Modelling strategic responses to factors influencing mode choice in completely built units transportation

Andrew Mukanyima

A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration

Johannesburg, 2017

ABSTRACT

The purpose of this research to model strategic responses to input drivers influencing road and rail transportation of completely built units (CBUs) in Gauteng's automotive industry.

Due to the global economy and free market trade, like all industries Original Equipment Manufacturers (OEMs) are shifting plants to locations were lower production and shipment costs are (Black, 2001). This concept is identified by Christopher (2011) who points out that leading-edge companies have realised that the real competition is not company against company but rather supply chain against supply chain. Within the context of South Africa being geographically positioned further from the markets, there is need for improved operational efficiencies within the OEM supply chain. By modelling the strategic responses of input factors in various scenarios, outputs can be used to inform business of the likely impact of certain decisions.

The research applied a mixed method approach (qualitative and quantitative) to generate a fuzzy cognitive map and model which was used to simulate various scenarios in the study. Literature review was used to formulate the draft FCM which was then participated to eight industry experts through a semi-structured interview. Making use of the experts' feedback the draft FCM was updated/refined into the final FCM which was used to model the various scenarios.

Within South Africa, road and rail are the key modes of transport of CBUs over the long haul. The OEM supply chain is hybrid of cost sensitive and service sensitive. Cost because the industry needs to be competitive against other markets who they are competing for production contracts with and service sensitivity because movement of vehicles should be timeous, reliable, flexible and ensure integrity of cargo to meet market needs.

Through scenario testing the sensitivity of supply chain cost and service outputs to changes in influencing factors from a road and rail base were examined. In general, the results indicate that there is positive and negative responsiveness to these factors whilst in some few instances outputs are unchanged. Business needs to be

able to have a long-term view of these factors and the likely impact on business process and outputs considering the highly competitive global environment.

Road and rail transportation of CBUs in SA complement each other. The decision to use either mode is informed by multi-criteria analysis governed by cost sensitivity and service sensitive parameters. The integration of road and rail services will mitigate the impact of primary input factors and provide optimised cost and service needs that will provide coopetition i.e. cooperative competition for the benefit of the South African CBU transportation industry.

DECLARATION

I, Andrew Mukanyima, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

(Andrew Mukanyima)

Signed at …………………………………………………

On the …………………………….. day of ………………………… 20…..

DEDICATION

This research is dedicated to my wife Tendai for her love, support, understanding and encouragement throughout my studies.

I would also like to dedicate this research to my beautiful daughters Anatswanashe and Makanakaishe, who make it all worthwhile, I love you girls.

Finally I dedicate this research to my parents (Peter and Beatrice) who have always been a pillar of support, love and encouragement.

ACKNOWLEDGEMENTS

Firstly and foremost I would like to thank Jehovah El Shaddai for blessing me with the opportunity to carry out this research.

I wish to thank my supervisor Prof Stacey for his support and guidance rendered during the course of working on this research report.

I want to thank my darling wife Tendai for all the support and encouragement even in times when I doubted myself, I love you. Special mention goes to my parents and siblings thank you for the love and support.

To all friends and family whom I have not mentioned by name but supported me throughout this research, thank you.

A special mention goes to all the industry and professional experts who gave valuable input and critique to my draft FCM so that it could be refined into the final FCM used in this study. I also would like to thank Dr Anne Fitchett for proof-reading my work and being a sounding board.

Lastly, I would like to thank my colleague Gerard for kindling my interest in logistics and supply chain management.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

The purpose of this research to model strategic responses to input drivers influencing road and rail transportation of completely built units (CBUs) in Gauteng's automotive industry. The modelling shall be done through the development of a fuzzy cognitive map which will provide for the causal relationship of factors.

Transportation is critical in the supply chain as it can be viewed as the glue that makes the supply chain function. The critical outcomes of the supply chain are "to deliver the right product at the right time, in the right quantity and quality, at the right cost, and to the right destination" (Coyle, Langley, Novack, & Gibson, 2016, p. 21).

The outcome of this study is expected to inform drivers for CBU's transport movements, inform scenario planning outputs through modelling the impact of the drivers, provide for automotive freight transport efficiency/optimisation and give benefits to the automotive industry as well as the body of knowledge.

1.2 Context of the study

Within the automotive industry, the completely built unit (CBU) represents the finished goods ready for the market and it is not only important for this product to reach the market but it must do so timeously with no damage or mileage. Black (2001) highlights that due to the global economy and free market trade, like all industries Original Equipment Manufacturers (OEMs) are shifting plants to locations where lower production and shipment costs are, so as to respond to the need for improved operational efficiencies. This concept is identified by Christopher (2011) who points out that leading-edge companies have realised that the real competition is not company against company but rather supply chain against supply chain. This implies that the location of the nodes and links are important to ensure that logistics costs are minimised in the supply chain. The Gauteng automotive sector is not only a hub for production of CBUs for the local market but caters for a growing export market and therefore must be able to compete at the same scales and efficiencies.

Alfaro, Bizuneh, Moore, Ueno, and Wang (2012) state that within the automotive industry South Africa's biggest competitors are other developing markets such as Mexico, Thailand, China and Egypt. However, unlike these other production centres, SA is geographically further from its markets and is thus disadvantaged. Considering such a fact, it becomes more pertinent to optimise costs within the South African supply chain and in this regard, this research seeks to review influencing factors around CBU transportation so as to benefit the business flow.

According to the Lamprecht (2015), Gauteng automotive industry accounts for approximately 22.9% of the South African production market share. Gauteng is geographically landlocked with supporting road and rail networks offering connectivity to the coastal ports. Since the nature of OEM manufacturing is such that producers win contracts for the supply of the global market, the majority of units produced in Gauteng are export bound and hence an efficient and cost effective logistics solution is paramount to ensure global competitiveness. In this regard a review of the Gauteng OEMs' freight logistics strategy becomes relevant.

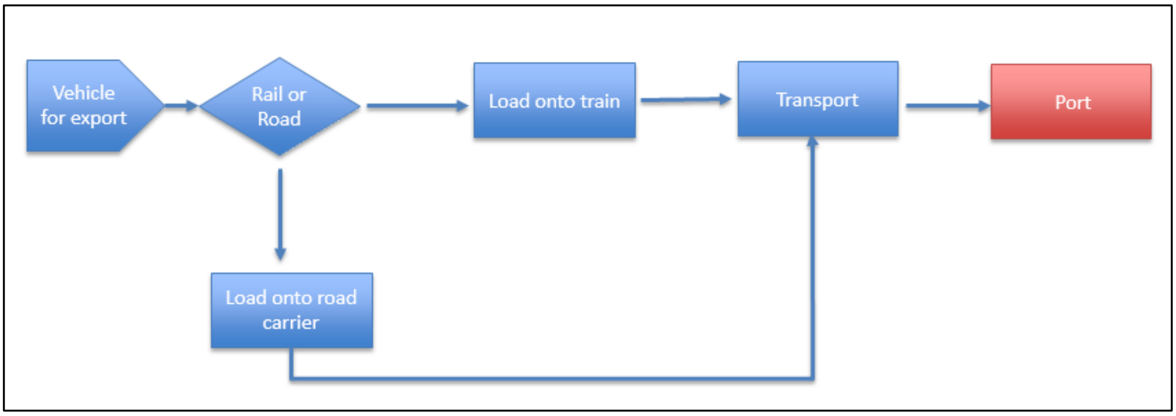


Figure 1: Export vehicle flow

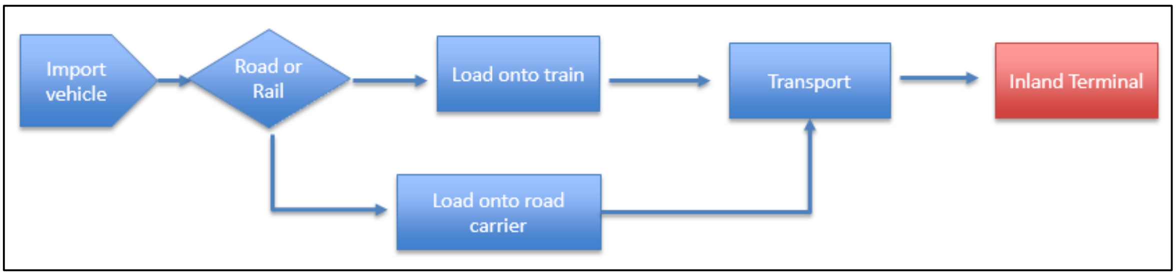


Figure 2: Import vehicle flow

Furlonger (2016 online) reports that: “the global motor industry executives consider SA the second most important emerging automotive market over the next five years”. Therefore it is this research supposition that, in order to be able to be adequately positioned, a review of factors influencing mode choice in CBU transportation becomes pertinent as it ultimately impacts on competitiveness.

Automotive Logistics (2006) stresses that rail transport has demonstrated its advantages over road due to its lower costs, particularly for higher volumes. Movement by rail also reduces road congestion, which in turn improves environmental quality/sustainability and can improve logistics efficiency. This importance of sustainable logistics is further captured by Automotive Logistics (2013, p. 42) quoting Wallenius Wilhelmsen Logistics (one of the largest shipping companies in the world) saying: “We are dedicated to reducing the impact of our shipping and logistics activities on the environment." Adding to this notion is Williams (2014, p. online) who quotes Anders Madsen, president of Logent Ports & Terminals, saying through the completion of a rail track at the car terminal at Gothenburg port in Sweden: "We are now able to offer the automotive industry more efficient, climate-smart distribution solutions which is extremely pleasing”. He goes further to state that: “There are also firm indications that rail will be in a strong position when it comes to car transport in the future." The above points on sustainability highlight that supply chain activities are no longer limited to traditional factors of cost, time and reliability, but require a multi-criteria analysis in order to get the right balance for cost-effectiveness, sustainability and service.

Notwithstanding the above, Automotive Logistics (2006) further argues that rail is generally less flexible than road due to its volume requirements and scheduling restrictions. Considering these different arguments there is more to what meets the eye when it comes to factors influencing mode choice in the transportation of completely built units. In this regard, a review of these factors and their influences becomes pertinent as it will inform business planning and processes.

Figure 3: Automotive trains, source (Automotive Logistics, 2013)

Figure 4: Road: Road car carriers, source (Automotive Logistics, 2013)

1.3 Problem statement

1.3.1 *Main problem*

To model strategic responses to the impact of changes in influencing factors to road and rail transportation of CBU's in the automotive industry in South Africa.

1.3.2 *Sub-problems*

Sub-problem one: Identifying the influencing factors to road and rail transportation of CBU.

Sub-problem two: Developing a semi-quantitative model that will take into account the causal relationship of factors influencing road and rail transportation.

Sub-problem three: Modelling different scenarios examining the effects of changes in the influencing factors to key supply chain outputs.

1.4 Significance of the study

The study will examine and model factors influencing road and rail transportation of CBUs and provide causal relationship outcomes on the different factors investigated. Through scenario testing, the model outputs will provide industry with insights on the impact of changes influencing factors to supply chain outputs and business processes.

Coyle et al. (2016) point out that transport is a major component of the supply chain, which exceeds other services such as warehousing, inventory management etc., and must therefore be accounted for in developing supply chain strategies and processes. The end result is that transport has a major economic impact on financial performance of businesses (Coyle et al., 2016).

This significance is reinforced by Kujawa (2015) who states that transportation management is a critical factor as choosing the appropriate mode of transport minimises logistics cost and ensures efficient operations. This will spill over into the whole supply chain through lower inventory costs, lower total cost of ownership and improved customer service.

In this regard, this research will allow for informed decision making in transportation of CBUs taking into consideration financial performance of the business. Furthermore, through sensitivity testing of the factors, the research will provide for business scenario planning, whilst offering insight to the expected impact of changes on key supply chain outputs which are important to industry.

The study will also benefit academia.

1.5 Delimitations of the study

The influencing factors identified shall be from a global perspective and are not expected to form an exhaustive list. The model will therefore offer an exploratory view of the relationships of these factors in relation to the South African automotive industry as defined.

The automotive industry in this study is limited to OEMs, Naamsa, AIDC, Transnet and Road Carriers. As the study is focused on the movement of completely built units, automotive parts manufacturers have not been considered.

The study is limited to South African automotive transportation industry for CBU to and from Gauteng i.e. long distance movements only. This is mainly as a result that mode choice over long distance movement is categorised by road and rail whilst the short movements (last mile) mainly favour road due to lack of rail infrastructure for door to door deliveries.

1.6 Definition of terms

Definitions of terms in the study:

Original Equipment Manufacturers (OEMs) – refers to companies that are responsible for the making and assembling of the vehicles

Completely built unit (CBU) – refers to light passenger car or light commercial vehicle (LCV) which is completely built and is ready for market or shipment

Automotive Industry Development Corporation (AIDC)

National Association of Automobile Manufactures South Africa (NAAMSA)

Department of Trade and Industry (Dti)

Uni-modal is the use of one form of transport e.g. road from end to end.

Inter-modal is the use of more than one form of transport e.g. a combination of road and rail

Single deck wagon refers to a wagon with one platform and can be used in the transfer of a high profile vehicles e.g. twin cabs, SUVs

Double deck wagon refers to a wagon with 2 platform and cars can be stacked on top of each other in one wagon. This wagon is used to transport low profile vehicles e.g. sedans.

Rolling stock defines locomotives, carriages, wagons, or other vehicles used on a railway.

1.7 Assumptions

The research assumes the following:

- The influencing factors to road and rail transportation of CBU's can be modelled.
- The literature review will provide enough information for the study outcome to have acceptable validity and reliability.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Havenga et al. (2015) argue that logistics is a strategic resource for the South African economy and is central to providing a global competitive advantage. In consideration of the above assertion, it therefore, becomes important to provide the optimum transportation mode of either road or rail or a fusion/hybrid of the two in the movement of built up units. Road and rail represent two of the most common and competitive modes of transportation in today’s world. However with volatile fuel prices, ever-growing vehicle production, inadequate infrastructure, increasing congestion, environmental concerns, and new legislation governing road/rail transport, business needs to be able to have a long term view of these factors and the likely impact on business process and outputs considering the highly competitive global environment.

The following topics will therefore be reviewed in the literature in order to address the research problems identified:

- Overview of the South African Automotive Industry and CBU transportation
- The role of road and rail in freight transportation as well as their characteristics
- Identification of influencing factors in road and rail transportation
- Identification of key supply chain outputs applied in multi-criteria decision making process of choosing transport solution.

2.2 Overview of South African Automotive Industry

Galbraith (2014) points out that the South African motor industry plays a pertinent role in the South African economy, contributing approximately 7% of the country's Gross Domestic Product (GDP). The industry consists of manufacturers, distribution, servicing and maintenance of motor vehicles.

For the purposes of this research, the industry shall be limited to manufacturers commonly referred to as OEMs. According to Creamer (2016), the major passenger car and light commercial vehicle (LCV) manufacturers active in South Africa include the local subsidiaries of seven global automotive companies – BMW, Ford, General Motors, Daimler (Mercedes-Benz), Nissan, Toyota and Volkswagen. Although there are also truck assemblers namely Fuso, Freightliner, MAN, Tata, Isuzu Trucks, Hino, Volvo, Renault, Hyundai, FAW and UD Trucks (Creamer 2016), the focus of the study is on passenger car and LCV referred to as CBUs.

The local production clusters are indicated in Figure 5

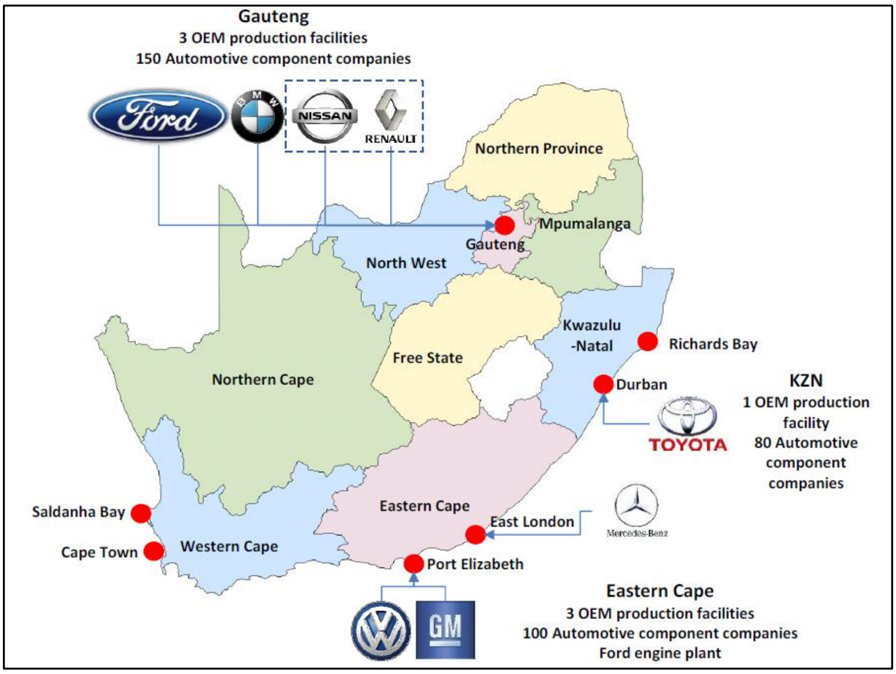


Figure 5: OEM production clusters, source (Department of Trade and Industry, 2015)

Creamer (2016, p. 10), making reference to NAAMSA industry statistics, highlights that in 2015: "South Africa's automotive industry produced 615 658 vehicles, including 341 025 cars and 242 974 light commercial vehicles (LCVs). Total vehicle production was up 8.7% on production in 2014, while production of passenger cars and LCVs were up 22.9% and 5% respectively on the previous year." NAAMSA forecasts a continued growth outlook and mainly attributes this to the Automotive Production and Development Programme (APDP).

The current installed capacity at South Africa's major car and LCV producers is about 850 000 vehicles a year (Creamer, 2016). Since the current volumes are lower than the installed capacity. It is important to review the impact of increased production volumes in relation to the transportation modes and infrastructure available so as to be able to meet the requirements of the SA automotive industry.

According to research done by Barloworld Logistics (2010), within the SA automotive industry the top five leading short term objectives by order of importance are:

- Reducing inventory;
- Lowering procurement costs;
- Risk sharing with suppliers;
- Improving communication with customers; and
- Optimising inbound transportation;

Key to note is the need to optimise transportation costs which falls within the confines of this research.

Barloworld Logistics (2010) also published the top five challenges in the SA automotive industry as:

- Waste and inefficiencies across the supply chain;
- Transforming supplier relationships into true collaboration;
- Implementing efficient planning and forecasting tools;
- Potential failure of key suppliers; and
- Cost of fuel & shift in strategic direction of organisation;

Of the factors above, the need to improve supply chain efficiency talks to transportation among other factors, whilst the cost of fuel is also seen as a challenge facing the industry.

It should be noted that some of these issues are not unique to South Africa: Coyle et al. (2016) list challenges affecting transportation providers as fuel costs, shortages of drivers and changes in driver hour regulations. The authors go further to point out that challenges also exist with regard to existing transport infrastructure maintenance (roads, bridges, tracks, airports etc.) as there is pressure to build more capacity so as to accommodate increasing demand.

2.3 Automotive CBU transportation in South Africa

2.3.1 *Transnet*

Transnet Freight Rail (TFR) is the operating division responsible for moving CBU on rail. TRF has specialised car wagons which consist of single and double decks so as to carry low and high profile CBUs. According to (Transnet, Online), the trains are dedicated per route thereby providing predictability which results in a cost efficient service.

2.3.2 *Road car carriers*

There are a number of road carries operating in South Africa, of whom the largest organisations are:

- Motorvia
- Grinrod
- VDS
- KDG
- Onelogic

The road car carriers use different vehicles which are able to carry 6, 8 and sometimes 10 vehicles at one go. The dependency factor on consignments is whether the CBU is rated as a high or low profile.

2.3.3 *Self-drive*

Self-drive is commonly used as a first or last mile for the OEM due to standing legislation in South Africa which limits the distance that a CBU can travel on a public road without registration. However, as per the research delimitations, this mode will not be discussed as it is not used in long haul movements of CBUs.

2.4 Road and rail in freight transportation

Automotive Logistics (2006) states that globally CBU freight movements are mostly handled via rail, as the costs are lower and more volumes can be moved. This is also supported by Williams (2014) who points out that the opening of a new rail link through Gothenburg in Sweden will increase CBU traffic flow. However, considering recent statistical data in South Africa, CBUs to and from OEMs are being shipped with almost an even split between road and rail (Creamer, 2016).

The confirmation of a high degree of road movements as compared, to international trends, is given by Havenga and Simpson (2014) who point out that within South Africa there has been a growing trend in terms of road freight transport over long haul despite the fact that approximately 50% of this freight is rail suitable. The authors argue that this set-up is at a huge risk to the industry as it is dependant on imported fuel, with the additional concern of the associated emissions. They point out that electrified rail, even if it is coal powered, has lower emissions than road transport emissions. Moreover, the abundance of coal deposits within the country mean that the logistics costs can be better controlled.

McKinnon (2006), writing on the UK freight industry, notes that road and rail In CBU transportation offer a complementary linkage. The author states that a complete modal substitution is difficult due to limitations in rail infrastructure to and from manufacturing premises, rolling stock and operating procedures. There will always, to a great extent, be a need for a road service in the first and last mile.

According to Forkenbrock (2001), rail and road compete in markets, however, the peculiarity is in that the associated distances are relatively short for rail whilst there are relatively long for road freight. Rail, as a mode is more suited for long distance in this regard, the distances that the two compete in are an overlap, which in rail terms is described as relatively short whilst for road it is considerably long.

Woodburn (2003) argues that the transfer of freight from road to rail is critical for developing sustainable transport systems: however, the author cautions that this must be done with an understanding of how supply chains operate for the different industries. In this regard, such an effort requires a degree of co-operation and collaboration so as to be actively realised and cannot be pushed onto industry as it will require a gradual shift. This research will therefore make use of the sensitivities in the supply chain outputs to be able to model the impact of changes in influencing factors on road and rail transportation.

Woodburn (2003) further highlights that the development of models such as just-in-time (JIT) have resulted in the movement of small volumes as and when required, which weakens rail position when it comes to competing with road, since rail is more oriented to being a mass carrier (large volumes). However, the author believes that, despite these odds, there is a growing expectation that rail will play a bigger role in meeting industry needs in the future.

Vasco Sanchez, Stantchev, Potter, Naim, and Whiteing (2008) highlight that freight transport should be used in a flexible and responsive manner, taking into consideration customer demand and mitigating transport impact on the environment. In this regard, the authors argue that there is need for integrated transport operations in order to ensure an optimised supply chain and any one solution does not have to be the one or the other, but can be a mix. Stamas (2009) adds that it is therefore not about pitting one mode against the other, but providing integrated solutions that benefit all modes whilst ensuring environmental sustainability.

Thambiran and Diab (2011) citing Lane (2009) argue that road freight has some advantages over rail in terms of accessibility, competitive pricing and the ability to travel on average more mileage on a month to month basis. These advantages are also supported by Stamas (2009) who points out that the disadvantage of rail includes the lack of timely transport, especially for businesses that need just-in-time logistics.

Havenga and Simpson (2014), cite Simpson (2013) who highlights that, within South Africa, rail capacity exists to move some of the existing road freight to rail. However, it is expected that this infrastructure capacity, if not maintained or improved, will be used up by 2030. Simpson further indicates that this argument also holds true for the road infrastructure and therefore this convolutes the debate.

Chopra and Meindl (2016) concede that road transport costs are higher than rail but the mode offers distinct advantages in door-to-door deliveries as well as short turn-around times for delivery. However, Coyle et al. (2016) point out that there are low barriers to entry when it comes to road carriers, whilst expenses related to freight movement such as wages, fuel, maintenance, tyres are the primary influence on the business costing of road logistics service providers

Coyle et al. (2016) suggest that for rail to be more effective it must be able to cast aside its associations with being slow, inflexible and inconsistent.

2.5 Identification of factors

In consideration of the industry background and rail and road mode share, this section will aim to identify influencing factors to mode choice.

Winebrake et al. (2008) in their research on the Geospatial Intermodal Freight Transport (GIFT) model which aimed to evaluate the cost, time-of-delivery, environmental, and energy impacts associated with uni-modal and intermodal freight transport, recommended for future study the impact of carbon taxes, fuel taxes, or modal subsidies in their model. Havenga and Simpson (2014) point out that within South Africa uncertainty with regards to oil price volatility, exchange rate volatility and emission tax influence cost of logistics. These external factors therefore influence the logistics cost within a country.

It is important to note that the identified factors are discussed in detail in the sections below and will be modelled as input drivers to road and rail transportation of CBU's in the SA automotive industry.

2.5.1 *Fuel price.*

Havenga (2010, p. 460) states that: "research shows that South Africa's logistics costs are higher than the global average. The majority of these costs are attributable to road transport, of which the biggest cost driver is fuel, which in turn is determined by volatile oil prices." The author recommends that these costs can be mitigated through a shift from road to rail on long distance freight routes.

Havenga and Simpson (2014) point out that the ever increasing fuel prices exerts pressure to road freight transportation as they have become a growing concern in the supply chain as compared to inventory carrying costs, production cost, warehousing etc. This concern is further exacerbated by the fact that in South Africa the major driver for logistics transport cost is the price of diesel. It is estimated that more that 36% of the road transport cost are spent on fuel and this is more than double the cost of the second-rated component, which is wages (Havenga & Simpson, 2014). In this regard, the authors point out that addressing this factor in South Africa requires collaboration within industry from a national perspective.

Macharis, Van Hoeck, Pekin, and van Lier (2010), in their research on the impact of fuel price in Belgium on freight transport modes, show that increasing fuel prices results in a move away from a uni-modal transport system to an inter-modal system making use of rail and other options. The market share of other modes is increased when a significant rise in fuel happens; however if the fuel price rise is small no changes are anticipated. Stamas (2009) adds to this notion, pointing out that with steep increases in fuel, the cost-effectiveness of long and (to some degree) short hauls favour rail traffic as compared to road.

Black (2001) argues that although South Africa has lower wages than Europe, the automotive industry in South Africa still pays a premium with regard to logistics cost. In the light of such an assertion, the importance of optimising mode choice for CBU transportation is very pertinent as it allows for global competitiveness. Simply put, Forkenbrock (2001, p. 321) says: “low-cost, dependable movement of freight helps a business to be competitive.”

Havenga and Simpson (2014), citing research conducted by the Association of American Railroads (2011), state that energy consumption of road freight transport is about four times higher than that of rail. Moreover, road uses more fuel and results in more emissions. In line with this research, the influence of volatility in fuel price will be modelled to see the resultant effect on CBU transportation.

According to Alfaro et al. (2012), rising fuel prices can be attributed to the economic growth of rapidly emerging markets, which has resulted in higher economic activities and this trend is not expected to stop soon. As part of this research, the effect of variability of fuel price shall be examined in relation to road and rail transportation of CBUs.

Fluctuations in freight and fuel costs have a high impact on profit for a global supply chain (Chopra & Meindl, 2016). These authors point out that, if the trend continues, business will most likely restructure their products and supply chains so as to reduce transport costs.

Considering the impact of fuel price on road and rail transportation it becomes important to have it in the model as literature clearly articulates its impact when it comes to cost. Since South Africa is located further from European and American markets, the need for cost optimisation in logistics is pertinent.

2.5.2 *Production volumes*

Kujawa (2015), citing Coyle, Bardi, and Langley (2003), points out that when it comes to freight movements, volumes are important as higher transportations costs can be a result of frequent shipping of smaller quantities at higher rates.

According to Black (2001), the automotive industry is very cyclical and this affects production as well as employment. The CBU production volumes are influenced by global market trends as well as contracts within the various OEMs so an interesting factor is to review how the impact of changes in these volumes influences road and rail transportation of CBUs.

Black (2001) further points out that the automotive industry in South Africa has been subject to rapid structural changes in policies which have seen a rise in imports, whilst at the same time manufacturers have been encouraged to produce more exports. Taking into consideration the export growth, Black (2001) argues that, due to increasing international competition, the survival of local subsidiary manufacturers must be banked through the generation of economies of scale (increased production volumes). It therefore, becomes not enough to manufacture or import vehicles and have no way of transporting them sustainably and competitively. Considering the above, it is evident that production volume dynamics feed into demand for an effective transportation system of CBUs to and from other markets.

Within South Africa, a major driver in export and import volumes has been the introduction of the Automotive Production and Development Programme (APDP), implemented in 2013. This is an original equipment manufacturer incentive scheme for CBUs with four main pillars:

- Import duty;
- Vehicle assembly allowance;
- Production incentive; and
- Automotive investment scheme.

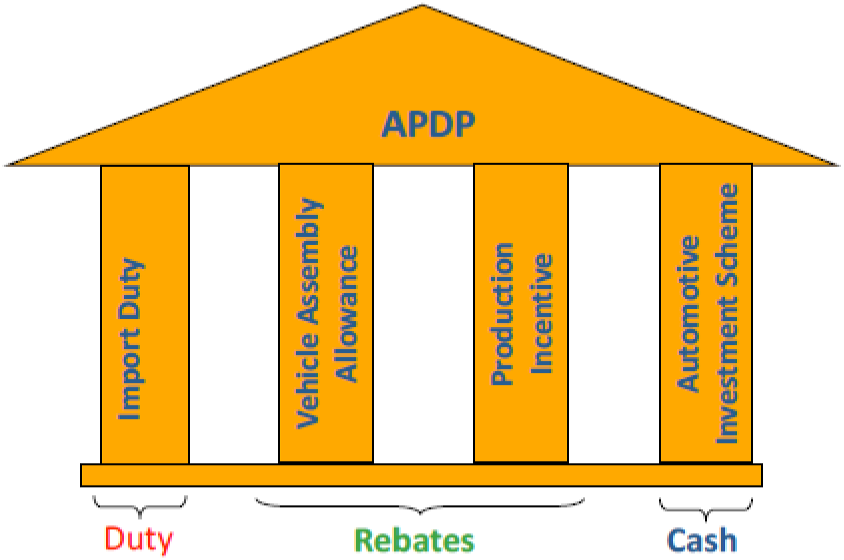


Figure 6: APDP, source (Galbraith, 2014)

All four pillars collectively work to increase CBUs' volume flow in South Africa, through imports or local manufacturing for export, by means of duty relaxation, rebates and cash incentives. This is important to this research as we model the influence of production volumes which in turn inform appropriateness of mode choice.

The National Association of Automobile Manufacturers of South Africa (NAAMSA) projected that, as a direct impact of the implementation of the automotive production and development programme (APDP) in 2013, local CBU production volumes would increase to 1.2 million units by the year 2020 (SouthAfricainfo, 2014).

2.5.3 *Distance*

Coyle et al. (2016) accede that rail is typically suited for long distance and low-value goods. However the author points out that it can also be used for transportation of high value goods such as automobiles.

According to Bowersox, Closs, Cooper, and Bowersox (2013) distance has a major impact on road transportation cost since it has a direct bearing on variable costs such as labour, fuel and maintenance.

Although rail and road are two major stand-alone modes of transportation, due to long distance haul needs and last mile distribution needs Coyle et al. (2016) point out that intermodal transportation (use of more than one mode to move from origin to destination) is a growing trend with traction (growing momentum/uptake) due to the wider reach it caters for.

2.5.4 *Carbon Tax*

Across the world there is a growing awareness on the impact of emissions on the climate and it is almost certain that taxation of emissions will also apply to South Africa (Havenga & Simpson, 2014). However, citing South African National Treasury 2010, proposals the authors note that although no cost has been formally adopted, it is estimated that typical emission cost shall be R225 per ton of CO_2, R36 472 per ton of SO_2, R5 471 per ton of CO, R5 471 per ton of HC and R18 692 per ton of NOX.

Alton et al. (2014) weigh the concept of the introduction of carbon tax in South Africa. They suggest that the introduction would most likely result in marginal decreases in national welfare as well as employment i.e. 1.2 % and 0.6% respectively. Alton et al. (2014) add that a major worry for business will be the loss of competiveness.

Chopra and Meindl (2016) point out that growth trend on transport demand and emissions is unsustainable and will most likely result in government policy intervention as well as research into better technologies. They further state that two common approaches to mitigate emissions are carbon tax and cap-and-trade system. Through enforcing carbon tax it is envisaged that, this will act as an incentive to transporters to make use modes of transport with lower emissions. In line with this research the influence of such interventions will be modelled to see the resultant effect on CBU transportation

In the SA automotive industry such an introduction is expected to affect road transport more, considering the carbon emissions associated with burning fuel. In this regard, modelling the impact of such a factor should feed into this research.

2.5.5 *Emissions*

Thambiran and Diab (2011) citing Lane (2009), highlight that in South Africa, the contribution of road freight transport emissions can be attributed to the fact that some of the largest vehicle combinations (vehicle carrying capacities and dimensions) in the world are permitted to operate for general freight haulage. These emissions of air pollutants and greenhouse gases are a key concern with regard to this research, so it becomes a key factor to model the impact of the control mechanisms (scenarios) on CBU mode choice.

The Stern report (2007) on economic of climate change, identified that transport accounts for approximately 14% of global green-house gas emissions, making it the third highest emitter; however the report further points that 75% of the transport emissions are as a direct result of road transport, whilst aviation accounts for one eighth and rail and shipping constitute the balance (Stern, 2007). This information clearly outlines the extent of road transport contribution to emission regardless of private cars or road freight.

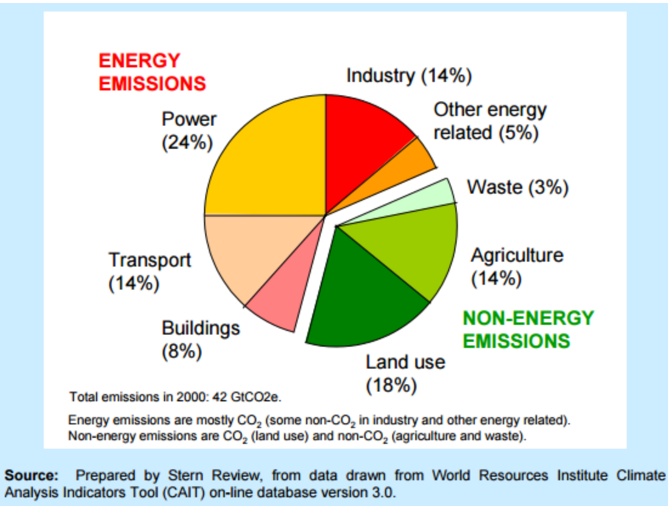


Figure 7: Greenhouse-gas emissions in 2000, source (Stern, 2007)

Chapman (2007), cited by Thambiran and Diab (2011), recommends that a possible way of mitigating or limiting road freight emissions is to provide new technologies that will help road haulers to co-operate and achieve economies of scale, thereby optimising trips by ensuring that spare capacity is used as well as avoiding empty return trips. The authors' further point out that through a combination of taxes, regulations, better technology and demand restraint, CO_2 emissions can be mitigated; however the effect thereof on the economy as well as the transport sector is unknown. Such an assertion provides reference to this research as it tries to examine the impact of influencing factors to road and rail transportation in CBU transportation.

(Ford, 2014/15, p. 557) states that the most effective leverage points in reducing emissions are:

- Improving the design and operation of transportation;
- Increasing the use of greener modes of transport (such as rail and water);
- Reducing miles travelled; and
- Increasing vehicle utilization.

Macharis, Pekin, Caris, and Jourquin (2008) citing the European Commission (2003) point out that the external costs of heavy goods freight transport comprises of accidents, air pollution, up and downstream costs, global warming and congestion.

2.5.6 *Road freight legislation*

de Saxe (2012) highlights that, until recently car-carriers in South Africa could operate under a regime of finite relaxation in legal height and length limits through the use of abnormal load permits, however this practice is being phased out with a migration to car-carriers which comply with performance based standards (PBS).

These standards have the effect of limiting the size of completely built units which can be transported by a car-carrier per trip. It becomes very important to review the effectiveness of moving volumes to market on this mode. On the other hand rail, although a traditional source of transportation, has at times been affected by factors such as operator inefficiencies and limited infrastructure coverage among many other factors.

Macharis et al. (2008) point out that, within the transport sector, governments can offer subsidies or incentives to ensure modal shift, especially towards intermodal transport activities.

Kujawa (2015) points out that there are two major forms of regulation within transportation, namely safety and economic regulations. Whereas safety is more focused on labour practices, working conditions, vehicle maintenance, insurance, dangerous goods and public safety. Economic regulation influences decision making in business as it affects mode and carrier selection. This is mainly attributable to the impact of this regulation on rates charged for shipment, service levels, routing and scheduling.

2.5.7 *Performance indicators*

Coyle et al. (2016, p. 439) point out that of the studies undertaken to identify important performance capabilities in mode selection, the following factors rate highly:

- Cost;
- Reliability;
- Transit time;
- Type of product;
- Accessibility; and
- Product safety and security.

According to Coyle et al. (2016), inexpensive transport is of no value to a supply chain if the goods do not reach their destination in time or intact. In essence, availability and efficiency are not adequate without effectiveness of the system. This thinking is in line with Bowersox et al. (2013) who state that unless transportation is managed in an effective and efficient manner, the supply chain processes will not meet expectations.

Kujawa (2015) argues that a product is of a lesser value to a customer if it is not available precisely when it is needed. This thinking talks to opportunity costs and in this regard a transportation service should be on time.

According to Coyle et al. (2016, p. 439) transportation mode choice is a function of three components:

- Modal capabilities;
- Product characteristics; and
- Modal freight pricing.

2.5.8 *Cost of Logistics*

Coyle et al. (2016) argue that by keeping transport costs at a minimum, the total landed cost of a product (production plus transport costs) allows it to be competitive in a number of markets. Geographically, the SA automotive sector is located further from its markets, hence cost optimised logistics provide room for the end product to be competitive against other markets.

Kujawa (2015) affirms that as competition increases and organisations seek cost cutting, transportation and logistics activities are among the key factors that business is leveraging to manage costs. The author further adds that it is therefore important to secure the lowest total cost through selection of the mode with the best combination of rates and service.

2.5.9 *Mode Pricing*

In the event that a mode of transport has capability to meet demand, Kujawa (2015) points out that freight rates will influence the modal share, with lower rates pushing more traffic to that mode. However in the event of no price changes, the author citing Bardi, Coyle, and Novack (2006) argues that modal demand is more sensitive to service levels i.e. transit time, reliability, accessibility, capability, security, schedule, equipment used and other intangible factors like employee courtesy. These factors are among the supply chain outputs CBU transportation is measured on and a review of the sensitivity of these factors to changes in influencing factors is modelled in this research.

2.6 Conclusion of Literature Review

The literature review clearly shows that freight transportation is not a new concept; a lot of work has been put into investigating factors that affect transportation of freight via road and rail.

Rail and road are among the traditional modes of moving freight and literature points to the fact that to be able to ensure operational efficiency there is need for the two modes to play a complementary role.

Literature seems to indicate that there is a growing trend to align freight transportation with environmental sustainability, with the urge to curb emissions. This growing trend is expected to influence governments to introduce carbon tax, which is one of the factors to be reviewed by this research.

The volatility of fuel price and its influence on total transportation costs is a major concern as captured in the literature review. In a world, were business seek to optimise supply chain and improve financial performance, transportation mode choice becomes central in aligning transport needs and cost of the business.

According to Furlonger (2016), there is a growing demand for new cars globally and this is expected to influence production volumes for SA manufactures. A key question will be how best to move the CBUs over land, that is by road or rail.

Considering the above trends as suggested in literature and industry, the following three propositions were thus constructed.

2.6.1 *Proposition 1:*

From literature there are specific factors influencing the transportation of CBUs, the consequences of these factors feed into the end decision of whether to use road or rail within South Africa. These factors are:

1. Fuel price;
2. Production volume;
3. Distance; and

4. Carbon tax.

2.6.2 *Proposition 2:*

There exist causal links between the transportation of CBUs by road or rail and key supply chain performance indicators namely cost optimisation, economies of scale as well as multi-criteria decision making outputs (cost of logistics; speed; flexibility; reliability; on time delivery etc).

2.6.3 *Proposition 3:*

Literature suggests that there are external factors, strategies and policies which can have an impact on the CBU transportation supply chain in South Africa and consequently on the decision to use road or rail. Hence the model will test the impact of the following:

1. Volatility of fuel prices and impact;
2. Impact of a weak Rand in SA and government incentives in automotive industry translating to production volumes growth;
3. Impact of increased environmental legislation and high CO_2 emission taxing;
4. Distance and its impact;
5. Combined effect of increase in fuel price and carbon tax;
6. Combined effect of decrease in fuel price, production volumes;
7. Impact of decreased fuel price and increased production volumes; and
8. Impact of fuel, production volumes, carbon tax and distance.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Method selection

The literature review of books and industry journals around CBU transportation points to various factors influencing road and rail mode choice. It is also evident that some modelling has been applied to investigate the impact of factors such as fuel price, cost, time-of-delivery and environmental on freight transportation (Winebrake et al., 2008).

Taking cognisance of this, the research employs an exploratory semi-quantitative model to answer the research questions.

The first objective is to find causal relationships between the input factors and develop an exploratory model to test causal relationships of influencing factors through fuzzy cognitive mapping (FCM). The FCM allocates weights (quantitative approach) to the causal or interdependence of factors influencing CBU transportation in the automotive industry. Using semi-structured interviews (qualitative approach), input from industry experts is used to refine and validate the draft model links. In this regard, the research makes use of a mixed method approach.

Taking cognisance of the role of models in scenario planning, the second objective was to test various scenarios in the model so as to get a measure of impact on the supply chain outputs as a consequence of the decision to use rail or road. These scenario tests are done quantitatively through the model.

3.2 Research methodology/paradigm

3.2.1 *Fuzzy Cognitive Maps*

Fuzzy cognitive maps were developed by Bart Kosko in 1986 (Kosko, 1993), this was an enhancement of the cognitive maps which had been introduced by Axelrod.

Stylios and Groumpos (1999) point out that fuzzy cognitive maps enhanced cognitive maps through allowing for fuzzy reasoning in the weighting of the causal links and their application was spread across various scientific fields.

Kosko (1993) defines FCM as a causal picture which ties values, processes, policies etc. thereby allowing the ability to model how complex system interact and associated outcomes. The FCM is a network of nodes with causal links or connections, positive (+) means a causal increase whilst as negative (-) means a causal decrease (Kosko, 1993)

Kim and Lee (1998) point out that fuzzy cognitive maps provide feedback, which can be applied to model the real world problems as a collection of concept variables and causal relationships.

Stylios and Groumpos (1999) citing Tsadiras, Margaritis, and Mertzios (1995) highlight that FCM has been applied in strategic planning and business analysis in the car industry and considering the above, its application in this research augurs well. Scenario planning as well as policy changes in the automotive industry in SA are complex and can only be predicted and analysed through a tool such as FCM.

This concept is further supported by Winebrake et al. (2008) in their research on the Geospatial Intermodal Freight Transport (GIFT) model, which aimed to evaluate the cost, time-of-delivery, environmental, and energy impacts associated with uni-modal and intermodal freight transport. They recommended, as future study, the test of the impacts of carbon taxes, fuel taxes, or modal subsidies in their model. The complexity of this relationships are acknowledged by this research and will be modelled using FCM.

3.2.2 *Model Formulation*

Table 1: Influencing factors (input) scenarios

Factor	high	unchanged	low
Fuel price	1	0	-1
Production volume	1	0	-1
Distance	1	0	-1
Carbon tax	1	0	-1
Choice of road	1	0	-1
Choice of rail	1	0	-1

3.2.3 *Model Causal relationship*

Kardaras and Karakostas (1999) highlight that in FCM, causal relationships link variables to each other through positive (+) and negative (-) relationships. In a positive relationship, an increase or decrease in a cause variable causes the effect variable(s) to change in the same direction (e.g. increase for increase), whilst in a negative relationship, the change which the effect variable undergoes is in the opposite direction (e.g. an increase in the cause variable causes decrease to the effect variable).

In this research, the causal links for each of the arrows are defined as to whether the causality is strong (0.6), moderate (0.3) or weak (0.1). These three scales were chosen through an iterative process in order to find mathematical convergence within the model. Convergence is important in modelling as it is important to understand that the model output will approach a limit under certain conditions. In this regard, the test can be replicated and will give a valid output.

Making use of literature as well as assumptions tested with industry experts' weightings and causal weightings and causal links were applied (see

Table 2 - Table 7) to primary influencing factors so as to formulate the draft fuzzy cognitive map depicted in Figure 8.

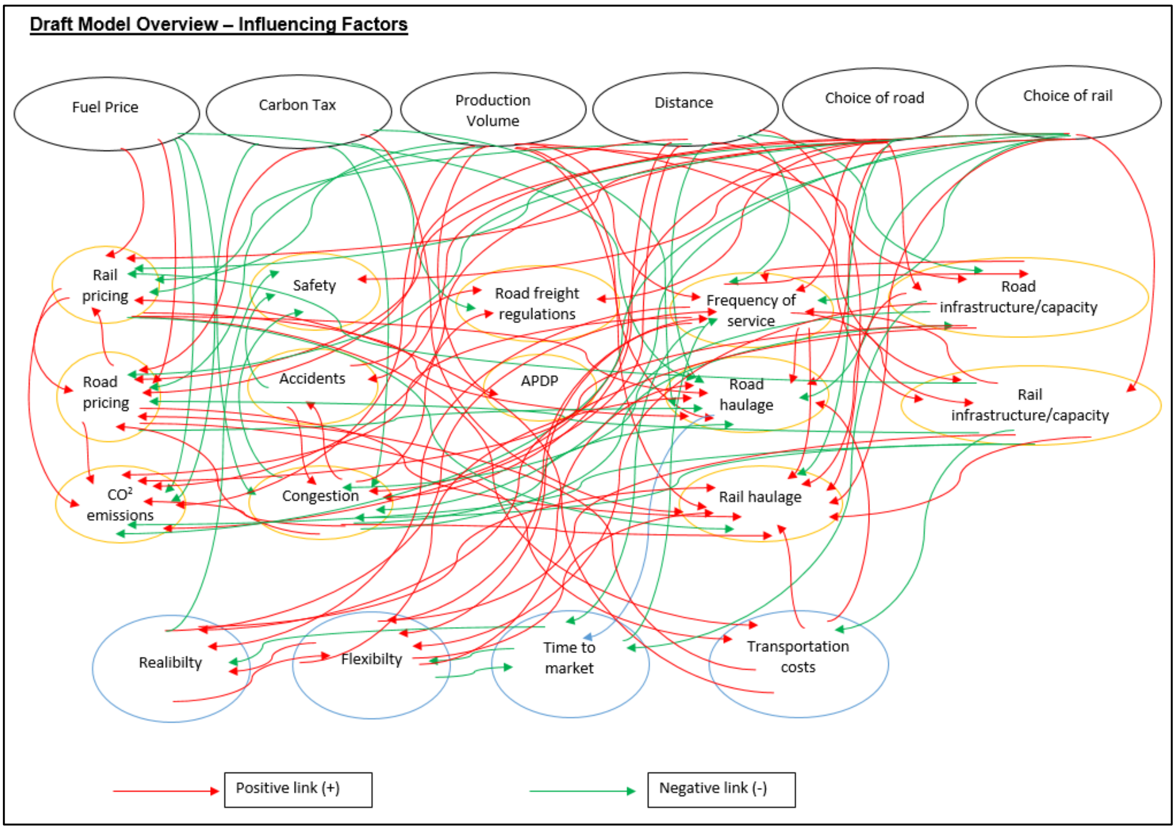


Figure 8: Draft model overview

Table 2: Effects of Fuel Price

Factor	Effect	Comment	Source
Rail pricing	+	low effect	(Havenga & Simpson, 2014)
Road pricing	+	Road pricing sensitive to fuel price; strong effect	(Havenga, 2010) (Havenga & Simpson, 2014)
Congestion	-	Low effect	(Winebrake et al., 2008)
CO_2 emissions	-	Low effect	(Alfaro et al., 2012) (Winebrake et al., 2008)
Road haulage	-	Moderate effect	(Havenga, 2010) (Havenga & Simpson, 2014)
Rail haulage	+	low effect	(Macharis et al., 2010) (Stamas, 2009)

Table 3: Effects of Production Volume

Factor	Effect	Comment	Source
Rail pricing	+	Economies of scale; low effect	(Black, 2001) (Woodburn, 2003)
Road pricing	+	Low effect	(Black, 2001)
Rail infrastructure capacity	+	Low effect, as it will not be primary driver	assumption
Road infrastructure capacity	+	Low effect	assumption
Frequency of service	+	More service required; moderate effect	(Woodburn, 2003)
CO_2 emissions	+	Low effect	(Alfaro et al., 2012)
Road haulage	+	Moderate effect	(Automotive Logistics, 2006)
Rail haulage	+	Moderate effect	(Automotive Logistics, 2006)

Table 4: Effects of Carbon Tax

Factor	Effect	Comment	Source
Rail pricing	+	Low effect	(Havenga & Simpson, 2014)
Road pricing	+	Road pricing sensitive to carbon tax; moderate effect	(Alton et al., 2014) (Havenga & Simpson, 2014)
Congestion	–	More efficient trucks; strong effect	(Lane, 2009)
CO_2 emissions	-	Strong effect	(Chopra & Meindl, 2016)
Road haulage	-	High effect	(Stern, 2007)
Rail haulage	+	low effect	(Stern, 2007)

Table 5: Effects of Distance

Factor	Effect	Comment	Source
Rail pricing	+	Rail works best over distance; low effect	(Forkenbrock, 2001)
Road pricing	+	Long distance, more fuel price, maintenance; moderate effect	(Forkenbrock, 2001)
Rail infrastructure capacity	+	Moderate effect	assumption
Road infrastructure capacity	–	Low effect	assumption
Frequency of service	-	Moderate effect	assumption
CO_2 emissions	+	Moderate effect	(Alfaro et al., 2012)
Time to Market	+	Direct relationship; low effect	(Stamas, 2009)
Logistics Cost	+	Increase in total cost; low effect	(Black, 2001)
Road haulage	-	Low effect	(Forkenbrock, 2001)
Rail haulage	+	Strong effect	(Forkenbrock, 2001)
Cargo safety	-	Low effect	assumption

Table 6: Choice of road

Factor	Effect	Comment	Source
Rail pricing	-	Moderate effect	(Automotive Logistics, 2006)
Road pricing	+	Price; moderate effect	assumption
Congestion	+	Increase in trucks; moderate effect	(Automotive Logistics, 2006)
Accidents	+	Low effect	(Macharis et al., 2008)
Road infrastructure capacity	+	Moderate effect	(Havenga, 2010)
Frequency of service	+	Moderate effect	(Stamas, 2009)
Road-freight legislation	+	Moderate effect	(de Saxe, 2012) (Macharis et al., 2008) (Kujawa, 2015)
CO_2 emissions	+	Moderate effect	(Stern, 2007) (Thambiran & Diab, 2011) (Lane, 2009)
Time to Market	-	Strong effect	(Stamas, 2009) (Bardi et al., 2006)
Cost of logistics	+	Low effect	(Black, 2001) (Havenga & Simpson, 2014)
Road haulage	+	Strong effect	assumption
Rail haulage	-	Strong effect	assumption

Table 7: Choice of rail

Factor	Effect	Comment	Source
Rail pricing	+	Moderate effect	assumption
Road pricing	-	Road pricing competitor; moderate effect	assumption
Congestion	-	Less trucks; moderate effect	(Automotive Logistics, 2006)
Rail infrastructure capacity	+	Not put in place for automotive; moderate effect	assumption
Frequency of service	+	Moderate effect	(Bardi et al., 2006)
CO_2 emissions	-	Moderate effect	(Alfaro et al., 2012)
Road haulage	-	Strong effect	assumption
Rail haulage	+	Economies of scale; strong effect	(Black, 2001) (Woodburn, 2003)

3.2.4 *Semi-Structured Interview*

Semi-structured interview(s) were used to interrogate the draft model and get input from industry experts' on influencing factors to CBU transportation within the automotive industry. This approach is qualitative as it offers:

- Description, that is reveals the nature of the programme;
- Verification, ascertains the validity of assumptions and theories;
- Evaluation, provides means to judge the effectiveness of subject(s) under review; and
- Interpretation, opens up new insights, concepts and perspectives.
  (Leedy & Ormrod, 2010)

3.3 Research Design

The research makes use of a mixed-method approach incorporating both qualitative and quantitative approaches. These approaches are discussed in the sections below to:

3.3.1 *Literature Review*

The literature review provides information on investigations and perspectives related to the research topic (Leedy & Ormrod, 2010). Within this research, it therefore provides a basis on understanding of factors influencing road and rail transportation of CBUs and provides background for the development of the fuzzy cognitive map, bearing in mind causal relationships identified in the existing body of knowledge.

Table 8: Strengths and weakness of literature review

Strengths	Weaknesses
• Generally accepted body of Knowledge over a period of time. • Unobtrusive – information exists prior to the research. • Data sources can be established and sources are verifiable. • Informs the researcher of the relevance content of the topic. • Independent information available • Appreciation of the subject matter. • Allows global, regional, countrywide comparison basis.	• Wide variety of views. • Information might be largely a result of author bias.

3.3.2 *Fuzzy cognitive mapping (Model development and analysis)*

Kim and Lee (1998) point out that a FCM provides feedback, which can be applied to model the real world problems as a collection of concept variables and causal relationships. In this regard the method allows this research to simulate scenarios and observe their impact/outputs on the drivers influencing road and rail in CBU transportation.

Table 9: Strengths and weakness of FCM

Strengths	Weaknesses
• Model complex relationships • Applicable across several industries • Accepted way of modelling	• Developing model is time-consuming • Subjective and dependent on opinion of experts.

3.3.3 *Semi-Structured Interview*

The semi-structured interview provides a way to validate and discuss the model with industry experts so as to produce an updated FCM. The interview provide specific and relevant input to the research and allows comparison of data with literature. The interview provides this research the opportunity to probe industry experts' views on factors influencing road and rail transportation of CBUs.

Table 10: Strength and weakness of structured interview

Strengths	Weaknesses
• Detailed information can be obtained • Insightful, provides opportunity to the researcher to observe respondents body language with each question. • Most answers to questions are collected • Quick collection of information	• Participants might omit information due to format of questions • Responses might be biased • Time-consuming

3.4 Population and sample

3.4.1 *Population*

The research targeted population were automotive industry experts with specific focus on:

- Transnet;
- Road Car Carriers (e.g. Grinrod, Motorvia, Onelogic, VDS, KDG);
- NAAMSA;
- AIDC;
- OEMs; and
- Professional experts.

3.4.2 *Sample and sampling method*

The sample used in this research comprises respondents with experience within the automotive industry in Gauteng and authority to answer the research questions. In essence, the respondents are industry experts who can give valuable input to the FCM model.

Table 11: Profile of respondents

Organisation	Position
Nissan SA	Supply Chain Manager
R&H Rail	Director of R&H Rail
National Association of Automobile Manufacturers of South Africa (NAAMSA)	Chairperson of the NAAMSA supply chain and logistics work stream
Arup (Pty) Ltd	Supply Chain Specialist Editor of Strategic Logistics Management – A supply chain management approach
Transnet	Transnet Executive – Automotive Business
CNR Logistics	Director
KDG Logistics	Business Process Engineer, KDG Logistics
Automotive Industry Development Corporation (AIDC)	Senior Manager Business Development,

3.5 The research instrument

A semi-structured interview is used to discuss the draft fuzzy cognitive map with industry experts. The experts' input provides this research the opportunity to probe input into factors influencing transportation mode choice. A sample of the interview is included in Annexure C.

3.6 Procedure for data collection

A draft fuzzy cognitive model was developed based on factors identified from literature influencing road and rail transportation of CBUs. On completion of the draft model, semi-structured interviews were held with industry experts were conducted so as to workshop the draft FCM. In preparation for the interview a cover letter of the research was emailed so as to ensure the experts had enough background. In the interview, time was allowed for the identified experts to first be briefed on the model and how it works. The draft fuzzy cognitive model was shown to the experts so as to get their opinion and input on causal links, weightings as well as missing links. The feedback from these experts was taken into account in designing a refined FCM map and updating the model.

The main discussion themes with the experts are summarised as:

- Comments with regards to identified primary influencing factors to road and rail transportation decisions in CBU movements;
- Perception of the draft model and relevance of the links and weighting;
- Proposed changes or recommendations to the map; and
- What strategies can be implemented from a supply chain perspective to balance CBU freight volumes on road and rail?

3.7 Data analysis and interpretation

Making use of the respondents' feedback, the draft fuzzy cognitive map and model was updated into a final FCM for this research. The resulting FCM:

1. Defines the interdependent relationships and supporting scenarios;
2. Defines the fuzzy weights for the relationships;
3. Defines the direction of causality;
4. Simulates scenarios on changes in influencing factors; and
5. Provides decision analysis of the impacts

(Kardaras & Karakostas, 1999)

The outcome of the above process is interpreted in line with the following:

1. The main problem of this research i.e. to model strategic responses to the impact of changes in influencing factors to road and rail transportation of CBU's in the automotive industry. In essence the research drew on these findings to inform the impact of changes.
2. A comparison of the outcome to existing literature.
3. Practical significance.
4. Identifying limitations of the study (Leedy & Ormrod, 2010).

3.8 Limitations of the study

The limitations of the study include:

- Subjectivity in defining the weighting of the relationships, which will ultimately impact on the influencing factors. The input from the parties involved in the research holds the key to the outcomes.
- Little or no primary data sources are used in the research.
- Availability of the identified experts.

3.9 Validity and reliability

Leedy and Ormrod (2010, p. 97) point out that validity of research is tested by answering two questions “does the study have sufficient controls to ensure that the conclusions we draw are truly warranted by the data?” and “can we use what we observed in the research situation to make generalisations about the world beyond the specific situation?” The subsequent answers give rise to internal and external validity.

3.9.1 *External validity*

Leedy and Ormrod (2010) point out that external validity refers to how applicable the research results are in the broader picture that is outside the research itself.

Kim and Lee (1998) point out that fuzzy cognitive maps provide feedback, which can be applied to model the real world problems as a collection of concept variables and causal relationships.

This research is conducted in a “real life setting” as described by Leedy and Ormrod (2010) so as to improve external validity. Through workshopping the research to a diverse grouping of industry experts and incorporating a wide range of literature it is expected that the research outcome has some degree of external validity but it is expected to be context specific to the South African automotive industry in Gauteng.

3.9.2 *Internal validity*

Internal validity refers to the extent to which research design and data provides the researcher accurate conclusions about cause and effect relationships in the data (Leedy & Ormrod, 2010).

By making extensive use of well-established literature and getting input from industry experts on the model development this research generates convergence with regards the topic. In this regard, the research holds a degree of internal validity.

3.9.3 *Reliability*

"Reliability is the consistency with which a measuring instrument yields a certain result when the entity being measured hasn't changed" (Leedy & Ormrod, 2010, p. 29). Reliability is therefore one of the conditions to be met to ensure validity.

Applied to research, the above definition speaks to the outcome and whether it can be consistently achieved. Reliability in the research is provided through ensuring mathematical convergence in the model. Convergence is important in modelling as it is important to understand that the model output will approach a limit under certain conditions. In this regard the test can be replicated and will give a valid output.

The research outcome is also expected to be reliable given that there is a body of knowledge on the subject matter as the modelling tool to be applied is accepted as a way to model real world problems. It is not expected that the knowledge will be overturned in the near future but with development and technological advancements over time, the outcome might be expected to change.

CHAPTER 4. PRESENTATION OF RESULTS

4.1 Survey Results

The survey respondents supported the fuzzy cognitive map as they agreed that it captured the primary underlying factors i.e. fuel price, production volume, distance and carbon tax which influence road and rail usage in the transportation of CBUs from a South African industry perspective. The importance of key supply chain outputs mainly cost, reliability, transit time, flexibility, product safety and security were reinforced. The experts clearly articulated that the ultimate decision to make use of road or rail was not in isolation but was informed by a multi-criteria decision analysis which the model provided to an extent as it could model the sensitivity to the key outputs through the variation of input factors. This is in line with Kannan, Khodaverdi, Olfat, Jafarian, and Diabat (2013) who highlight that, within the supply chain, selection problems involve quantitative and qualitative criteria and hence it is a strategic decision which must be taken after weighing multiple factors.

Among the primary drivers in the model, the inclusion of factors such as economic activity, inflation and exchange rate were mooted and discussed with the experts. Ultimately it was settled by the fact that in the automobile transportation industry all of these factors cascade into production volumes, either an increase or decrease in volume. Noe, Hollenbeck, Gerhart, and Wright (2006) allude to this concept in stating that as businesses develop global markets and seek to increase competitiveness, they will naturally export jobs to countries where labour and other costs are lower. An example is: a weaker Rand will mean production contracts will shift to SA as labour rates on the global scale will be cheaper and when it comes to the topic under review this will be linked to an increase or decrease in production volumes. In that regard, it was agreed that the draft FCM has captured the dynamics of the economic factors.

Carbon tax was identified as one of the primary factors which are not necessarily top of the list in SA logistics. This compared starkly to Europe: in this regard, the agreement was that it be kept as a primary driver but its weighting is slightly adjusted. The reason that respondents recommended it be kept is within the SA industry there is a tendency to gravitate towards environmental considerations and going into the future it is expected to grow in terms of impact. According to Kannan et al. (2013), growing global concerns over the environment and pollution have seen a rise in the emergence of green supply chain management and this trend is expected to grow.

A criticism of the model was that within the South African context, Transnet as the main rail service provider with no competition operated on a fixed pricing model. The sensitivity of factors affected to rail and road dynamics in SA are therefore not as easily weighted as suggested by literature. There is no direct link between road pricing and rail pricing but a causal link exists between rail pricing and road pricing since rail is a price setter as a result of being a monopoly, whilst road is a price taker as a result of the significant competition from rail and among vehicle carriers themselves.

The respondents also pointed out that the fact that weightings on drivers were done on the same basis (weak, moderate and strong) was not ideal. The different factors have different weightings (importance) in decision-making processes, hence each would have better been weighted differently in order of importance in the supply chain which would result in an overall aggregate weighting as commonly applied in multi-criteria decision analysis.

Also as part of the interview process, recommendations were given with regard to the draft FCM so as to enhance its relevance from a South African perspective. The existing limitations were also highlighted and possible enhancements were proposed.

The experts' input as well identified omissions and proposed amendments in terms of causal relationships/weightings and have been incorporated in the refined FCM. These are summarised below:

- The safety node was not clearly defined but one of the key supply chain outputs for the industry is cargo safety & security i.e. cargo integrity. On review, safety was therefore redefined as cargo safety and security and positioned as an output and not a secondary factor. The notion of it being an output is supported as CBUs in transit need to reach the market in a pristine condition.

- Cargo damage was discussed as an industry concern and therefore the link between cargo safety and security (cargo integrity) to road or rail transportation was introduced and weighted taking into consideration industry trends for both modes. According to the experts in SA, damage on rail is ten times higher on rail than on road and this has been reflected in the weightings.
- The sensitivity of choice of road to road pricing was adjusted as respondents pointed out that the main driver of price was not the choice itself.
- Positive link between fuel price and cost of logistics in now included and is weighted. The link had been omitted in the draft model and on discussion with the experts was pointed out. This was also supported by the literature as fuel price is viewed as one of the influences to cost of logistics in SA (Havenga & Simpson, 2014).
- Positive link between production volumes and cost of logistics and its weight. From the industry engagement production volume will influence the number of shipments required and in this way impact on the cost of logistics. Kujawa (2015) suggests that number of shipments influence cost of logistics.
- Positive link between carbon tax and rail capacity and its weighting was pointed out by one of the expert, this was also supported by the literature. Chapman (2007) postulates that an introduction of carbon tax will enforce capacity optimisation among the different transportation modes. Since road has higher emissions than rail, an introduction of carbon tax is expected to yield more capacity for rail.
- Negative link between carbon tax and road capacity and its weighting was pointed out by one of the expert, this was also supported by the literature. Chapman (2007) postulates that an introduction of carbon tax will enforce capacity optimisation among the different transportation modes. Since road has higher emissions than rail, an introduction of carbon tax is expected to yield less capacity for road.
- Positive link between carbon tax and cost of logistics and its weight. The link had been omitted in the draft model and on discussion with experts it was agreed

that the implemented of carbon tax has a direct bearing on cost of logistics. This is also supported by literature, Alton et al. (2014) points out the impact of carbon tax to cost is significant and can result in loss of competitiveness.

- Change in sensitivity of the positive link between distance and time to market, from low to moderate. Applying local knowledge the experts deemed that the effect of this link moderate as compared to the low assigned in the draft FCM.
- Change in sensitivity of the negative link between choice of road and rail pricing, from moderate to low. The experts advised that rail pricing was not informed by the choice of road as much as Transnet (rail) had their own costing base.
- Change in sensitivity of the positive link between choice of road and frequency of service, from moderate to strong. The respondents recommended that, this link be strong as road was associated with a frequent service with quick turn-around times.
- Change in sensitivity of the positive link between choice of road and CO_2 emissions, from moderate to strong. The respondents recommended that, this link be strong as road has significantly higher emissions than rail.
- Positive link between choice of road and reliability and its weight. The link had been omitted in the draft model and on discussion with the experts was pointed out. In SA, road is considered a more reliable transport mode as compared to rail.
- Positive link between choice of road and flexibility and its weight. The experts pointed out that in SA, road service provides a flexible service as compared to rail.
- Change in sensitivity of the negative link between choice of road and rail haulage, from strong to moderate. The expert opinion was that this was not a direct relationship as they were a number of factors to be considered in this regard they recommended that instead of having a strong inference, a moderate relationship would be more appropriate.
- Change in sensitivity of the positive link between choice of rail and rail pricing, from moderate to low. The expert opinion was that this was not a direct relationship as rail would price based on their overheads and not much will

change. In this regard, they recommended that instead of having a moderate relationship, a low effect would be more appropriate.

- Change in sensitivity of the positive link between choice of rail and frequency of service, to a negative link with low sensitivity. The experts pointed out that since trains are scheduled, frequency would not be expected to be high. However, they recommended that a negative link, with low sensitivity be used to describe the relationship.
- Negative link between choice of rail and road freight legislation and its weight. The new link was recommended as the experts pointed out that road freight legislation has been used as a control of accidents, congestion, emissions however the choice of road would not see any aggressive need for road freight legislation.
- Negative link between choice of rail and reliability and its weight. The link had been omitted in the draft model and on discussion with the experts was pointed out. In SA, road is considered a more reliable transport mode as compared to rail and in that regard a negative relationship was recommended.
- Positive link between choice of rail and time to market and its weight. The experts pointed that rail can be categorised as a slow mode of transport. Therefore the choice of rail would result in an increase in time to market and the link had to be captured in the updated model.
- Negative link between choice of rail and cost of logistics and its weight. Rail provides a cheaper service and this is captured through the introduction of this link.
- Negative link between choice of rail and flexibility and its weight. The experts pointed out that in SA, rail service is not as a flexible and in that regard the relationship needed to be captured through the introduction of a service as compared to rail.
- Change in sensitivity of the negative link between choice of rail and road haulage, from strong to moderate. The expert opinion was that this was not a strong relationship as they were a number of factors to be considered in mode choice hence a moderate relationship would be more appropriate.

- Infrastructure capacity for both road and rail was also highlighted as a key node because within South Africa the availability of capacity is quite important in the movement of CBUs. The influence of these factors were subsequently re-weighted to take into account these dynamics.
- Sensitivity of road freight legislation to cargo safety, road capacity and cost of logistics were also updated.

4.2 Enhanced FCM

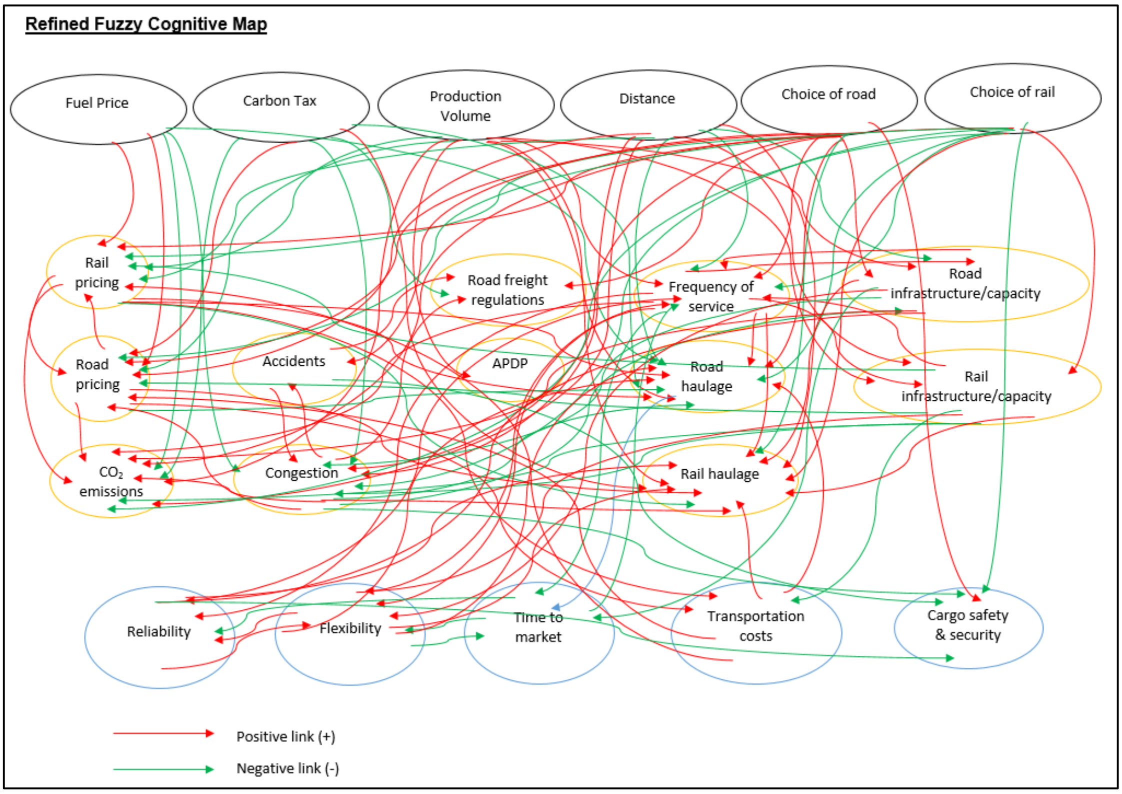


Figure 9: Refined Fuzzy Cognitive Map

Making use of the survey results (see section 4.1), the fuzzy cognitive map and model were refined. Figure 9, illustrates the refined map, whilst Table 12 to Table 17 capture the changes that have been included.

Table 12: Effects of Fuel Price (updated)

Factor	Effect	Comment	Source
Cost of logistics	+	Strong effect	(Black, 2001) (Havenga & Simpson, 2014) Industry

Table 13: Effects of Production Volume (updated)

Factor	Effect	Comment	Source
Cost of logistics	+	Moderate effect	(Kujawa, 2015) (Coyle et al., 2003) Industry

Table 14: Effects of Carbon Tax (updated)

Factor	Effect	Comment	Source
Rail infrastructure capacity	+	Low effect	(Chapman, 2007) (Thambiran & Diab, 2011) Industry
Road infrastructure capacity	-	Low effect	(Chapman, 2007) (Thambiran & Diab, 2011) Industry
Logistics Cost	+	Strong effect	(Alton et al., 2014) Industry

Table 15: Effects of Distance (updated)

Factor	Effect	Comment	Source
Rail infrastructure capacity	+	Moderate effect	Industry
Road infrastructure capacity	-	Low effect	Industry
Frequency of service	-	Moderate effect	(Hesse & Rodrigue, 2004) Industry
Time to Market	+	Moderate effect	(Stamas, 2009)
Cargo safety & security	-	Low effect	Industry

Table 16: Choice of road (updated)

Factor	Effect	Comment	Source
Frequency of service	+	Strong effect	(Stamas, 2009) Industry
CO_2 emissions	+	Strong effect	(Stern, 2007) (Thambiran & Diab, 2011) (Lane, 2009)
Reliability	+	Moderate effect	(Stamas, 2009) (Bardi et al., 2006)
Flexibility	+	Moderate effect	(Bardi et al., 2006)
Rail haulage	-	Moderate effect	Industry
Cargo safety & security	+	Moderate effect	Industry

Table 17: Choice of rail (updated)

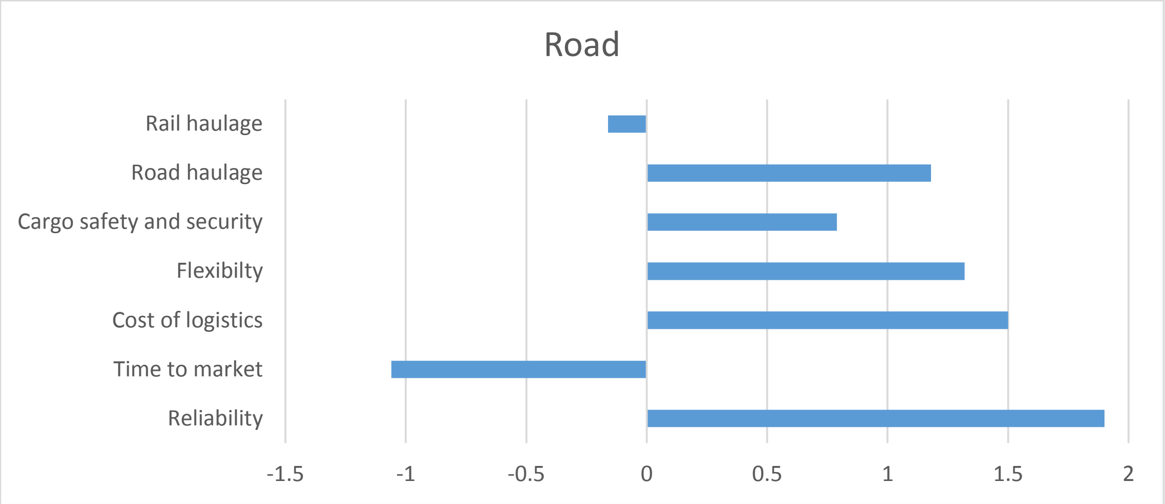
Factor	Effect	Comment	Source
Rail pricing	+	Low effect	Industry
Flexibility	-	Low effect	(McKinnon, 2006) Industry
Congestion	-	Less trucks; moderate effect	(Automotive Logistics, 2006)
Rail infrastructure capacity		No link	Industry
Frequency of service	-	Low effect	(Bardi et al., 2006)
Time to market	+	Moderate effect	(Stamas, 2009)
Cost of logistics	-	Low effect	(Black, 2001) (Havenga & Simpson, 2014)
Road haulage	-	Moderate effect	Industry
Cargo safety & security	-	Moderate effect	Industry

CHAPTER 5. FUZZY COGNITIVE MAP INTERPRETATION

The updated Fuzzy Cognitive Map attempts to model the strategic responses to the factors influencing road and rail transportation of CBUs and the sensitivity of key supply chain outputs used by industry to inform transportation mode choice. A trade-off between cost and service is usually applied as a supply chain can be "cost-sensitive" or "service sensitive" (or in some cases a hybrid between the two).

The FCM allows for various scenarios to be tested, with the complex nature of interactions within the model giving rise to unintended consequences and this is where the benefit is derived from “fuzzy” cognitive mapping. Complex system interactions can therefore be reduced into results. Decision makers within the automotive industry can make use of the model outcomes to anticipate the impact on their business processes.

The analysis of the results takes into consideration two bases, namely road base and a rail base. Making use of the power of choice in road or rail usage in CBU transportation and input from respondents, the model was refined to depict attributes associated with each particular choice.



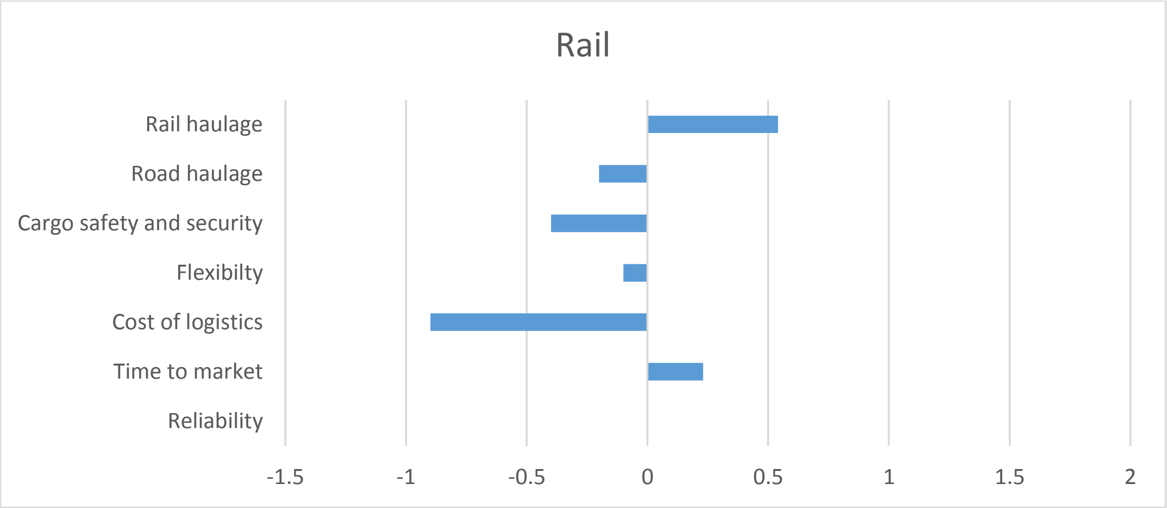


Figure 10: Base scenario for road and rail

Using these bases, the sensitivity of and responsiveness of the links to various scenarios are tested to give a measure of impact to road and rail transportation of CBUs respective to supply chain outputs.

A positive number indicates an increase whilst a negative represents a decrease or lowering of the factor. As an example in Figure 10, considering a road base, the positive increase on cost of logistics in any scenario would highlight an increase in the cost whilst if it lowers that will be a decrease in cost. For an output such as time to market a further negative value will mean further reduction in time, whilst if the values get positive it means an increase in time.

The input factors are tested individually in the system so as to understand their sensitivity in relation to the road base and the rail base. Once each of the drivers has been tested, plausible combination scenarios are tested, as in business it is common understanding that factors seldom act in isolation but are interlinked. In this regard, reviewing the impact of associated scenarios will give a good input to scenario planning especially, of worst-case scenarios.

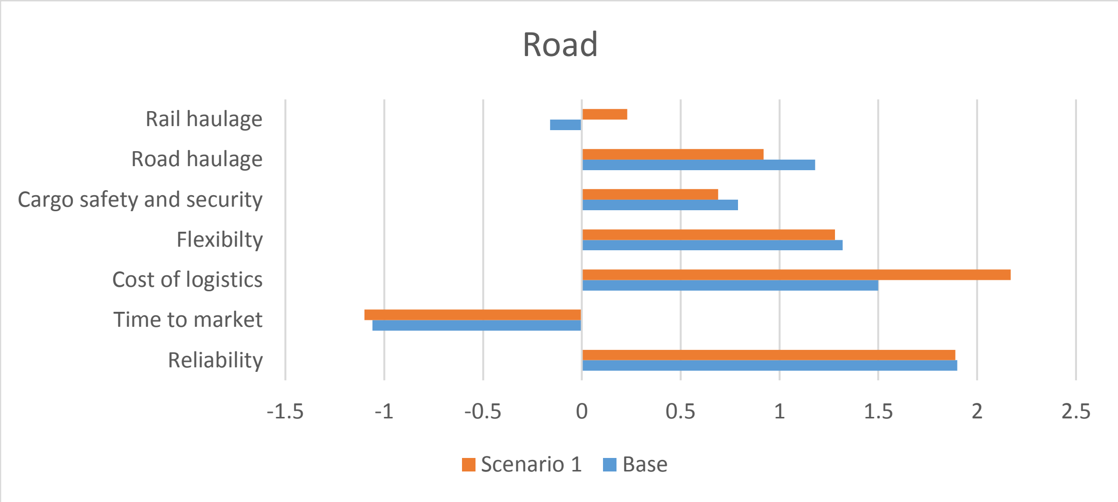
5.1 Scenario 1: Volatility of fuel prices and impact

The scenario activates an increase in fuel price and its impact on road and rail transportation of CBUs. The sensitivity of the results is discussed in comparison with the road and rail base results as indicated in Figure 11. Detailed excel outputs are in Annexure B.

From a road base, the analysis results indicate that with an increase in fuel price the key sensitive link will be an increase in the overall cost of logistics. Havenga (2010) attributes the cost of fuel as the major driver to road based freight transport in South Africa. In this regard, since South Africa is an oil importing country, it becomes pertinent to mitigate the nature of this impact through investment in alternative modes of transport so as to lower transport costs in a global competitive environment.

The road haulage and rail haulage nodes are also sensitive to the increase in fuel price, as the market will seek to look at substitute modes of transport to counteract the higher costs of doing business by road. From the output, road haulage is expected to decrease slightly and rail haulage increase.

Reliability node will remain fairly insensitive to the fuel increase, whilst flexibility, time to market and cargo safety & security will have nominal changes to the road base scenario.



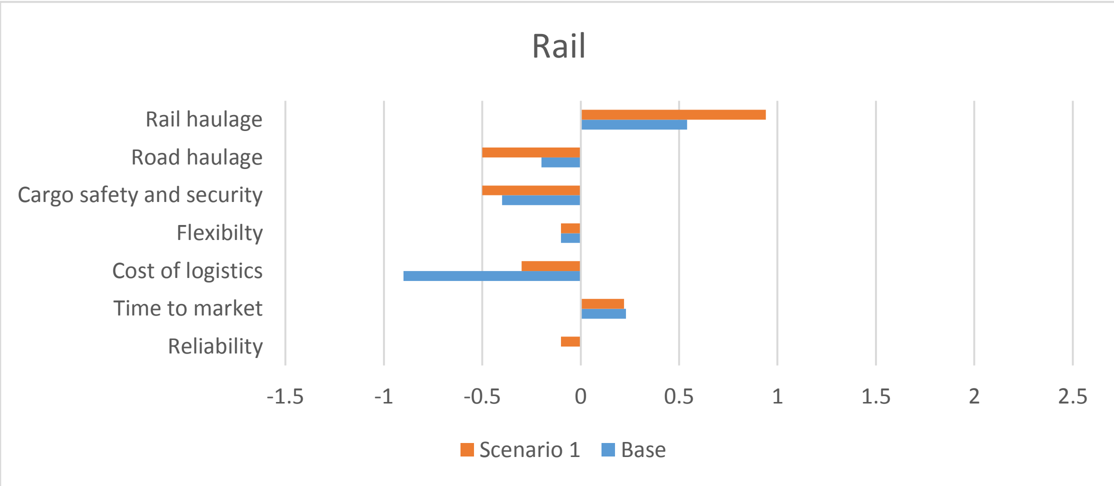


Figure 11: Volatility of fuel prices and impact

Considering the impact of the fuel increase on the rail base, it can be seen that the sensitive links are the cost of logistics and rail haulage. Fuel increase will increase the cost of logistics although the impact will still be on a negative base.

Rail haulage will increase due to the positive sensitivity to market adopting substitute modes of transport, whilst road haulage will see a continued decline from its base in this scenario.

Reliability is also active on a negative base as a result of the difference in characteristics and service which will be experienced by an increased use of rail. Cargo safety and security also sees a continued decline, as existing damage on rail is higher than on road. Time to market and flexibility, however, experience no changes from the base.

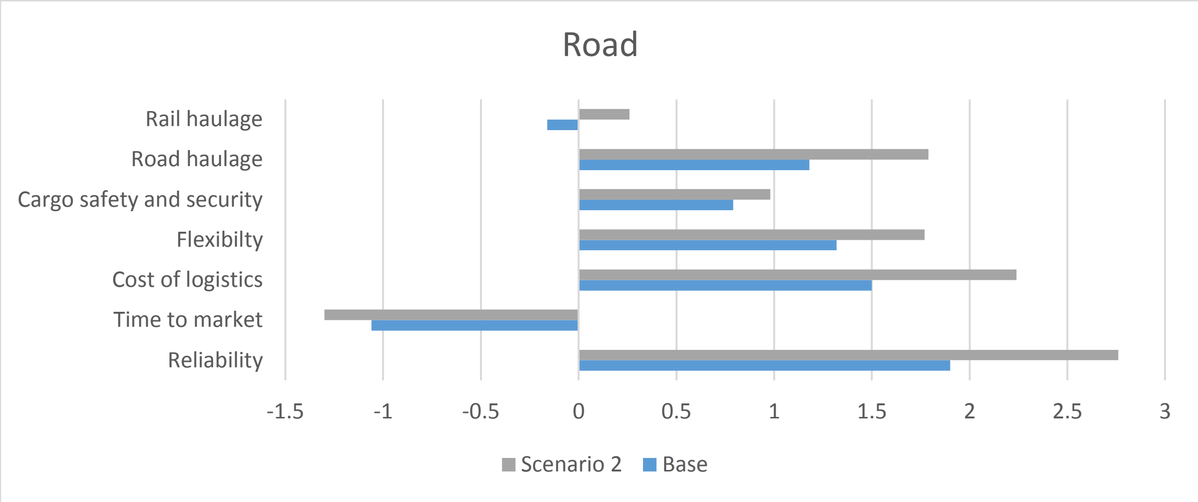
5.2 Scenario 2: Impact of weaker rand and government incentives in automotive industry translating to production volume growth

This scenario activates production volumes: it is anticipated that a weaker rand would result in SA being a low labour cost centre which would allow for a boost in production volumes. The production growth is anticipated to continue to grow as a result of government incentives such as APDP. Detailed model outputs are in Annexure B.

From Figure 12, the model results indicate that from a road base an increase in CBU production volumes will see sensitivity among all outputs. Time to market is expected to be further reduced as result of increased road service to meet the production demands.

Cost of logistics, reliability, and road haulage all respond strongly positively to the increase in production volumes.

The associated use of road to meet higher demand gives in to the higher cost of logistics, which is mainly due to frequent transportation of the volumes in smaller quantities (Coyle et al., 2003). By its nature, within South Africa road transportation is viewed more reliable and flexible than other transport means and there is a positive sensitivity to these factors with increased production volume.



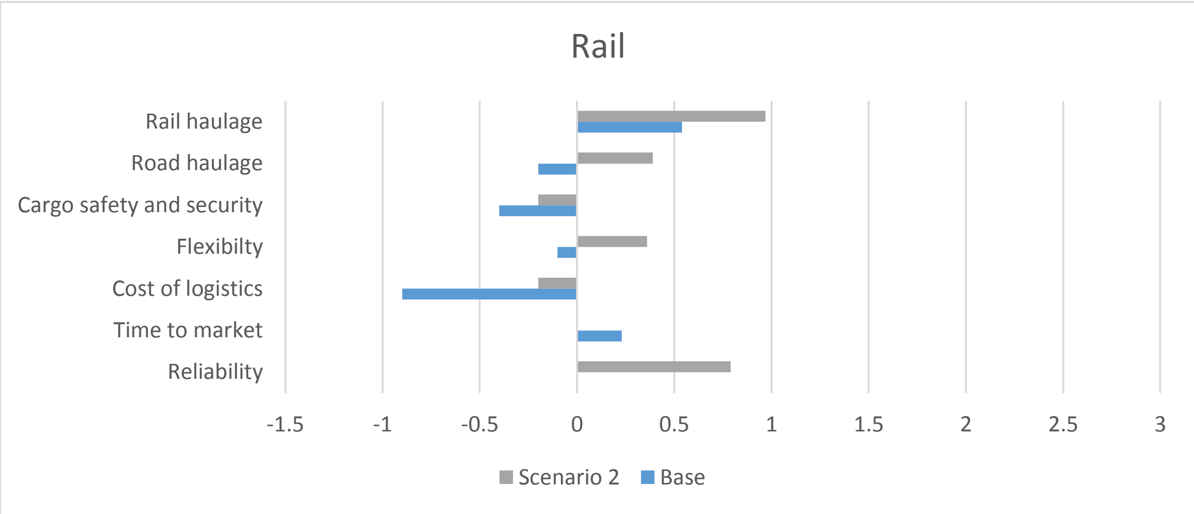


Figure 12: Impact of weaker rand and government incentives in automotive industry translating to production volumes growth

With an increase in production volumes, Figure 12 shows all output nodes are active. Rail haulage is expected to increase as a result of the need to move volumes. Although road haulage will also increase since production volumes to be transported will be high, this growth in road haulage is expected to be less than for rail.

The cost of logistics is expected to reduce as a result of increased mass movement by rail. This reinforces Kujawa (2015), citing Coyle et al. (2003), who state that volumes are important in freight transportation as higher costs are usually a result of frequent shipping in smaller numbers. Rail as a mode therefore provides optimised flow once production volumes are significantly high.

A dormant node in the rail base is reliability: however, with increased production volumes and choice of rail, this node is highly sensitive. The increased volumes result in providing “a reliable” transportation of the volumes as only rail can fully meet the demand.

Cargo safety and security is expected to decrease as a result of the damage associated with rail as a mode of transport.

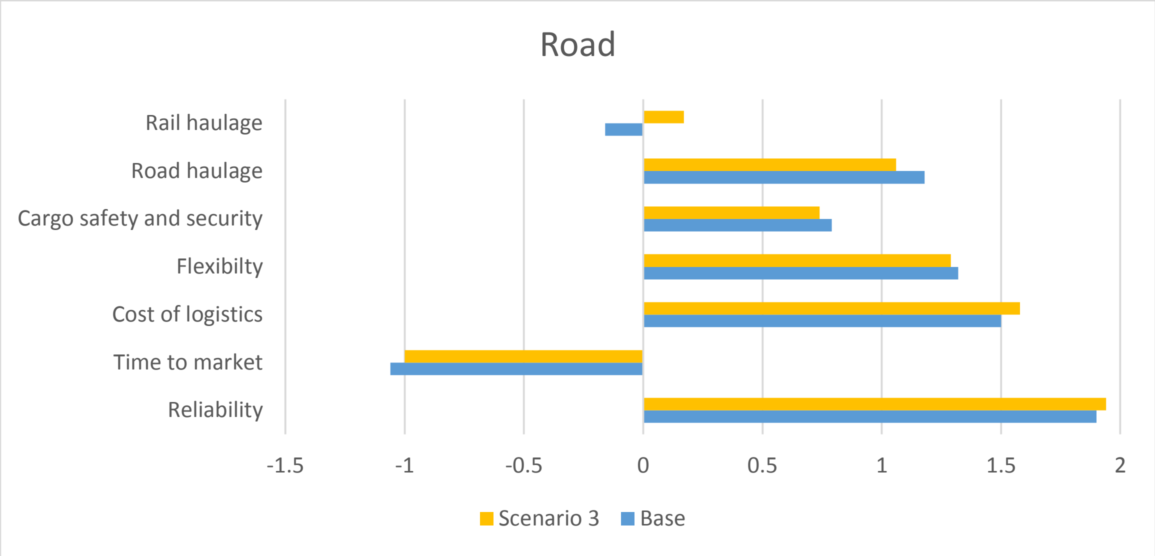
5.3 Scenario 3: Impact of increased environmental legislation and high CO_2 emission taxing

As alluded to by the industry experts, growing trends are to move towards environmentally responsible transportation. Green logistics is being actively advocated across the globe, with Europe among the leaders in carbon taxation. It is expected that it is only a matter of time before significant carbon taxes are levied in the South African freight industry (Havenga & Simpson, 2014). This scenario therefore activates carbon tax for the road and rail base so as to see the sensitivity that will arise on the outputs. Detailed model outputs are in Annexure B.

The existing carbon tax levy is small and as agreed with the experts there are marginal changes to the outputs. Figure 13 notes the impact of carbon tax introduction as well as the sensitivity to the outputs.

The introduction of carbon tax will see a positive sensitivity to the cost of logistics. The rise of these costs will mainly lead to a loss of competiveness (Alton et al., 2014).

Road haulage is expected to decrease slightly in this scenario with an increase in market share of rail haulage. This is mainly attributable to rail been a more environmentally responsible transportation mode. Overall this shift will see a reduction in flexibility and cargo safety & security.



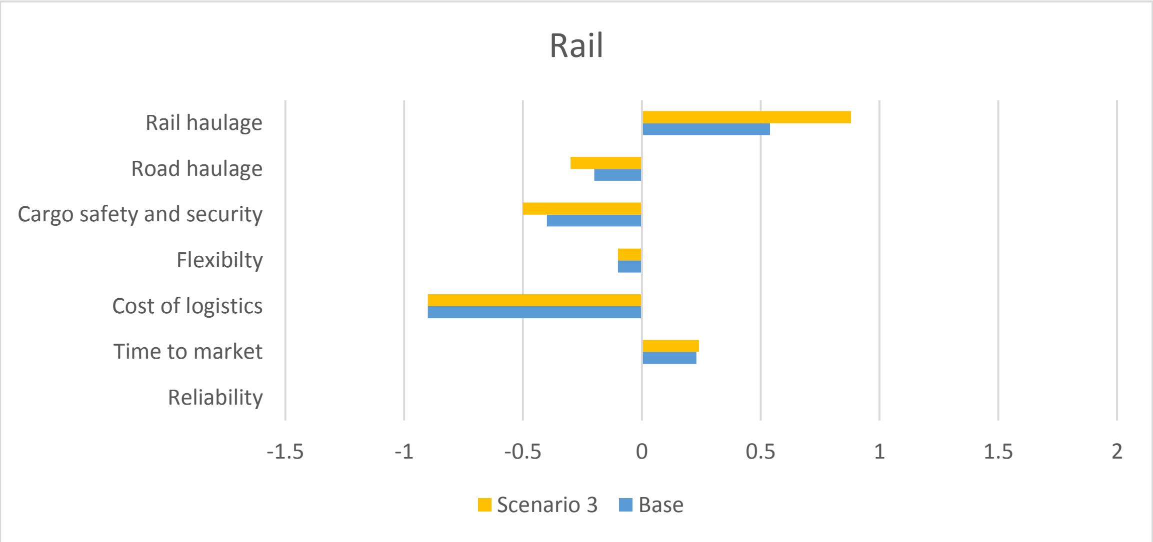


Figure 13: Impact of increased environmental legislation and high CO_2 emission taxing

From Figure 13, the introduction of carbon tax on the rail base will see a positive sensitivity to rail haulage. Rail provides an available substitute that can be used to mitigate any stiff carbon tax regime. As rail grows, the market for road transportation will also decrease slightly.

Since carbon taxation will have limited effect on rail transportation, the cost of logistics in this scenario is expected not to be sensitive to its implementation.

Cargo safety and security is expected to decrease as result of rail having a bigger market share, whilst the time to market will increase as rail being the favoured mode of transport has certain attributes characterising the service which include lack of timeous transport (Stamas, 2009).

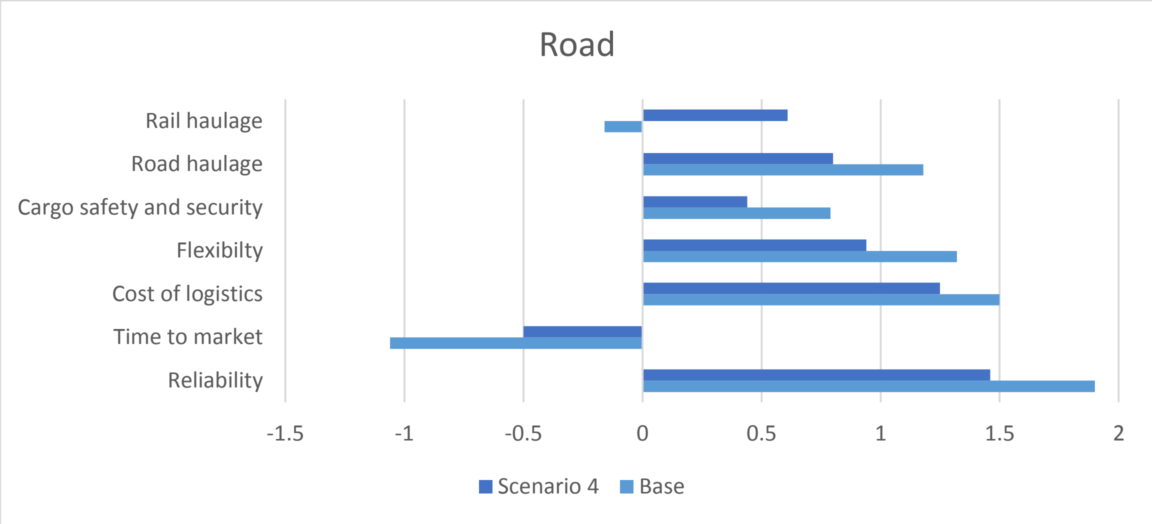
5.4 Scenario 4: Increased distance and its impact

The scenario activates an increase in distance and its impact on road and rail transportation of CBUs. Within Gauteng most of the CBU movements are to and from Durban port, however the port is faced with capacity constraints and congestion (Hall & Robbins, 2007). In this regard, traffic might need to be re-routed to other ports such as Port Elizabeth or Cape Town which are significantly longer distances in comparison to Durban. The sensitivity of the results will be discussed in comparison with the road and rail base results as indicated in Figure 14. Detailed excel outputs are in Annexure B.

The increase in distance will see a decrease in road haulage with rail haulage increasing market share. This is mainly attributable to that rail is more suited to long distance movements unlike road (Coyle et al., 2016).

The subsequent decrease in road market share as a result of the increased distance will see a decrease in cost of logistics. According to Bowersox et al. (2013) this is due to variable costs such as labour, fuel and maintenance having a direct bearing on road transportation.

The scenario also sees a decrease in flexibility, reliability and cargo safety & security. These are all service components associated with road transportation and with the substitution of road as a result of the increased distance, these factors will be sensitive.



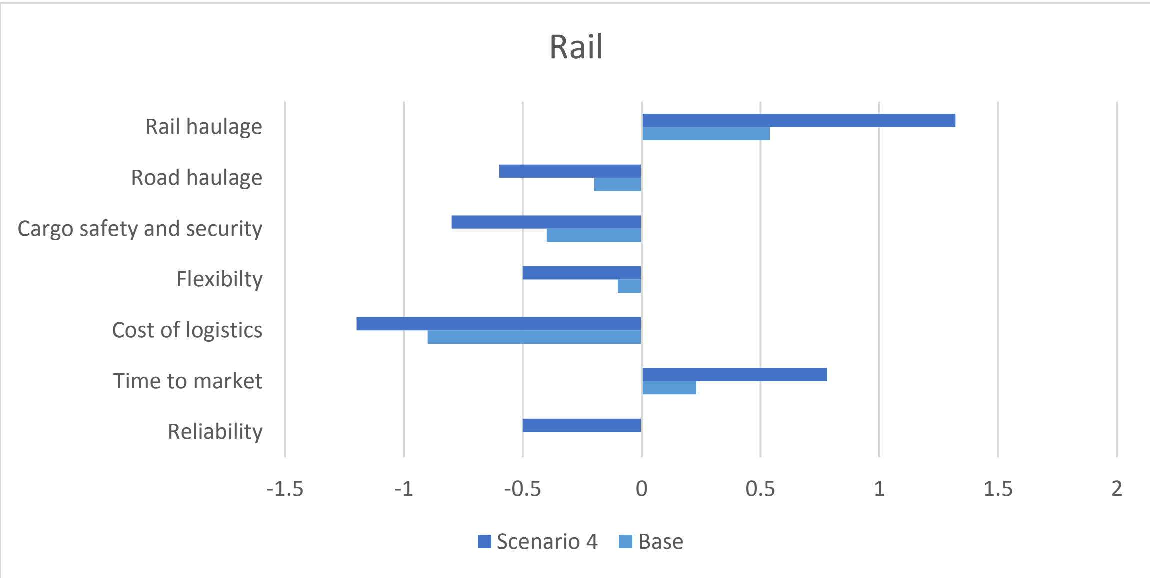


Figure 14: Increased Distance and its impact

Figure 14 results show that an increase in distance on the rail base will see a positive sensitivity to rail haulage and a decrease in road haulage. As discussed above, an increase in distance favours rail as a mode of transportation.

The cost of logistics is expected to decrease, as rail will have a higher market share as a mode, but it should be noted that flexibility and cargo & safety will also decrease in this scenario.

Reliability, which was a dormant node in the base, shows a negative sensitivity to distance increase, whilst time to market shows positive sensitivity as rail is not a timeous mode of transport (Stamas, 2009).

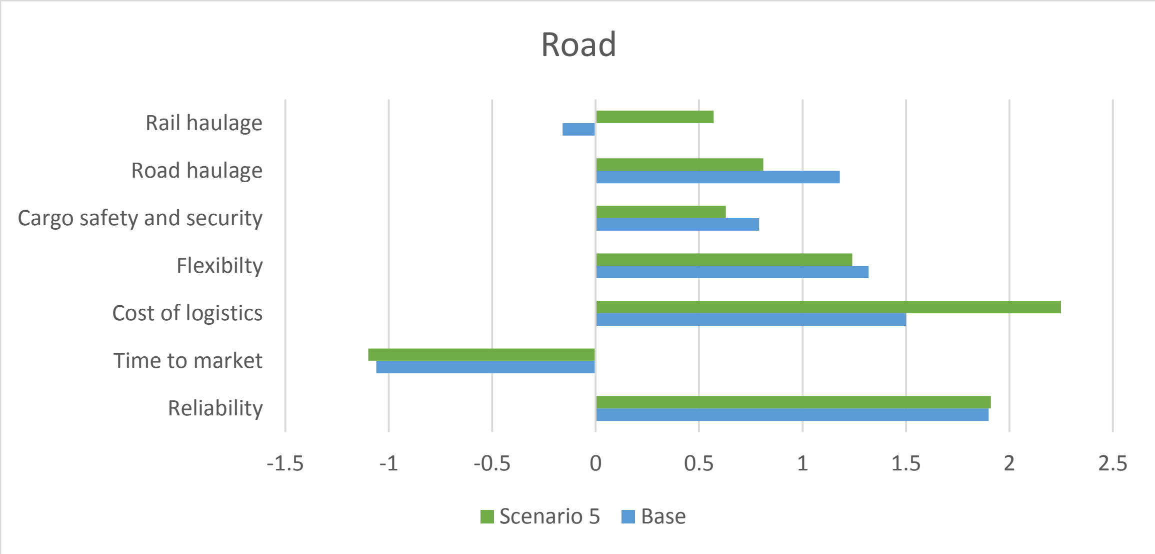
5.5 Scenario 5: Combined effect of increase in fuel price and carbon tax

The previous scenarios modelled the singular impact of input factors on a road and rail base. However, scenario planning provides for an analysis of worst case scenarios where input factors can act in combination rather than in isolation. Since South Africa is an oil importing country, we are prone to cyclic increases in fuel price, and with the introduction of green logistics and initiatives such as carbon tax a scenario of the combined impact of these factors was investigated. This scenario, therefore, activates fuel price increases and carbon tax on the road and rail base so as to see the sensitivity that will arise on the outputs. Detailed model outputs are in Annexure B.

From a road base, Figure 15 indicates that activity in the fuel price and carbon tax nodes will have a positive sensitivity to the costs of logistics. As identified in scenario 1 (fuel price) and 3 (carbon tax) in isolation, the factors result in an increase of costs; however, their combined impact will see a significant rise in cost of logistics from a road base.

Road haulage is expected to drop, with rail haulage enjoying growth as a result of sensitivity to the two active factors.

Reliability is expected to be unchanged, mainly attributable to the fact that this is service based and is an associated with road transportation, whilst flexibility and cargo safety & security are expected to decrease marginally.



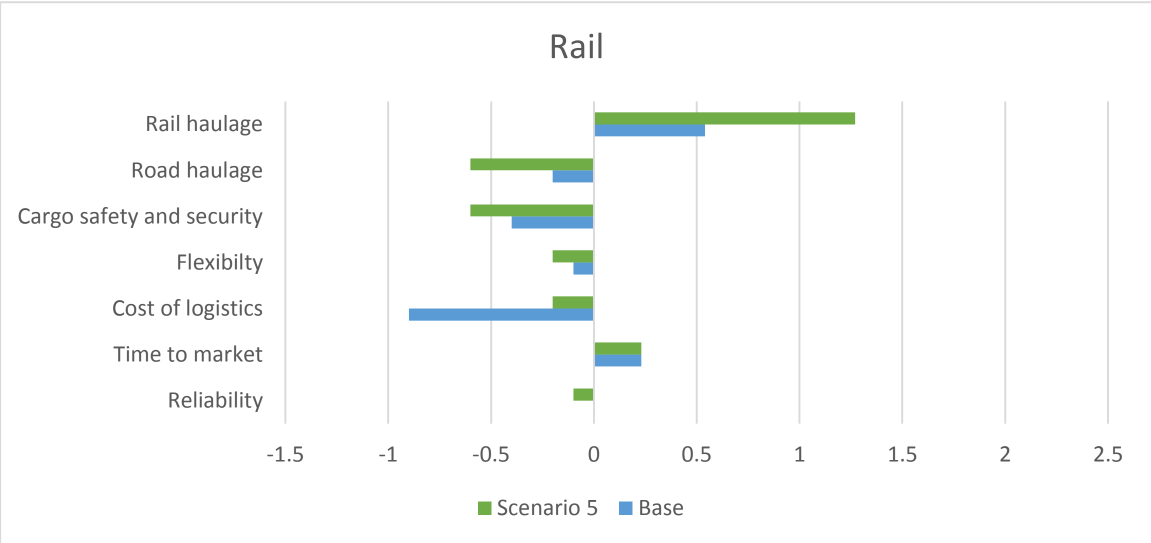


Figure 15: Combined effect of increase in fuel price and carbon tax

Figure 15 shows that with active carbon tax and fuel price, rail haulage has a positive sensitivity and will increase, whilst road haulage will decrease. This is mainly as a result of rail being a greener mode of transport and is less fuel dependant (Ford, 2014/15)

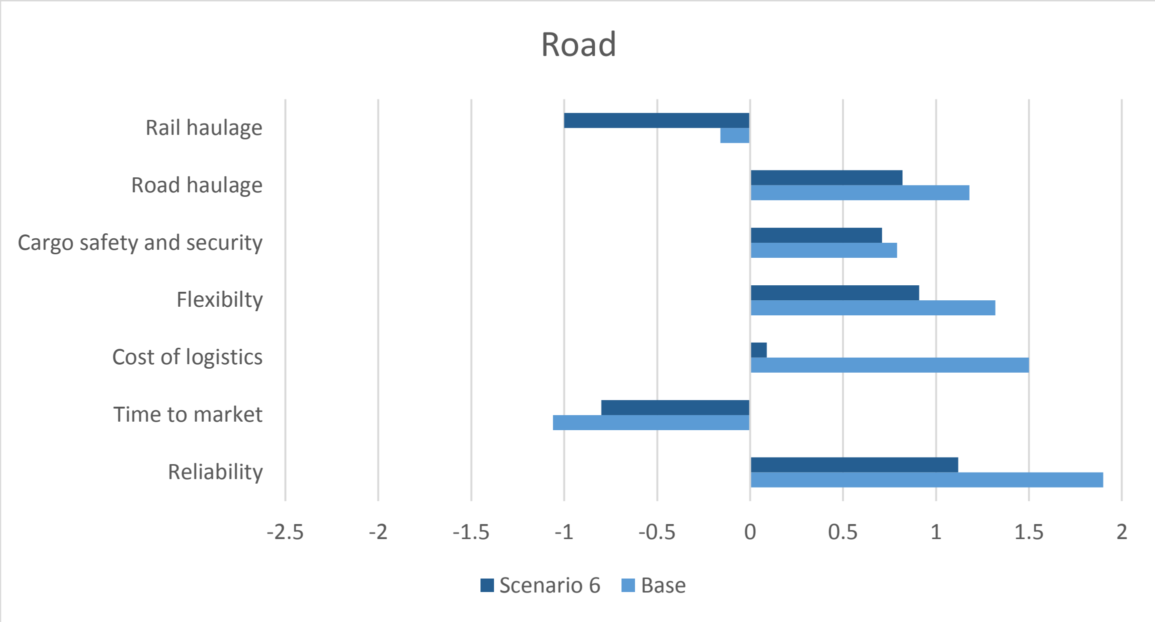
5.6 Scenario 6: Combined effect of decrease in fuel price and decrease in production volumes

This combination scenario provides for an analysis of a decrease in both fuel price and production volumes. Since South Africa is an oil importing country, the strength of the Rand as well as global demand at times pushes the fuel price down. Poor economic growth, like the global recession of 2008, results in a lower manufacturing of CBUs. This scenario therefore activates fuel price decreases and lower production volumes on the road and rail base so as to see the sensitivity that will arise on the outputs. Detailed model outputs are in Annexure B.

The reduction in fuel price and production volume as indicated in Figure 16 from a road base indicates a significant decrease in rail haulage. The lower volumes also see a reduction in road as a mode as there is decreased demand from the lower production volumes.

The cost of logistics is greatly reduced as a result of the reduction of the major variable cost (fuel price) which influences road pricing (Havenga, 2010). The lower volumes also compound the reduction in cost of logistics.

The flexibility of the service and reliability also decrease but remain on a positive base.



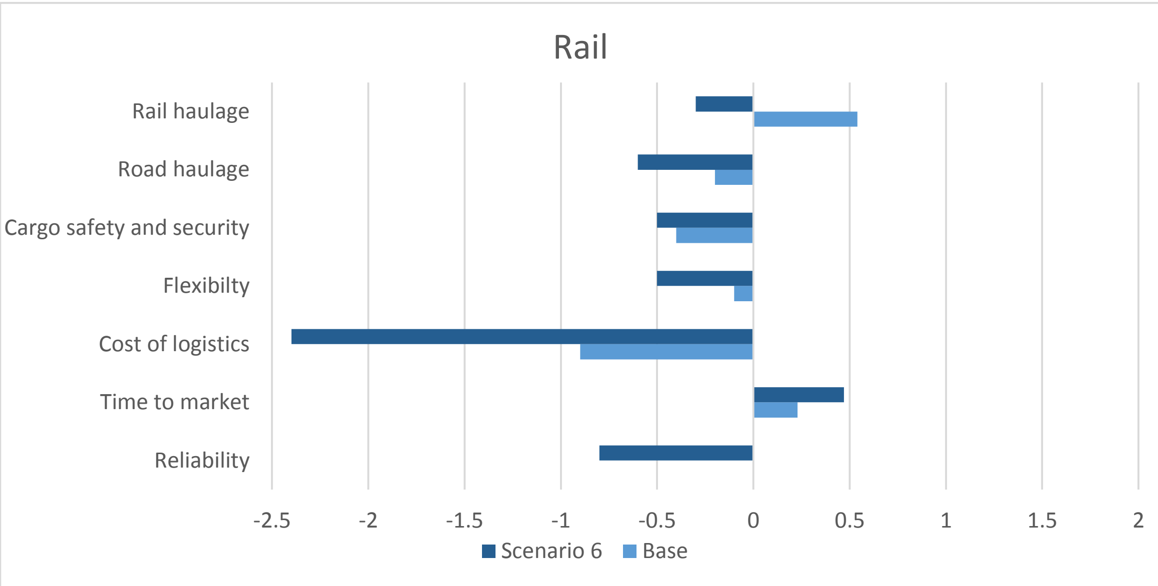


Figure 16: Combined effect of decreases in fuel price, production volumes

Figure 16 shows the impact of reduction in volumes and fuel price from a rail base. Both rail and road haulage see significant drops in requirements as production volumes mainly influence the need for their service.

Flexibility and reliability both decrease further: as rail is a volume mover, the reduction in demand means that the service will be highly variable as it takes volumes to fill up car trains. This variability also sees an increase on the time to market.

Cost of logistics is negatively sensitive and sees a significant decrease as a result of lower fuel prices as well as production volumes.

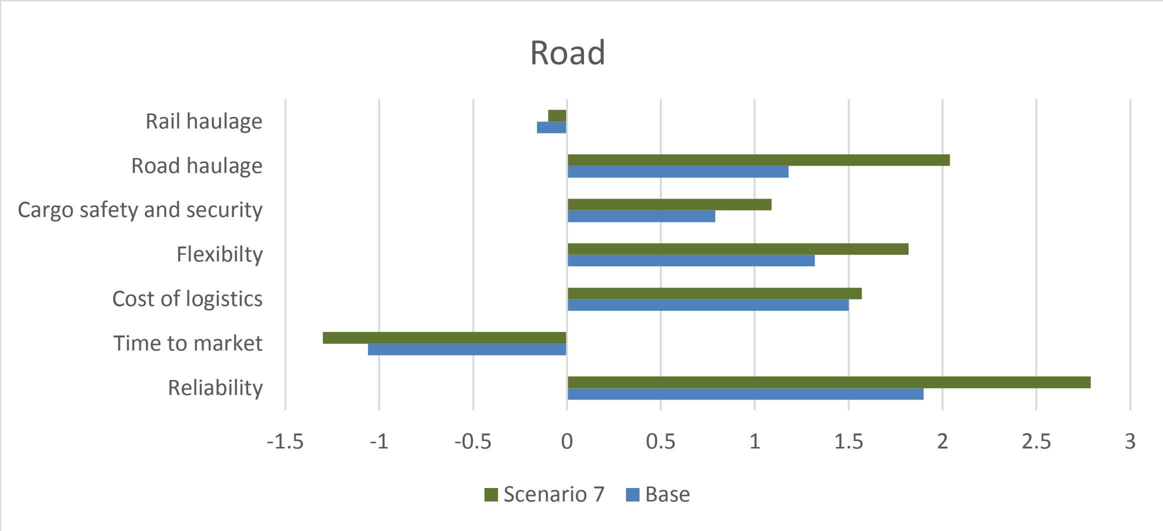
5.7 Scenario 7: Impact of decreased fuel price and increased production volumes

This combination scenario provides for an analysis of a decrease in fuel price whilst production volumes increase. Global supply and demand dynamics dictate that oil prices experience occasional slumps.

The reduction in fuel price, whilst production volumes increase as indicated in Figure 17 from a road base, indicates a significant increase in road haulage. The increase cascades into better flexibility, cargo integrity and reliability.

The logistics costs increase slightly as a result of the increased shipping requirements of the huge production volumes as captured by Kujawa (2015), who states that frequent shipping of small loads increases cost of logistics.

In order to meet demand, considering the cheaper fuel price, road market share is expected to increase significantly. This is expected to see a further decrease in time to market as result of road providing a timeous service (Stamas, 2009).



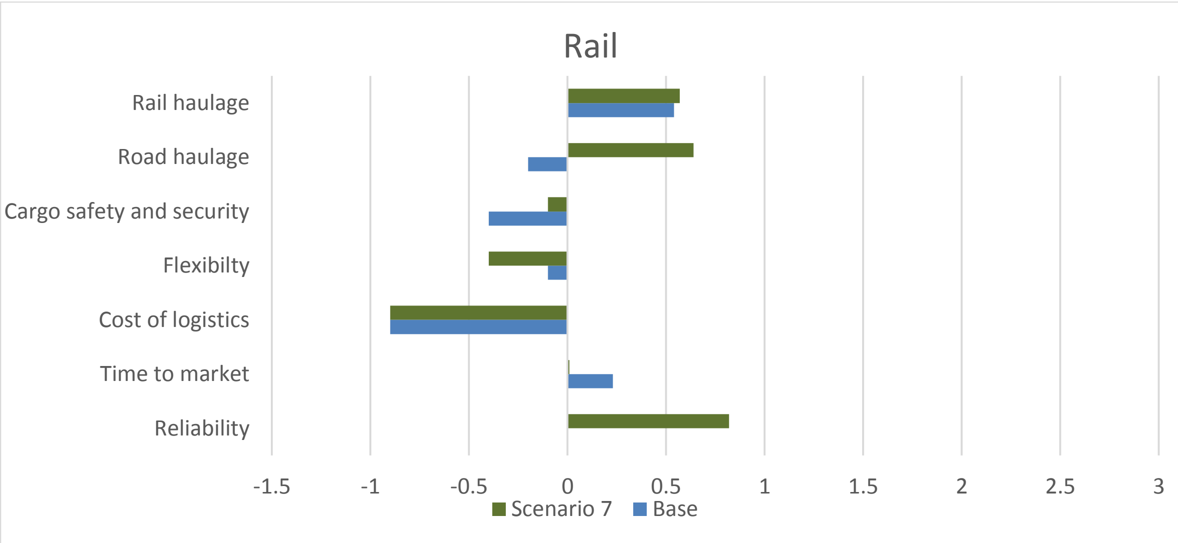


Figure 17: Impact of decreased fuel price and increased production volumes

Figure 17 shows the impact of reduction in fuel price and increased volumes from a rail base. In this scenario, rail haulage is expected to increase slightly as compared to road haulage.

The overall cost of logistics is expected to be unchanged. Flexibility is expected to decrease, however reliability is expected to increase significantly. Rail, as a mode, rides on volumes (Automotive Logistics, 2006) and in this scenario it will still be able to provide mass evacuation of volumes on the long haul.

5.8 Scenario 8: Impact of increased fuel price, production volumes, carbon tax and distance

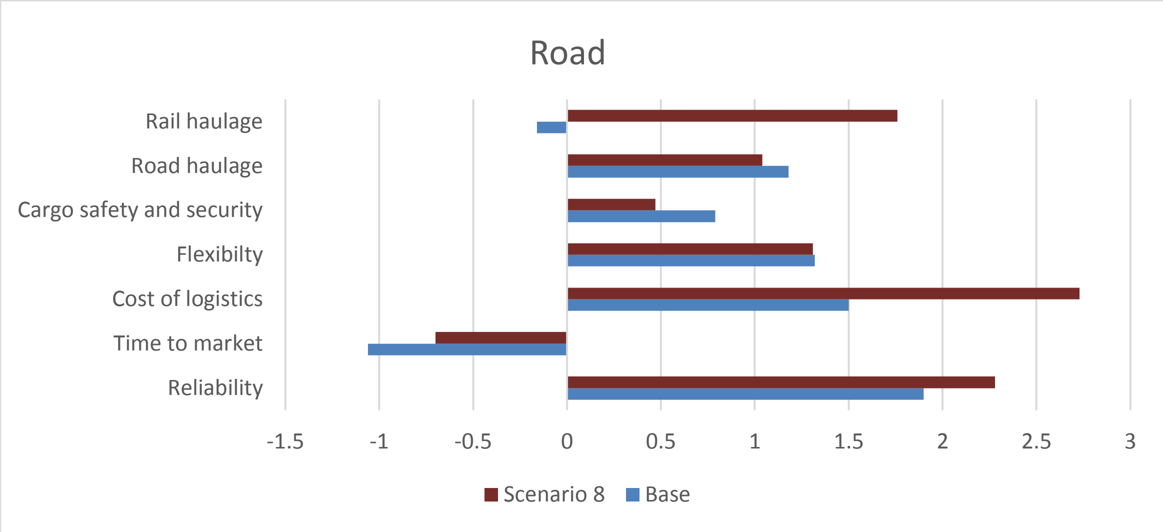
The previous scenarios modelled the singular impact of input factors on a road and rail base. However, scenario planning provides for an analysis of worst case scenario where all input factors can act in combination rather than isolation. This scenario, therefore, investigates the impact of volatility of fuel price, production volume, carbon tax and distance. Detailed model outputs are in Annexure B.

With all primary factors activated, Figure 18 shows that from a road base cost of logistics and rail haulage will experience positive sensitivity. The cost of logistics will be significantly higher, whilst the rail market share is expected to increase. The increased production volumes will increase number of trucks required, with higher fuel cost intertwined with a longer distance, which will certainly push operating expenses. The carbon tax also compounds the situation for road operators, as it increases their prices, thereby impacting the cost of logistics.

Cargo safety & security is expected to decrease, mainly as a result of the growth in rail haulage, whilst time to market will increase slightly as road is being substituted for rail.

Reliability is expected to have a positive sensitivity in this scenario, but flexibility will remain unchanged.

As part of the fuzzy fusions within the model, it shows that, with all the interactions of these input drivers, the time to market will slightly increase.



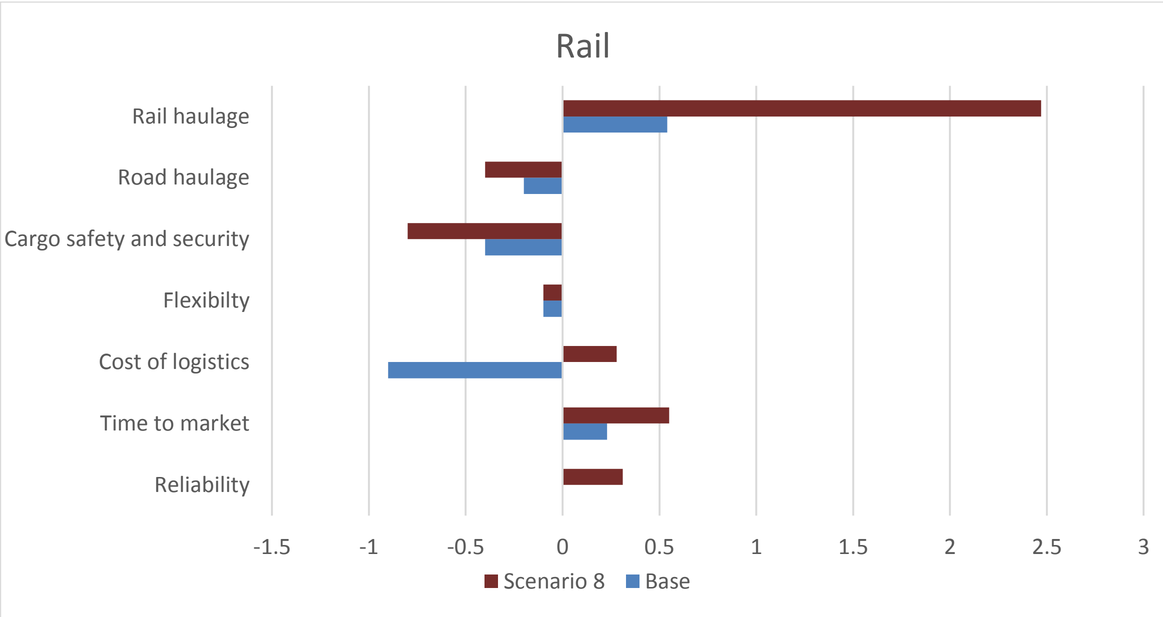


Figure 18: Impact of increased fuel price, production volumes, carbon tax and distance

Figure 18 shows that from a rail base, activating all the influencing factors will result in positive sensitivity on rail haulage. The increase in influencing factors favour rail as a mode of transport. The increase in distance bodes well for rail (Coyle et al., 2016). Rail is naturally a mover of high volumes and provides an avenue to use a more environmentally responsible mode in the advent of a stiff carbon taxation regime.

In isolation, rail provides for cheaper cost of logistics, but with the interaction of the various input factors, this output also changes from a negative base to a positive, signifying an increase.

Time to market also increases, as the combination of factors and use of rail will result in lower turnaround times, whilst cargo safety & security also worsens on a negative base.

CHAPTER 6. CONCLUSIONS

6.1 Introduction

This chapter seeks to highlight important aspects of the research findings. This will provide guidance to the automotive industry as well OEM supply chain managers on the impact of influencing factors in road and rail transportation of CBUs on supply chain outputs. The findings better positions them to optimise their supply chains, knowing better the impacts that can arise with variations in the influencing factors.

6.2 Conclusions of the study

Road and rail transportation of CBUs in South Africa is influenced by a number of factors. The sensitivity of these factors was established from literature and discussed with industry experts so as to custom suit them for the South African industry. Amongst other factors, the influencing factors are production volumes, fuel price, carbon tax and distance; however several secondary or intermediate factors also exist.

Globally supply chains are competing mostly on a cost and service sensitivity base and the automotive industry in South Africa is no exception. CBU production in SA is mostly bound for international markets, with a smaller reverse flow quantum of imports.

As business operations seek cost-optimisation, logistics has become a strategic resource to competiveness. However with volatile fuel prices, variable demand for vehicle production, infrastructure capacity issues, environmental concerns, changes in legislation governing road and rail transport. Business needs to be able to have a long term view of these factors and the likely impact on business process and outputs, considering the highly competitive global environment.

From the discussion with industry experts in SA, road and rail are the key modes of transport of CBUs over the long haul. The supply chain is a hybrid of cost sensitive and service sensitive aspects, cost because the industry needs to be competitive against other markets with whom they are competing for production contracts and service sensitivity because movement of vehicles should be timeous, reliable, flexible and ensure integrity of cargo to meet market needs.

Through scenario testing, the sensitivity of supply chain cost and service outputs to changes in influencing factors from a road and rail base were examined. In general, the results indicate that there is positive and negative responsiveness to these factors, whilst in some instances outputs are unchanged. The analysis of the responses of the model outputs gives industry a measure of the likely sensitivity to changes in primary factors. Considering the scenario tests outputs the following can be deduced:

- Increased fuel price drives road costs of logistics higher and will affect competitiveness of road as a mode choice. Rail market share is expected to increase on this backdrop as it will still provide a lower total cost of logistics. However, without rail service improvements, this will result in lower service levels, which will directly impact on business meeting its market needs.
- A production volume boom will see growth in road and rail market share but costs of logistics of road will significantly be higher than those of rail. Since rail is a transporter of high volumes, it is expected to provide a comfortable degree of flexibility and reliability for business.
- In South Africa, because of the low base on carbon taxation, it currently has little impact on the road and rail movement of CBUs. However in a world of increasing environmentally conscious consumers and business, increased carbon taxation is expected to yield growth in rail market share.
- An increase in distance (e.g. change from Port of Durban to Port Elizabeth) is expected to see a growth rail market share as longer distance favour rail. Although logistics costs will be low, service outputs will be negatively impacted and in the long term service improvements will be required to make rail a sustainable mode choice.
- A combination of fuel and carbon tax will result in higher rail market share, whilst it will push up the cost of logistics for road.

- Fuel is a significant cost in road transportation and its reduction in combination with lower volumes will result in road being a preferably mode as it already provides better service and rail can best be optimised when high volumes exist.
- With increased fuel price, production volumes, carbon tax and distance, rail commands significant market share in comparison to road. Cost of logistics is expected to increase as well as time to market.

Considering the variability of primary factors, road and rail transportation of CBUs optimally and competitively can only be achieved through multi-criteria decision analysis to meet a hybrid of cost and service requirements.

One of the internal risks of the industry was identified as uncompetitive transport costs, compromising global competiveness. However, it is expected that operators and OEMs will always be able to achieve competitive rates due to local competition. Another risk will be the change of APDP, which boosts production volumes through duty, rebates and cash incentives; however this is expected to be mitigated by the fact that automotive industry employs a large number of workers and withdrawal of the scheme will result in significant job losses.

The external risk will include global economic recession which will impact demand of CBU movements to other markets. It is expected that, due to economic cycles, such a recession will still be followed by a boom and the movement of units will still be required.

6.3 Recommendations

As global trends in most manufacturing industries are to shift production to lower cost centres, South Africa needs to remain a viable cost-centre due to the big role automotive manufacturing plays in the GDP. Since SA is located further away from its traditional markets in comparison with its competitors, optimised transportation supply chains have to be implemented so as to keep competiveness; therefore businesses must review their supply chain needs so as to meet market expectations and demand. In light of the above, the following are recommended:

- In order to improve rail competitiveness to automotive businesses in SA, service improvements are required to improve reliability, flexibility and cargo integrity. Rail however, provides a lower cost of logistics over the long haul.
- For service sensitive supply chains, road provides more responsiveness in terms of supply chain outputs, but the costs of logistics are higher.
- The responses from the industry experts seem to point to the view that within SA logistics the presence of road and rail operators acting as 3PL[1] (Third party logistics) services is one of the reasons that effectiveness in CBUs transportation has not been fully realised. The introduction of a 4PL[2] (Fourth party logistics) service which integrates/manages road and rail services will mitigate the impact of primary input factors and provide optimised cost and service needs that will provide coopetition i.e. cooperative competition for the benefit of the South African CBU transportation industry.
- Infrastructure improvements and capacity provision for both road and rail should be provided, as they are key determinants in the cost as well as service sensitivity of the supply chain.

6.4 Suggestions for further study

The following areas of study may well complement the research conducted in this report.

6.4.1 *Refining Fuzzy Cognitive Model*

The existing FCM allocates causal weighting on one common base; however, from a supply chain perspective, there are various degrees of importance allocated to each of the input and intermediate factors in CBU transportation. It is suggested that even greater value might be achieved by implementing aggregate weightings relative to the importance of the various causal links in the FCM. The suggested

[1] 3PL is a provider of outsourced logistics services e.g. in this research, Transnet; Motorvia; KDG etc.
[2] 4PL integrates/manages 3PLs and making use of capabilities and technologies provides complete supply chain solutions.

refinement of the model would allow the model output to be weighted in line with importance thereby allowing a clearer decision making hierarchy to become apparent.

6.4.2 *Infrastructure impact on road and rail transportation*

Havenga and Simpson (2014), cite Simpson (2013), who highlights that within South Africa rail capacity exists to move some of the existing road freight to rail. However, it is expected that this infrastructure capacity, if not maintained or improved, will be used up as of 2030. Simpson (2013), further indicates that this argument also holds true for the road infrastructure.

In consideration of the above a further area of study would be to evaluate the existing road and rail infrastructure capacity to transport CBUs and the impact if no additional infrastructure is provided by the year 2030.

6.4.3 *4PL services and their likely impact on road and rail transportation of CBUs*

One of the inefficiencies of running road and rail transportation as two parallel activities in isolation is the lack of consolidation and management of demand. Information is not consolidated thereby limiting service which affects the transportation supply chain competitiveness.

It is proposed that a further area of study would be to conduct a case study of a 4PL service provider and use it to inform business operations and processes in CBU transportation in the automotive industry.

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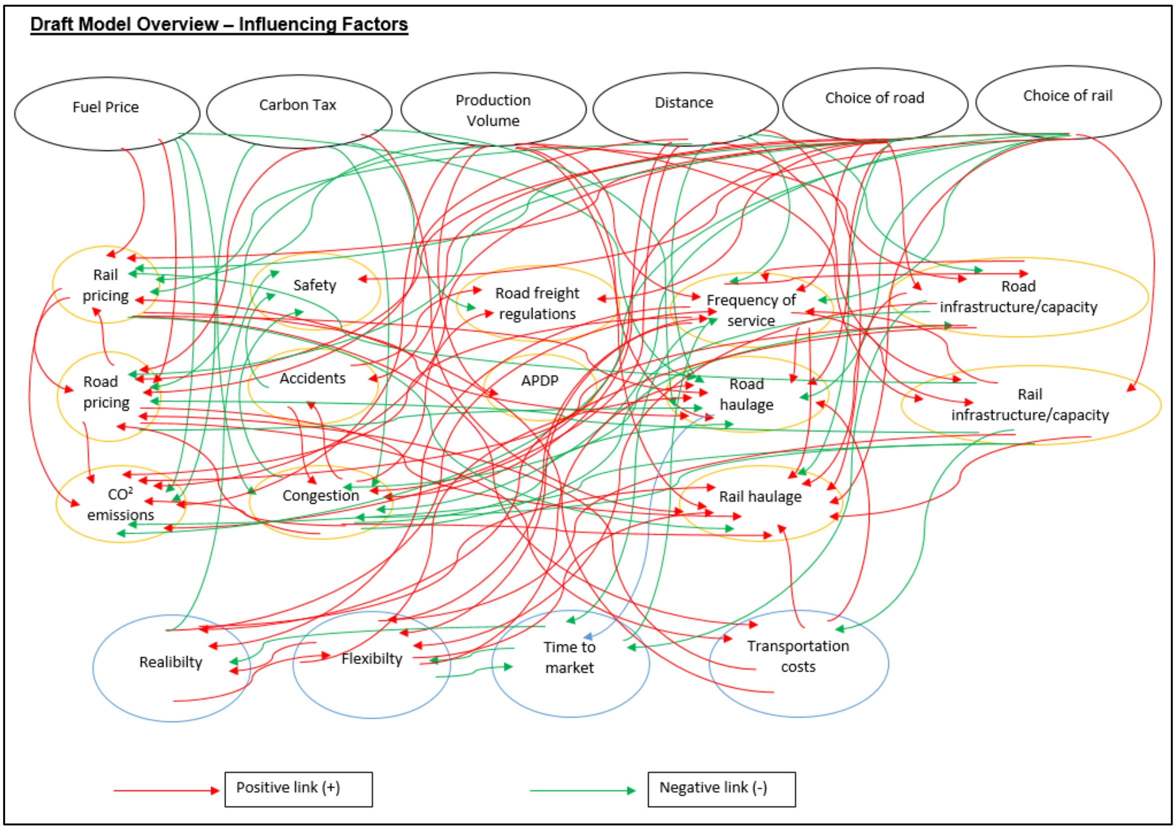
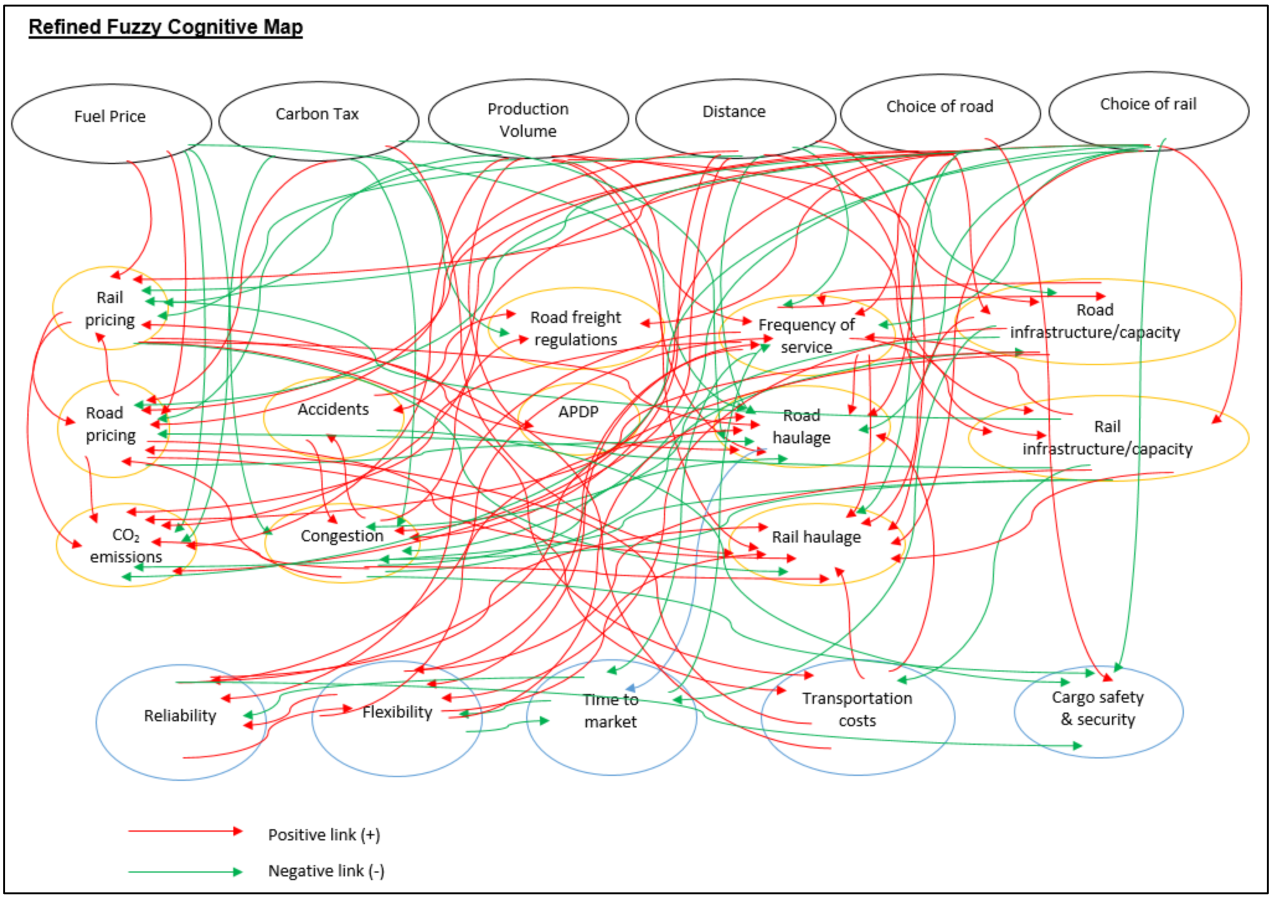
APPENDIX A: FCM

A1. Draft FCM



A2: Refined FCM



APPENDIX B: Model outputs

Base scenario: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	0	0	0	1	0	-0.1	0.58	0.57	0.19	0.02	0.21	1.74	1.34	0.72	1.92	-1.1	1.5	1.32	1.18	-0.2	0.79

Base scenario: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	0	0	0	0	1	0.15	-0.5	-0.4	-0.1	0.32	0.09	0.15	-0.6	-0.5	-0	0.23	-0.9	-0.1	-0.2	0.54	-0.4

Scenario 1: Road output

Adjacency Matrix		Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price	Transmitter nodes							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume								0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax								0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance								0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road								-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail								0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing	Normal and Receiver Nodes								0.30										0.30		0.10	-0.10	
Road pricing																			0.60		-0.10	0.10	
Congestion									0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents										0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity									-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity								-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																	0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation									0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions															0.30								
Reliability														0.30				-0.10		0.10			
Time to market														-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																					0.10	0.10	
Flexibilty														0.10			0.10	-0.10	0.10				
Road haulage									0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage								0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security											-0.10				0.30		0.10		0.10	0.10			
Steady State:		1	0	0	0	1	0	-0	1.1	0.36	0.14	0.04	0.24	1.73	1.07	0.45	1.89	-1.1	2.17	1.28	0.92	0.23	0.69

Scenario 1: Rail output

Adjacency Matrix		Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price	Transmitter nodes							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume								0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax								0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance								0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road								-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail								0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing	Normal and Receiver Nodes								0.30										0.30		0.10	-0.10	
Road pricing																			0.60		-0.10	0.10	
Congestion									0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents										0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity									-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity								-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																	0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation									0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions															0.30								
Reliability														0.30				-0.10		0.10			
Time to market														-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																					0.10	0.10	
Flexibilty														0.10			0.10	-0.10	0.10				
Road haulage									0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage								0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security											-0.10				0.30		0.10		0.10	0.10			
Steady State:		1	0	0	0	0	1	0.28	-0	-0.6	-0.1	0.34	0.12	0.14	-0.9	-0.8	-0.1	0.22	-0.3	-0.1	-0.5	0.94	-0.5

Scenario 2: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	1	0	0	1	0	-0	0.73	0.65	0.2	0.17	0.33	2.63	1.68	0.97	2.76	-1.3	2.24	1.77	1.79	0.26	0.98

Scenario 2: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	1	0	0	0	1	0.28	-0.4	-0.3	-0.1	0.47	0.21	1.04	-0.3	-0.3	0.79	-0	-0.2	0.36	0.39	0.97	-0.2

Scenario 3: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	0	1	0	1	0	0	0.8	0.4	0.15	0.14	0.14	1.75	1.14	0.44	1.94	-1	1.58	1.29	1.06	0.17	0.74

Scenario 3: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	0	1	0	0	1	0.29	-0.3	-0.6	-0.1	0.44	0.02	0.17	-0.8	-0.8	-0	0.24	-0.9	-0.1	-0.3	0.88	-0.5

Scenario 4: Road base

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legislat	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibility	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	**0**	**0**	**0**	**1**	**1**	**0**	**0.05**	**0.66**	**0.38**	**0.17**	**0.38**	**0.12**	**1.2**	**1.02**	**0.63**	**1.46**	**-0.5**	**1.25**	**0.94**	**0.8**	**0.61**	**0.44**

Scenario 4: Rail base

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legislat	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibility	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	**0**	**0**	**0**	**1**	**0**	**1**	**0.33**	**-0.5**	**-0.6**	**-0.1**	**0.68**	**0**	**-0.4**	**-0.9**	**-0.6**	**-0.5**	**0.78**	**-1.2**	**-0.5**	**-0.6**	**1.32**	**-0.8**

Scenario 5: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibility	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	**1**	**0**	**1**	**0**	**1**	**0**	**0.14**	**1.32**	**0.2**	**0.1**	**0.17**	**0.17**	**1.74**	**0.87**	**0.17**	**1.91**	**-1.1**	**2.25**	**1.24**	**0.81**	**0.57**	**0.63**

Scenario 5: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibility	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	**1**	**0**	**1**	**0**	**0**	**1**	**0.42**	**0.21**	**-0.8**	**-0.2**	**0.47**	**0.05**	**0.15**	**-1.1**	**-1.1**	**-0.1**	**0.23**	**-0.2**	**-0.2**	**-0.6**	**1.27**	**-0.6**

Scenario 6: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	-1	0	-1	1	0	-0.5	0.34	0.68	0.21	-0.5	0.17	1.39	1.31	0.56	1.55	-1.4	1.02	1.25	0.95	-1.4	0.96

Scenario 6: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	0	-1	0	-1	0	1	-0.2	-0.8	-0.3	-0.1	-0.2	0.06	-0.2	-0.6	-0.7	-0.4	-0.1	-1.4	-0.2	-0.4	-0.7	-0.3

Scenario 7: Road output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legislat	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and s
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax			Transmitter nodes				0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation			Normal and Receiver Nodes					0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	-1	1	0	0	1	0	-0.1	0.21	0.86	0.25	0.15	0.3	2.64	1.94	1.24	2.79	-1.3	1.57	1.82	2.04	-0.1	1.09

Scenario 7: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of service	Road freight legislat	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and s
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax			Transmitter nodes				0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation			Normal and Receiver Nodes					0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	-1	1	0	0	0	1	0.14	-0.9	-0.1	-0	0.45	0.18	1.05	0	0	0.82	0.01	-0.9	0.4	0.64	0.57	-0.1

Scenario 8: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	1	1	1	1	1	0	0.46	1.56	0.08	0.08	0.68	0.2	2.09	0.9	0.32	2.28	-0.7	2.73	1.31	1.04	1.76	0.47

Scenario 8: Rail output

Adjacency Matrix	Fuel price	Production volume	Carbon tax	Distance	Choice of road	Choice of rail	Rail pricing	Road pricing	Congestion	Accidents	Rail capacity	Road capacity	Frequency of servic	Road freight legisla.	CO2 emissions	Reliability	Time to market	Cost of logistics	Flexibilty	Road haulage	Rail haulage	Cargo safety and
Fuel price							0.10	0.60	-0.10						-0.10			0.60		-0.30	0.30	
Production volume							0.10	0.10			0.10	0.10	0.30		0.30			0.30		0.30	0.30	
Carbon tax	Transmitter nodes						0.10	0.30	-0.10		0.10	-0.10			-0.10			0.10		-0.10	0.30	
Distance							0.10	0.30			0.30	-0.10	-0.30		0.30		0.30	0.10		-0.10	0.60	-0.10
Choice of road							-0.10	0.30	0.30	0.10		0.30	0.60	0.30	0.60	0.30	-0.60	0.10	0.30	0.60	-0.30	0.30
Choice of rail							0.10	-0.30	-0.30		0.30		0.10	-0.10	-0.30	-0.10	0.30	-0.30	-0.10	-0.30	0.60	-0.30
Rail pricing								0.30										0.30		0.10	-0.10	
Road pricing																		0.60		-0.10	0.10	
Congestion								0.10		0.30	0.10	-0.10	-0.10	0.30	0.30	-0.10	0.30	0.10	-0.10	-0.10	0.10	-0.10
Accidents									0.30		-0.10	-0.10	-0.10	0.30		-0.10	0.30	0.30	-0.10	-0.10	-0.10	-0.30
Rail capacity								-0.30	-0.10				0.10		-0.30		0.10		0.10		0.30	
Road capacity							-0.10		-0.10				0.30		0.30		-0.30		0.30	0.30		
Frequency of service																0.60	-0.10	0.30	0.30	0.30	0.10	
Road freight legislation	Normal and Receiver Nodes							0.10	-0.10			-0.10			-0.30			0.30		-0.10	0.10	0.10
CO_2 emissions														0.30								
Reliability													0.30				-0.10		0.10			
Time to market													-0.10		0.10	-0.10		0.30	-0.10	-0.10	0.30	-0.10
Cost of logistics																				0.10	0.10	
Flexibilty													0.10			0.10	-0.10	0.10				
Road haulage								0.10	0.30			0.10	0.30	0.30	0.30	0.30	-0.10	0.10	0.10		-0.10	0.30
Rail haulage							0.10	-0.10	-0.10		0.10		0.10		-0.30	0.10	0.10	-0.30	-0.10	-0.10		-0.10
Cargo safety and security										-0.10				0.30		0.10		0.10	0.10			
Steady State:	1	1	1	1	0	1	0.74	0.45	-0.9	-0.2	0.98	0.08	0.5	-1	-0.9	0.31	0.55	0.28	-0.1	-0.4	2.47	-0.8

APPENDIX C: Semi – Structured interview

My name is Andrew Mukanyima student number 345949 from the University of the Witwatersrand in Johannesburg. I am currently carrying out a research on the influencing factors impacting road and rail transportation of completely built units (CBUs) within the automotive industry as part of my Masters in Business Administration Degree and would appreciate your input with regard to the Model depicted below. My study will review and model factors influencing transport logistics and their impact to key supply chain outputs and business processes used in multi-criteria analysis of mode choice. This will provide insight on outcomes and aid business scenario planning, cost optimisation and decision making.

My Supervisor is Prof Anthony Stacey; contact details Anthony.Stacey@wits.ac.za, 011 717 3587

Please note that this discussion will be for academic purposes so as to inform my research. All the information provided shall be used for this sole purpose.

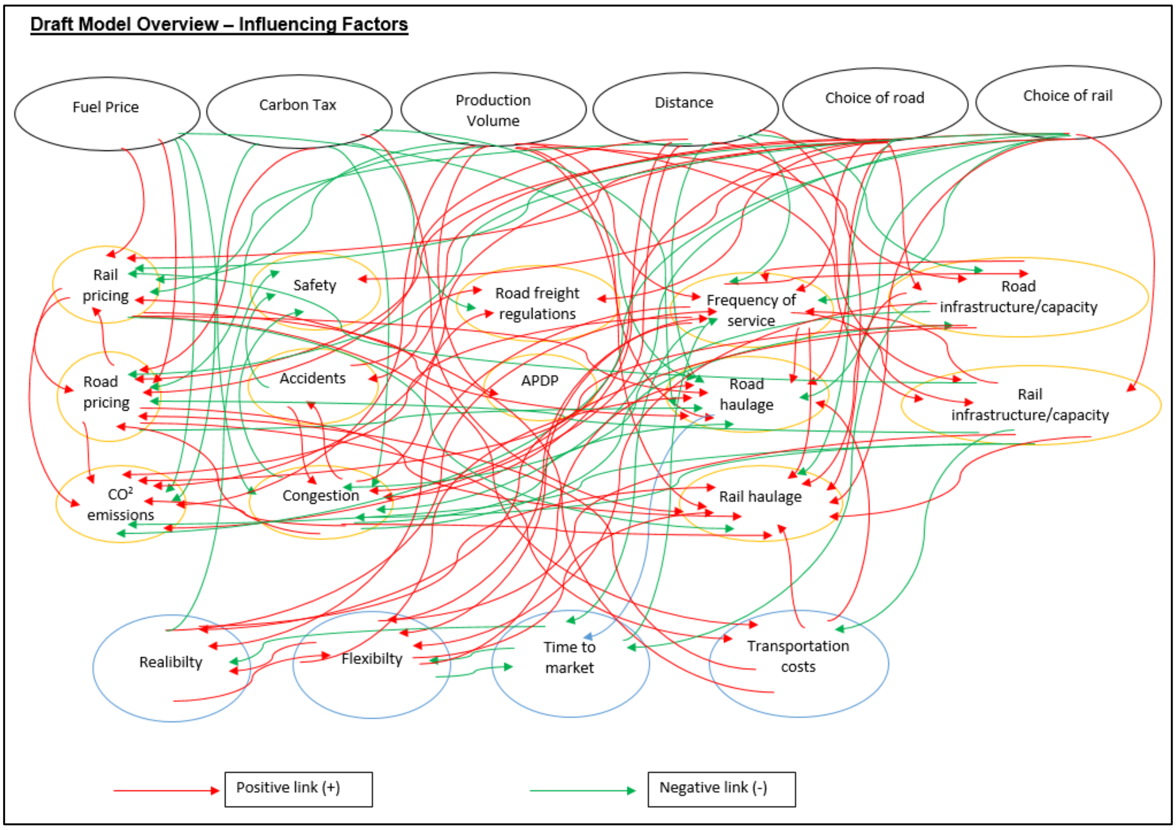
I have approached you as an expert within one of these fields supply chain, road and rail transportation and would require your review of my draft model.

ORGANIZATION NAME :

CONTACT PERSON :

CONTACT DETAILS :

DESIGNATION :



From an industry perspective would you consider the following as primary influencing factors to road and rail transportation decisions in CBU movements?

Factors	Yes	No
Fuel Price		
Carbon Tax		
Production volume		
Distance		
Preference of Road		

Preference of Rail		
Other: Specify….		

How do you perceive the draft model on the influencing factors affecting CBU transportation – How relevant are the links and weighting in your experience.

What are your changes or recommendations to the map?

What strategies can be implemented from a supply chain perspective to improve road/rail transportation of CBUs.

APPENDIX D: Consistency Matrix

Table 18: Consistency matrix

Research problem stated here					
Sub-problem	**Literature Review**	**Hypotheses or Propositions or Research questions**	**Source of data**	**Type of data**	**Analysis**
Identifying the influencing factors to CBU transportation mode choice	(Alfaro et al., 2012) (Alton et al., 2014) (Black, 2001) (Chapman, 2007) (de Saxe, 2012) (Havenga, 2010) (Havenga & Simpson, 2014) (Lane, 2009) (Macharis et al., 2010) (Stamas, 2009) (Stern, 2007) (Thambiran & Diab, 2011)	The literature suggests that literature there are specific factors influencing the transportation of CBUs, the consequences of these factors feed into the end decision of whether to use road or rail within South Africa. These factors are: 1. Fuel price 2. Production volume 3. Distance 4. Carbon tax	Literature review Industry experts	nominal	Describe the specific analysis method you will use

Research problem stated here					
Sub-problem	**Literature Review**	**Hypotheses or Propositions or Research questions**	**Source of data**	**Type of data**	**Analysis**
Developing a semi-quantitative model that will take into account the causal relationship of factors influencing mode choice	(Winebrake et al., 2008) (Kosko, 1993) (Stylios & Groumpos, 1999) (Kim & Lee, 1998)	There exist casual links between the transportation of CBUs by road or rail and key supply chain performance indicators namely cost optimisation, economies of scale as well as multi criteria decision making outputs (cost of logistics; speed; flexibility; reliability; on time delivery etc).	Literature review	ordinal	FCM

Research problem stated here					
Sub-problem	**Literature Review**	**Hypotheses or Propositions or Research questions**	**Source of data**	**Type of data**	**Analysis**
Modelling different scenarios examining the effects of changes in the influencing factors to supply chain outputs.		There are external scenarios which can have an impact on supply chain outputs in the road and rail of CBUs in South Africa and consequently on the decision to use road or rail. 1. Volatility of fuel prices and impact 2. Increase of Production volumes 3. Impact carbon taxation 4. Distance and its impact 5. Combined effect of increase in fuel price and carbon tax 6. Combined effect of decrease in fuel price, production volumes 7. Impact of decreased fuel price and increased production volumes 8. Impact of fuel, production volumes, carbon tax and distance		ordinal	Scenario testing