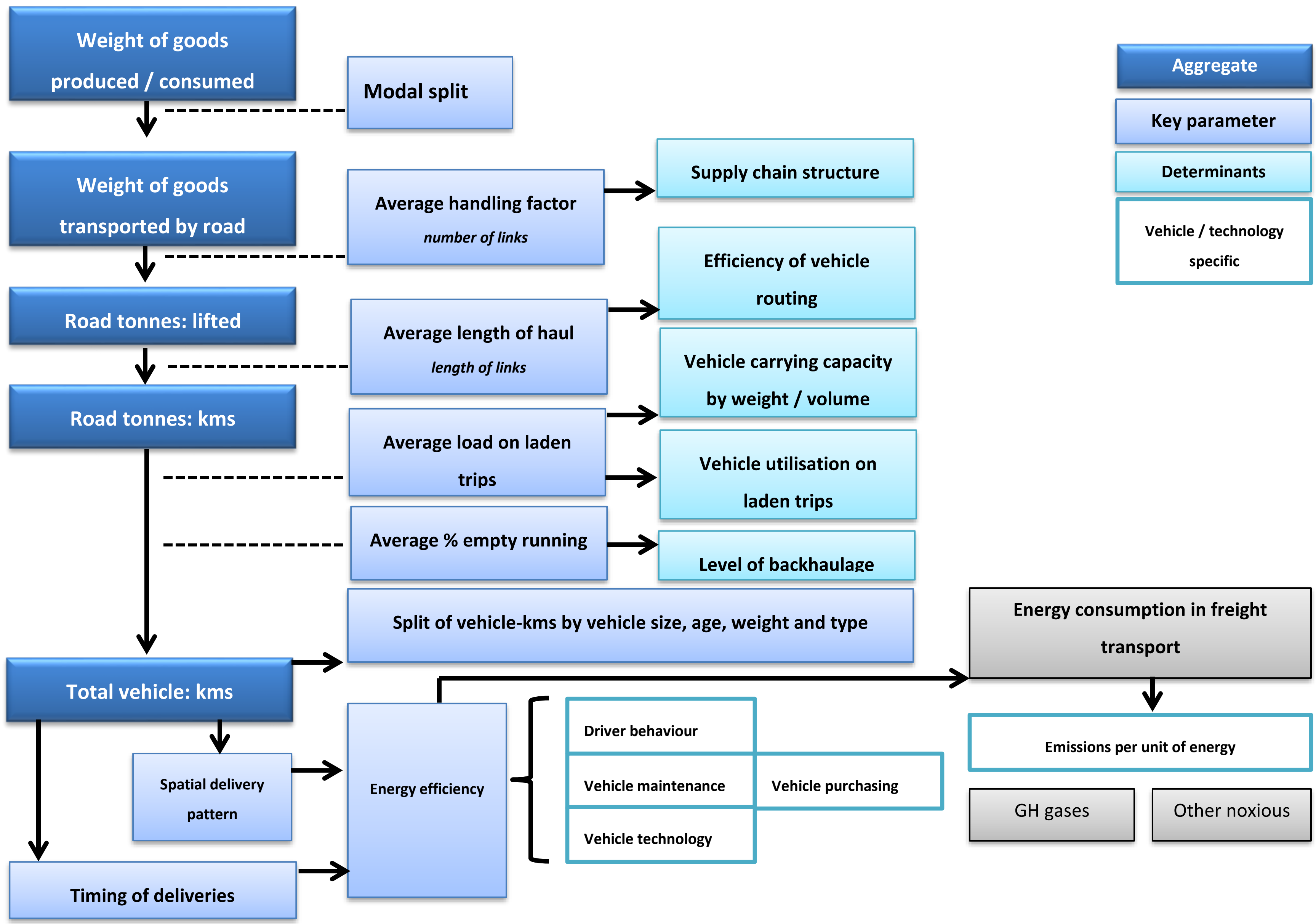

Figure 4.2 McKinnon's decarbonisation framework for road freight transport

Source: Adapted from McKinnon, 2015a

4.9 SOUTH AFRICA'S ROAD TRANSPORT MANAGEMENT SYSTEM

The Road Transport Management System (RTMS), is defined as "an industry-led, government-supported, voluntary, self-regulation scheme that encourages consignees, consignors and road transport operators to implement a management system (a set of standards) that demonstrates compliance with the Road Traffic Regulations and contributes to preserving road infrastructure, improving road safety and increasing productivity" (RTMS, 2018).

The RTMS is SABS approved and has its own SANS documentation (SANS 1395 -1:2014). The scope of the RTMS (and SANS 1395) is road safety, ensuring the roadworthiness of vehicles, optimisation of loading conditions, driver wellness, improvement of driver behaviour, productivity and efficiency, and the preservation of the road infrastructure.

The four main components of the RTMS, are loading control, safety and compliance, driver wellness and training and development. Nordengen & Naidoo (2014) also believe South Africa faces a 'culture of non-compliance', which continues to be a challenge for South African companies, particularly the implementation of freight regulations. Table 4.9 summarises the main themes for each of the components. The successes of implementing the RTMS into South African companies can be seen in the improvements the system has brought in various companies.

Table 4.9 The four main components of the RTMS

Loading control	Safety and compliance	Driver wellness	Training and development
• Prevention of overloading. • Optimising payloads. • Safer loading practices. • The compliance of dimensional limits.	• Systematic vehicle maintenance. • Minimising vehicle breakdowns. • Verify daily vehicle inspections. • Preventing speed violations. • Avoiding crashes. • Minimising traffic violations. • Managing routing risks. • The monitoring of safety indicators.	• Obtaining medical certificates of fitness for drivers. • The management of chronic diseases (i.e. diabetes). • Fatigue management. • Rest day allocations. • The monitoring of driving hours. • Provision of resources.	• Training plans. • Driver recruitment processes. • Competency evaluation. • A structured training programme. • Driver assessments. • Effective communication on safety and compliance.

Source: Adapted from Nordengen & Naidoo, 2014

The City of Cape Town has implemented the RTMS system for the Electricity Fleet Maintenance and Maintenance Services Department and has seen numerous improvements. Fuel consumption went down from 17 litres per 100 kilometres to 13 litres per 100 kilometres, which saved R5.7 million over the period 2008 to 2016. The carbon footprint improved by 24%, and in 2016, the department saved 4.2 million rands on repairs and maintenance (Janse van Rensburg, 2016). The number of traffic violations also showed a linear decrease since implementing RTMS with a 56% reduction in traffic violations from June 2015 to May 2016. Fleet incidents also declined from 27% per million kilometres in 2009 to only 6% in 2016 (Janse van Rensburg, 2016). Companies such as Dawn Logistics reported a 42% reduction in truck breakdowns within three years of implementing RTMS and a decrease from 218 traffic fines in 2013 to only 56 in 2015, a 74% decrease (Truck & Freight, 2016).

In an article published in FleetWatch (2016:7), the high-risk components of heavy vehicles were highlighted. Many of these components can be addressed by improving driver behaviour, but there are also a large number of components that are the result of a poor compliance culture. The summary of the risks can be seen in Table 4.10, and these are also the components that are addressed when implementing RTMS. South Africa faces not only a culture of compliance challenges with risk components, but also has a freight transport challenge due to the high volumes of freight moving on South African roads.

Table 4.10 Heavy vehicle risk components

Heavy vehicle risk components	Intermediate outcomes	Final impact
Overloading	Damaged roads	Quality of life
Inadequate vehicle maintenance	High crash / collision rates	Global competitiveness
Roadworthy vehicles	Injuries Fatalities	Sustainable environment
Unsafe loading	Congestion	
Incorrect routes	Delays	
Speeding	Excessive costs	
Harsh acceleration	High fuel consumption	
Reckless driving	Excessive emissions	
Excessive shift hours	Unsafe roads	
Excessive driving hours		
Medical fitness		
Driver intoxication		
Unlicensed drivers		
Unlicensed vehicles		
Untrained drives		
Monitoring and reaction to traffic offence		
Monitoring and reaction to accidents/incidents		
Analysis and reaction to stakeholder feedback		

Source: Table adapted from FleetWatch, 2016:7

RTMS addresses various crucial aspects within its four pillars and the system itself is the first of its kind within South Africa that places focus on low-risk, high yield components through a self-regulating scheme. Through the research conducted via the RTMS implementation, it was found that a large part of South Africa's road freight transport companies have a low implementation of basic transport regulations (vehicle maintenance, driver training, tyre management etc.) (Nordengen & Naidoo, 2014) and the RTMS by itself has large potential to assist companies in achieving improved results on various aspects within a company that are low in risk, but will result in high yield opportunities. The four pillars of RTMS highlight basic transport components that may not currently be implemented in developing countries, such as South Africa.

4.9.1 Adaptability

Not all companies have the same level of RTMS compliance. Some companies have rolled out RTMS in all departments, making RTMS and its results very successful. Other companies are, however, still in the process of expanding RTMS to all of the departments in the company. Imperial Logistics' Consol fleet is RTMS certified and is investigating the accreditation process for all fifteen of its fleet divisions (Supply Chain Online, 2017). RTMS itself was specifically developed for the South African road freight environment, thus no additional adaptation would be needed.

4.9.2 Development opportunity

RTMS includes a holistic approach that consists of four components. Further development opportunities for RTMS will be to include a larger scale of carbon reduction strategies, but results show that RMTS is already contributing to the reduction of carbon emissions from road freight activities.

4.9.3 Feasibility

The system has already been implemented in numerous companies within South Africa, which have presented positive results.

4.9.4 Evidence of results

Numerous companies have seen carbon reductions from implementing RTMS. Barloworld reported an 18% reduction in carbon emissions when applying RTMS to a Toyota cross-docking case study and Goldfields Logistics an 11% reduction in carbon emissions when implementing performance-based standard trucks through RTMS accreditation (Van Tonder, 2016; Kruger, 2016). RTMS shows a range of improvements and is not only limited to carbon emission improvement, but can contribute to the overall performance and welfare of a company.

4.10 OTHER GLOBAL INITIATIVES

There is a lot of overlap between the different methods of decreasing carbon emissions. Countries such as Australia and China also have similar strategies in place (Climate Counsel Australia, 2016). Three main targets for Australia's Climate Change Authority to decrease carbon emissions are to increase vehicle efficiency, switching to energy-efficient fuels and demand management, similar to what was discussed in Chapter 3.

In the article by authors Lou, Dong, Dou, Liang, Ren and Fang (2016:198), China's carbon state for road freight movement is discussed, and proposals are given to reduce the CO_2 emissions for road freight, which are to avoid/shift/improve, restricting vehicle use, explore alternative energy usages and to increase the investment in low-emission transport systems (Luo *et al*., 2016.).

Clean Air Asia, a non-governmental organisation, developed a Green Trucks Toolkit (GTT), which is a Microsoft Excel-based tool providing a cost-benefit analysis for intervening in the following:

- Eco-driving;
- Improved maintenance;
- Aerodynamic styling;
- Tyres and wheels;
- Idling reduction;
- Reduction of sulphur in diesel and petrol;
- Reduction/elimination of lead in petrol;
- Emission control devices;
- Replacement of diesel and petrol trucks with liquid petroleum gas or methane gas.

The GTT has seen many benefits when implemented, with fuel economy increasing by as much as 48% and driver training programmes resulting in an increase of 93%, from 6 litres per kilometre to 3 litres per kilometre (Kumar & Mejia, 2015).

4.11 CONCLUSION

It is apparent that there is a host of research material available to decrease carbon emissions from the transportation sector. While global and some South African research indicates various SFSTs for the reduction in carbon emissions, opportunities to adapt and expand an SFST for South Africa exist. This chapter summarised briefly what types of SFSTs are available and indicated how these could be applied by governments or companies.

Each of the SFSTs mentioned was discussed regarding the criteria for selecting an SFST that can be further developed within South Africa. The research from the various SFSTs conformed with the literature review in that the has been research conducted to prove carbon emission contribution for various different contributing influences. The WEF, WWF, McKinnon and RTMS showed promising detail regarding carbon reduction opportunities with extensive research having been done. It was noted during the literature research that the SFST does not mention carbon synergies between carbon reduction factors and does not provide carbon spend for certain road freight activities in South Africa. Synergy in carbon reduction will also be taken into account when developing a road freight decarbonisation SFST for South Africa.

Given the process of elimination through the criteria in which the SFSTs were evaluated, and literature confirmation, it was the opinion of the researcher that the McKinnon road freight decarbonisation framework showed encouraging opportunity to be investigated further within the South African road freight environment. McKinnon introduces various carbon contributing factors that were highlighted in Chapter 3. The framework presents road freight movement in the form of aggregates and parameters and discusses how each of these can be utilised more efficiently to decrease carbon emissions, a valuable contribution that was absent from the other SFSTs. McKinnon has done prominent research in the field of logistics, and this research would be a valuable contribution to South Africa’s journey to a lower carbon road freight environment. The following chapter discusses the McKinnon framework in more detail.

CHAPTER 5 MCKINNON'S ROAD FREIGHT DECARBONISATION FRAMEWORK

This chapter provides a more detailed explanation of McKinnon's road freight decarbonisation framework with material provided for each aggregate and key parameter. McKinnon's full road freight decarbonisation framework can be seen in Figure 4.2. The chapter also further details the comparison and similarities of other SFSTs to the McKinnon framework.

5.1 DEFINING AGGREGATES

The aggregates in the McKinnon framework represent several elements and concepts that can be expressed in numerical or measurable values. The aggregates in the framework contain five key parameters. These parameters are directly linked to aggregates and have a direct effect on each of the separate aggregates that are linked to the parameters. These are the weight of goods produced/consumed; the weight of goods transported by road; road tonnes-lifted; road tonne-kilometres, and total vehicle kilometres.

5.2 THE WEIGHT OF GOODS PRODUCED/CONSUMED

The first aggregate has a direct relationship to economic growth. Freight transport tonnes per kilometre have traditionally been seen to have a close relationship with gross domestic product (GDP). The higher the economic growth and activity, the more goods are supplied and demanded and therefore transported. The ratio of the variables may, however, decline depending on development in the economy and as services increase to the total output. If an increase in tonne kilometres is not accompanied by an increase in rail market share more freight will be moved by road leading to more CO_2 emissions and creating a direct link between economic output and logistics-related activities (McKinnon, 2015b). The 2016 Logistics Barometer report for South Africa, shows steady logistics costs as a percentage of GDP, but if services are excluded logistics costs as a percentage of the mining, agricultural and manufacturing GDP are rising since 2011 (Figure 5.1) with little growth in comparison to the increase in logistical costs (Havenga, Simpson, King, De Bod & Braun, 2016).

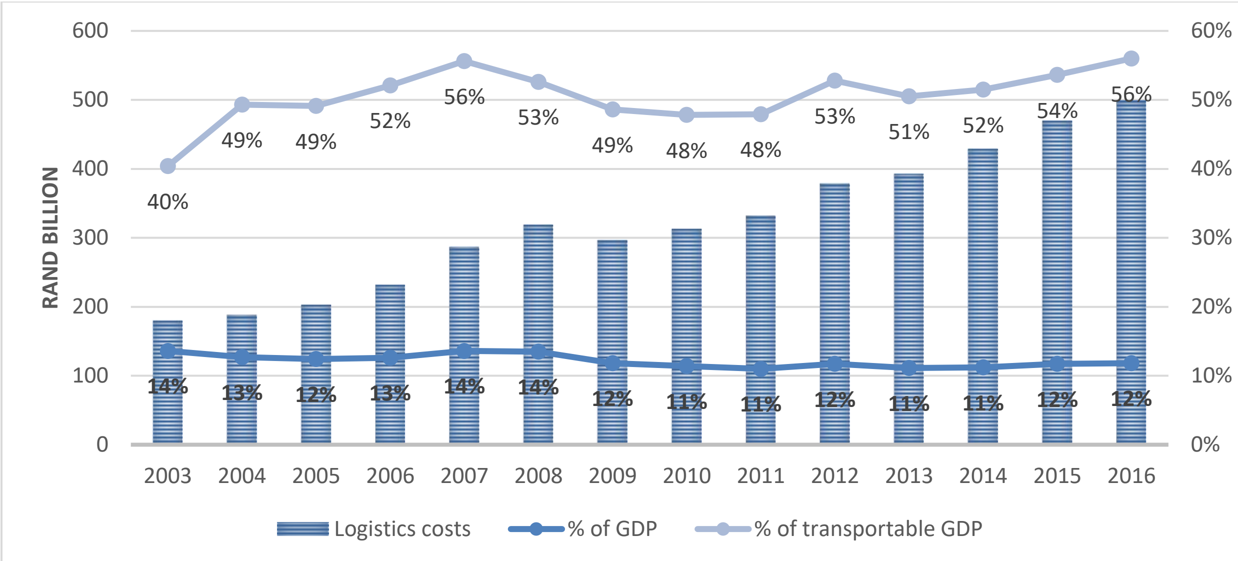

Figure 5.1 South Africa's GDP and logistical costs

Source: Adapted from Havenga *et al*., 2016

In South Africa, companies have limited opportunity to move road freight to rail due to the nature of the product being moved, rail's current available technology and the current perception of unreliability. It was deduced from the literature review that companies prefer to move freight by road due to the flexibility that road deliveries can provide both to suppliers and customers. Further analyses also highlighted that an estimated total of 7.5% from road freight could be moved to rail freight should the bulk goods, which can be moved, adhere to the criteria Havenga and Simpson (2016) detailed in the research from the FDM.

5.2.1 Road tonnes lifted, road tonne-km and total vehicle kilometres

The weight of goods transported by road aggregate (as also with all the aggregates) has a direct relationship with road tonnes-lifted, road tonne-kilometres and total vehicle kilometres. With the weight of goods being produced and consumed, a certain amount of these goods will be transported by road freight at some stage. The trend of increased transportation by road has mainly been driven by processes of wider sourcing and centralisation of economic activity (McKinnon, 2010:2). The road tonnes-lifted is the weight of goods being moved from one destination to another. The weight being moved can be divided by the number of kilometres the goods are travelling, thus proving how many tonnes are being moved per road freight kilometre. For example, if 2 500 tonnes of goods are travelling 500 kilometres, the road tonne-kilometres will be 1.25 milliontonne-kilometres (2 500 multiplied by 500) (Eurostat, 2013). In this case, the tonnes lifted is 2 500, the transport distance is 500 kilometres, and the tonne-kilometres is 1.25 million.

To determine vehicle kilometres, the carrying capacity of the vehicle must be considered. If in this example the carrying capacity is 25 tonnes, 100 trips will be required, and the vehicle kilometres will be 50 000 (2 500 divided by 25 and multiplied by 500). If only vehicle kilometres and tonne-kilomertes are known, the average load can be calculated by dividing tonne-kilometres with vehicle kilometres. For South Africa, the FDM estimated road tonnes moved annually equates to 503 103 740 tonne kilometres (Havenga, 2015; Havenga & Simpson, 2014; Havenga, 2013), which represents a skewed relationship compared to what is being moved by rail freight. Companies must, therefore first explore first the avenue of moving ‘rail friendly’ road freight to rail as it will not only be less carbon intensive, but the cost per kilometre to move freight via rail is also less expensive (Swarts *et al*., 2012).

5.3 PARAMETERS

The framework consists of key parameters, which have a direct effect on the corresponding aggregates. The following section describes the parameters and also places some of the parameters in a South African context to understand how these parameters may have an influence in the South African environment.

5.3.1 Modal split

The modal split parameter refers to the proportion of the freight that will be transported by different modes of transportation such as pipelines, shipping, road, air or rail. The framework focuses explicitly on road freight transport, but as mentioned by the World Economic Forum (2009), road freight is the most carbon-intensive mode of transportation. It should therefore be considered, where possible, to make use of more carbon-friendly modes of transport such as railway, pipelines or waterborne transport.

South Africa has limited options available for freight haulage. Thus, this option might be easily adaptable in countries with more options available to move freight to more carbon-friendly modes of transportation. The reality in South Africa is that the majority of freight will remain on the road should investments in the rail sector not improve in the future. It should therefore, also be investigated how road freight, which is readily available in South Africa, can be improved. The McKinnon framework focuses on road freight practices and how road freight can be improved, making the framework more adaptable in the South African environment.

5.3.2 Average handling factor and the average length of haul

McKinnon (2012) explains how reducing the number of times a product is handled and moved can be done by bypassing logistics agencies and the number of nodes in the supply chain. This can be executed by managing the vertical integration of processing and reducing the journeys that materials and products have to make between processing plants and customers. Length of haulage reduction can be done by starting to source more inbound supplies locally and to decentralise processing, storage and distribution operations (McKinnon, 2013).

In the South African reality, there are more challenges that need to be taken into account when investigating the handling factor. The literature review covered how South Africa is plagued by challenges such as strikes, hijacking and theft. These factors must also be taken into account and investigated to understand what roles these challenges have in South Africa and what their impact is. The challenges were investigated further during phase one, and two of the data gathering and the impact of the challenges is discussed and quantified in Chapter 6 and Chapter 7.

5.3.3 Average load on laden trips and the average percentage of empty running

The average load per trip can be increased, so the CO_2 per tonnage moved per road will decrease. To accomplish this, just-in-time schedules can be re-evaluated to allow larger loads on one trip as opposed to small, more frequent trips. Other methods also include starting to consolidate loads with shared-user contracts. This will allow when one party cannot fill a truck, a second or even a third party to maximise the load utilisation of one truck. The use of more space-efficient packaging can also be adopted together by eliminating the amount of primary and secondary packaging material (McKinnon, 2013).

Empty running vehicles are not only highly cost inefficient, but also produce more CO_2 per tonnage moved, and per kilometre travelled. To counter this, companies can implement matching services such as online freight exchanges and web-based procurement. The use of collaborative initiatives on both vertical and horizontal levels can also be used. Backloading entails moving goods to one customer, reloading the truck at the customer for reverse logistics purposes and moving the freight load back to the point of origin (McKinnon, 2013).

McKinnon lists five key reasons why trucks would not be fully utilised. These can be market-related decisions, regulatory obligations, inter-functional decisions, infrastructural hurdles or equipment related difficulties (McKinnon, Cullinane, Browne & Whiteing, 2010).

5.3.4 Vehicle operation, fleet management and timing of deliveries

More efficient vehicle operations and fleet management can reduce CO_2 emissions. Extending the operating hours (timing of deliveries) and rescheduling deliveries that fall outside peak periods will reduce the level of congestion on the roads, which in turn will lower the total carbon emissions of the road transport sector. Improved vehicle routing via computerised vehicle routing systems can be implemented for improved scheduling as well as zone deliveries. This will indicate which route is the best and will minimise peak traffic congestion (McKinnon, 2013).

RTMS in vehicle operations will have a significant effect on how a company's fleet and personnel are managed. As stated by Nordengen and Naidoo (2014), South Africa tends to struggle with a culture that is prone to non-compliance of regulations. By implementing RTMS in a company, it can assist in creating a culture of compliance, which will reap the benefits when complying to set rules and regulations.

5.3.5 Energy efficiency and carbon intensity of the energy

Focusing on improving the fuel efficiency of vehicles is one of the first steps when considering energy efficiency and the intensity of the energy used. This key parameter is directly affected by energy consumption. Methods to improve energy consumption will have a direct linkage with an increase in energy efficiency and the intensity of energy. To reduce the intensity of energy, more energy efficient vehicles such as the use of hybrid vehicles, electric vehicles, biogas vehicles and dual-fuel vehicles can be used. This will, in turn, also decrease the dependency on fossil fuels (McKinnon, 2013).

The energy efficiency of the vehicles also has a strong relationship with driving behaviour, as was mentioned in the literature review (Chapter 3). Harsh driving styles can increase the fuel consumption of a vehicle, which will, in turn, increase the carbon emissions. Energy efficiency is also directly linked to vehicle maintenance, vehicle technology and vehicle purchasing. All of these aspects are also part of the RTMS.

5.3.6 Energy consumption

Reducing energy consumption consists of implementing measures on vehicle designs and settings so the vehicle will use less energy while operating. These measures are summarised in Table 5.1. By implementing these measures, vehicles will become more energy efficient and produce fewer carbon emissions by consuming less fuel (McKinnon, 2010:5).

Table 5.1 How to reduce a vehicle's energy consumption

How to reduce a vehicle's energy consumption			
Adopt vehicles with automatic transmission.	Install body/trailer side panels.	Fit low resistance tyres.	Increase the proportion of evening deliveries.
Set fixed limiters of the vehicles to a lower speed.	Use trailers with a sloping front roof for double deck and high cube vehicles.	Fit super singles.	Use of telematics to optimise vehicle routing.
Install an anti-idling device.	Make use of a tear-drop trailer.	Install automatic tyre pressure adjustment.	Accelerate turnaround times at collection and delivery points.
Switching from powered to fixed-deck trailers.	Reduce the height of the vehicle.	Use a fuel additive.	
Reduce the vehicles tare weight.	Implement regular tyre inflation checks.	Use low friction oils or lubricants.	
Install cab-roof fairing.	Provide drivers training on fuel efficiency.	Measure and monitor driver fuel performance.	

Source: Adapted from McKinnon, 2013

5.4 CONCLUSION

Every aggregate and parameter has a close relationship within the McKinnon framework. Both aggregates and parameters consider and incorporate the aspects of the supply chain, and McKinnon (2013) provides a thorough framework of concerns affecting road freight carbon emissions.

The aggregates and parameters provide examples to implement changes in the supply chain to reduce the carbon emissions. With these examples and explanations, the correlation between higher or lower carbon emissions in the supply chain can be seen. Simple changes, such as changing delivery schedules, may result in the reduction of carbon emissions. There are also, however, implementations that may be more difficult to implement and one must consider the probability and viability of a road freight supply chain implementing these methods. For instance, it may not be within financial reach for a company to switch to electric or hybrid vehicles that produce lower carbon emissions, but it must also be considered that long-term action plans can be accomplished if decisive planning and implementation are involved.

McKinnon's (2010) framework is easy to perceive, understand and interpret on how to switch to more energy-efficient modes or to increase transport efficiency and it provides a more comprehensive approach specifically focused on factors that a company in South Africa can manage and improve upon. McKinnon's framework was thus a good candidate framework to apply in the South African environment as the framework incorporates a holistic approach to all phases and decision-making factors that play an essential role in both decarbonisation and road freight:

- Transport intensity;
- Freight modal split;

- Vehicle utilisation;
- Energy efficiency;
- Carbon intensity of the energy source.

CHAPTER 6 RESEARCH RESULTS

Based on the methodology set out in Chapter 2, this chapter focuses on phases one, two and three of data gathering. The results from the three phases are represented, discussed, and the South African decarbonisation framework is introduced.

6.1 PHASE ONE DATA CAPTURING: QUESTIONNAIRE

6.1.1 Method

For the first phase of data gathering, a questionnaire was distributed via email to potential participants, from which 20 responses were received (refer to Section 2.4.1 for participant selection criteria). The data provided in the first phase initiated the research process to gain insight into road freight companies and what the current challenges in the road freight industry may be. Themes that were focused on in the questionnaire were:

- Sustainability;
- Decarbonisation;
- Road freight challenges.

Participants were asked to elaborate on questions such as “Do you believe that your road freight business is sustainable?” and “Do you believe in decarbonising the road freight sector?”. Frequently mentioned road freight themes from the participants’ answers were summarised by counting the number of times similar answers were given by the participants. Documentation of the road freight challenge themes was done to reference the themes again to participants taking part in the interviews during the second phase of data gathering to gather more detail on these themes.

6.1.2 Data capturing and results

6.1.2.1 *Open-ended questions*

The questionnaire consisted of eight open-ended questions and an additional ten questions based on a five-point scale format. The first open-ended question to the participants was “Do you believe that your road freight business is sustainable?”. From this, 72% of participants answered ‘No’ and commented that road transportation is not sustainable. Participants commented that points of supply and demand are seldom close to one another, and long distances must be travelled to reach suppliers or clients. This correlates with the literature review, which noted the heavy traffic that is experienced on the national roads for the transportation of freight with a focus on the Cape

Town, Johannesburg and Durban routes. Participants commented that vehicle technology is an essential factor in improving the performance of vehicles, such as fuel efficiencies and that transporters rely on this technology to decrease carbon emissions. One participant commented that there are no regulations in place to limit the number of carbon emissions being emitted from road freight and that the participant is yet to be made aware of any future sustainable practices that might be implemented. Another commented that there is still much to do in terms of road freight sustainability and that, in South Africa, there are still many opportunities and avenues that need to be explored. The dependence on fossil fuels was also a concern for participants, as South Africa relies so heavily on this finite resource.

The second question ("Do you believe in decarbonising the road freight sector?") related to the decarbonisation of road freight. One hundred percent (100%) of the participants believed in the need to decarbonise the road freight sector. The dependence of fossil fuel was again highlighted by the participants and that there are no reliable, sustainable alternative means of freight transportation available in South Africa. Global warming was mentioned frequently, and participants believed that this is a reality and a threat to the planet. A participant commented that there is no possible way to completely decarbonise road freight in South Africa unless the way of business, thinking and consuming is radically changed. The lack of intermodal transportation was highlighted as intermodal transport can be an avenue to explore in reducing road freight emissions. It was indicated that other countries are already enforcing decarbonisation practices, but that South Africa is lagging in this approach. Vehicle technology was also mentioned and the fact that companies rely on the technology of vehicles to limit carbon emissions. Social responsibility and the earth's sustainability were important to the participants.

One of South Africa's biggest challenges ("What do you think is South Africa's biggest challenge in the transport industry?") concerning road freight was high fuel prices, which was a predominant theme across all participants. This is due to the high dependence South African companies place on road freight, and fuel prices will affect the overall financial expenditure on transportation. The lack of intermodal transport was highlighted as a challenge as companies cannot rely on the rail system. The lack of responsibility and trust that staff members show towards business conduct was also mentioned in addition to South African labour unions affecting how employees work. Driver training was identified as it was mentioned that the standard of a South African driver is not the same as the standard of a driver in first world countries. Thus, drivers tend to make more mistakes or cause road crashes.

The most significant time-wasting component identified by the participants ("What is the most time-wasting/wasteful component in transportation?") was road congestion, and the time it took to load and offload a truck with specific time slots not being adhered to. Inadequate equipment being used to load and offload trucks also led to long delays during the loading and offloading process. In some cases, this was linked to forklifts breaking down. Participants also commented that time was lost when trucks have long idling times, waiting to be loaded or offloaded. Strikes were also mentioned by one participant as they can cause disruptions to deliveries. Empty loading was seen as a wasteful component due to trucks not being loaded to full capacity. Trucks can also be sent back empty to loading depots and may travel thousands of kilometres with an empty load when travelling from Johannesburg to Cape Town.

The final open-ended question ("What would you do to decarbonise the transport sector and make it more sustainable?") asked of participants what can be done to decarbonise road freight and make road freight transport more sustainable. A participant commented that oil equals money, and as long as there is a demand for oil, a sustainable future for road freight seems very limited. It was commented that unless radical changes are made in the road freight industry, business will be conducted in the same manner, and harmful emissions will still be emitted. Continuous awareness training was mentioned, for example, by training drivers to consider the environment in all tasks and services that are completed. Intermodal transport was again mentioned as was the poor implementation of regulations to force companies to decrease carbon emissions. Finally, participants also believed that improved truck technology is vital to limiting road freight emissions.

From the open-ended questions, recurring themes started to emerge from the participants' answers. By counting the number of times the same theme occurred during all the open-ended questions to all the participants, it was concluded that specific themes were more common than others. This data was used to develop Figure 6.1, with the percentage of reoccurrence of each theme (how many times the same theme occurred), on the x-axis. The themes indicate what the major concerns, in road freight, were for the participants.

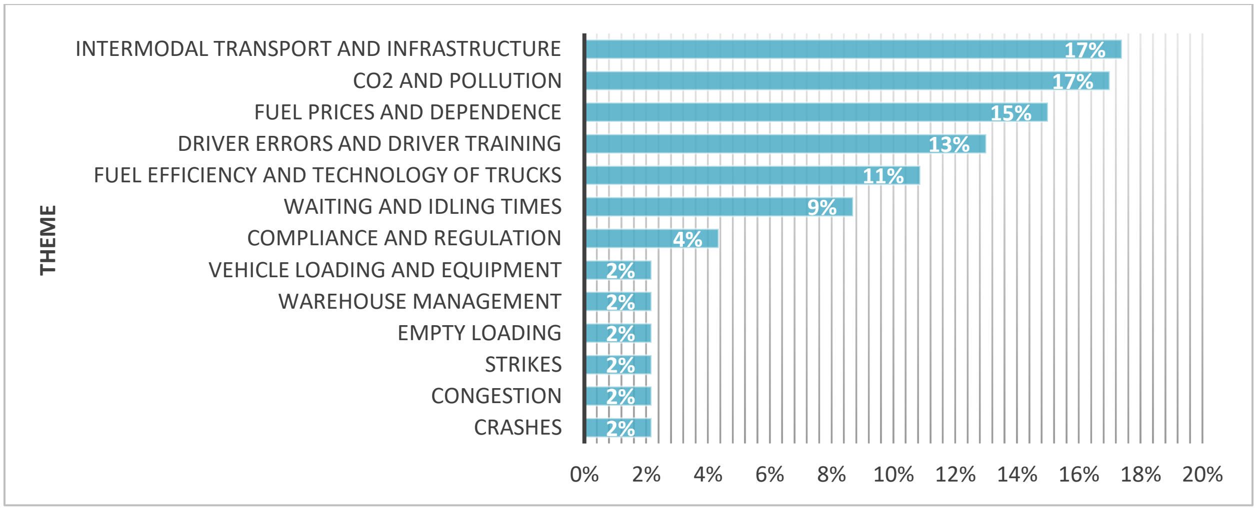

Figure 6.1 Percentage of reoccurring themes in phase one

Intermodal transport and road infrastructure were mentioned most by participants, followed by CO_2 and pollution being a concern, fuel prices and dependence and driver training. The technology of trucks played a predominant role with participants believing that it can be used to decrease carbon emissions and to increase fuel efficiency (CO_2 and pollution). Themes that were mentioned the least were vehicle loading equipment (indicated as a time-wasting component), warehouse management (time-wasting component), empty loading, strikes, congestion, driver errors and crashes. It became apparent with the predominant themes that the logistical efficiency of the network may play an important role in road freight. This can be done by placing supply closer to the demand signal to limit road freight kilometres, planning trips more efficiently by reducing the amount of empty loading, limiting the number of unnecessary trips taken and adhering to slot times to reduce missed deliveries, which leads to unnecessary trips. The implementation of this can form part of a company's strategic long-term planning to reduce carbon emissions.

6.1.2.2 *Scale-based questions*

The second part of the questionnaire consisted of scale-based questions to determine the degree of agreement or disagreement with the statements made regarding sustainability. The scale-based questions ranged from strongly disagree, to strongly agree. Participants could also answer 'not applicable' should the question not be of relevance to the participants' company. An example would include when a company makes use third-party logistics. Thus, the company making use of the service may have limited influence on driver training, and what vehicle technology is being used. The 'not applicable' responses were excluded in the analysis of the data.

From the scale questions (seen in Figure 6.2), it was concluded that the participants are of the opinion that sustainability is important. Participants also believe that the most efficient routes are taken when scheduling deliveries and that employee training is important to educate drivers to improve driving efficiency. Global warming is important to most companies, but it seems that most participants commented that efficient technology vehicles are not used for lower fuel consumption. The results from the scale-based questions correlate with what participants answered in the open-ended questions, which is that companies have an interest in enhancing sustainability.

The question that recorded the highest scores of ‘strongly disagree’ and ‘disagree’ was the use of vehicle technology. This was one of the prominent themes in the open-ended questions, where participants believed that vehicle technology could be used to decrease carbon emission. Although participants answered in the open-ended questions that this is a good means for decreasing carbon emissions, the results of the scale-based questions show that, contrary to this, most participants do not make use of this technology. On the question “Carbon tax is a concern”, 27% of participants strongly disagreed with this statement, and 18% disagreed. This may imply that participants are not worried about the future impact, implementation, or how it will affect a company, may it be financially or operationally.

A concern that was mentioned frequently by the participants in the open-ended questions was the lack of availability of intermodal transport, but 33% of the participants strongly agreed with the statement “Modal splits are used”, 33% commented neutral, and 11% strongly disagreed to this statement. This may be for various reasons; namely that the question may have been incorrectly interpreted by the participants, that the participants generalised the questions to be applicable to the whole of South Africa and not only to the participant’s company, or that the participant’s company does make use of intermodal transport.

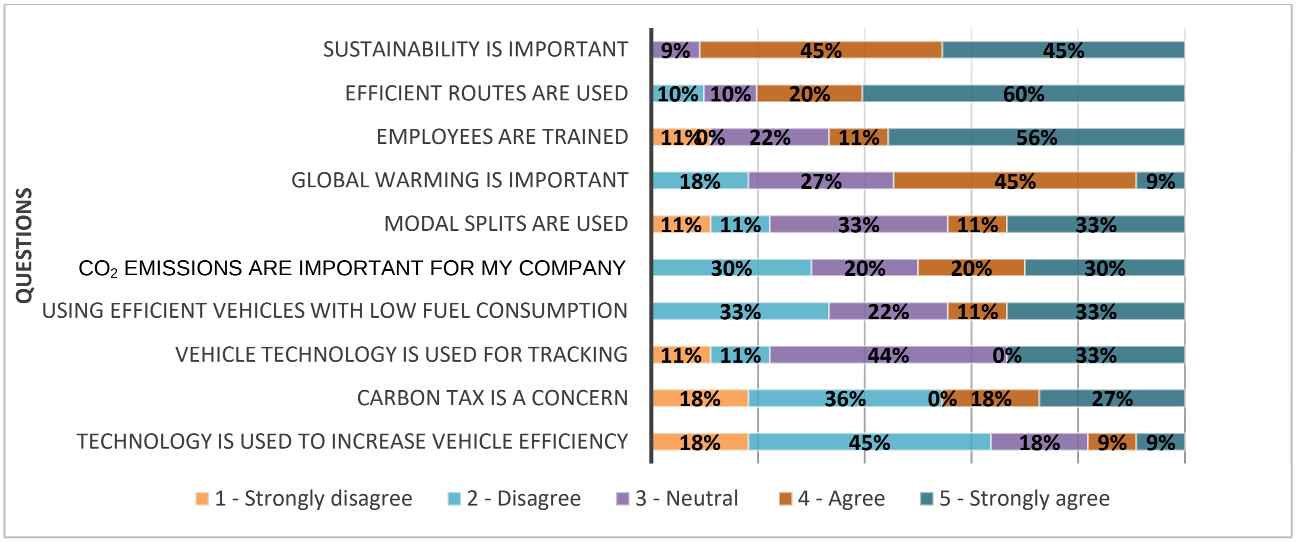

Figure 6.2 Findings from preliminary questionnaires

6.1.3 Importance and conclusions

Together with the literature review, the data gathered in the first phase of questionnaires showed promising results that there is an opportunity in South Africa for a road freight decarbonisation framework to be developed and that there is interest in the decarbonisation of road freight.

The themes identified highlighted further developments that can be made to the McKinnon framework. Themes that occurred during the first phase and that can be directly linked to the McKinnon framework are:

- Energy efficiency of the trucks;
- The efficiency of vehicle routing;
- Energy consumption of transport.

The key conclusions from the first phase can thus be summarised as:

- Road freight transport is believed not to be sustainable in South Africa;
- Vehicle efficiency and technology must be used to decrease carbon emissions;
- South Africa has a high dependence on fossil fuel;
- A change in behaviour is needed to decrease road freight emissions;
- The carbon tax is not a concern for most companies.

The McKinnon themes that were identified during the first phase of data gathering and the key conclusions made were used to guide the questions during the interview phase. Specific themes can also be linked to the RTMS, which can address both vehicle efficiencies, behaviour and energy efficiency. The following section discusses the interviews with participants and the conclusions from the interviews.

6.2 PHASE TWO DATA CAPTURING: INTERVIEWS

6.2.1 Method

Interviews were held with 20 management professionals in the road freight industry to discuss current road freight operational practices and McKinnon's road freight decarbonisation framework. The interviews were a means of understanding what additional improvements and opportunities exist that can be added to the McKinnon framework. Themes of supply chain sustainability, decarbonisation and challenges unique to South Africa were discussed that were identified in the first phase of data gathering. Participants were asked to describe in detail the operation of the participant's road freight transportation processes and practices. During the interviews, participants were also asked to elaborate on previous common themes that occurred during the first phase of questionnaires.

A two-phase approach was initiated with the interviewees. First, all participants were asked to discuss the questions set out in Appendix B. Questions were asked, such as "Is the transport supply chain of your company a sustainable practice?"; "What is the major challenge (or struggle) for your companies' transport?" and "What type of infrastructure problems do you encounter for road freight transport?". After all discussions were completed regarding the participant's road freight operations, participants were shown the McKinnon framework. This was to prevent any biased answers in favour of road freight decarbonisation and sustainable practices within the participant's company during initial discussions. For the data analysis, discussions were divided into 'unprompted' and 'prompted' categories where 'unprompted' refers to discussions prior to the framework being shown and 'prompted' refers to the feedback that followed post framework discussion.

6.2.2 Unprompted responses

The interviews started with the question to describe the current road freight activities of the company. Participants were encouraged to discuss current constraints and challenges towards infrastructure hurdles and participants were asked to elaborate on the themes that were identified during the first phase, which were:

- Crashes;
- Congestion;
- Strikes;

- Empty loading;
- Warehouse management;
- Vehicle loading and equipment;
- Compliance and regulation;
- Waiting and idling times;
- Fuel efficiency and technology of trucks;
- Driver errors and driver training;
- Fuel prices and dependence;
- CO_2 and pollution;
- Intermodal transport and infrastructure.

Theft and hijacking were challenges that were mentioned frequently by the participants. It was commented that drivers who deliver high-value goods are targeted and will not stop in rural areas for fear of being robbed. It was also indicated that trucks delivering low-valued goods could also be targeted in rural areas. These trucks typically carry canned foods or maize (low value) or cigarettes (high value). Where deliveries had to take place in rural areas, testimonies of companies were given where trucks' tarps are often cut open while a truck is stationary and goods are stolen while the truck was idling. The results from this theft led to unnecessary trips due to deliveries having to take place again to the same destination to redeliver the stolen goods. Many participants also commented on the trustworthiness of the driver and that managers cannot rely on drivers to deliver the goods on time and in full, because goods go missing or trucks make unnecessary stops. Many of the trips also take place on different levels of road quality that incur different levels of operational costs and carbon emissions.

South Africa has a unique road infrastructure combination as deliveries can take place in various areas such as cities, towns, townships and farms. In more rural areas, such as the townships, low-hanging electrical wires prevent trucks from making deliveries. Deliveries in specific areas are also hampered due to low bridges. In these instances, companies need to rely on smaller trucks with more frequent trips to deliver the goods to these small local markets. Examples were also provided where time was lost due to truck drivers not being able to gain access to a rural road due to a gate being locked, hampering the truck's access to a road and ultimately leading to an undelivered load that needed to be loaded and delivered again once access to the road is obtained. Roads may not be paved for long distances and delivery to farms, or outlying areas can become a costly operation. These types of roads are gravel roads with numerous potholes and possible flooding, making the roads dangerous during rainy seasons. Durban was also highlighted by participants as a city with a high flood-obstruction rate due to poor road infrastructure.

Strikes were also mentioned as affecting the route planning for companies as certain designated routes cannot be taken if a strike is taking place. In the case of a strike, alternative routes must be taken. These routes may be longer, increasing the kilometres travelled to the destination and increasing the carbon intensity of the trips. Larger companies make use of route planning and monitor what companies call ‘the strike seasons’ (typically during winter months). During strike season, route planning is done on roads that are not primarily used for a strike. High-risk roads during strike seasons were identified by the participants as roads leading to Parliament and near mining areas. Urban roads are also a high risk when a taxi strike is taking place where some participants commented that trucks are likely to be set on fire if a ‘strike-route’ is taken where the strike action has turned violent. During strikes, certain clients’ offloading sites become inaccessible due to protesters blocking the entrance to a client. There are also clients who close offloading bays during a nearby strike without informing the delivery companies of the closure. These occurrences lead to many futile trips being taken to an offloading bay, which is closed. This also leads to delayed deliveries and more trips that need to be taken at a later stage when a client’s receiving bay is accessible again.

It was also indicated that older model refrigerated trucks have a high diesel consumption due to the cooling units on the trucks being outdated. Participants in more environmentally friendly companies remarked that an initiative would be needed to replace old technology trucks with gas refrigeration trucks, which emit fewer carbon emissions than a diesel-powered refrigeration truck and are also more fuel-efficient. Participants commented that most of South Africa’s refrigerated trucks still make use of diesel cooling units.

Another reoccurring theme was the frequency of unplanned trips taken. Some of the reasons for these trips were strikes, security concerns, traffic congestion and missed slot times. Many participants admitted that due to missed slot times, trucks are not being offloaded and would have to return to the client at a later allocated time or on a different day to complete the delivery.

Finally, it was mentioned that, due to driver incompetence, trucks were denied access or denied offloading as the driver was not able to describe the nature of delivery or able to explain a unique, approved, delivery circumstance. Missed or delayed deliveries can be contributed to poor communication by both the driver and the client. These instances occurred mostly at border posts where specific documentation needed to be explained to border post officials and, in one specific case, a product specification could not be identified by the driver and the truck was denied access to cross a border and ordered by the border officials to return the goods to the supplier's warehouse. Proper communication with the driver could have prevented the truck from being denied and sent back to the supplier.

Participants were asked what current decarbonisation practices are in place to limit the number of carbon emissions in the road freight industry. A few participants mentioned RTMS, with most participants admitting that there are currently not any decarbonisation practices in place for the company. Companies, however, do tend to plan the most efficient route to travel by, to increase the total number of deliveries per day, but this is hampered by roadworks, congestion and the delayed loading and offloading of the trucks. Key themes that were derived from the unprompted responses can thus be summarised as:

- Strikes and security being a concern for management;
- Hijacking playing a role in the loss of goods in transit;
- Theft of stationary trucks in rural delivery areas;
- Managers' trust in drivers;
- Unnecessary trips leading to extra kilometres;
- Slot time adherence plays an important role and can be linked to unnecessary trips;
- Limited road freight decarbonisation practices are currently in place within companies;
- RTMS has been implemented in some companies.

6.2.3 Prompted responses

After discussions on the themes and challenges of road freight, participants were shown McKinnon's road freight decarbonisation framework, which was explained in detail to each participant. After discussions on McKinnon's decarbonisation framework, participants were asked to study the framework and to identify any possible improvements that could be made to the framework within a South Africa-specific environment. In these discussions, participants again highlighted the themes identified in Section 6.2.2. It was indicated that these themes could be included in the framework for a more holistic South African decarbonisation framework. It was specifically mentioned that more emphasis could be placed on the behaviour of the drivers, the culture of compliance and the logistics network efficiency of a company.

Modal split comments from the participants were very limited with most of the transportation taking place on road freight due to the railway infrastructure not being available at preferred delivery points closer to the demand. Unreliability and long lead times of the railway were also a concern for participants. Thus, road freight remains the preferred method of delivery in South Africa. The handling factor averaged on goods being handled twice, with companies having goods sent from the production sites to warehouses (once-handled) and then from a warehouse to a customer (twice-handled). The average load on trips taken to customers was dependent on the trucks' capacity. No overloading could be detected during interviews, but loading utilisations seemed to vary from type of goods transferred and the season of the year.

Summer seasons tend to have a higher loading utilisation in the clothing industry, because summer fashion is denser and smaller, increasing the utilisation of the truck above that of winter loads. In winter, the trucks deliver high bulk loads of items (winter jackets, winter duvets and blankets) making the truck utilisations lower in the winter months resulting in more trips being taken.

The timing of deliveries seems to vary between participants with only one of the participants interviewed who makes use of night-time deliveries to minimise road congestion and other disruptions that may hamper a load being delivered during the day. The energy efficiency of the trucks also varied between the participants. Participants who are RTMS certified had updated truck technologies and serviced the vehicles frequently to ensure trucks are all in a good, stable working condition. Participants who were not RTMS certified tended to have older trucks, which were not serviced regularly. Following the prompted responses, the following main themes were identified:

- Driver behaviour;
- The culture of compliance within a company can play an important role;
- Logistics network efficiency plays a role in the efficiency of goods delivery;
- Rail's unreliability;
- Most companies make use of day-time delivery.

6.2.4 Importance and conclusions

Through analysing the findings from the interviews, it was possible to derive road freight-specific themes for South Africa. Themes were identified that are also recognised in McKinnon's framework. The themes also indicate what developmental opportunities exist to expand the McKinnon framework and for the development of a South African decarbonisation road freight framework. Table 6.1 summarises themes deducted from the interviews and identifies whether the themes can be categorised as a McKinnon theme or a newly emerging theme that can be added to the South African framework.

Table 6.1 Themes identified during interviews

Identified as McKinnon	Identified within South Africa
Driver behaviour	Unnecessary trips
Logistics network efficiency	Slot time adherence
Average handling factor	Strikes and security
Empty loading	Hijacking
	Theft
	Culture of compliance

6.3 CONCLUSION FROM PHASES ONE AND TWO

To simplify the conclusions from phase one and two, the themes identified can be categorised into what can be referred to as the decision-making influences for South African companies. Each of the themes can be affected by management's decision to act upon by either improving or ignoring the theme. The decision can thus either have a positive or negative influence on the number of carbon emissions emitted. Table 6.2 consolidates the themes from phases one and two and categorises the themes into the four different decision-making influences. The table also determines if the themes originated from McKinnon or South Africa. The four decision-making influences form the foundation on which the South African road freight decarbonisation framework was developed.

The four decision-making influences are **modal shift**, **logistical network efficiency**, **operational efficiency** and **culture of compliance**. Three out of the four decision-making influences can directly be linked to the McKinnon framework and culture of compliance was added as a new decision-making influence, which originated during the data gathering process.

Within each of the decision-making influences, a range of variables can contribute to the number of carbon emissions being emitted. These variables can be altered when management decides to react and implement a decision-making influence to respond upon a variable to change a variable's negative state. The state of a variable may be negative when the variable impacts the company negatively by either inducing more carbon emissions or by incurring more cost expenses for the company. The four decision-making influences can have a hierarchy of implementation with modal shift being the first influenced decision that can be made, followed by the logistical network efficiency, operational efficiency and culture of compliance. The following sections (6.3.1-6.3.5) are dedicated to summarising from the research what carbon variables can be allocated to each of the decision-making influences. This is significant for the research, as the South African decarbonisation framework is based upon the four decision-making influences with corresponding variables.

Table 6.2 Decision influences for South Africa with corresponding themes

Decision influence	McKinnon	South Africa
Modal shift	Road versus Rail	
Logistical network efficiency	Empty loading	Slot time adherence, unnecessary trips
Operational efficiency	Mechanical and Behavioural	
Culture of compliance		RTMS, theft and hijacking

6.3.1 Modal shift

For the hierarchy of implementation, it is assumed that the first decision management will make is to determine how the freight will be delivered, which is the **rail versus road** decision (this is also defined in McKinnon's framework as the modal split parameter). This essentially means that the second, third and fourth decision-making influences will be made on a reduced fleet with a smaller total of annual road freight kilometres travelled. The concept of synergy must thus be introduced to describe the interaction between the influences and variables. When combined, the influences and the variables' total and full decarbonising effect may be different than if only one theme or variable is implemented. This is discussed in Section 6.4.

To shift freight from road to rail, companies must take into consideration what type of freight is 'rail friendly' and the reliability of the lead times via rail freight. Once the freight that will be moved from road to rail has been identified and lead time reliability has been established, companies need to take into consideration the potential hurdles when moving freight by rail. One such hurdle is the longer and possible unreliable lead time for rail freight. It is possible to overcome these lead time constraints by planning and calculating when the demand needs to be met. Should the lead time, for instance, be seven days to move freight by rail, managers can use this as an advantage to plan accordingly. A buffer in lead times should also be considered, and current stock levels at the client.

6.3.2 Logistical network efficiency

The second decision-making influence is the logistical efficiency of the network. McKinnon highlights this in the framework (handling factor, number of links, empty loading), but it was found during the first and second data requisition phases that further carbon variables can be included into the network decision-making function. The variables **slot time adherence**, **unnecessary trips** and **empty loading** were added to the carbon variables for the decision-making influence of the logistical network efficiency. The decisions of logistical network efficiency will include executing route planning, taking into account the identified variables, as certain routes may be more efficient than others when taking into consideration the road infrastructure, congestion and safety of the route.

Labour unions in South Africa can play a large role in strike actions taking place. These strikes disrupt daily commuting and road freight activities and have an impact on whether deliveries can take place or not. Should negotiations take place for a planned strike, the affected company can plan ahead, so that the strike does not have a significant impact on customer service and deliveries. However, when strike actions take place without warning, companies suffer as a result of road freight deliveries not taking place. In some cases when a strike is known in advance, transport companies still neglect to plan routes away from dangerous routes where the strike is taking place. Strikes in South Africa can become violent with trucks being set alight. On occasion, truck drivers have been threatened with death should work, and deliveries continue. South African companies must be aware at all times of the strikes taking place that can hamper deliveries and threaten the lives of their employees. Companies who do not communicate to all stakeholders when a planned strike is to take place must start implementing open communication channels to all who would be affected by the strike. This would allow all stakeholders to plan accordingly to prevent delays or denied offloading.

Slot times are allocated to customer deliveries so that trucks will arrive at a predetermined time that was allocated for delivery. The slot time is to aid receivers to efficiently plan the receiving bays, the workforce needed for offloading, total truck deliveries for the day and making sure all deliveries are not delivered in the same time frame, which can cause a backlog at the receiving bays. Some companies cannot accommodate multiple deliveries at the same time, because receiving areas are limited due to space constraints. Trucks must thus arrive at allocated slot times for ease of off-loading and planning.

To decrease the number of unnecessary trips, companies must start to actively investigate what the root causes for these trips are. It was found during the research that companies tend to not track or quantify the impact these trips have on the company (refer to Appendix F for more detail regarding the possible impact of unnecessary trips). Together with the financial impact of driving more than necessary, the extra carbon emissions due to these trips can also be limited. Further recommendations would be to implement open communication channels between clients and suppliers, as in some cases an unnecessary trip can be prevented by simply making a phone call such as in the instance when a warehouse has reached full capacity.

Empty loading can either occur when a truck has not been utilised to full capacity upon loading, or it can occur when a truck returns empty to its warehouse after the day's deliveries have been completed. For the research, the focus was placed on empty loads returning to the warehouse as the carbon emissions per tonne-kilometre are much higher when a truck is driving with no load. Empty loading may be due to market-related decisions, regulatory obligations, inter-functional decisions, infrastructural hurdles or equipment-related difficulties. Empty loading is one of the largest carbon contributors for South Africa, and it can also have a sizeable financial impact when trucks return empty to a warehouse, especially when the truck has travelled long distances. There were also instances mentioned by participants where trucks were denied loading due to health and safety regulations of the truck not having been met.

To avoid empty trips, collaborative initiatives can be considered by management to utilise trucks on the return journey. This can take place in the form of recycled goods being returned to the supplier or the use of matching services.

6.3.3 Operational efficiency

Following logistical network efficiency, two carbon variables can be altered, which can be executed in parallel with one another, namely the **mechanical efficiency** of the truck and the ability of the driver to drive more efficiently, thus the **driver's behaviour**. This will fall into the scope of operational efficiency and in the McKinnon framework, under energy efficiency.

The driving behaviour of a driver and the vehicle efficiency can influence fuel consumption, as discussed in Section 3.6.6. During the interviews, it was discussed that the compliance towards regulations in the road freight industry can still improve and that companies tend to neglect or not comply with regulations. Companies can make use of various driver-training courses as the benefits of training drivers cannot only decrease carbon emissions, but will also have a positive financial impact for the company.

6.3.4 Culture of compliance

It was observed that **RTMS**, **theft** and **hijacking** are unique carbon variables in South Africa. Companies commented that there is a culture of non-compliance (as also mentioned by Nordengen and Naidoo (2014)) or an inherent rebellious nature in South African transport companies and drivers.

The culture of compliance was a prominent theme during the interview process. Many companies still feel that the workforce is not compliant with company rules, policies and procedures. Culture also forms part of Hawks' (2001) fourth pillar of sustainability. This pillar states that culture must be taken into account for environmental responsibility and economic viability. RTMS will address the non-compliance culture South African companies are facing today by providing more incentives to drivers to perform well in the business environment.

RTMS was included in the South African decarbonisation framework as it is believed, based on interview discussions, that RTMS will become more prominent in future legislation and company dealings in South Africa. South African companies seem to have a low implementation of basic transport regulations, which may be experienced within a developing country, and the RTMS's four pillars will assist transport companies to achieve a higher level of transportation regulating maturity. It was observed in the interviews that there are already customers forcing suppliers to become RTMS compliant in order to remain a partner in business transactions. In addition, RTMS provides numerous benefits to companies implementing this system such as lowered fuel usage and CO_2 outputs, fewer traffic fines, fewer kilometres travelled and fewer mechanical breakdowns. RTMS will aid companies to reach efficiency by implementing basic transport regulation rules that will have a quick impact with early results.

Hijackings are taking place on high-valued goods in transit or trucks carrying high-demand items such as maize and canned goods. This, in turn, leads to deliveries being retaken due to the load either being rejected by the customer or in the case of goods being stolen, redelivery taking place. Companies must take into account high-security risk areas that are prone to hijacking or in-transit theft. Should the area of delivery not be avoidable, proper or extra security precautions must be taken. Route planning can also be done to avoid taking high-risk routes.

The safety of the drivers can also affect the business operations as it could be argued that drivers would be hesitant to deliver goods in areas that have a known history of theft and hijacking. Tarps that are cut while trucks are idling in high-risk areas would also have a financial impact on a company as not only would the stolen goods have to be replaced, but the damaged tarp would be needed to be repaired or replaced. Further research can also be conducted on the replacement value of the goods versus the replacement value of damaged assets in these cases where goods were stolen in transit.

6.3.5 Adjustments to the McKinnon framework

Through the analyses from phase one and phase two data gathering, it was possible to identify the developmental opportunities that exist in the current McKinnon framework. The new decision influences were added to the McKinnon framework and are presented in Figure 6.4. The figure indicates where the new carbon variables fit into the existing McKinnon framework. The process to identify new carbon influences and variables are summarised in the flowchart, Figure 6.3.

Modal shift remains at the top of the framework, as this will be the first decision when moving freight. Slot time adherence and unnecessary trips, from the logistical network efficiency, were allocated under the total vehicle kilometres, as both these carbon variables have a direct relationship with the total kilometres travelled. The culture of compliance decision-making influence was also allocated under total vehicle kilometres as RTMS and hijacking may have a direct relationship with total annual kilometres travelled, as discussed in Section 6.3.4.

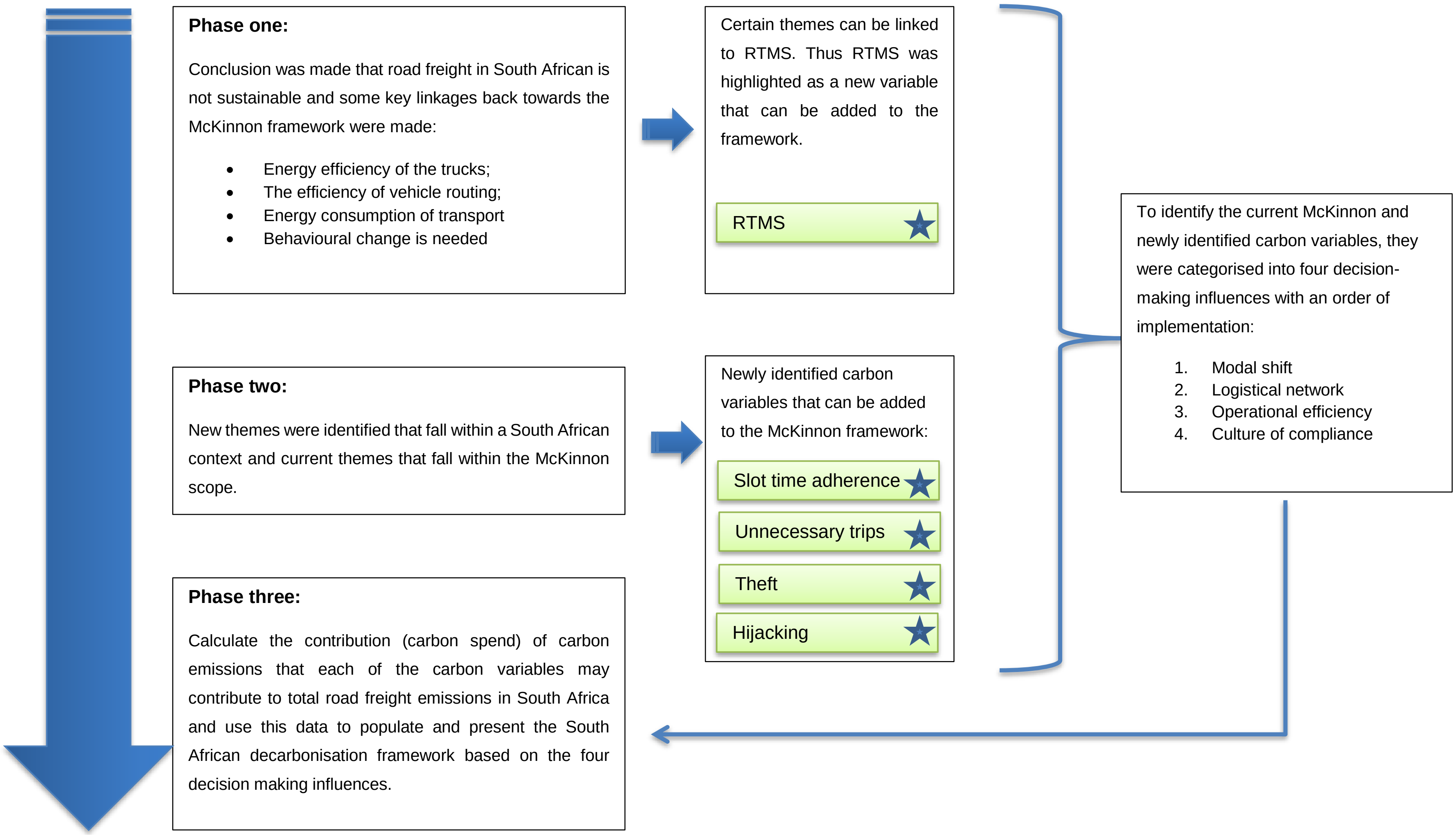

Figure 6.3 Flowchart for identifying new parameters and aggregates

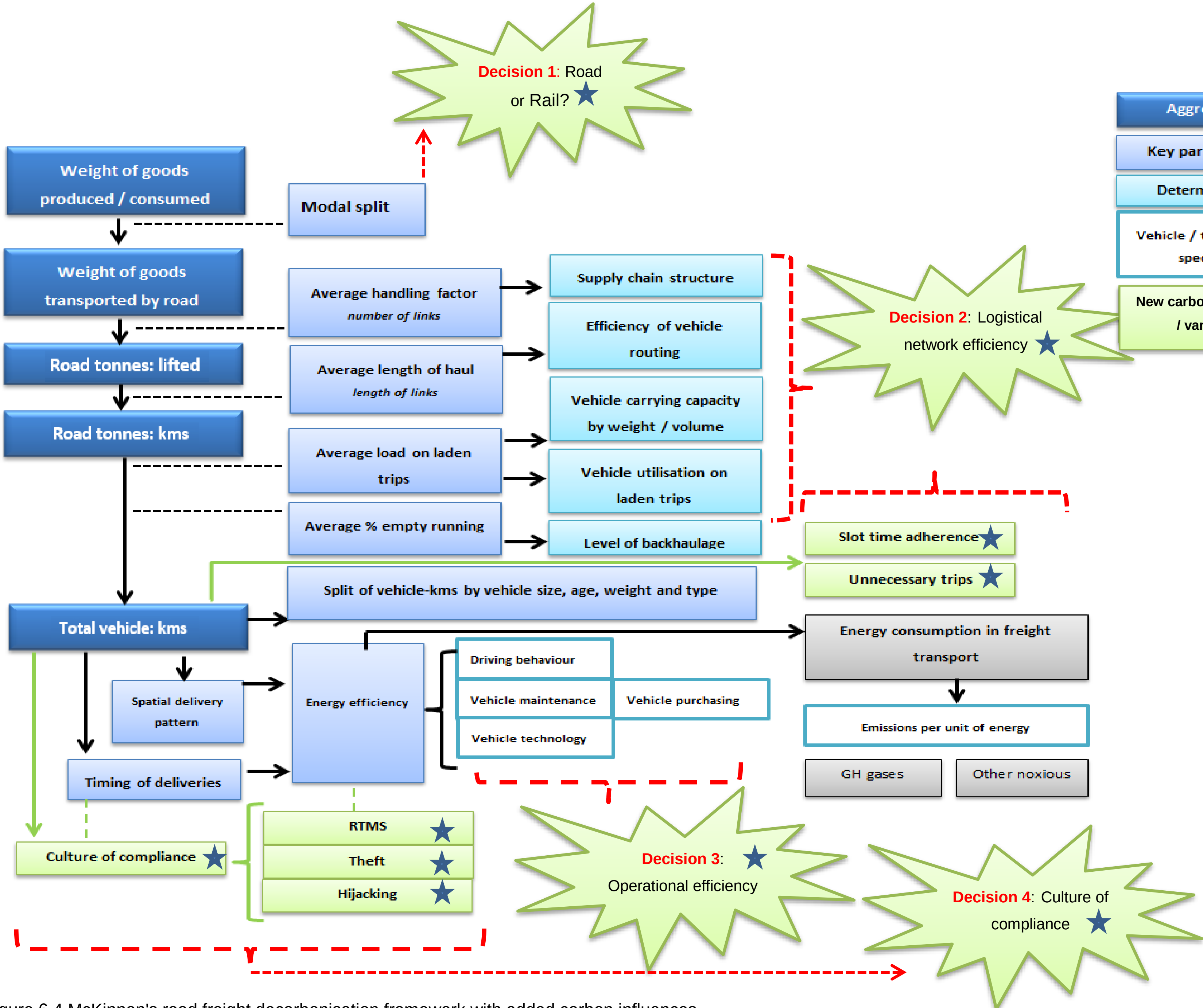

Figure 6.4 McKinnon's road freight decarbonisation framework with added carbon influences

Source: Adapted from McKinnon, 2015a

6.4 INTERRELATIONSHIPS AND SYNERGY

Within each of the decision-making influences, the carbon variables may have an interrelationship with one another, and total synergy can be achieved when implementing all of the decision making influences sequentially. The first decision-making influence, road versus rail, will decrease the total number of kilometres travelled by road when freight is moved to rail, and this will, in turn, decrease the total amount of road freight carbon emissions as fewer kilometres will be travelled on the road. Although rail freight will also have a carbon emission component, it is estimated to be four times more energy efficient than that of road freight transport (Havenga & Simpson, 2014). In general, optimal rail freight has a lower carbon footprint than road. (Havenga *et al.,* 2016). The focus of the decarbonisation framework is, therefore, on decreasing road freight emissions, which is the most significant carbon emissions contributor for freight movement. Thus, this research will only focus on the effect on road freight emissions and will not focus on the rail component of carbon emissions and its relationships.

The first decision will consequently have an interrelationship between the second, third and fourth decision by decreasing the total preliminary kilometres and carbon emissions from each decision before executing. An example of this could be, should the total number of road freight kilometres of a company amount to 100 000 kilometres per year, and the company decides to move 20 000 of the kilometres to rail, by changing the routing of deliveries, this decision will amount to 20 000 kilometres less travelled on road and fewer carbon emissions emitted on road, which would have originated from the 20 000 kilometres. Following this decision, the second decision making influence now only has 80 000 kilometres travelled on the road (100 000 minus the 20 000) and fewer carbon emissions emitted already by decreasing the kilometres travelled by moving freight to rail. More in-depth calculations are provided in Chapter 7.

When the next decision is made to engage on improving the logistical network, 80 000 of road freight kilometres and road freight emissions pertaining to the kilometres, can be reduced by improving upon slot time adherence, reducing unnecessary trips and minimising empty loading. If the rail decision were not made, the logistical network would have had to be improved on more kilometres (the 100 000) and more carbon emissions. Thus, decision one’s outcome will directly affect decision two. The same interrelationship will exist between all of the decision making influences. When the first decision is made, the subsequent decisions may have fewer kilometres and carbon emissions to execute upon. Figure 6.5 illustrates the interrelationship.

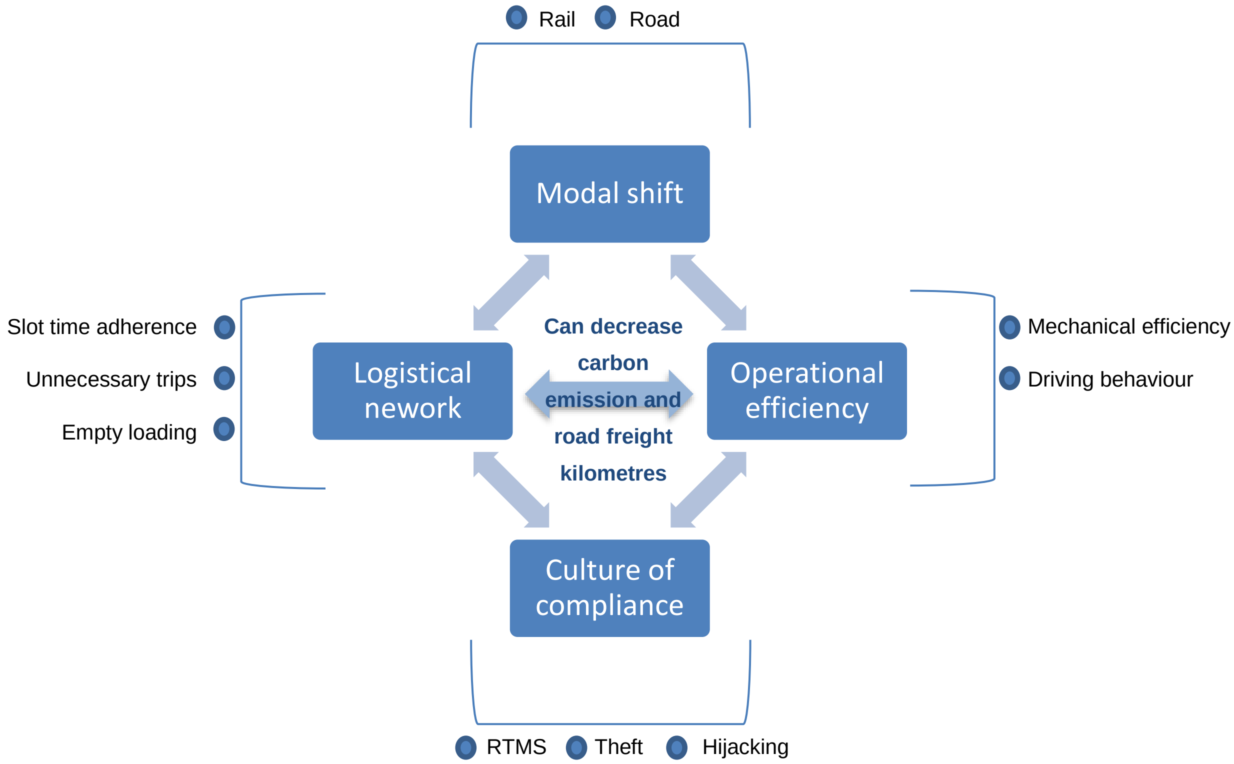

Figure 6.5 Interrelationships of influences and variables

The logistical network may have a direct impact on the operational efficiency of a company where the carbon variables, slot time adherence and unnecessary trips, can improve should the driver's behaviour adhere to company policies. Should a driver adhere to policies such as following specific planned delivery routes, slot times may improve, and empty loading can decrease when operational efficiency includes policies to limit empty loading. Mechanical efficiency can improve slot time adherence and decrease unnecessary trips to prevent truck breakdowns. Further interrelationships such as road safety, transport costs and service delivery can also co-exist between the carbon variables. Overall, road safety can improve when operational efficiency and the culture of compliance components are incorporated into company policy, while transport costs can decrease and improve service delivery. The decrease of carbon emissions can also have a cost reduction on the overall Rands per kilometre of the trucks by improving the logistical network, operational efficiency and the culture of compliance.

Synergy can be achieved when all of the decision-making influences and carbon variables are implemented sequentially. This will ensure that the total decrease in carbon emissions will be more substantial in comparison to should only one decision-making influence be acted upon. Synergy cannot be accomplished without the interrelationship between the decision-making influences. The synergy calculations are discussed in Chapter 7.

6.5 PHASE THREE DATA CAPTURING: QUESTIONNAIRE AND TRIANGULATION

6.5.1 Method

The parameters and aggregates in the McKinnon framework and the new decision-making influences with corresponding variables were populated using two different data sources, the FDM and phase three's data questionnaire (Appendix D). The purpose of the data population was to:

- Adapt the McKinnon framework with South Africa's road freight data;
- Identify the potential total national percentage reduction in total road freight kilometres for each decision-making influence and carbon variable within South Africa that would, in turn, lead to a decrease in carbon emissions;
- Calculate the carbon spend for the identified road freight carbon variables.

Data gathered from the FDM was used to triangulate the data gathered from the research questionnaires to validate the responses received from the questionnaires. In total, 132 companies responded to the questionnaire. The majority of the respondents were bulk carriers (58.46%) with refrigeration having the lowest response rate (1.54%), as seen in Figure 6.6.

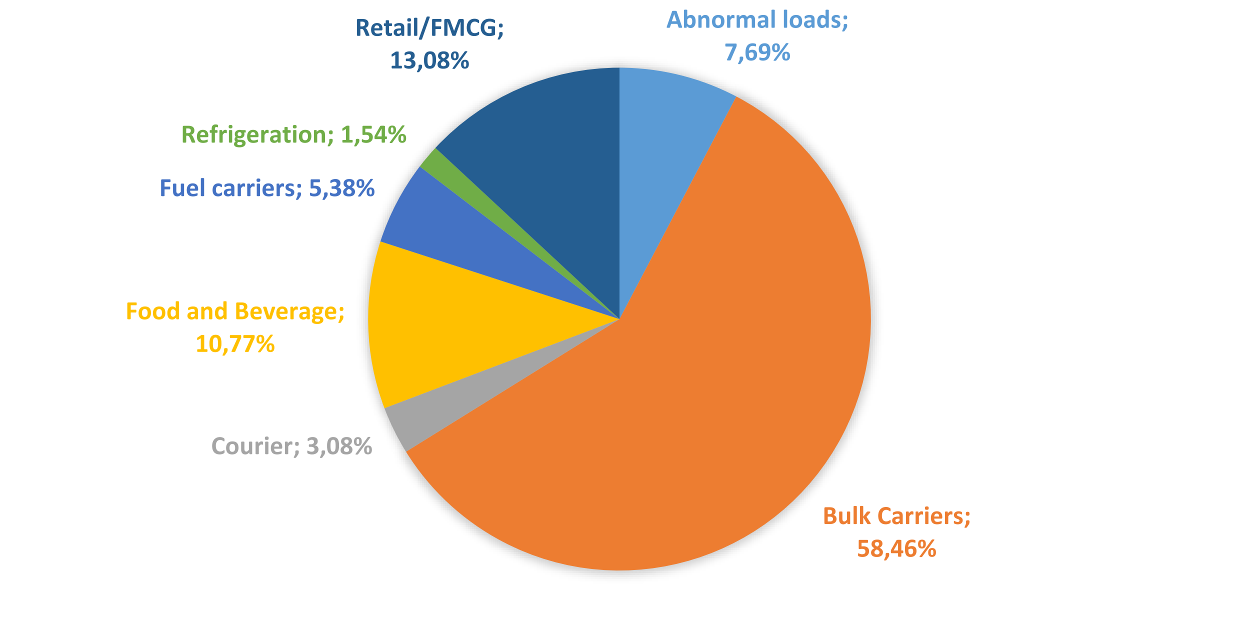

Figure 6.6 Companies from third phase data questionnaires

The company respondents were categorised into seven operating categories, according to the primary operations within the company (Figure 6.6). Table 6.3 provides a further detailed breakdown with regards to the categorisation of the companies. The categorisation of the companies was done to make the data interpretations more manageable. Bulk carriers thus have a wide variety of company representatives due to the variety of types of bulk the companies may carry. Companies, such as refrigeration, the primary focus is to only transport refrigerated goods, thus categorised in its own category, but can also be classified as a bulk carrier due to the nature of goods being transported.

Table 6.3 Categorisation of companies

Bulk Carriers	Abnormal loads	Fuel carriers	Food & Beverage	Retail/FMCG	Courier	Refrigeration
Palletised break bulk	Engineering parts	Petrol	Grain carriers	Clothing	Door-to-door customer deliveries	Perishables
Refuse/Rubble removal	Machinery	Diesel	Consumable liquids (wine, oil)	Perishable consumables	Door-to-door company deliveries	Medical supplies
Electronics	Large building materials	Coal	Livestock	Non-perishable consumable		
Building materials (sand, stone etc.)	Mining					
Manufacturing materials (consumable and non-consumable)	Forestry					
Fragile goods						
Household furniture						
Hazardous materials						
Container transport						
FMCG products, including perishables						
Agriculture						

The data were categorised into categorical and non-categorical through the STATISTICA analysis software. The first dataset analysed the descriptive statistics of non-categorical data. The number of companies represented in each variable (n) varied from each descriptive statistics due to some of the companies having left responses blank. Thus, the valid n refers to the respondents that filled in the questions. The non-categorical data focussed on the quantification of the aggregates and parameters within the McKinnon framework and newly identified carbon variables. The aggregates, parameters and carbon variables were categorised into the four decision making influences to calculate the reduction potential of carbon emissions and road freight kilometres for each of the decision-making influences. This is discussed further in Chapter 7. The second dataset analysed the categorical answers from the companies and also provided further insights into tuck hijackings and RTMS.

Table 6.4 indicates to which aggregate, parameter or new carbon variable, the questionnaire question was aimed to populate within the framework, and if the origin of the variable was from McKinnon or South Africa. The table also identifies which aggregate, parameter or variable may have an interrelationship with one another. Furthermore, the table categorises the variables into the four decision-making influences.

Table 6.4 Summary of questions with corresponding variables

Variable/Question	Aggregate	Parameter	McKinnon	South Africa	Decision-making influence
Total annual km that can be reduced by adhering to slot times	Total vehicle kilometres	Slot time adherence		x	Logistical network efficiency
Total annual km that can be reduced by unnecessary trips	Total vehicle kilometres	Unnecessary trips		x	Logistical network efficiency
Percentage empty loading of trucks when returning to the depot	Total road tonnes and total vehicle kilometres	Empty loading %	x		Logistical network efficiency
Does the company replace a hijacked load	Total vehicle kilometres	Hijacking		x	Culture of compliance
Average weight of goods transported in tonnes	Road tonnes lifted	Average load on laden trip	x		Logistical network efficiency
Average km length of a trip	Road tonnes per km	Average length of a haul	x		Logistical network efficiency
Average handling factor of goods	Total vehicle kilometres	Average handling factor	x		Logistical network efficiency
Is the company RTMS Compliance	Total vehicle kilometres/ Culture of compliance	RTMS		x	Culture of compliance
Percentage of loads replaced due to theft	Total vehicle kilometres/ Culture of compliance	Theft		x	Culture of compliance
Slot time adherence	Total vehicle kilometres	Slot time adherence		x	Logistical network efficiency

6.5.2 Data analysis and conclusions

The data was imported into STATISTICA, and descriptive statistics were derived, as seen in Table 6.5. The spread of the data where the most notable standard deviations from the mean occurred was the number of kilometres that can be reduced by unnecessary trips (0.29), empty loading (0.35), the average length of a trip (3013.19) and slot time adherence (0.19). For the average length of a trip, the lower quartile showed results of 250 kilometres, with a minimum of 15 kilometres, while the upper quartile resulted in 11 000 kilometres with a maximum of 23 000 kilometres.

Table 6.5 Descriptive statistics from non-categorical data

Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper quartile	Standard deviation
Km reduced by slot times adherence %	111	0.13	0.10	0.01	0.95	0.03	0.15	0.16
Km reduced by unnecessary trips %	122	0.15	0.10	0.01	3.00	0.02	0.02	0.29
Empty loading %	121	0.44	0.30	0.00	1.00	0.10	0.72	0.35
Average weight of goods transported (tonne)	128	29.05	28.00	0.12	300.00	17.08	0.40	31.99
Average length of a trip (km)	120	1320.03	550.00	15.00	23000.00	250.00	11000.00	3013.91
Average handling factor	131	2.36	2.00	0.00	9.00	1.00	3.00	1.39
Loads replaced due to theft %	126	0.02	0.00	0.00	0.40	0.00	0.01	0.05
Slot time adherence %	126	0.85	0.90	0.10	1.00	0.80	0.95	0.19

ANOVA testing was conducted to identify if differences exist in the response variables among the company operational categories. Least significant difference (LSD) multiple comparisons among the response variables' means were calculated and the least square (LS) means with a 95% confidence intervals were plotted with lettering ('a','b', or 'ab') above the graphs indicating if these means differ significantly or not. The values 'a', 'b' and 'ab' have similarities with one another where all 'a's show similar results, the same for 'b' and 'ab'. Differences in the mean variables for 'Empty loading %', 'Average handling factor' and 'Loads replaced due to theft % was identified'. This can be seen in Figures 6.7 – 6.9.

A difference was indicated for 'Couriers' in the average handling factor of goods indicating that couriers handle freight more and 'Abnormal loads' was identified as an outlier in loads being replaced due to theft. Further analysis of descriptive statistics indicated that the 'Abnormal loads' mean for the average handling factor was five times with an upper quartile of 7. This is significantly higher than 2.36, which was the mean of the total sample. Abnormal loads indicated a mean of 9% with the median being 2%. Upon further investigation, two large data outliers were identified within the abnormal load category having a theft replacement rate of 40% and 30% respectively, skewing the total results of the analysis. These two companies specialise in the movement of large, highly valued loads and also indicated in the questionnaire that loads are being hijacked. Should these two data outliers be excluded, the mean decreases to 1.59%, more in line with the total sample mean.

The ANOVA f-values for empty loading was recorded as 1.7, handling factor as 3.4 and loads replaced due to theft as 4.0. These results indicate that although there is an indicated difference in the LS means for the different operations, there is statistically no significant difference.

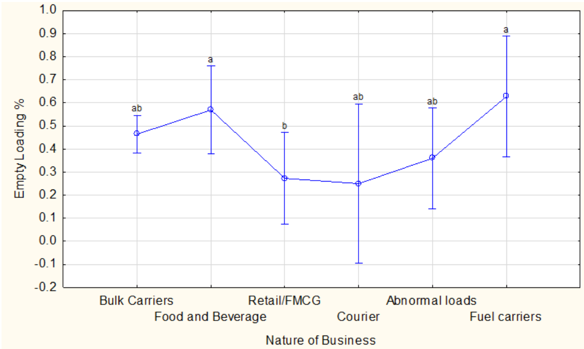

Figure 6.7 LS means per operation for empty loading %

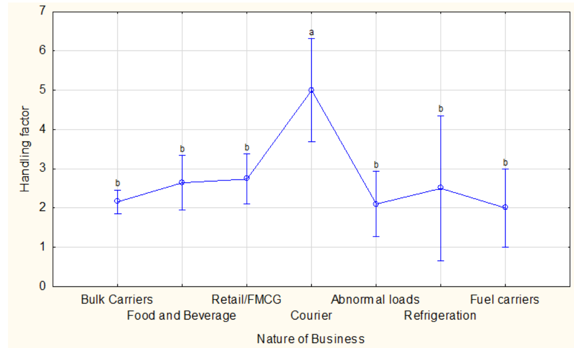

Figure 6.8 LS means per operation for handling factor

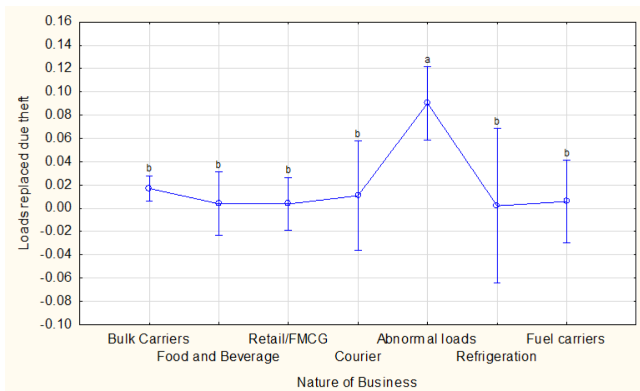

Figure 6.9 LS means for loads replaced due to theft

Probability plots were used to check if the residuals from the ANOVAs were approximately normally distributed. The residuals for ‘Kilometres reduced by slot times adherence %’, ‘Empty loading %’, ‘Average handling factor’ and ‘Slot time adherence %’ were relatively normally distributed, but the residuals for variables ‘Kilometres reduced by unnecessary trips %’, Average weight of goods transported (tonnes)’, ‘Average length of a trip’ and ‘Loads replaced due to theft %’ were not, as indicated in the following departures from the red line indicating normally distributed data (seen in Figures 6.10 - 6.13). For the non-normal variables, the Kruskal-Wallis test was applied.

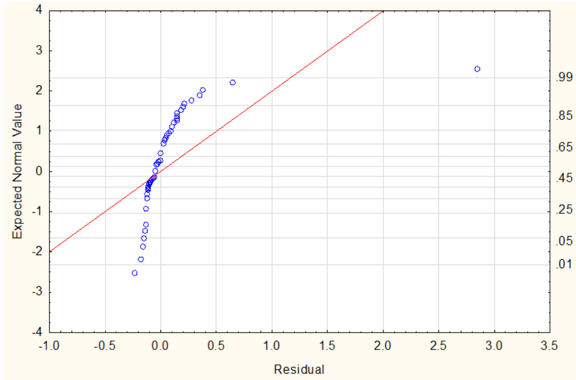

Figure 6.10 Probability plot: unnecessary trips

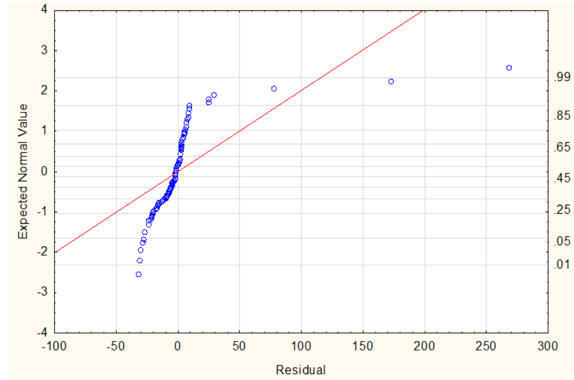

Figure 6.11 Probability plot: average weight goods

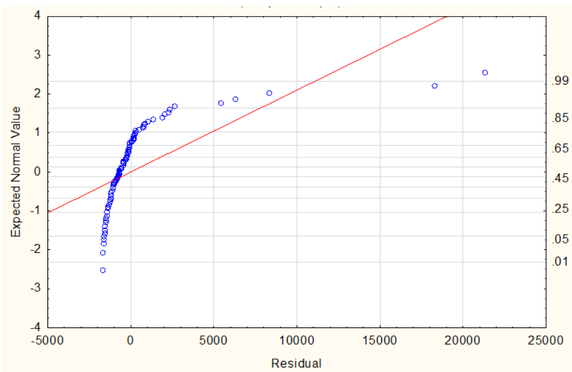

Figure 6.12 Probability plot: length of a trip

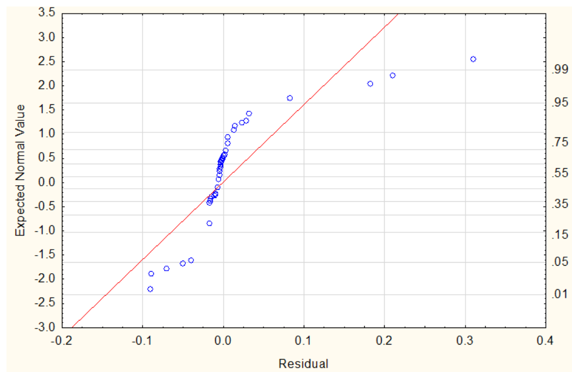

Figure 6.13 Probability plot: loads replaced due to theft

The Kruskal-Wallis test followed the LS mean plotting to determine if there is a statistically significance between the companies and the variables. The hypothesis for the p-values was thus:

$$H_o = \textit{there are no differences between the companies per variable}$$

$$H_1 = \textit{there are differences between companies per variable}$$

Large p-values ($p > 0.05$) were recorded for each of the variables, thus H_o could not be rejected. This concluded that there are no significant statistical differences between the variables for the different types of operational road freight companies. The p-values for all variables in the Kruskal-Wallis test can be seen in Table 6.6.

Table 6.6 Kruskal-Wallis test p-values

Variable	p-value for Kruskal-Wallis
Km reduced by slot times adherence %	0.76
Km reduced by unnecessary trips %	0.31
Empty loading %	0.05
Average weight of goods transported (tonne)	0.51
Average length of a trip	0.28
Average handling factor	0.15
Loads replaced due to theft %	0.67
Slot time adherence %	0.92

To determine the independence of the categorical data (replacing a hijacked load and RTMS compliance), Chi-square tests were performed. Replacing a hijacked load resulted in a score of 2.98 (degrees of freedom = 6), with a p-value of 0.81. RTMS compliance resulted in a chi-square of 11.02 (degrees of freedom = 6) with a p-value of 0.08. The chi-square thus indicated that there are no significant statistical differences between the variables for the different types of operational road freight companies, given the p-values are larger than 0.05.

For the categorical data, cross-tabulations with histograms were used to summarise the frequencies per freight operations, where the frequency or number of observations (y-axis) refers to the number of companies (n) represented in each road freight category (Figures 6.14 – 6.15). The majority of companies responded that a load would not be replaced should a hijacking occur. The total resulted in 62% of participating companies that would not replace a hijacked load, while 38% would. RTMS compliance seems to be spread between the different freight operations with ‘Food and Beverage’, ‘Retail/FMCG’, ‘Abnormal loads’ and ‘Refrigeration’ showing large differences between either complying or not.

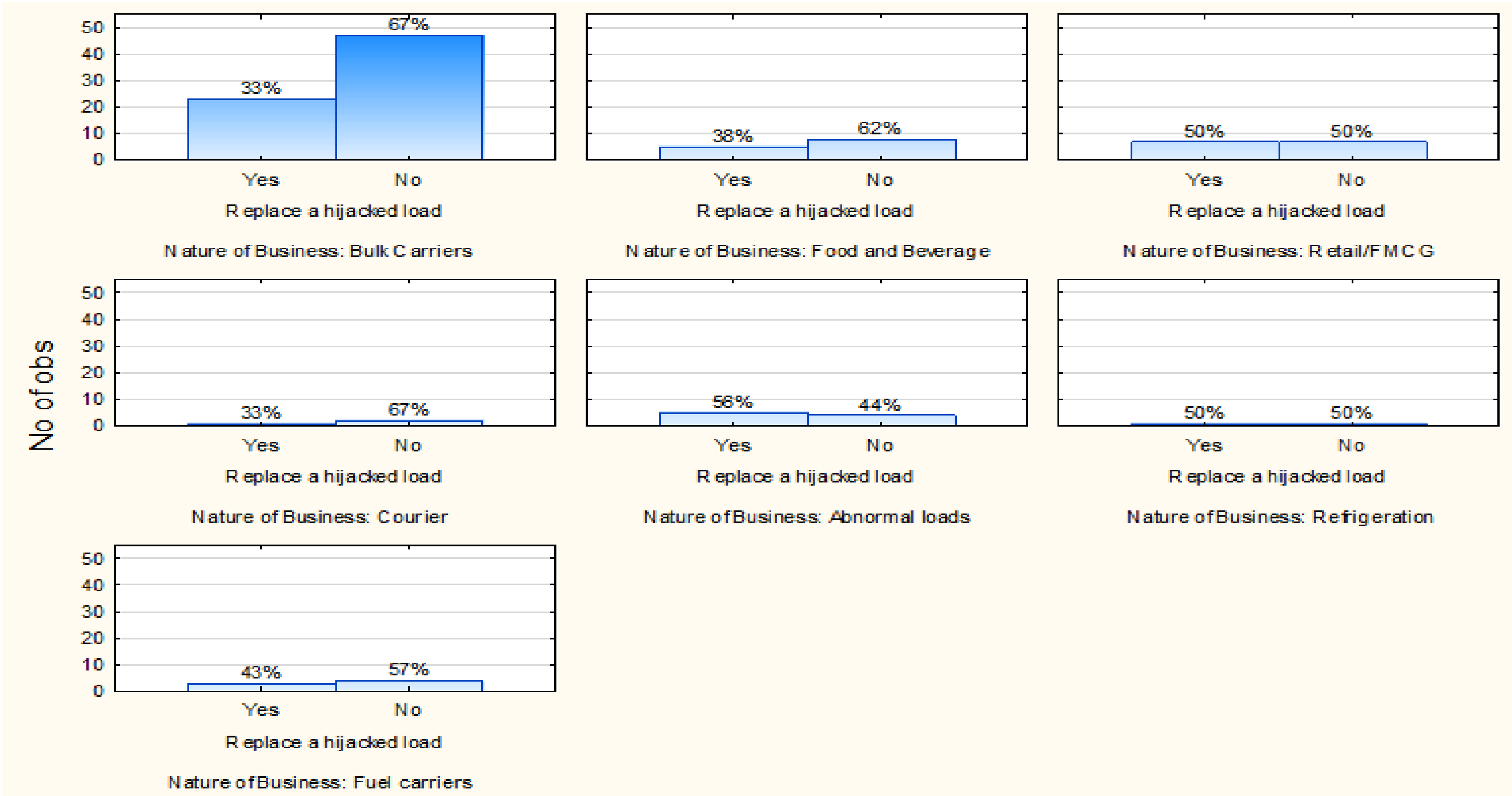

Figure 6.14 Summary per company: replace a hijacked load

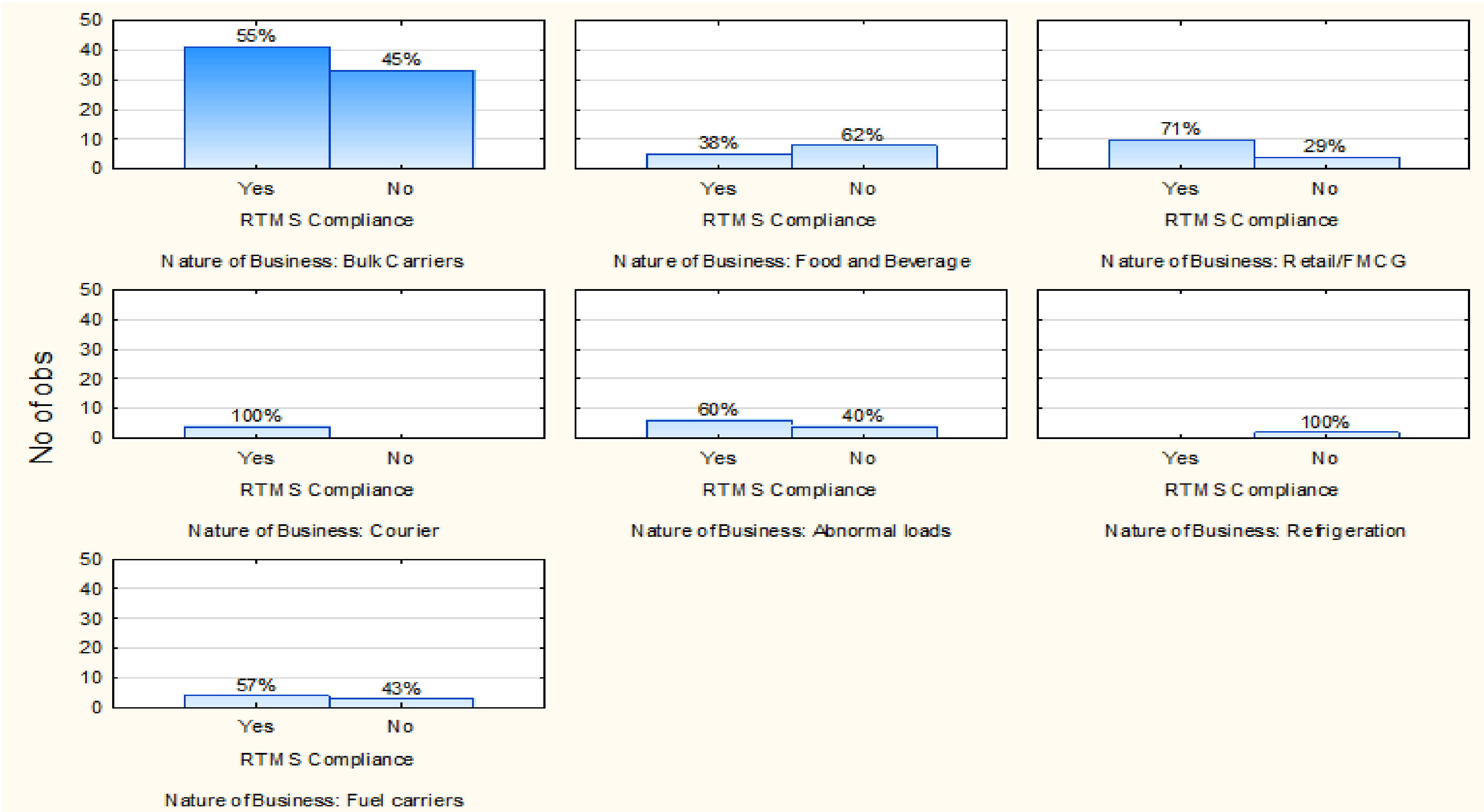

Figure 6.15 RTMS compliance for each freight operation

Due to some data outliers in variables, it was concluded not to use the current calculated mean as the average potential reduction of total annual road freight kilometres due to the outliers skewing the total results of the analysis, and ultimately the calculated reduction in carbon emissions. Normalisation of the data was required to establish a new average of the non-categorical data. To normalise the data, the data outliers were excluded. With the use of Tukey's rule (Tukey, 1977), outlier coefficients were identified via Boxplots and excluded. Tukey's rule states that the outliers are values more than 1.5 times the interquartile range from the quartiles (Refer to Appendix G for Boxplots and outliers). It was deemed that data normalisation would show a more accurate reflection on data conclusions. Data that were normalised were:

- Large questionable percentage (> 40%) reductions in total annual kilometres should unnecessary trips be eliminated (excluding slot times);
- Large questionable percentage reductions (> 40%) in total annual kilometres should slot times be adhered to, which eliminated unnecessary trips;
- Large questionable percentages (>50%) of trucks returning empty to depots;
- Large questionable lengths of trips (>10 000km) as single long trips may indicate cross-border deliveries, which does not form part of South Africa and is out of scope for this research;
- Answers that participants left blank.

Table 6.7 represents the adjusted valid n from each percentage variable used for kilometre and carbon reduction calculations. The 'n' thus also indicates total companies that were excluded due to the normalisation (an n smaller than 132). Weighted average calculations for the answers were used as all the represented companies do not have the same fleet size (or annual kilometres), which may also have resulted in a skewed result should only the average quantitative responses have been used. The weighted averages were calculated in Microsoft Excel with the SUMPRODUCT notation that allows a higher weight to be allocated to larger fleets, as larger fleets will have a larger impact on total kilometres travelled on the road and impact on the variables. All answers were rounded up in the calculation.

Table 6.7 Adjusted weighted averages

Variable	Adjusted n	Weighted average
Km reduced by slot times adherence %	105	7%
Km reduced by unnecessary trips %	117	9%
Empty loading %	75	11%
Average weight of goods transported (tonne)	128	28
Average length of a trip	116	750
Average handling factor	131	2.41
Loads replaced due to theft %	126	1%
Slot time adherence %	126	80%
Loads that would be replaced due to hijacking	120	38%

Table 6.8 provides a complete summary of the results calculated from both the questionnaires and the FDM. The results are broken down into each of the separate aggregates from the McKinnon framework with the corresponding parameter. The newly identified aggregate, culture of compliance, is included together with data also provided for all the new carbon variables.

Table 6.8 Total summary of questionnaire and FDM results

Parameter	Aggregate / Carbon variable	Data questionnaires	FDM
Total annual weight of goods transported per road	Modal split		7.5%shift to rail
	Average handling factor or number of links	2.41	2.31
Road tonnes lifted and kilometres	Average length of a haul	750 kilometres	558 kilometres
	Average load per trip	28 tonnes	27 tonnes
	Changing driver behaviours reduction	**15%	*
	Percentage empty loading reduction	11%	30%
	Unnecessary trips reduction	9%	*
	Energy efficiency reduction	**5%	*
	Slot time adherence reduction	7%	*
Culture of compliance	Level of RTMS reduction	**18%	*
	Theft reduction	1%	*
	Hijacking reduction	0.0021%	0.0016%

*Data that is new to this research and cannot be calculated by the FDM

**Data gathered from the literature review

The total percentage of road freight tonnes that can be moved to rail was calculated by Havenga and Simpson in 2016 (Havenga & Simpson, 2016:327). This was estimated at 7.5%. The average handling factor for the FDM of 2.37 was derived from the figure of 500 million tons of road freight demand resulting in 1 183 million tons of road freight shipments that was published in the State of Logistics Survey of 2011 (Simpson & Havenga, 2011). However, the updated, unpublished figure from the latest FDM of 2017 was used for this calculation, which was 2.31. The average handling factor for South Africa was calculated for the first time in 2007 by Havenga (2007), for the years 1993, 1997, 2003 and 2004. The six observations since 1993 are 1.82, 2.08, 2.26, 2.27, 2.37 and finally 2.31.

The FDM results for the average length of haul was calculated by taking the total annual kilometres travelled per truck in the year, divided by the total workdays the truck was in operation for the year to calculate the total kilometres travelled per workday for the specific truck. The weighted average was then derived from all the trucks' per day kilometres travelled, more weight being allocated to trucks that carry more loads and travel more kilometres per year. The same calculations were again done to calculate the average load per trip for the questionnaires and the FDM data. Empty loading was also calculated from the weighted average of the companies' answers. The FDM empty loading percentage was derived by a three-step process:

1. First, the total annual tonnes per kilometres loaded per truck was calculated. In the FDM, it is indicated what the loading factor for each of the trucks is.
2. Given the loading factor, step two was to calculate what the total tonnes per kilometres would have been should each truck have been utilised at a 100% loading factor.
3. By deducting the total possible loading from the actual loading and calculating the weighted answer, given the total kilometres travelled, the total empty loading percentage equated to 30%.

This is different from the results obtained from the data questionnaires. It must be acknowledged that the data questionnaires provided market research data from companies in the sample size whereas the FDM results were a calculated percentage given the assumption of the trucks' total capacity payload and actual payload as given by the FDM.

For energy efficiency and culture, the percentages were derived directly from the weighted averages in the answers received from the data questionnaires and from previous studies, which was covered in the literature review. Two separate conclusions were made for efficiency and culture. Efficiency represents both behaviour and mechanical efficiency. The mechanical efficiency of 5% was derived from the literature review that shows that an average of 5% of carbon emissions can be saved when focusing on the mechanical efficiency of a truck. This percentage was used as it was deemed by the researcher to be a conservative average percentage to use as numerous improvements can be made on mechanical efficiencies, which can improve the fuel efficiency of a truck. For behaviour, the data bank from MasterDrive South Africa was used as

MasterDrive reported at least a 15% saving on carbon emissions when training South African drivers on driver behaviour improvements.

The weighted average, given the fleet size, between three companies for implementing RTMS was used as an actual carbon emissions savings that averaged at 18%. This percentage may seem high, but it must be acknowledged that RTMS includes a variety of operational improvements and the sum of all the improvements is very likely to result in a total saving of 18%. For this dissertation, it was assumed that the total RTMS implementation would result in an overall 18% reduction in both kilometres and carbon emissions due to the limited amount of RTMS data available.

Finally, theft and hijacking were calculated in two separate equations. Theft was calculated using a weighted average, given the fleet size, of all the respondents' answers on how much of total annual road freight kilometres can be reduced by eliminating theft in the company. Theft was reported as a small percentage of total road freight emissions, which was not expected because when the literature review was conducted, theft seemed to be a high concern for companies. The conclusion was made that although theft is a high concern for companies, little of this takes place in transit. Most freight theft takes place before the goods are loaded, as there is little opportunity to steal while a truck is being loaded, and all items must be accounted for before the truck leaves. Companies elaborated on all the security measures in place while a truck is being loaded or offloaded. Opportunities for theft tend to creep in during unsupervised hours in warehouses and not during the loading or offloading of a truck. The small percentage of theft via road emphasises the efforts companies take to minimise in-transit theft.

Hijacking was calculated by using the hijacking truck data from the literature review in Section 3.6.2, where 1 202 trucks were hijacked in 2018. From the data questionnaires, 38% of participants answered that deliveries would be replaced after a truck is hijacked (Table 6.7). Calculating 38% from the 1 202 trucks that were hijacked in 2018, equated to a rounded-up number of 456 trips that might possibly have been replaced. The estimated total number of trips in the FDM amounted to 28 000 000 trips annually. This was calculated by dividing the total annual road freight kilometres (16 000 000 000) by the average length of a haul from the FDM (558). Dividing the number of trips that could have been replaced (456) by the total number of trips (28 000 000) provides the conclusion that from the total annual estimated trips in South Africa, only 0.0018% of all trips would have been redelivered due to hijacking (shown in the calculation.) This is small in comparison with the total number of estimated trips. In the calculation, the assumption was made that the full trip needs to be replaced, irrespective of when during the trip the hijacking took place.

$$Total\ trips\ redeliverd\ due\ to\ hijacking = \frac{Replaced\ trips}{Total\ estimated\ annual\ trips}$$

$$= \frac{456}{28\ 000\ 000}\ x\ 100$$

$$= 0.0016\%$$

To calculate by what percentage the total percentage of road freight kilometres can be reduced by should hijacking be eliminated, the total kilometres from the replacement trips were calculated by multiplying the average length of a trip (haul) from the questionnaires (Table 6.7) by the total replacement trips and dividing this by the total annual estimated road freight kilometres. From the FDM, total annual road freight kilometres is estimated at 16 000 000 000. This is calculated by the total annual tonne per kilometre travelled per truck, divided by the truck total tonne payload per truck. The calculation derived a value total annual kilometres travelled when trucks are full and are carrying no empty loads. By dividing the load factor from the FDM for each truck by the total kilometres travelled, empty trips are also taken into account for the total road freight kilometres being travelled. Thus, a rounded 16 000 000 000 total road freight kilometres were determined.

$$Reduction\ percentage = \frac{Replacement\ trips\ x\ average\ length\ of\ a\ haul}{Total\ estimated\ annual\ road\ freight\ kilometres}$$

$$= \frac{456\ x\ 750}{16\ 000\ 000\ 000}\ x\ 100$$

$$= 0.0021\%$$

The same equation can be followed to calculate what the percentage in reduction will be from the FDM average length of a haul data, which equals 0.0016%. The results from the questionnaires and the FDM do not differ significantly, given the very small percentage of kilometres that can be eliminated.

Another calculation could also been made to determine the total annual freight kilometres for the questionnaires and the FDM. This would entail multiplying the average length of a haul from the questionnaires and the FDM by the total estimated trips taken per year, which was 28 000 000.

$$Total\ estimated\ annual\ road\ freight\ kilometers\ (Qustionnaire)$$
$$= average\ lenght\ of\ a\ haul\ x\ total\ annual\ trips$$
$$= 750\ x\ 28\ 000\ 000$$
$$= 21\ 000\ 000\ 000$$

$$Total\ estimated\ annual\ road\ freight\ kilometers\ (FDM)$$
$$= average\ lenght\ of\ a\ haul\ x\ total\ annual\ trips$$
$$= 558\ x\ 28\ 000\ 000$$
$$= 15\ 624\ 000\ 000$$

If these total road freight kilometres are used in the reduction percentage of hijacking, the following computations can be made:

$$Reduction\ percentage\ (questionnaire) = \frac{Replacement\ trips\ x\ average\ length\ of\ a\ haul}{Total\ estimated\ annual\ road\ freight\ kilometres}$$
$$= \frac{456\ x\ 750}{21\ 000\ 000\ 000}\ x\ 100$$
$$= 0.0016\%$$

$$Reduction\ percentage\ (FDM) = \frac{Replacement\ trips\ x\ average\ length\ of\ a\ haul}{Total\ estimated\ annual\ road\ freight\ kilometres}$$
$$= \frac{456\ x\ 558}{15\ 624\ 000\ 000}\ x\ 100$$
$$= 0.0016\%$$

Both these calculations resulted in the exact same amount of 0.0016%. Thus, there was no difference between using the different average total annual kilometres calculated for the questionnaires and the FDM. By using the actual 16 000 000 000 total road freight kilometres that were derived from the FDM, the hijacking reduction resulted in a 0.0021% reduction with the questionnaire's average length of a haul data and 0.0016% with the FDM average length of a haul data. The difference in these four calculations are so small that it will have insignificant effect on the actual reduction percentage. For the purpose of this dissertation, the maximum reduction is used, which is 0.0021%, and total annual kilometres of 16 000 000 000 is used for calculations.

Given the interviewees' responses that hijacking is a challenge in South Africa, a higher percentage of replacement trips was expected. This can be possibly be explained by the theory that hijacking can cause a high emotional impact on an individual (refer to Section 3.6.2) and would be remembered as a high impact event in that individual's daily operations, thus resulting in hijacking being mentioned frequently in the interviews.

Given the final calculations to quantify the four decision-making influences, Figure 6.16 was developed to represent the developed South African road freight decarbonisation framework with the four key decision-making influences identified, the carbon variables that correspond to each of the decisions and what total percentage reduction for road freight kilometres and carbon emissions can be achieved per variable separately. The figure also, for the first time in South Africa, quantifies the carbon spend from each of the decision-making influences and carbon variables. To support the data calculations methods that were used to derive Figure 6.16, Table 6.9 summarises the various methods of calculations used.

Table 6.9 Revision of calculations used for the South African decarbonisation framework

Aggregate / Carbon variable	Data questionnaire calculation	FDM calculation
Modal split		Literature review reference: Havenga & Simpson, 2016:327
Average handling factor or number of links	Adjusted weighted average calculated in Statistica	Literature review reference: Simpson & Havenga, 2011 Havenga, 2007
Average length of a haul	Adjusted weighted average calculated in Statistica	Weighted average calculated in Microsoft Excel with data from the FDM: $\frac{\text{Total annual kilometres travelled per truck in the year}}{\text{Total workdays the truck was in operation for the year}}$
Average load per trip	Weighted average calculated in Statistica	Weighted average of all loads calculated in Microsoft Excel with data from the FDM
Changing driver behaviours reduction	Literature review reference: Kimberley, 2018	
Percentage empty loading reduction	Weighted average calculated in Statistica	A 3-step method described on page 116, calculated in Microsoft Excel.
Unnecessary trips reduction	Weighted average calculated in Statistica	N/A
Energy efficiency reduction	Literature review reference: FleetCarma, 2014 Kimberley, 2018 National Research Council, 2015	N/A
Slot time adherence reduction	Weighted average calculated in Statistica	N/A
Level of RTMS reduction	Literature review reference: Van Tonder, 2016 Kruger, 2016	N/A
Theft reduction	Weighted average calculated in Statistica	N/A
Hijacking reduction	Reduction percentage from questionnaire data: $\frac{Replacement\ trips\ x\ average\ length\ of\ a\ haul}{Total\ estimated\ annual\ road\ freight\ kilometres}$	Reduction percentage from FDM data calculated in Microsoft Excel: $\frac{Replacement\ trips\ x\ average\ length\ of\ a\ haul}{Total\ estimated\ annual\ road\ freight\ kilometres}$
Total road freight kilometres		Total road freight kilometres travelled data calculated in Microsoft Excel from FDM data: $\frac{\text{Total annual tonne per kilometre travelled per truck / Total tonne payload per truck}}{\text{Load factor of the truck}}$
Total annual trips		Total annual trips from FDM data calculated in Microsoft Excel: $\frac{Total\ annual\ road\ freight\ kilometres}{Average\ lenght\ of\ a\ haul}$

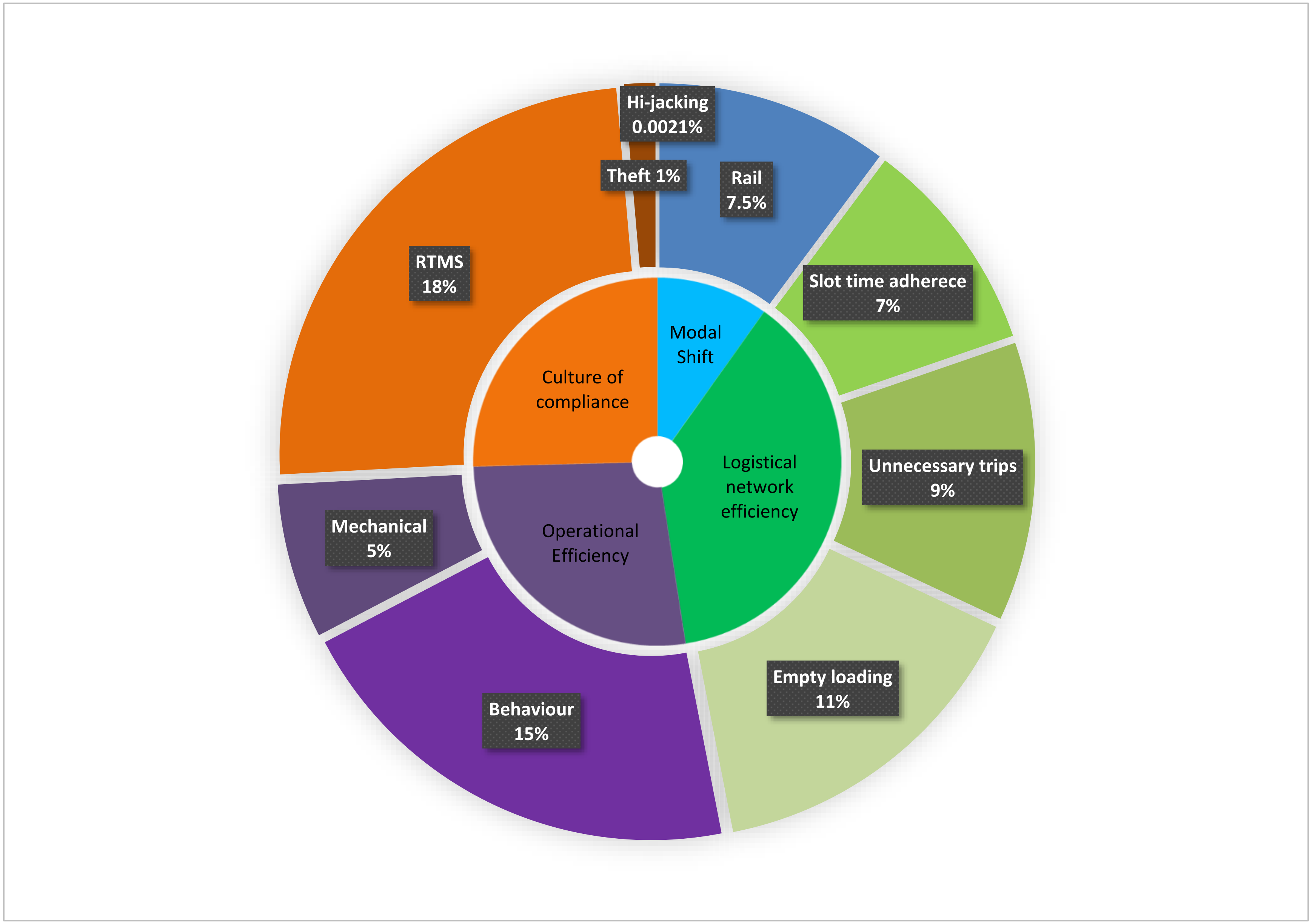

Figure 6.16 The South African decarbonisation framework

6.5.3 Conclusions from the Likert scales

For the carbon variables unnecessary trips and slot time adherence, participants were asked to rate on a scale from one to five the reasons why slot times are missed and why unnecessary trips are taking place. It was essential to understand the origins of why trucks are missing slot times and what causes unnecessary trips to enable companies to use the data to investigate further what can be done to reduce the number of slot times missed and unnecessary trips taken. On the scale, 1 represented an occurrence that does not occur frequently, and 5 represented a very frequent occurrence. Table 6.10 describes the types of unnecessary trips taking place for Figure 6.17 and Table 6.11, the types of missed slot times for Figure 6.18.

Table 6.10 Details for unnecessary trips

Unnecessary trips	Detail
Driver error	Drivers are delivering goods to the wrong address.
Flooding	Heavy rains that floods a road preventing offloading. Durban is a high risk for road flooding.
Incorrect delivery	Incorrect goods delivered or goods are missing from an order.
Poor production performance	Low stock or building stock to prevent out of stock events.
Poor weather conditions	Poor visibility and strong winds are preventing offloading. Strong winds are especially dangerous for large trucks on high pass roads.
Road works	Routes being closed and deliveries having to take place on a different date when the delivery can be rescheduled.
Strike	Strike actions blocking roads or off-loading points, making deliveries not possible.
Truck breakdown	The truck had a breakdown, and the delivery had to take place with a different truck on the same or different day.
Truck was hijacked	High valued or high demand commodity items can cause a truck to be hijacked
Warehouse challenges	Market uncertainty leading to overstocked warehouses. The opening of new warehouses leading to overstock full capacity storage.

The main cause for unnecessary trips, with the highest score of 'very frequent' at 14%, is warehouse constraints. Companies can experience warehouse challenges due to a few reasons. Poor supply chain planning, poor communication, low forecast accuracy or the lack of constraint plans and warehouse capacities resulted in ineffective decision making and market uncertainty. All of these aspects have an effect on the stock holding of a company. Thus, to avoid poor supply in volatile demand periods, companies tend to overstock during, or prior to, specific periods where it is difficult to predict how the market will react to current or future events. Some examples that were given by the participants during the interview phase, which typically takes place a couple of times per year, are price increases and the opening of warehouses.

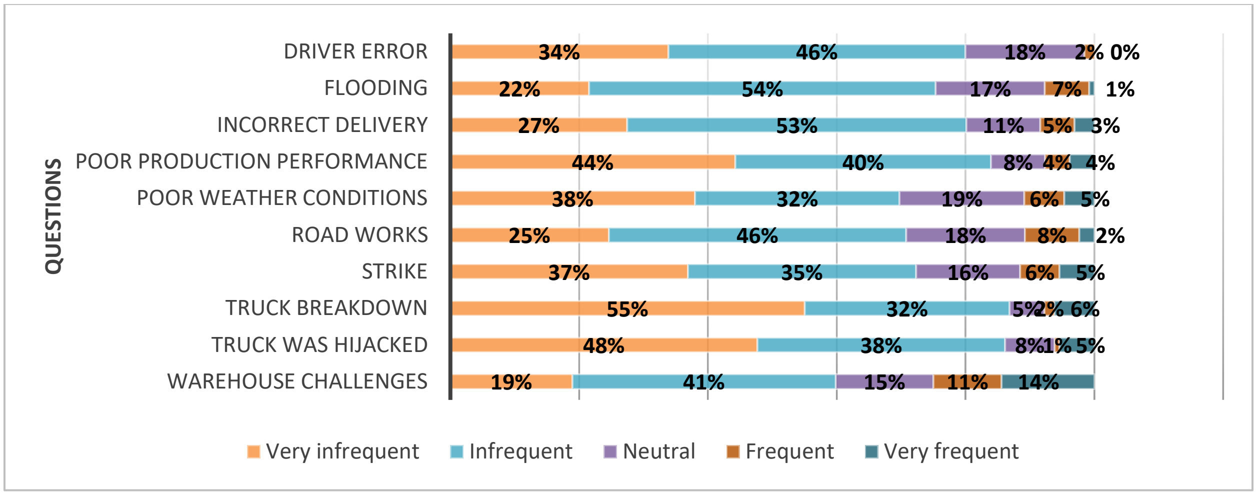

Figure 6.17 Root causes for unnecessary trips

Participants revealed during interviews that overstocking situations are common when new warehouses are opened. Clients place large orders to fill-up a new warehouse, not always taking into account the warehouse's capacity. Again, trucks arrive for delivery and are shown away when the warehouse has already reached full capacity.

Another concern for companies is the new national budget, announced every year in February, which also includes new tax rates. In preparation for price increases on a range of products from various industries, which historically follows post the budget speech, many companies start placing a large number of orders for goods prior to the budget speech. Companies purchase stock at the lower listed price before the announced price increase in order to utilise the lower price, which will lead to cost savings for the company. With the influx of sudden orders when there is not yet demand from clients for the stock, warehouses become largely overstocked. Trucks delivering goods may reach a warehouse that has already reached full capacity, and the trucks are turned away and denied off-loading.

Poor production performance can also lead to more substantial stock levels. A company can increase stock levels for a planned downtime of a production line, or for a known poor production performance in the future (strikes, planned maintenance etc.), which again leads to warehouses being over capacity. Poor production performances near the demand signal can also lead to out of stock situations where the production performance could not keep up with customer demand. In such a case, the stock will be transferred from warehouse to warehouse to prevent low stock situations at the poor performing production plant. Stock transfer trips are seen as unnecessary, as it is deemed that these trips can be limited or avoided should effective planning processes, activities and communication be in place. Truck breakdowns were one of the highest scores on responses (6% responded very frequent) for the cause of unnecessary trips. With the implementation of RTMS, the frequency of breakdowns can decrease considerably. Next, participants were asked to rate the reasons for slot times not being adhered to.

Table 6.11 Details for poor slot time adherence

Slot time adherence	Detail
Bad road infrastructure	Potholes, blocked roads, low hanging bridges and electrical wires can delay delivery.
Bad weather	Very much the same as the unnecessary trips where poor visibility or strong winds can delay delivery.
Load pilferage	Goods can be stolen in transit, delaying deliveries.
Roadblocks	Police roadblocks or trucks being diverted to weigh at weighbridges may take a tedious amount of time.
Slow drivers	Drivers are driving below the recommended speed or taking unplanned detours for personal reasons.
Truck was hijacked	An attempted or successful hijacking has occurred, and the truck will miss the delivery.
Full warehouses	When a warehouse is full, trucks can in some cases, wait until space is available, delaying all other deliveries that still have to take place on the same day.
Late off-loading at prior client	Various reasons such as long offloading times, delays at document processing and preference were given to cold storage trucks or urgent deliveries.
Strikes	Strike actions can block certain routes that can cause a delay in delivery when an alternative route must be sought.
Traffic congestion	Traffic congestion.

The reason for missed slot times with the highest scores of 'very frequent' is slow drivers, traffic congestion, late off-loading at prior clients and truck hijacking. The delays at the offloading sites occur for similar reasons for many of the companies. Delayed offloading times, delayed document processing, preference being given to cold product deliveries and urgent deliveries were the main reasons provided for late offloading.

Slow drivers may also be as a result of traffic congestion, both scoring an 11% on 'very frequent'. Bad weather conditions scored the highest as 60% of companies do not feel very strongly that slot times are not missed due to bad weather.

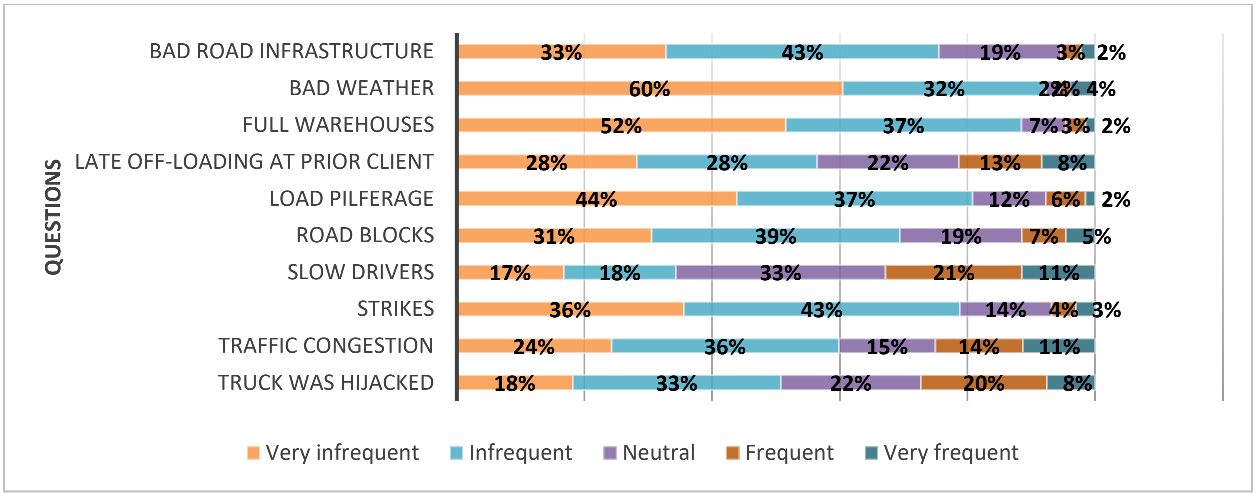

Figure 6.18 Root cause for missed slot times

6.6 CONCLUSION

The research results present findings with regards to the quantification of the four decision-making influences and the presentation of the South African road freight decarbonisation framework. A limited amount of triangulation could be done with the data gathered from the FDM and phase three data gathering. The FDM does not focus on road freight challenges, but instead presents road freight movement activities in South Africa. The FDM is thus a good tool to use when a total view of South Africa's freight flow activities is needed. The data gathered through the three-phase data-gathering process provided valuable insights into South African road freight challenges and made it possible to gain further knowledge on the occurrence of unnecessary trips and poor slot time adherence.

Through the quantification of the four decision-making influences, the possible carbon spend for the road freight variables, or activities, was derived. This enables a further national quantification of the South African decarbonisation framework and also provided road freight companies with a guide to where the possible most significant contribution of carbon emissions lies within the company. The following chapter, Chapter 7, provides further analysis of how the quantification of the carbon variables can lead to carbon emissions synergy when all the decision-making influences are enabled within all companies in South Africa, providing a national outcome of carbon emissions reduction. Chapter 7 provides further insight and quantification on the total potential carbon deficit within the South African road freight industry.

CHAPTER 7 QUANTIFYING THE SOUTH AFRICAN ROAD FREIGHT DECARBONISATION FRAMEWORK

This chapter provides a further interpretation of the data gathered in the data analysis phases and presents an explanation of the possible synergistic effect to decrease road freight kilometres and carbon emissions when applying the decision making influences.

7.1 QUANTIFYING THE CARBON DECISION-MAKING INFLUENCES AND CARBON VARIABLES

After each possible carbon reduction percentage (Figure 6.16) from the carbon variables established in Chapter 6, further calculations were done to quantify and present the potential reduction a decision-making influence can deliver for South Africa should all the variables be implemented either one at a time and when in unison with one another. The concept of synergy is also shown by calculating the decision-making influences separately, and then also in coalition with one another to form synergy.

To begin the calculation process, fixed parameters were used for total annual road freight kilometres, carbon emissions and carbon tax, shown in Table 7.1. From the FDM, total annual road freight kilometres were estimated at 16 billion road freight kilometres. In the literature review, it was found that the total road freight emissions for South Africa were estimated at 16.8 million tonnes of CO_2 per annum. Carbon tax is set out to be fully taxable at R120 per tonne (without any rebates) (Hemraj, 2016).

Table 7.1 Parameters used for calculations

Parameter	Value	Source
Total annual road freight kilometres	16,000,000,000	FDM, 2017
Total annual road freight carbon emissions tonnes	16,800,000	Swarts *et al*., 2012
Fully taxable carbon tax per tonne	R120	Hemraj, 2016

Table 7.2 represents the total reduction potential for each of the carbon variables given the four carbon decision-making influences with carbon tonnes savings as well as potential carbon tax savings should tonnes be fully taxable at R120 per tonne CO_2.

Table 7.2 Carbon reduction summary

Influence	Variable	Total % potential in annual kms that can be reduced	Total tonnes of CO_2 saved from kms reduction	Total Rands saved in carbon tax
Modal shift	Rail	7.5%	1 260 000	151 200 000
Logistics network efficiency	Slot time adherence	7%	1 176 000	141 120 000
	Unnecessary trips	9%	1 512 000	181 440 000
	Empty loading	11%	1 848 000	221 760 000
Operational efficiency	Behaviour	15%	2 520 000	302 400 000
	Mechanical	5%	840 000	100 800 000
Culture	RTMS	18%	3 024 000	362 880 000
	Theft	1%	168 000	20 160 000
	Hijacking	0.0021%	353	42 336

Each reduction is calculated in isolation from all the other potential variables listed in the table. The saving shown in Table 7.2 does not evaluate altering multiple variables sequentially for synergy. The calculations were done to show the potential of each carbon variable in isolation, for companies to realise the savings potential from each of the separate variables. To achieve synergy, the calculation entails implementing all the variables successfully to reduce both the annual kilometres travelled by road freight and the CO_2 emissions emitted by all the carbon influences, thus total synergy will be achieved.

The culture of compliance variable includes RTMS, theft and hijacking. As RTMS already includes variables such as driver behaviour and would potentially also have an influence on the operational efficiency of a company together with theft and hijacking when route management is done, it was not included in the synergy calculations due to the overlapping of the variables.

When altering all the variables for synergy, a calculation process was followed to identify what the total impact would be. First, it was calculated what the total savings would be individually for the three influences; modal shift, logistics efficiency and operational efficiency for the kilometres reduced and carbon emission tonnes (calculations were rounded). This is summarised in Table 7.3.

Table 7.3 Total potential reductions from the decision-making influences

Influence	Total potential % reduction	Total kms reduced ('000 000)	Total carbon emission tonnes reduced ('000 000)
Modal shift	7.5%	120	1.3
Logistics efficiency	7% + 9% + 11% = 27%	432	4.5
Operational efficiency	15% + 5% = 20%	320	3.4

Secondly, to calculate the total synergistic reduction potential for both kilometres and carbon emissions, the three remaining carbon influences were calculated in conjunction with one another using the total reduction percentages in Table 7.3. This calculation is shown in Table 7.4

Table 7.4 Remainder of kilometres and carbon emissions

Influence	Total kms reduced	Remainder kms after all variables are altered	Total CO_2 reduced	Remainder CO_2 after all variables are altered
Modal shift	120	120 x (1-0.27) x (1-0.20) = 70	1.3	1.3 x (1-0.27) x (1-0.20) = 0.76
Logistics network efficiency	432	432 x (1-0.075) x (1-0.20) = 320	4.5	4.5 x (1-0.075) x (1-0.20) = 3.33
Operational efficiency	320	320 x (1-0.075) x (1-0.27) = 216	3.4	3.4 x (1-0.075 x (1-0.27) = 2.30

To illustrate the synergy effect, the three influences are shown in a Venn diagram, as seen in Figure 7.1. Each circle represents one influence. However, in the calculations in Table 7.4, it must also be taken into account that there will be some overlapping of the variables with one another. In the figure, it is seen that modal shift and logistics network efficiency (ML), modal shift and operational efficiency (ME), logistics network efficiency and operational efficiency (LE) and modal shift, logistics network efficiency and operational efficiency (MLE) overlap with one another.

This essentially means that M (modal shift), L (logistics network efficiency) and E (operational efficiency) will have smaller values of savings from kilometres and carbon emissions as the overlapping portions must still be deducted from the totals of M, L and E. Thus, the overlapping portions must be calculated and deducted to ensure that the total potential savings are correctly reflected when all three influences are initiated together to form synergy.

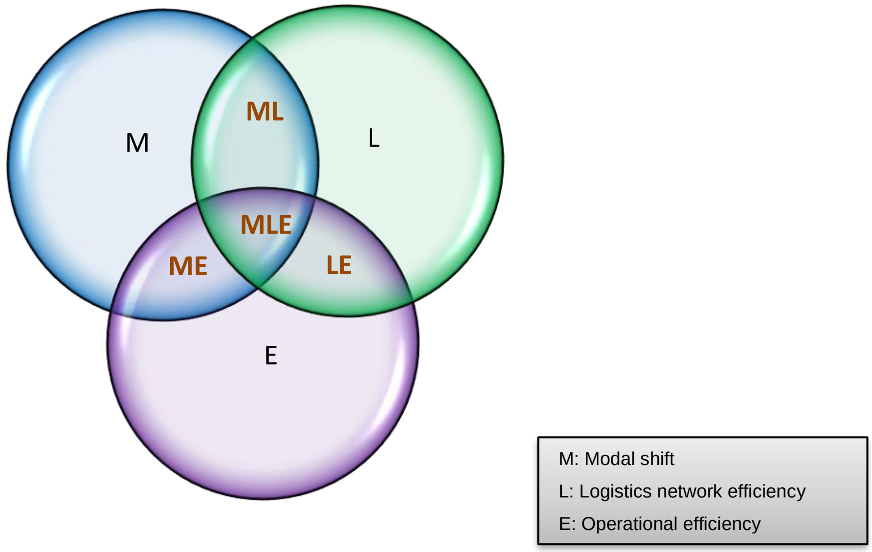

Figure 7.1 Overlapping of variables in the Venn diagram

The calculations for the overlapping parts in the Venn diagram are shown in Table 7.5, and the completed synergy concept with overlapping values is shown in Figure 7.2. Should all the influences be implemented at once to achieve synergy, a total calculated carbon savings of 7.7 million tonnes of CO_2 can be achieved along with a reduction of 7.36 billion road freight kilometres. This can possibly result in an average of 46% reduction in both road freight emissions and total annual road freight kilometres as shown in Figure 7.2 (note that due to the rounding in the calculations, the actual percentage and value may differ slightly).

In Table 7.5, to calculate the value of the remainder of the kilometres and carbon emissions saved when implementing all the influences, the following steps were taken:

1. Calculate the total saved kilometres and carbon emissions when implementing one influence by multiplying the total kilometres and total carbon emissions by the percentage saving (Table 7.4).
2. From the total saved kilometres and saved carbon emissions, deduct the potential second and third savings percentages from the total saved kilometres and carbon emissions. This must be deducted from the influence that is being calculated.
3. The second and third savings, which are being deducted, is deducted from '1' to determine what the remainder of the calculated influence will be after the second and third influences were implemented (Table 7.5).
4. To calculate the overlapping areas (ML, LE, ME), only the overlapping influence must be deducted. It must be noted that in this calculation, area MLE is still part of the areas ML, ME and LE and must thus still be deducted (Table 7.5).

- ML = M - (M x (1-L))
- LE = L - (L x (1-E))
- ME = M - (M x (1-E))

5. The final step is to calculate the final overlapping area of MLE. This could have been done in three different calculations, which will result in the same answer:
   - (ML + ME + Remainder of M) minus Total of M
   - (ML + LE + Remainder of L) minus Total of L
   - (ME + LE + Remainder of E) minus Total of E

   All three of these calculations will provide the answer of 6 and 0.07 for the overlapping area of MLE (Table 7.5).
6. The final step is to calculate the new values of ML, LE, ME now that MLE was established. This is done by deducting MLE from the total values of ML, LE, ME (Table 7.5).

Table 7.5 Calculation process of the overlapping areas

Influence	Remainder kms after all variables are altered	Remainder CO_2 after all variables are altered
ML (Modal shift + Logistics network) including MLE	120 - (120 x (1-0.27)) = 32	1.3 - (1.3 x (1-0.27) = 0.35
LE (Logistics network + Efficiency) including MLE	432 - (432 x (1-0.20)) = 86	4.5 - (4.5 x (1-0.20)) = 0.90
ME (Modal shift + Efficiency) including MLE	120 x (120 x (1-0.20)) = 24	1.3 - (1.3 x (1-0.20) = 0.26
MLE (Modal Shift + Logistics network + Efficiency)	(32 +24+70) -120 = 6	(0.35 + 0.26 + 0.76) – 1.3 = 0.07
New ML (Modal shift + Logistics network) minus MLE	32 – 6 =26	0.35 – 0.07 = 0.28
New LE (Logistics network + Efficiency) minus MLE	86 – 6 = 80	0.90 – 0.07 = 0.83
New ME (Modal shift + Efficiency) minus MLE	24 – 6 = 18	0.26 – 0.07 = 0.19

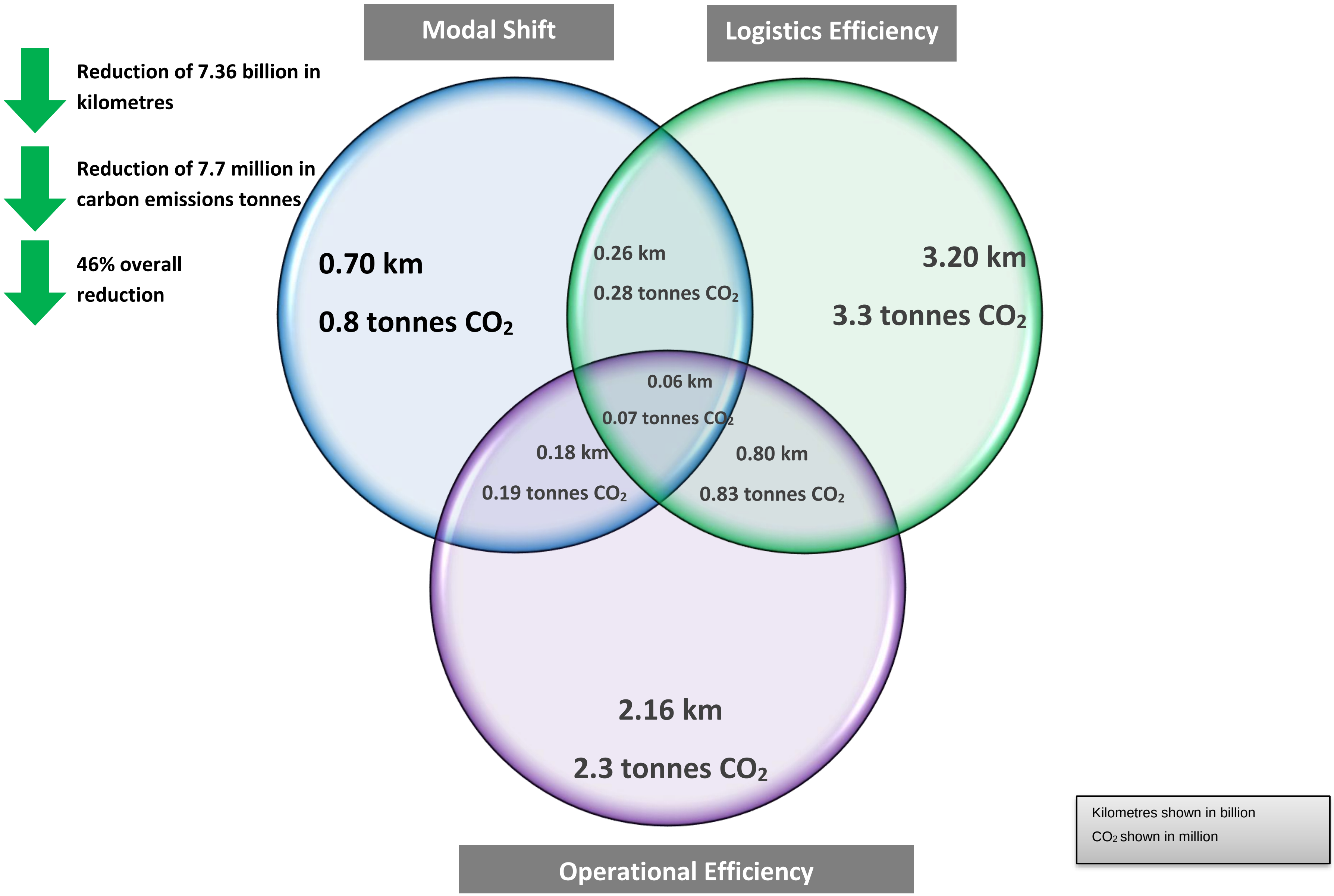

Figure 7.2 The completed Venn diagram with overlapping numbers

7.2 SYNERGY EFFECT

The Venn-diagram indicates the synergy effect that can be achieved when implementing all of the decision-making influences, not mutually exclusive from one another. The South African decarbonisation framework (presented in Figure 6.12) indicates how each decision-making variable contributes to road freight carbon emissions in South Africa. The framework was taken a step further, and the combined implementation of the framework was calculated and presented in a synergy effect. The combined effect of the decision-making influences is greater than the sum of the effect of an individual decision-making influence. Together, three decision-making influences can potentially contribute to a maximum of a 46% reduction in carbons emissions should all of South Africa's road freight companies implement the three decision-making influences. Other decision-making influences, such as logistical network efficiency, may reduce carbon emissions by 27% (indicated in Figure 7.3). A shift to rail can contribute to a 7.5% reduction, while operational efficiency can contribute to a 20% reduction.

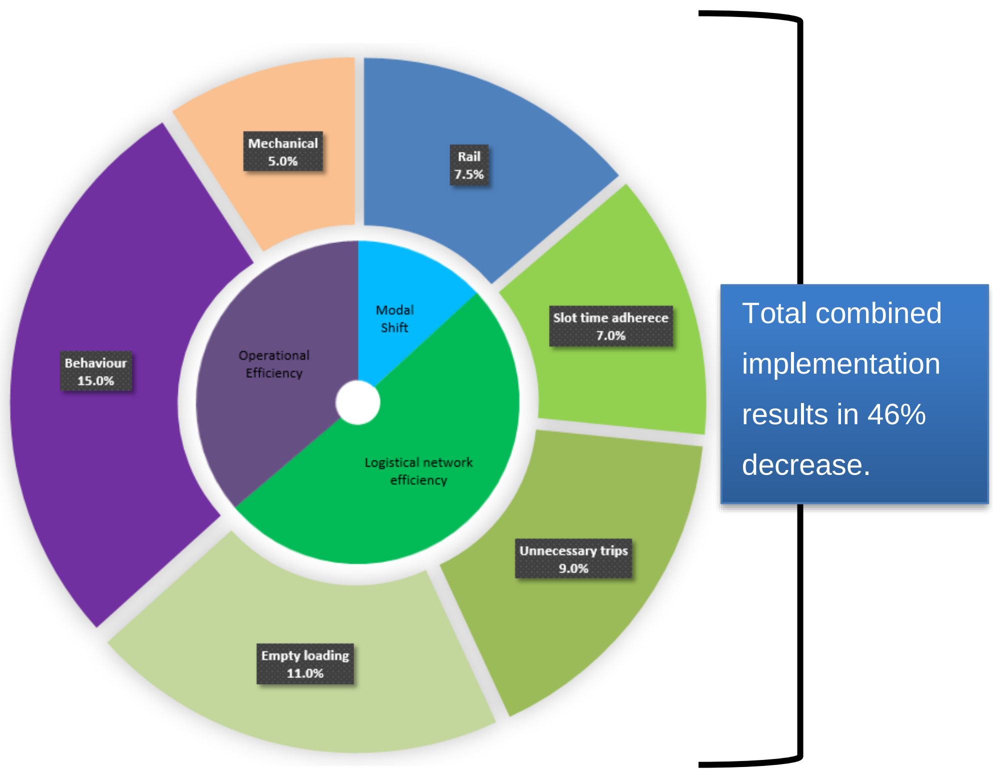

Figure 7.3 Synergy of carbon emissions

Of the three decision-making influences within the synergy calculation, the maximum reduction potential lies within the logistical network efficiency. It is thus vital for companies to realise that by focusing on increasing the efficiency of the logistical network, the majority of carbon emission and road freight kilometre reductions can be achieved within this decision-making influence and that this decision-making influence must be given priority.

7.3 ABILITY TO IMPLEMENT WITHIN SOUTH AFRICA AND COST INVOLVED

The implementation of the South African road freight decarbonisation framework can form part of a company's long-term strategic goals together with short-term operational and medium-term tactical alignment to achieve company targets. The framework can be used as a key performance indicator to various operational aspects that can provide both efficiency and financial performance benefits for a company. Both CSR and King IV reporting can be aligned on a company level with carbon emission reduction targets. It seems companies are yet to realise the implications of carbon tax, what this will entail, and how it will influence the financial performance of a company. Should companies not react and actively take part in reducing carbon emissions to lower carbon tax, the burden of increased tariffs to cover company tax, would most likely fall upon the consumer.

On a national level, the more actively involved companies become to decrease carbon emissions, the more total road freight emissions can be reduced. For increased participation from companies to take place in carbon reduction initiatives, governmental participation would be required. Given South Africa's signed agreement to take part in the global carbon reduction agreement (Paris Agreement), governmental involvement, awareness initiatives, support and policies would be required.

Governmental assistance, in the reduction of carbon emissions, would need to include attainable implementation strategies. In the literature review for carbon reduction SFST, most of the South African material available on the reduction of carbon emissions included switching to lower carbon-intensive transportation (rail), making use of biofuels or improving vehicle efficiencies. These types of implementations would require infrastructure changes on a national level to assist companies in achieving carbon reduction targets.

The cost to implement would vary from company to company and can possibly range from zero cost to an abundant of cash injections depending on the maturity of the company and the resources required to implement a decision-making influence. The case study, discussed in Chapter 8, required no additional cost for the company to implement the framework when decision-making influences were applied. More cost would be involved should a company to decide to decrease carbon emissions by providing driver training, upgrading vehicles to become more fuel efficient, upgrading vehicle technology etc. Any additional purchases or training would require a cash injection from the company. Little or no investment would be required if companies use the framework as a guideline to improve upon current road freight activities, such as decreasing unnecessary trips by acting upon and decreasing unnecessary trips.

7.4 CONCLUSION

It is now clear that through the different influences of decision-making and carbon variables, South African road freight companies can have a significant impact on carbon emissions resulting from road freight transport, the possible tax that will be spent in the near future when carbon tax becomes a reality in South Africa and the total road freight kilometres travelled annually. The decision-making influences, together with the carbon variables that can be altered, can now be quantified on a national level to indicate the impact these factors may have in South Africa. Furthermore, it is now possible to provide numerical values to companies on how much possible savings can be achieved when focusing on the variables to improve upon the efficiency and effectiveness within a company. A synergistic effect for carbon emissions was calculated to encourage companies to implement more decision-making influences. To test the South African decarbonisation framework, the framework was applied to a company that was willing to implement the framework. Chapter 8 provides the results from the testing phase.

CHAPTER 8 CASE STUDY

The following chapter presents a case study that was conducted. The case study served the purpose to practically apply the new South African decarbonisation framework in a South African environment.

8.1 CASE STUDY: FRAMEWORK APPLICATION AND RESULTS

The case study took place over a period of three months in a small FMCG company situated in the Western Cape. The company agreed to test the South African decarbonisation framework on one privately owned lightweight truck to limit any potential financial or operational risks the implementation may have presented to the company. The truck is used for the delivery of goods to high-end private clientele. The rest of the deliveries and collections are outsourced.

To discuss the South African decarbonisation framework and to initiate the testing phase, various meetings were held on site with the logistics manager and general manager. The motives for the meetings were to explain in detail how the South African framework would help decrease carbon emissions and to provide guidance as to how the framework should be implemented. The framework was presented with the influences and carbon variables elaborated upon. The company's current freight activities were discussed in detail during meetings, and improvement opportunities were discussed on how best to adopt the South African decarbonisation framework to the current operations of the company.

For the first month, it was agreed that data should be gathered to document and capture current road freight activities when no intervention is done. This month would thus be used as a control against forthcoming months to assess whether there were any improvements when implementing the framework.

The calculations from the first month's data analysis showed total deliveries per day and delivery times being scattered across various days and times of the day with no concise delivery patterns. The logistics manager agreed that for a small operation of one vehicle, the number of trips and delivery times for the company did not have any financial benefits and did not make sense operationally. Frequent trips were taken to the same destinations more than once a week for very small deliveries. These small deliveries did not justify more than one trip per week. Consequently, it was advised that these trips could be limited to only once or at most twice per week. Figure 8.1 and Figure 8.2 represent the first months' delivery distribution and delivery times. It can be seen that delivery days and delivery times are scatted with no consistent pattern.

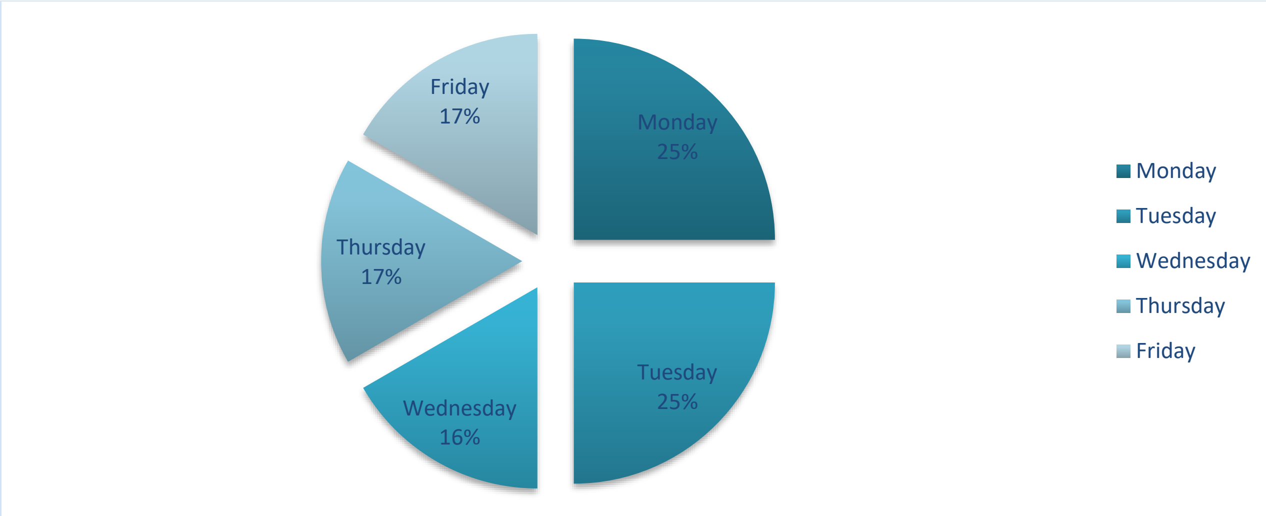

Figure 8.1 Daily delivery distribution percentages

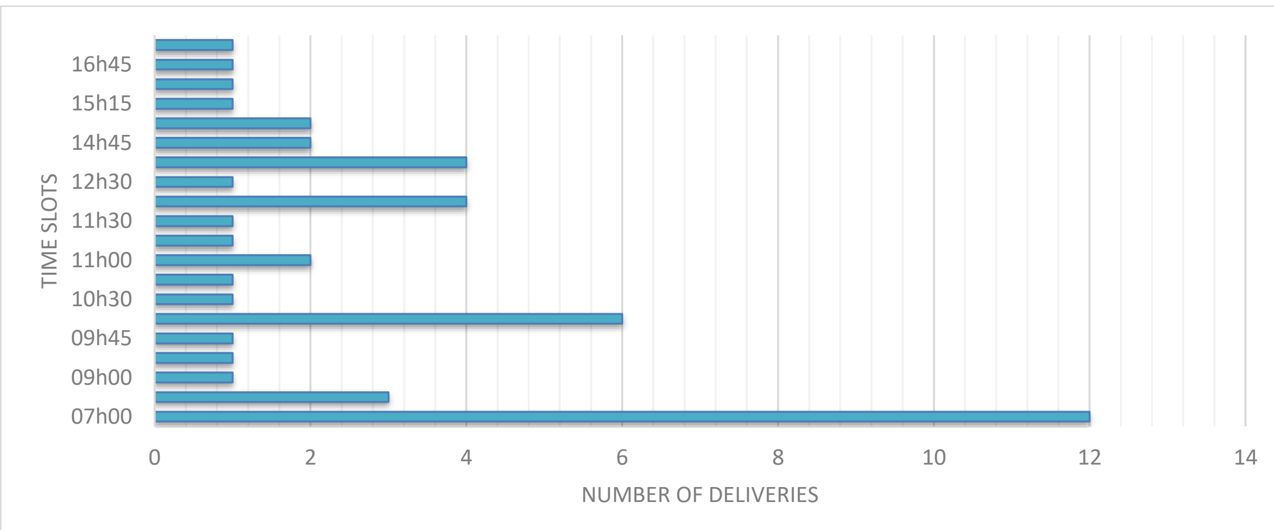

Figure 8.2 First month number of deliveries per allocated slot time

In one case presented for Client A, deliveries in the first month took place between two to three times a week. The deliveries were small, not utilising a full truck, and could be consolidated into one delivery for the week. Figure 8.3 represents the loading distribution for Client A before (during the first month), and after (during the second and third month) orders were consolidated to prevent unnecessary trips to the same client more than twice a week.

In the second month, deliveries took place on either a Tuesday or a Wednesday. The consolidated orders resulted in a higher truck utilisation creating a peak of goods delivered in the second month and resulting in fewer deliveries in the third month. The overall result of the consolidation of orders for Client A resulted in 67% fewer delivery trips from the company to the client between the first and second month. This subsequently also resulted in the same percentage reduction (67%) in CO_2 emissions from 23.2 kg to 7.2 kg (calculated in Table 8.1).

In the first month, the total kilograms loaded to the customer were 270 kg versus a total of 154.8 kilometres travelled. The second month presented a total of 360 kg loaded versus only 51.6 kilometres travelled and the third month 36 kg loaded with 12.3 kilometres travelled. Thus the kilograms loaded per kilometres (kg/km) increased from 1.7 kg/km to 6.9 kg/km but decreased again in the third month to 2.9 kg/km. The third month, clients possibly ordered less stock due to the large orders placed in the second month and inventory may still have been sufficient in the third month of ordering.

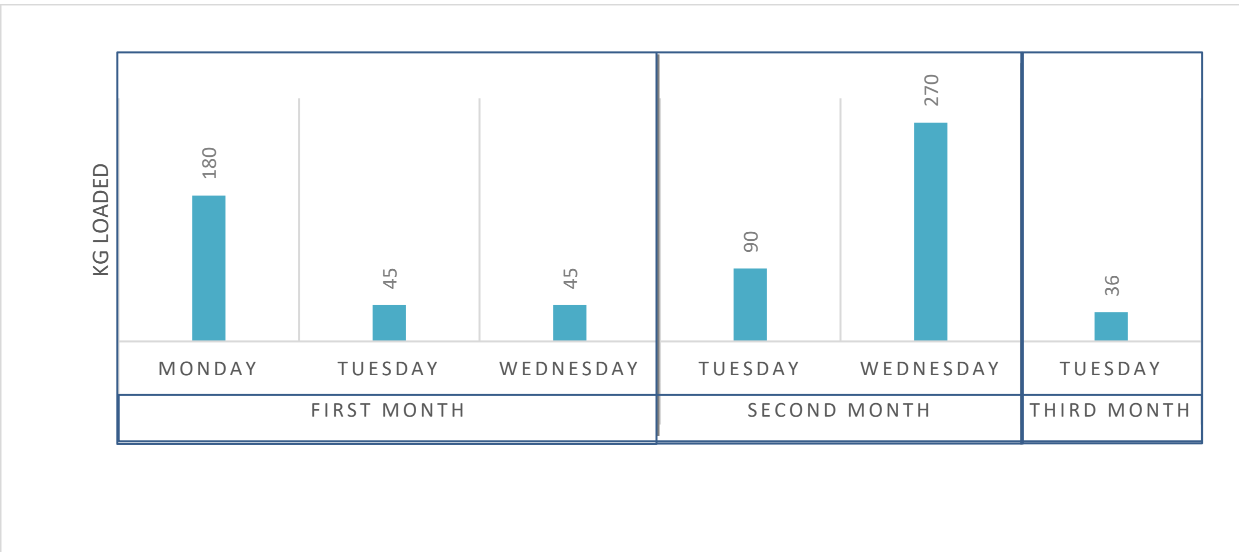

Figure 8.3 Client A loading distribution for three months

Table 8.1 Client A CO_2 savings calculation

	Kilometres travelled	CO_2 factor for diesel	Diesel consumption of the delivery vehicle	Total CO_2 kg	Kg loaded	Kg per Km loaded
First month (start)	154.8	2.65464	5.7 / 100 km	23.2	270	1.7
Second month	51.6	2.65464	5.7 / 100 km	7.7	360	6.9
Third month	12.3	2.65464	5.7 / 100 km	2.0	36	2.9

After the implementation of the consolidation of orders, the company's total delivery distribution patterns became less sporadic to other clients as well, with more structured delivery patterns on specific days of the week. The consolidation of deliveries to all clients can be seen in Figure 8.4. In the third month of execution, deliveries were made only on three days of the week instead of five days per week as in the first month. The reduction of delivery days was possible due to the small number of orders the company receives and it will most likely be challenging to replicate the same output for companies with a more extensive customer base and a larger fleet.

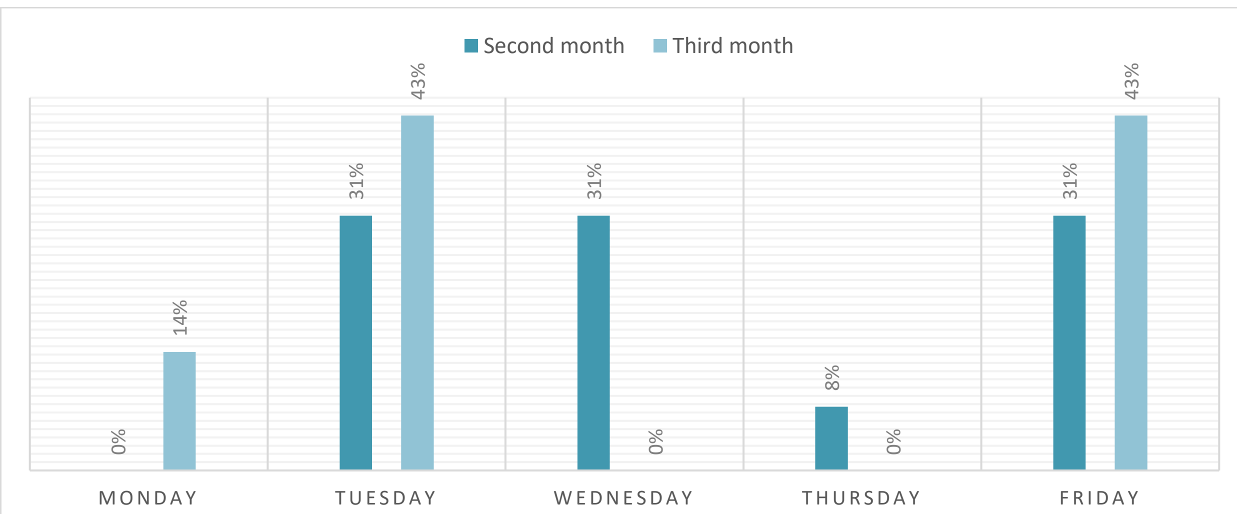

Figure 8.4 Total percentage of trips taken in the second and third month

In the second month (first month of implementation), the company made 25% more deliveries while keeping the total trips taken from the first and second month almost stable, only increasing from 12 to 13 trips. The kilometres travelled decreased from 901 to 897 kilometres, thus, more deliveries were made in the first month of implementation with fewer kilometres travelled. It can be concluded that the company increased the loading utilisation of the trucks to decrease the total trips taken, as seen in Figure 8.5.

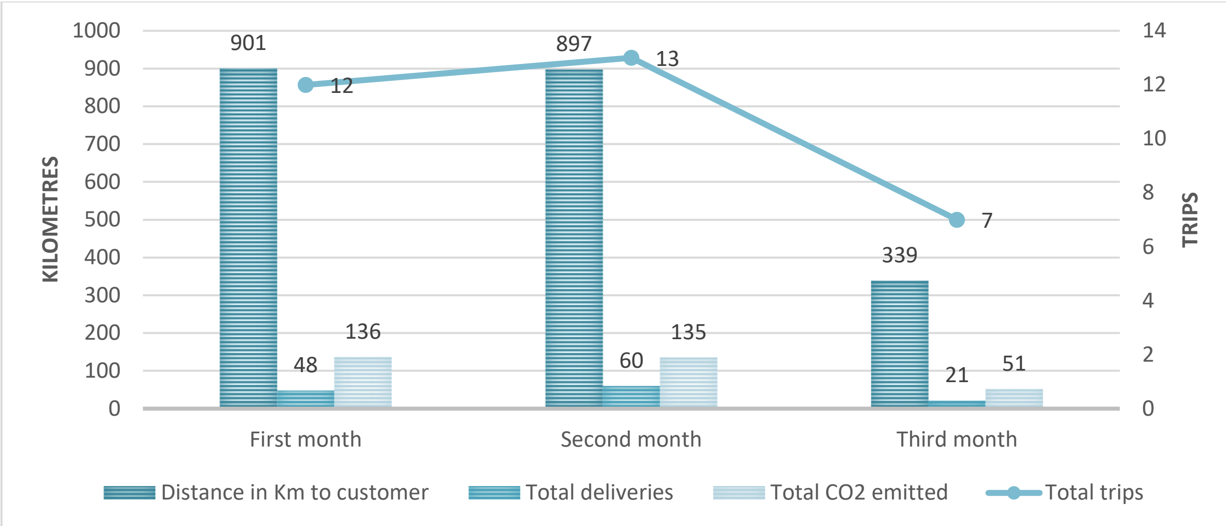

Figure 8.5 Total deliveries versus total trips

Relative to the higher number of deliveries made in the second month of distribution, total CO_2 for the company remained stable between the first two months before dropping 62% in the third month due to deliveries being consolidated in the second month, which resulted in fewer deliveries being made in the third month. The same calculations were applied as in Table 8.1 to calculate the total CO_2 emitted in each month. Although the carbon emissions did not reduce drastically from the first to the second month, it must be noted that the total deliveries increased while kilometres decreased (Figure 8.5). Thus, it can be concluded that for every delivery made in the second month was less carbon intensive than in the first month.

Subsequently, consolidating the orders to load more in one trip, delivery times also resulted in a decrease from 20 different delivery times in the first month to 16 delivery times during the second month and 10 in the third month, as seen in Figure 8.6. In addition, fewer deliveries took place during peak hours in the second and third months.

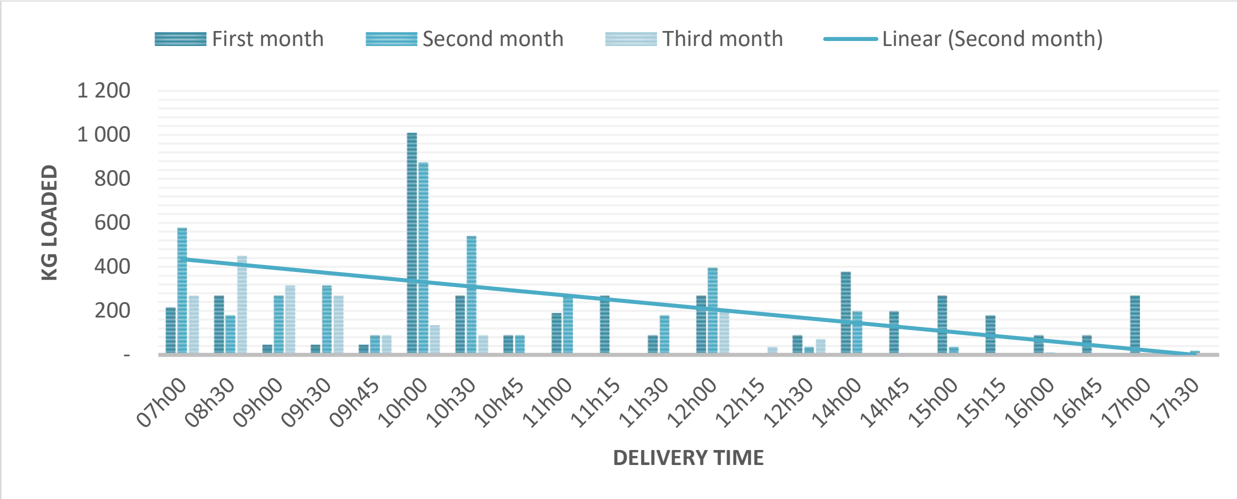

Figure 8.6 Time distribution of deliveries

It was deduced that from the time of implementing the framework, the company had accomplished the following:

- Decreased overall total trips were taken;
- Increased total deliveries in the second month, while remaining stable on total trips and kilometres;
- Reduced delivery times;
- Decreased unnecessary trips by consolidated orders;
- Increased the loading utilisation of the trucks.

The company achieved overall success by communicating to clients the changes in the ordering process. The ordering process of the company was a simple ‘order and deliver’. This term implies that when customers placed orders, orders would either be delivered on the same day or the following day. Orders were not necessarily consolidated, and clients did not consider ordering larger amounts to eliminate ordering more than once a week. It was requested by the logistics manager to the clients of the company, to attempt consolidation of small orders to one delivery per week.

By implementing the guidelines of the South African framework, the company analysed ordering and logistical data for the first time. With the data analysis and using an on-board GPS tracker, it was concluded that 20% of kilometres travelled in a month were due to unnecessary trips (the extra 20% of kilometres were excluded from the analysed data, and the data only focused on actual deliveries).

These trips were directly linked to a culture of non-compliance in the company where all of the unnecessary trips were taken by the driver for personal errands. Once deliveries and data started being tracked more frequently, recorded and analysed, the unnecessary trips were eliminated entirely. This also added to the contribution in decreased delivery time for the company, as deliveries took a shorter time to complete, thus, making it possible to increase the total deliveries done in one single trip and increasing slot time adherence by 15% for both months two and three, as seen in Figure 8.7.

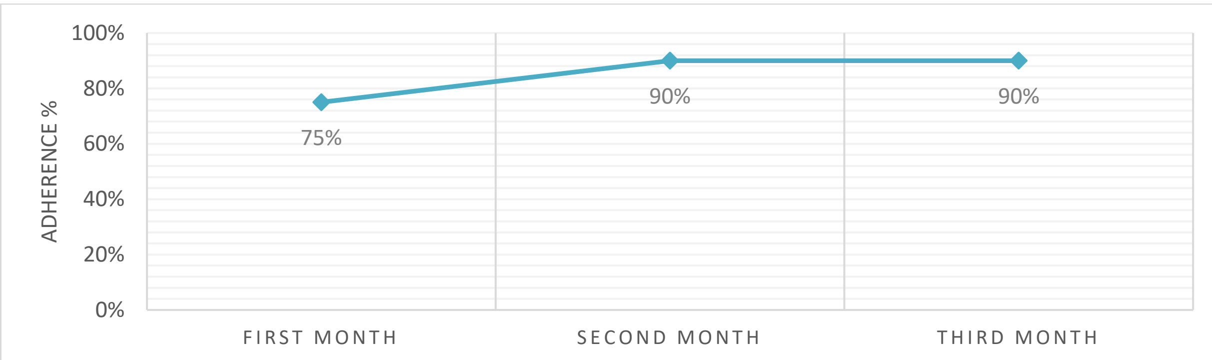

Figure 8.7 Slot time adherence

Discussing RTMS with the company resulted in positive reactions from the management staff, but although RTMS would prove a beneficial implementation for any company, management would only consider implementing RTMS should the company increase its fleet size. Implementing RTMS for one truck being used did not seem reasonable for the company, but management did have a productive meeting with the outsourced company handling all the deliveries about considering implementing RTMS in the future.

8.2 CONCLUSION FROM THE CASE STUDY

The implementation of the South African decarbonisation framework resulted in positive outcomes for the case study company. Total trips for the company decreased relative to the number of deliveries made. The company was able to consolidate orders to decrease sporadic ordering and deliveries made by and to customers, while keeping customer service high and carbon emissions stable and ultimately decreasing carbon emissions per delivery made in the second month. It is possible that the carbon emissions will fluctuate as customers order again in high quantities after the third month to build up stock again, but taking a holistic view, carbon emissions may decrease as a result of combining orders, eliminating unnecessary trips and increasing slot time adherence.

The managers' opinion of the decarbonisation framework was that the framework provides clear and precise carbon variables on how to be more carbon conscious in decision-making processes. By analysing the logistical data, managers were made aware of the unnecessary trips, which were costing the company both financially and in time.

Overall, the framework proved to be useful and insightful for this particular company when considering all the influences involved that can increase carbon emissions for a company. It was proved for this company that unnecessary trips, slot time adherence and a culture of compliance have a key role in increased carbon emissions. By following the guidelines set out by the framework, the company was made aware of the impact these decision-making influences and carbon variables can have on the operations, costs and carbon emissions in a company.

It must be noted that maturity in road freight transport will play a role in framework implementation and the carbon reductions that can be achieved. For the case study company, a low road freight business maturity was experienced, such as freight data not being analysed. Thus implementing basic transport rules may provide a more significant impact on the reduction of carbon emissions versus implementation on companies that have a high maturity in the road freight industry and have been in operation longer.

The framework implementation proved successful for this company, and it may be concluded that the framework may provide guidance for other companies as well on methods to decreasing carbon emissions. The case study was conducted on a small company and to demonstrate further reduction opportunities for the framework, additional research opportunities can include implementing the framework on more companies to measure the outcome of the reduction potential. The case study is not a representative study of South Africa, but is one of many South African companies that has not yet reached logistical maturity and has a vast amount of improvement opportunities available to expand upon all of the decision-making variables to decrease carbon emissions.

CHAPTER 9 FINAL REMARKS AND RECOMMENDATIONS

This chapter provides the final conclusions and comments from the research with a section discussing how the research contributed to new knowledge, which is followed by recommendations and opportunities for further research.

9.1 CONCLUSIONS FROM THE RESEARCH

South Africa is a country with an intensive road freight network that consists of 618 081 kilometres (excluding un-proclaimed roads). Research has shown that this is not likely to change soon and freight intensity on the road network is most likely to worsen as demand and supply in the South African market increase. Of all freight movements, the largest part takes place on the road network, increasing the carbon emission output for road freight.

Internationally, governments are taking action against global warming with the Paris Agreement marking a vast turning point in how governments will be regulating carbon emissions going forward. Temperatures are rising, that is causing devastating droughts in areas that are in desperate need of rainfall. Icebergs are melting, affecting both on the temperature of the ocean and the potential of flooding. Supply chain decarbonisation allows companies to lower the carbon emission output created by supply chain activities. Road freight decarbonisation allows organisations to focus on the emissions being emitted from road transportation. In South Africa, road transport is a crucial factor in business activities and has the potential to have a negative effect on profits should carbon tax be implemented in South Africa.

The research started by reviewing various SFSTs focusing on road freight and how to decarbonise road freight activities. After the McKinnon framework was chosen for further investigation in South Africa, it was found that further developments to the framework can be made with opportunities being available by adding South African challenges. It was found that there are freight activities that can be overlooked, which play a vital role in the number of carbon emissions emitted into the atmosphere and the total road freight kilometres travelled. It was found that the RTMS can be a significant contributor to lowering carbon emissions by applying the voluntary rules of RTMS set out to improve the culture of compliance in South African companies. In addition, it was found that unnecessary trips and slot time adherence are key contributors to freight emissions.

Through data gathering and analysis, common reoccurring themes to understand why unnecessary trips and missed slot times occur were highlighted, and for the first time, it was documented why these unnecessary trips are taking place. Through this discovery, companies will now be able to understand the frequent occurrence of these events and that these events are not isolated to only one company, but that they happen regularly to companies across South Africa from various road freight businesses and backgrounds. With this understanding, companies will be able to place emphasis on these events and allocate resources to promote the minimisation of the events, which in turn can save company revenue together with the positive effects it will have to the decline of carbon emissions. It was discovered that hijacking events and theft, although a concern in South Africa, do not have a significant impact on road freight activities, carbon emissions or total road freight kilometres. Companies do not tend to lose many resources from hijacking and theft also does not have a significant impact on overall road freight emissions.

The South African road freight decarbonisation framework was thus developed for South African companies to use the framework as an aid to lowering company road freight carbon emissions, as well as to quantify on a national level, the significance of road freight activities and the weight these activities carry in the total scope of road freight emissions. The main research question "Which road freight decarbonisation framework can be used to adapt and expand the framework in South Africa to include the current road freight carbon emission challenges South African companies experience" was thus answered by the summary in Table 9.1.

Table 9.1 Research summary

Sub-question	Outcome
1. What types of SFSTs for decarbonisation are available? **2. Which SFST will be best suited for South Africa?**	Various SFST were researched, and a set of criteria was developed to determine which SFST can be adapted to include South African road freight challenges. The literature review highlighted some of the challenges that are faced in the road freight industry. Chapter 4 discussed the SFSTs and McKinnon's framework was chosen based on the set-out criteria. Chapter 5 followed with discussing the McKinnon framework.
3. What gaps and opportunities exist within the chosen SFST? **4. What factors can be added to the newly developed SFST?**	A second and third phase of data gathering was conducted, which consisted of interviews and a research questionnaire. The interviews highlighted more carbon challenges and carbon influences and carbon variables were identified. These new carbon influences were added to the McKinnon framework. A new South African road freight decarbonisation framework was developed incorporating the newly identified challenges, influences and variables that affect the number of carbon emissions in the road freight industry

Table 9.1 continued Research summary

5.	**Can the South African decarbonisation SFST be quantified?**	A quantitative framework was developed that showed the carbon influences and variables expressed in numerical values to quantify the impact each of the influences and variables has on total road freight emissions and total annual kilometres. The phase three data gathering, plus data from the literature survey, quantified the new carbon influences and variables.
6.	**What are the possible benefits companies can achieve with the South African-focused SFST?**	The framework was tested on one company to quantify the possible reductions in carbon emissions and road kilometres. The case study company provided promising results and showed a decrease in both carbon emissions and kilometres travelled. The concept of synergy was also discussed and calculated to highlight the reduction that can be achieved when implementing three decision-making influences.

The South African decarbonisation framework has the potential to be adopted internationally. The framework is not limited to South Africa and identifies previous challenges not taken into account for logistical efficiency. These challenges can assist international companies in focussing on further potential improvements and making companies aware of the possible savings the carbon influences and variables can entail.

The South African road freight decarbonisation framework raises awareness for companies on activities in road freight, which previously did not receive the needed attention. As seen in the case studies, management teams are now aware of opportunities, which can not only decrease the carbon emissions, but also decrease costs. It is recommended that all stakeholders participating in road freight should use the South African decarbonisation framework for guidelines on activities where carbon emissions can be lowered. New potential carbon-decreasing opportunities have made companies aware that there are unique circumstances in South Africa that can increase carbon emissions, but that these circumstances can also be avoided.

9.2 UNIQUE CONTRIBUTION TO KNOWLEDGE

Through **confirmation** by means of a literature review, various road freight carbon emission influences were identified. This established the foundation upon which various SFSTs were investigated to confirm that the various SFSTs replicated the findings of the literature review. Different methods to decrease carbon emissions were explored in Chapter 4, SFSTs, and were **eliminated** by means of the criteria discussed in Section 2.2. Elimination was also supported by the literature review, which supported carbon emission influences in South Africa. **Replication** of the SFST's were supported by the literature review that highlighted that various carbon reduction possibilities have been researched and established.

McKinnon's road freight decarbonisation framework was chosen based on the process of confirmation and elimination. This was followed by the process of **expanding** the framework by including new knowledge within the South African environment identified through the research. Expansion was accomplished by interviewing South African professionals and research questionnaires. The expansion of the framework was supported by the literature review that confirmed the findings of both the interviews and research questionnaires.

Through expansion, the first South African decarbonisation framework was developed with four decision-making influences that were identified in the research with nine contributing carbon variables, which can be altered to decrease carbon emissions. The decision making influences with the corresponding carbon variables were:

- Modal shift: rail;
- Logistics network efficiency: slot time adherence, unnecessary trips and empty loading;
- Operational efficiency: behaviour and mechanical;
- The culture of compliance: RTMS, theft and hijacking.

The research calculated the estimated total potential carbon emissions savings and road freight kilometre reductions in South Africa, for the first time, should the decision-making influences with all the carbon variables be implemented. The calculation process involved calculating the savings separately (four decision-making influences), as well as in conjunction with one another (three-decision making influence) to reach a maximum achievable of 46% savings potential on both road freight emissions and road freight kilometres. It was concluded that the largest reduction potential of carbon emissions and road freight kilometres lies within the logistical network efficiency decision-making influences. The South African decarbonisation framework can also be used globally, contributing to global research, by companies adapting and fitting the framework to their own business needs and the hierarchy of implementation. Academic literature can now be expanded upon, by introducing the scientific contribution of the development and quantification:

1. Of a South African decarbonisation framework;
2. Of carbon emission reduction of four decision-making influences with synergy when implementing three carbon reduction decision-making influences.
3. Of the carbon spend for specific road freight activities in South Africa.

Finally, the South African decarbonisation framework was **applied** by means of a case study on a small company with a low logistical maturity to confirm the possibility of replication. The results from the case study was clear and positive and met with enthusiasm by the participating company. Through the four elements identified in Section 2.1, the dissertation confirmed current decarbonisation practices, eliminated SFSTs not feasible for implementation in South Africa, extended upon an existing framework by contributing new knowledge and quantification of carbon variables in South Africa and applied the framework via a case study to confirm framework application.

9.3 FURTHER RESEARCH RECOMMENDATIONS AND OPPORTUNITIES

Further research opportunities would be to expand the South African road freight decarbonisation framework to include other supply chain activities such as warehousing, packaging, production and sourcing to present a complete, total supply chain decarbonisation framework for South Africa. The opportunity also exists to update South Africa's carbon emissions as there are minimal resources available on the latest carbon emissions for South Africa with the trends that the emissions are taking in each of the different industries. Road freight must be included in this research as there is no recent data available on updated road freight emissions for South Africa.

Further avenues and opportunities to explore would be to raise awareness of the South African road freight decarbonisation framework to educate companies on the possibilities available for improvements in road freight that will decrease both costs and emissions. This awareness will assist companies in focused decision-making to ensure companies target the correct variables that emit the most carbon emissions, which will differ from company to company. Little research has also been done on the feasibility of alternative fuelling solutions and what this will entail should South Africa consider this as an option. The infrastructure in South Africa must be evaluated, and it must be quantified whether it will be possible to execute this option in South Africa. Possible solutions to electrical charging points for electric vehicles in South Africa can be investigated. As the annual BP (2016) report has stated, the time of an abundance of oil is coming to an end, and alternative solutions to move freight must be given the needed research attention.

A more in-depth investigation can be conducted on why unnecessary trips and missed slot times occur and the cultural aspect in South Africa and how culture can influence other business operations. This can either differ from one company to another or may have similar reasons, which can then be investigated further. It can be recommended that companies conduct a Pareto analysis and six sigma to problem-solving on both unnecessary trips and slot time adherence.

The South African framework can be implemented in more companies to expand the measurement of effectiveness within a company further. Further case studies can be conducted to implement and evaluate the impact of applying the road freight decarbonisation framework on more companies. Positive results of implementation will also assist in raising awareness of the framework. Management and governmental involvement and support to reduce carbon emissions will be most beneficial to induce the behaviours that can facilitate decarbonisation. In other aspects, specifically modal shift, government intervention and industry collaboration will be required. Further investigation on performance-based vehicles as a possible carbon reduction variable can be investigated to measure the effectiveness of decreasing deliveries and carbon emissions. Performance-based vehicles can be included in the operational efficiency decision-making influence.

Furthermore, investigation is required into the opportunity and feasibility of the implementation of Maglev freight trains in South Africa and what investments, infrastructure challenges and governmental policies and involvement would be required for these trains to be implemented within South Africa. Hyperloops can be investigated as an alternative for passenger transportation as well as how both Maglev trains and Hyperloops can decrease total carbon emissions within South Africa.

Finally, the cultural aspect, which is the fourth pillar of sustainability, can be investigated further to establish how culture may affect the decision influences within a community that effect carbon emissions and how this may influence the economic, social and environmental behaviour of companies and governmental policies.

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APPENDIX A: UNITED NATIONS SUSTAINABILITY GOALS

United Nations sustainability goals		
	Goal	**Detail**
1	No poverty	To ensure a sustainable livelihood for all.
2	Zero hunger	One in nine people in the world suffers from malnutrition. Poor nutrition results in 45% of all deaths in children under the age of five years. About 3.1 million children die per year.
3	Good health and well-being	To ensure healthy living and promoting well-being at all ages.
4	Quality education	Increasing access to education at all ages, particularly focusing on women and girls. 103 million youths worldwide lack education, 60% being women.
5	Gender equality	Providing women and girls with equal access to education, health care, decent work and representation in the political and economic decision-making processes.
6	Clean water and sanitation	Every year, millions of people die from inadequate water supply and diseases associated with water sanitation and hygiene. Water scarcity affects more than 40% of the global population.
7	Affordable and clean energy	One in five people today still do not have access to modern electricity. More than three billion people of the world population rely on wood, coal or charcoal.
8	Decent work and economic growth	In 2012, global unemployment had risen to 202 million from 170 million in 2007. Sustainable economic growth will allow people to have quality jobs that will stimulate the economy while simultaneously not harming the environment.
9	Industry, innovation and infrastructure	Basic infrastructure still remains scarce in many developed countries. A quality infrastructure can be directly linked to social, economic and political goals. Technological progress will be the foundation to achieve environmental objectives such as resource and energy efficiency.
10	Reduced inequalities	Income inequality increased by 11% from 1990 to 2010. To achieve sustainable equality, policies must be adopted on fiscal, wage and social protection.

Source: Table adapted from The United Nations, 2016

United Nations sustainability goals		
	Goal	**Detail**
11	Sustainable cities and communities	Cities only contribute to 3% of the earth's land but contribute to 60–80% of the energy consumption and 75% of carbon emissions. The rapid expansion of urbanisation is causing pressure on freshwater supplies, sewerage, public health and the living environment.
12	Responsible consumption and production	It is estimated that 1.3 billion tonnes of all food producedis being wasted due to poor transportation and harvesting practices. Households contribute to 29% of global energy consumption and 21% of global emissions. Consumers must engage in sustainable consumption and lifestyles through awareness and education.
13	Climate action	For every one degree of temperature increase, grain field yields decline by 5%. From 1901 – 2010, sea levels rose by nineteen centimetres due to melting ice caps. CO_2 emissions have increased by almost 50% since 1990.
14	Life below water	Over three billion people depend on the marine and coastal biodiversity for livelihood. The oceans absorb nearly 30% of the world's CO_2 emissions that buffers the impact of global warming and 40% of the oceans are directly affected by human pollution, fisheries and coastal habitats.
15	Life on land	13 million hectares of forests are being lost every year while the degradation of drylands has directly led desertification of 3.6 billion hectares. Of the 8 300 animal breeds that are known, 8% are already extinct with 22% looming on the edge of extinction.
16	Peace, justice and strong institutions	Corruption, bribery, theft and tax evasion are costing developing countries trillions of dollars each year. This money could have been used to help those in poverty. The rule of law must be promoted nationally and internationally to ensure equal justice for all.
17	Partnership for the goals	Urgent action is needed to mobilise, redirect and unlock the transformative power of private sector resources. Partnerships and goals must be built and developed on finance, technology, capacity building, trade and systemic issues such as policy and institutional coherence, multi-stakeholder partnerships and data, monitoring and accountability.

Source: Table adapted from The United Nations, 2016

APPENDIX B: PRELIMINARY DATA QUESTIONNAIRE

Questionnaire: South African Transportation Sustainability and Decarbonisation

Background: *Our global and local supply chain network is embarking on a new journey. There are new challenges and opportunities we haven't had the chance, or need, to explore. Supply chain sustainability, - decarbonisation and renewable energy and responsibility are new terms we have had the luxury to ignore. Currently, we are making extreme demands our planet needs to meet. We are satisfying our demands from a planet that will not continue to support our demands for future generations.*

Definitions:

"Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own need"

"Decarbonisation is the reduction or removal of carbon dioxide from energy sources"

Questions:

1. Do you believe that your road freight business is sustainable?

2. Why or why not?

3. Do you believe in decarbonising the road freight sector? (Removing or reducing harmful CO_2 gasses)

4. Why or why not?

5. What do you think is South Africa's biggest challenge in the transport industry?

6. In your opinion, where do you waste the most time in transportation? (Explain your answer)

7. In your opinion, what is the most wasteful component in transportation? (Explain your answer)

8. What would you do to decarbonise the transport sector and make it more sustainable?

Please rate the following questions by circling a number from 1 -5, where 1 is completely disagree and 5 is completely agree.

1. My company uses the best possible technology to increase vehicle efficiency.

1	2	3	4	5	N/A

2. Sustainability is important for my company.

1	2	3	4	5	N/A

3. In my company, employee training is important when it comes to driving the vehicles efficiently. (For example not idling the vehicle for long periods of time)

1	2	3	4	5	N/A

4. When outsourcing vehicles, or using own company vehicles, my company only uses energy efficient vehicles with low fuel consumption.

1	2	3	4	5	N/A

5. My company uses technologies to track vehicle efficiency.

1	2	3	4	5	N/A

6. CO_2 emissions are important for my company.

1	2	3	4	5	N/A

7. Global warming is important for my company.

1	2	3	4	5	N/A

8. My company is concerned about carbon tax laws. (Tax laws that make you pay for the CO_2 emissions you emit into the atmosphere)

1	2	3	4	5	N/A

9. When routing destinations, my company takes the most efficient route.

1	2	3	4	5	N/A

10. My company makes use of different types of modal splits. (For example trains, ships, trucks)

1	2	3	4	5	N/A

APPENDIX C: INTERVIEW QUESTIONS

Personal interview: South African Road Freight Sustainability and Decarbonisation

1. Please describe your road freight logistical practices. (Focus on challenges, infrastructure and questionnaire themes)

2. Is the transport supply chain of your company a sustainable practice?

3. Would you want to change this? Why/Why not?

4. What would you like to change and what is your vision?

5. What is the major challenge for your companies' transport?

6. Do you have any government challenges? Funding, tax, etc.

7. What type of infrastructure problems do you encounter for road freight transport?

8. Are you concerned about carbon tax in South Africa?

9. Next steps (show participants McKinnon's decarbonisation framework and document comments)

APPENDIX D: FINAL POPULATION DATA GATHERING QUESTIONNAIRE

Dear Participant,

Thank you for taking the time to complete this survey. The data in the survey will be used to calculate road freight carbon emissions in South Africa and to assist in the development and data population of a road freight decarbonisation framework for South Africa. The framework will assist companies to actively reduce road freight carbon emissions and can be used to increase corporate social value.
All data, company and participant names will be kept strictly confidential and will not be distributed to any 3rd parties. Company names will not be mentioned or published in the findings.
The questionnaire consists of 17 questions and will take approximately 10-15 minutes to complete.
Should you have any queries or would like to receive more information regarding the framework, please contact the researcher:

Lee-Anne Terblanche
15078957@sun.ac.za

***I have read the terms and conditions and give my consent that the data provided in the questionnaire may be used for research purposes.**

Yes
No

Participant Name:
Company Name:
Email address:
Company Size:
Fleet Size:

1. Please specify the average weighted tonnes moved per load:
If you have more than one truck capacity, please specify each truck separately.

2. What is the average distance travelled for one load in kilometres?

3. What is the total annual kilometres travelled for the whole fleet?

4. On average, how many times is a product handled, from production, before reaching the client:
This is only for road transport and does not include shipping and air freight.

1	2	3	4	+5

5. What percentage of trucks return empty after a delivery?

6. Do you re-deliver a lost load after a truck has been hijacked?
A lost load is defined as all the goods on the truck have been stolen and cannot be recovered.

Yes
No

7. If you answered "yes" in the previous question, please describe your answer:

8. Please rate all the statements below to the root cause for an unnecessary trip to take place. Where 1 is very infrequent and 5 is very frequent.
An unnecessary trip would be an unplanned trip that a truck had to take again due to an obstruction in the first delivery attempt.

	Likelihood				
	1	2	3	4	5
Road obstruction: Strike	○	○	○	○	○
Road obstruction: Flooding	○	○	○	○	○
Truck was hijacked	○	○	○	○	○
Stock transfers due to warehouse constraints	○	○	○	○	○
Road obstruction: Road works	○	○	○	○	○
Poor production performance leading to stock transfers	○	○	○	○	○
Incorrect delivery	○	○	○	○	○
Driver error	○	○	○	○	○
Truck breakdown	○	○	○	○	○
Poor weather conditions	○	○	○	○	○

9. What % of total annual kilometres can be reduced if unnecessary trips are completely eliminated?
(Please exclude slot times/re-delivery attempts from your answer)

10. If there are other reasons for unnecessary trips taking place, which are not listed above, please list them below:

11. How would you rate your own slot time adherence?
(Are deliveries made on the agreed time?)

10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
75%	80%	85%	90%	95%	99%	100%						

12. Please rate all the statements below to the likelihood of a missed slot time occurring. Where 1 is very infrequent and 5 is very frequent.

	Likelihood				
	1	2	3	4	5
Traffic congestion	○	○	○	○	○
Strikes	○	○	○	○	○
Road blocks	○	○	○	○	○
Late off-loading at prior client	○	○	○	○	○
Bad road infrastructure	○	○	○	○	○
Slow drivers	○	○	○	○	○
Full warehouses at client preventing off-loading	○	○	○	○	○
Off loading not allowed due to pilferage of load	○	○	○	○	○
Truck was hijacked	○	○	○	○	○
Bad weather	○	○	○	○	○

13. What % of total annual kilometres can be reduced if re-delivery attempts (missed slot times) to the same customer are completely eliminated?

14. If there are other reasons for missing a slot time, which are not listed above, please specify below:

15. What percentage of road freight kilometres can be reduced due to theft?
Please use a percentage of annual kilometres.

16. Are you fully RTMS compliant?
(The Road Transport Management System)

Yes
No

17. If you are not 100% RTMS compliant, what percentage of your company is?

10%	20%	30%	40%	50%	60%	70%	80%	90%	90%+
N/A									

Thank you for taking the time to complete this survey.

Should you have any queries or would like to receive more information regarding the framework, please contact the researcher:

Lee-Anne Terblanche
15078957@sun.ac.za

APPENDIX E: CALCULATION OF ROAD FREIGHT EMISSIONS

The environmental protection agency recommends that the carbon emission outset of a vehicle can be calculated by dividing the CO_2 outsets by the total miles per gallon to achieve the total emissions outset per mile (Environmental Protection Agency, 2017). By multiplying the total CO_2 outset per mile by the total miles travelled, the overall total for CO_2 grams for a trip can be derived. One gallon equals 3.7 litres where one mile equals 1.6 kilometres. The equation can thus be converted to fit the South African metric system:

$$Annnual\ CO_2\ emissions = \frac{CO_2\ per\ liter}{km\ per\ liter}\ x\ kilometers$$

The British Department of Environment, Food and Rural Affairs (DEFRA) made the CO_2 emitted conversion factors to use when calculating the outset of carbon emissions publically available for each fuel type. Nedbank South Africa also made use of DEFRA's conversions in the Nedbank Carbon Footprint Guide. As stated by the authors of the report, Lotz & Brent (2016), the DEFRA emission factors provide an accurate guide to use when calculating emission outsets. The best-suited carbon factor to use in the calculations for South Africa's road freight emissions would be 2.65464 kg CO_2 emissions per one-litre diesel fuel consumption 2.30250 kg CO_2 emissions per one-litre petrol consumption.

Table 1 DEFRA conversion factors for diesel fuels

Activity	Fuel	Unit	kg CO_2
Liquid fuels: Diesel	Diesel (average biofuel blend)	tonnes	3082.82224
		litre	2.59007
		kWh (Net CV)	0.25946
		kWh (Gross CV)	0.24389
	Diesel (100% mineral diesel)	tonnes	3164.33333
		litre	2.65464
		kWh (Net CV)	0.26540
		kWh (Gross CV)	0.24948

Source: Adapted from DEFRA, 2016

Table 2 DEFRA conversion factors for petrol fuels

Activity	Fuel	Unit	kg CO_2
Liquid fuels: Petrol	Petrol (average biofuel blend)	tonnes	2993.58479
		litre	2.19697
		kWh (Net CV)	24552
		kWh (Gross CV)	0.23324
	Petrol (100% mineral diesel)	tonnes	3149.82196
		litre	2.30250
		kWh (Net CV)	0.25319
		kWh (Gross CV)	0.24053

Source: Adapted from DEFRA, 2016

APPENDIX F: CASE STUDY ON UNNECESSARY TRIPS

A case study on unnecessary trips took place over a period of one year and focused on the unnecessary trips carbon variable. It was concluded in the data analysis phase in Chapter 6 that unnecessary trips can be a large cause of carbon emissions. It was also deducted from the first case study in Chapter 8 that unnecessary trips were one of the opportunities for the company to decrease the number of trips taken over the assessed period. The case study was initiated after a participant, representing the company, was interviewed in the second phase of data gathering. During the interview process, the participant commented that unnecessary trips are likely to be a culprit in the company for extra financial expenditure. It was decided that it would be both beneficial for the research study and to the company to track why these trips are taking place. The case study was conducted on a different company than the first case study.

Data was gathered for the case study from the company for the period of one year on the number of unnecessary trips the company was taking. An investigation took place on why these trips take place. Due to the large size of the company (R22 billion turnover per year), having more than 120 deliveries scheduled for a day, only one division of the company was focused on, which represents 40% of the company's gross income.

To define an unnecessary trip, guidelines were provided for the company as to what would constitute an unnecessary trip, namely, a trip that could have been avoided should certain planning practices, precautions and communication have been in place. Primary reasons at this company for unnecessary trips were poor production output, warehouses reaching maximum utilised capacity and out-of-stock situations in specific geographical areas. During the one year of data gathering, an estimated number of 742 unplanned trucks were requested to move stock between warehouses on a national basis due to unforeseen reasons. This is an estimated number as only the total number of requests was tracked and not the actual trucks that were sent as a result of the requests. The company does not keep track as to why trucks are being scheduled for stock deliveries, thus making it difficult to track unnecessary trips on actual trips taken.

The reasons and number of trucks are summarised in Figure 1. The main reason for unplanned trips was substitute demand due to production line inefficiencies. In this situation, the inefficiency of the production line had occurred over a long period of time where a major production breakdown caused the stock to be substituted from other regions to supply the demand in a region having a production breakdown.

A breakdown for this company would occur when stock cannot be supplied according to demand for a period of more than one month. The reason code ‘Line inefficiencies’ occurred when short periods of production breakdowns led to small weekly out-of-stock situations and demand had to be supplied from other regions. Warehouse space constraints were also a concern for this company as the capacity of the warehouses could either not keep up with the demand, poor sales led to over-stock situations or market uncertainties led to overstocked warehouses. In this specific year of data gathering, the company acquired a new storage location, which was calculated to be able to provide the needed capacity for the demand. However, as the company reached its peak period, the new warehouse lacked the space to contain the stock necessary for the peak period, and additional warehouse space had to be rented. Additional trucks had to move stock between permanent warehouses and additional rented warehouse space.

The estimated cost for these trips amounted to R10 860 000, which was calculated as the average cost to move freight for the company for the intended destinations at R15 000 per truck. Figure 1 presents that the highest cost occurred on production line inefficiencies. On further investigation, a mitigation plan for these unplanned and unnecessary trips must be developed as these trips can have a heavy cost implication on the company. Not only is this a high risk of over-budgeted expenditure for the company, but the extra trips also led to a high volume of carbon emissions, which could have been avoided.

Upon discussion with the management team, it was agreed that more accurate forecasting could prevent many of these unplanned trips and proper maintenance plans on the production lines can prevent breakdowns that lead to stock transfers from one region to another. Accurate growth forecasting could have prevented the new warehouse from being over-utilised during its first year of operation. Supply chain misalignment led to many of these unplanned trips and to an increase in carbon emissions being emitted by road freight.

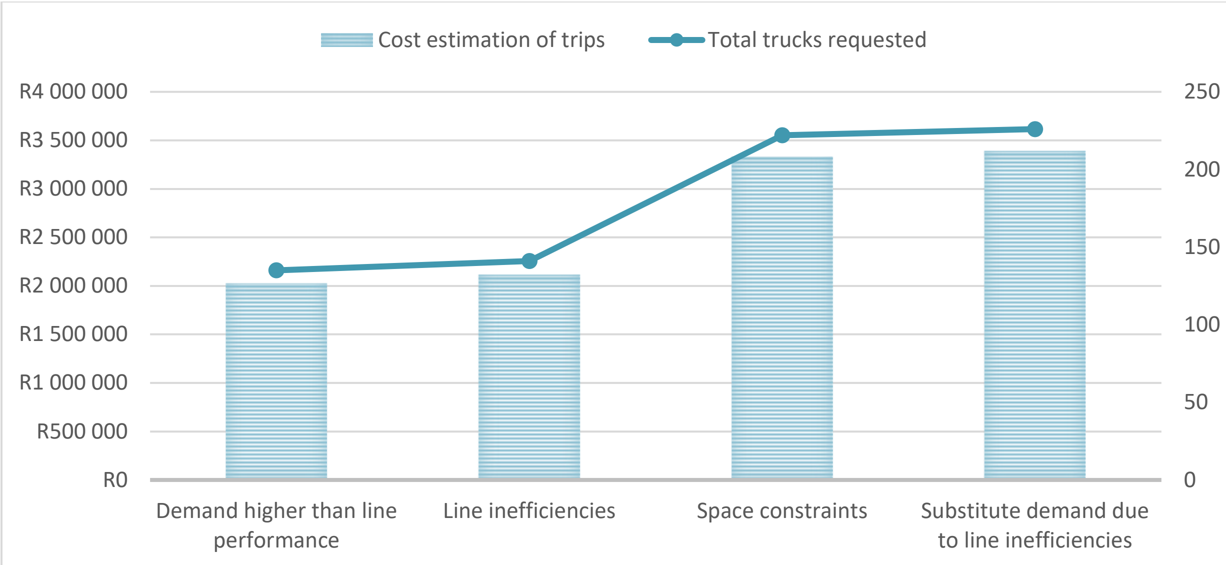


Figure 1 Number of unplanned trips per reason code and cost estimation

By using DEFRA's emission factors (Appendix E), the total carbon emissions can be calculated for diesel emissions for each reason. Details were not provided on what type of truck was used for these trips, but the most frequently used truck used by the company is a 14-tonne payload truck. Thus, CO_2 calculations were made using a 14-tonne payload truck. The average length of a trip was used, which is estimated at 1 443 km as the warehouses where the stock was needed are situated in the Western Cape and Gauteng regions. The CO_2 calculations are shown in Table 1.

Table 1 Total estimated CO_2 and carbon tax

Average kms travelled per trip	Total kms travelled	CO_2 factor for diesel	Diesel consumption of the delivery vehicle	Total CO_2 tonnes	Total carbon tax
1 443	742 trips x 1443km = 1 070 706	2.65464	47 per 100 km	1335.90	R 160 308

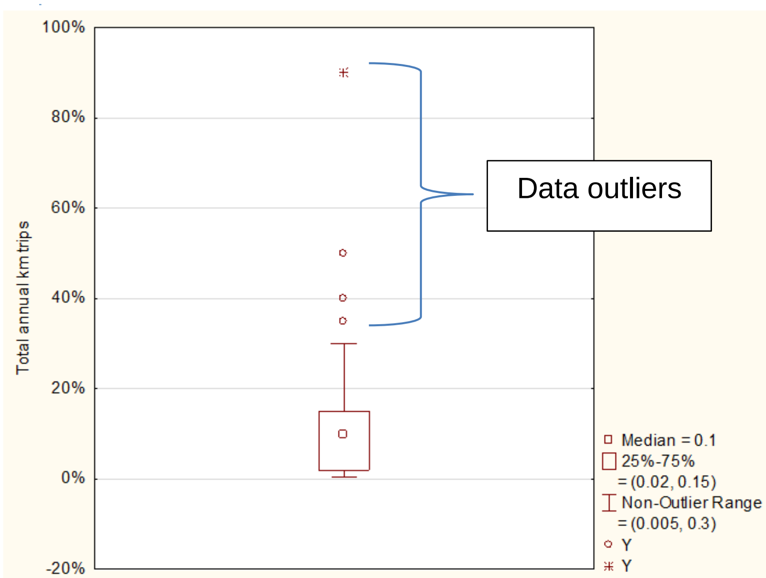
Conclusion from case the case study

The case study company had a large number of unnecessary trips within the year of data gathering. The company suffered a major breakdown on one of its main production lines and production on the line was stopped for two months. The breakdown led to more unplanned trips, which could not have been foreseen. It must thus be kept in mind that although unnecessary trips can have a major contribution to costs and CO_2 emissions, the case study was an outlier in the form of unnecessary trips and that in this specific case, the high number of unnecessary trips were not the norm for the company.

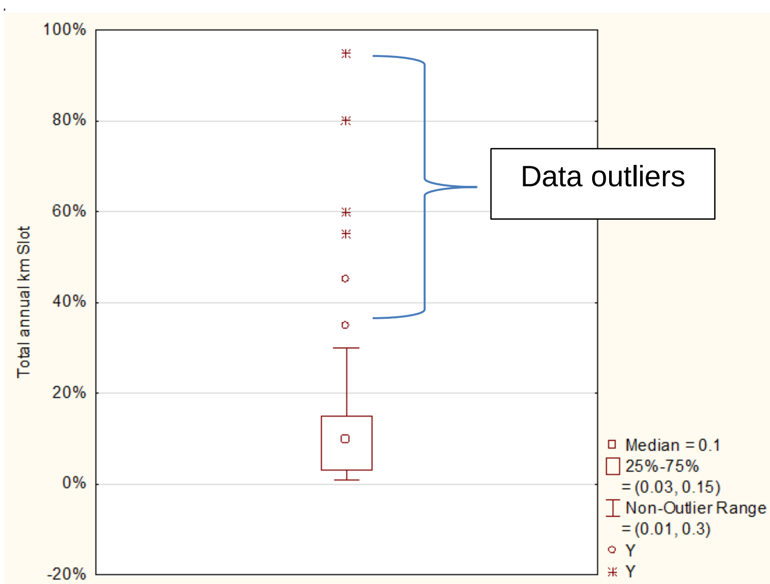
By using the guidelines of the South African decarbonisation framework, the company became more aware of costly activities affecting bottom line earnings. Over-budget expenditure is a concern and supply chain activities will now be investigated for a cost-saving initiative. Although the CO_2 emissions being emitted by this company's unplanned trips are a secondary concern, it must be noted that the South African decarbonisation framework led to supply chain activities being investigated, which was a positive turning point. Should carbon tax be implemented in South Africa, this company will benefit from the process of becoming more aware of the carbon variables affecting carbon emissions.

APPENDIX G: BOXPLOTS AND DATA OUTLIERS

Reductions in total annual kilometres should unnecessary trips be eliminated:



Total annual kilometres reduction should slot times be adhered to:



Lengths of trips: