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A Stratified Systems Framework for the North-South Rail Corridor in Southern Africa
(Business Model and Concept of Operations)

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A research project report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Masters in Engineering.

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DECLARATION

I declare that this research project report is my own unaided work. It is being submitted to the partial fulfilment of the Degree Master of Science in Engineering, MSc (Eng), to the University of the Witwatersrand, Johannesburg.
It has not been submitted before for any degree or examination to any other University.

_____
PM Bester

_____day of _____

ABSTRACT

The North South Corridor (NSC) runs from the southern Democratic Republic of the Congo (DRC) to the ports of Southern Africa, connecting the DRC, Tanzania, Zambia, Zimbabwe, Botswana, Swaziland, Mozambique and South Africa (RSA). The notoriously high transport costs on the NSC, compared to other major regions of the world, is a serious limitation on the economic development of the SADC region.

While total NSC (road and rail) freight traffic volumes have increased, the rail portion has declined. Rail volumes on the NSC have dropped by 80%, while rail market share has dropped by more than 67% between 1990 and 2016. The purpose of this study is to determine what has caused this dramatic decline and what can be done to reverse the trend.

By applying a systems approach, the NSC-Rail System was analysed from a business model and a concept of operations (CONOPS) point of view. A mixed-method research design which included both a qualitative and a quantitative element was used. The study provided an understanding of the NSC-Rail System with its multiple interacting sub-systems and context elements. It also provided a means of conceptualising the factors impacting its business model.

In the Stratified Systems Review process, Node Flow Mapping highlighted the numerous discontinuities in the NSC rail corridor and the sharp contrast in traffic density north of the RSA rail network. The Viable Systems Model analysis showed that the system fails at the Coordination (level 2) and Optimisation (level 3) levels of a viable system. Value Stream Mapping (VSMp) identified the non-value adding delays caused by customs clearances at the multiple border crossings and identified locomotive and crew change-over points as major causes of transit delays. The VSMp indicated that the rail transit time between Durban and the DRC should be circa 8 days as opposed to the reported the 30 days rail transit time.

The research concluded that the operations of the sovereign rail operators must be aligned and optimised at system level. Lack of information sharing and communication problems are blamed on the language barriers between the operators along the corridor. The business model must address all the elements required of an end-to-end transport system. Key elements to improving the NSC-Rail System are inland dry-terminals, security of freight, system effectiveness and operational efficiency, competitive pricing and dependable, short delivery times.

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I need to thank the SARA members, TFR International Business Unit, NBF-ID team and all other commercial stakeholders for participating in the research, by completing and returning the comprehensive questionnaire and for providing data and information to support this research.

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LIST OF ACRONYMS

3PL	Third (3rd) Party Logistics
AFDB	African Development Bank
AICD	Africa Infrastructure Country Diagnostic (Report)
AU	African Union
BB	Beitbridge
BBR	Beitbridge-Bulawayo-Railways
BMC	Business Model Canvas
BR	Botswana Railways
C-BRTA	Cross Border Road Traffic Agency
CFM	Portos e Caminhos de Ferre du Mozambique
COMESA	Common Market for Eastern and Southern Africa
CONOPS	Concept of Operations
CT	Cape Town
DBSA	Development Bank of South Africa
DFI	Development Finance Institution
DRC	Democratic Republic of Congo
EAC	East African Community
EL	East London
ERRAC	European Rail Research Advisory Council
EU	European Union
FMCG	Fast Moving Consumer Goods
Gau	Gauteng Province
GSM	Global System for Mobile (Communications)
JOC	Joint Operations Centre/Commission
LLC	Limited Liability Company
MDS	Market Demand Strategy
MOD	Ministry of Defence (UK)
mtpa	million ton per annum
MSC	Mediterranean Shipping Company
NBF	NEPAD Business Foundations
NBF-ID	NBF Africa Infrastructure Desk
NCC	National Command Centre
NEPAD	New Plan for African Development
NRZ	National Railways of Zimbabwe
NSC	North South Corridor (in Southern Africa)
NVA	Non-Value Adding
OSBP	One Stop Border post
PE	Port Elizabeth
PIDA	Programme for Infrastructure Development in Africa
PPP	Private-Public-Partnership
PRASA	Passenger Rail Agency of South Africa
RACI	Responsible, Accountable, Consult & Inform
RB	Richards Bay
RSA	Republic of South Africa
SAAFF	Southern African Association of Freight Forwarders
SADB	Southern African Development Bank
SADC	Southern African Development Community

SAHHA	South African Heavy Haul Association
SARA	Southern African Railways Association
SE	Systems Engineering
SNCC	Societe Nationale des Chemins de Fer du Congo (National Railway of Congo)
SOC	State Owned Corporation
SOI	System of Interest
SR	Swaziland Railways (changed to eSwatini Railways)
SST	Stratified Systems Theory
SSRF	Stratified Systems Review Framework
STO	Strategic, Tactical & Operational
TAZARA	Tanzania-Zambia Railway
TFR	Transnet Freight Rail
UK	United Kingdom
US$	United States of America Dollar nomination
VA	Value Adding
VSMd	Viable Systems Model
VSMp	Value Stream Map
ZRL	Zambia Railways Limited

1 INTRODUCTION

1.1. The North-South Corridor (NSC) Rail System in Southern Africa

The North South Corridor (NSC) in Southern Africa, as defined by the Southern African Development Community (SADC), stretches from the southern Democratic Republic of the Congo (DRC) to the sea ports of Mozambique and South Africa. The ports of Durban and Richards Bay are the primary ports servicing the Southern African interior for bulk and containerised import-export trade access. The NSC includes both a road and a railway connection between the origins and destination locations along this corridor. The NSC rail routes run across a minimum of four sovereign countries being; DRC, Zambia, Zimbabwe, and South Africa, with alternative routing options also going through Tanzania, Botswana, eSwatini (previously Swaziland) and Mozambique, thus 8 sovereign countries have an interest in the NSC-Rail System. The focus of this study is however on the rail connection between the DRC and Southern African ports, with the Tanzanian (Tazara) connection being considered as a competitive route.

1.2. Performance of the NSC-Rail System

The current (2018) freight volumes being delivered by the NSC-Rail System is expected to be circa *only* 0,6 million ton per annum (mtpa) and represents less than 10% of the bulk freight transported along the NSC (C-BRTA, 2018). The remaining 90% of freight is transported by road. This rail traffic volume is far below the traffic handled in 1990 (3 mpta) and way down on the design capacity of the railway system (quoted as 6 mpta) (Havenga, 2011). While the NSC-Rail System has been losing business of rail friendly bulk freight to the road transport mode in a growing market, the road transport mode is experiencing infrastructure capacity constraints to handle all the freight loads assigned to it.

This research analysed the perceived underperformance of the NSC Rail System, through applying a Stratified Systems Framework to the NSC-Rail System, with a focus on the Business Model and Concept of Operations (CONOPS) for this system, given its opportunities and its challenges.

1.3. Forecasted Growth of Traffic on the NSC

SADC economic development plans for the region have identified the NSC as a key prerequisite / enabler of growth for Sub-Saharan Africa (NBF, 2014). The diagram in figure 1.1 illustrates the population densities in the SADC region (with a current population of

circa 190 million) as well as the rich concentrations of minerals in the region (Buoron, 2016).

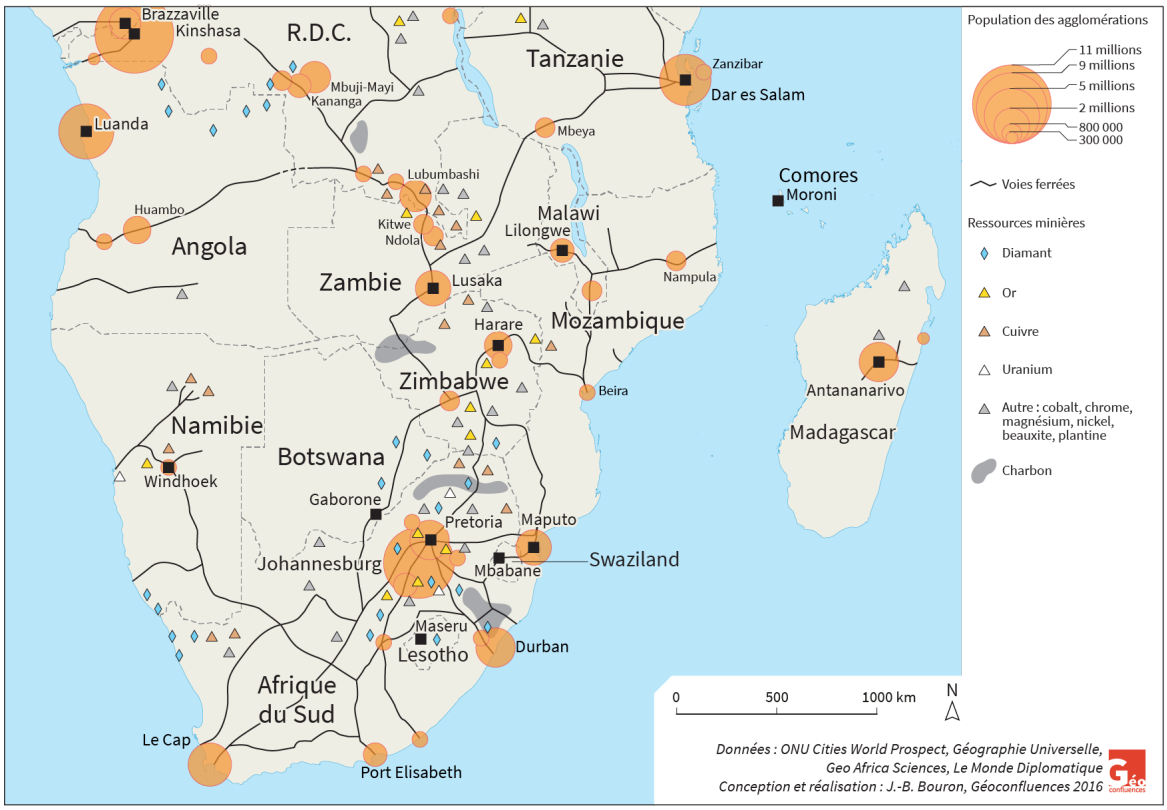


Figure 1-1: Population concentration and Minerals concentrations in the SADC Region (Buoron, TB. Geoconfluences (2016))

The Southern African Railway Association (SARA) is a sub-committee of SADC and has as its members all the railways stakeholders in Southern Africa. SARA promotes the 'harmonisation' of eleven SADC regional rail corridors as presented in figure 1.2. The most important of these is the North-South Corridor (NSC), also referred to as the Beitbridge corridor as indicated in figure 1.2.

The New Economic Plan for African Development (NEPAD) Business Foundation (NBF), Africa Infrastructure Desk is driving projects to rehabilitate the African infrastructure, to pave the way for the expected growth. A commissioned NBF study (NBF, 2014) aims to investigate and develop an infrastructure investment, planned to increase the freight volumes on the NSC-Rail System to 26 mtpa by 2019. This goal will obviously not be achieved, showing up that the NBF plan was flawed and is now outdated. In the 2019 NEPAD Annual publication, Africonomy (NEPAD, 2019), NBF states that "Efforts to increase traffic for rail have been thwarted by poor infrastructure conditions and low operating capital. The NSC project has now garnered enough political will and support to make it an integral part of SADC's regional railway masterplan."

The project is supported by the major shipping lines operating along the Southern African east coast and all rail operators on the NSC. As a first step in improving the service of the NSC-Rail System, a Joint Operating Center (JOC), based in Bulawayo, is coordinating train scheduling and movements along the NSC on a 24 hour a day basis (TFR, NSC JOC (2016)).

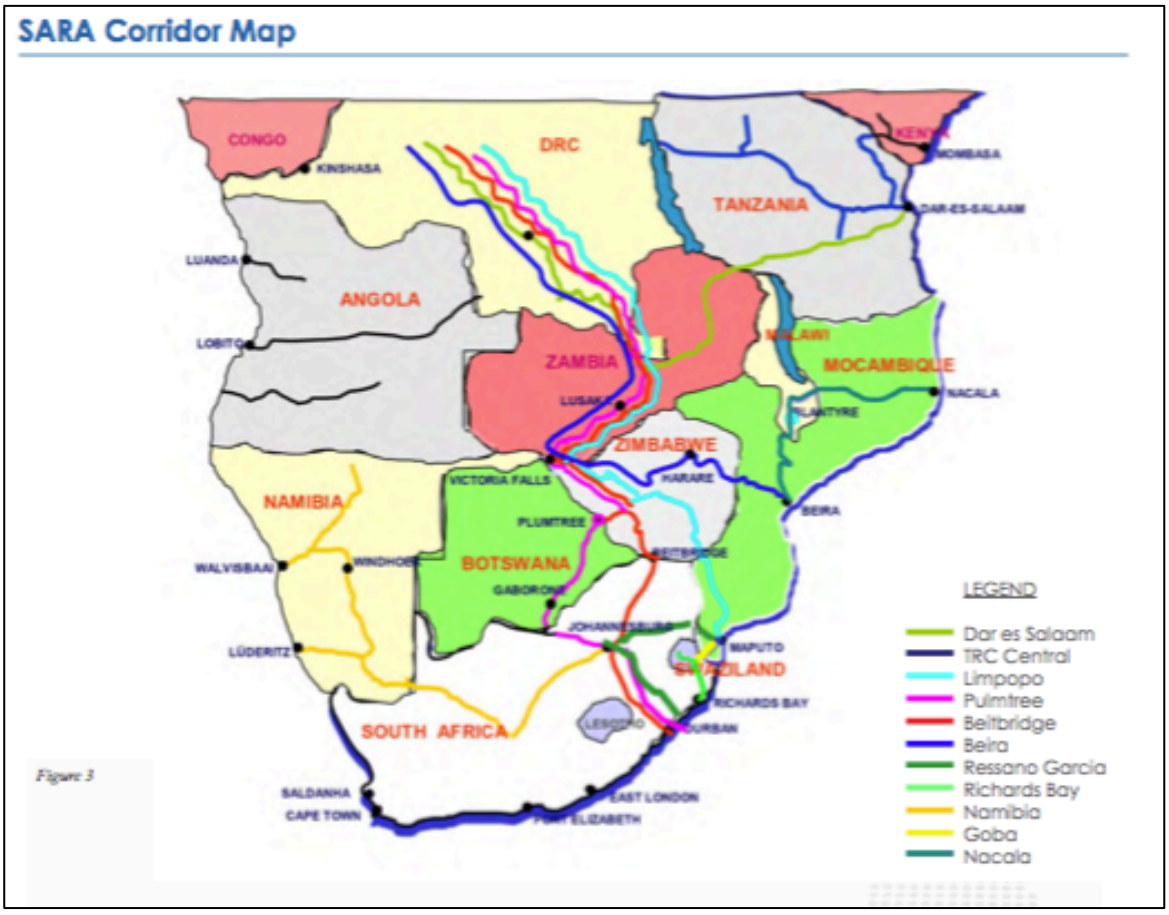


Figure 1-2: SARA Railway Corridors in the SADC Region

(SARA Information Brochure (May 2017))

1.4. Overall Aims of the Study

The main objective of this research is to determine an appropriate Conceptual Framework that can be used to model the NSC-Rail System. In future follow-up project phases, beyond the scope of this research project, the Conceptual Framework output from this research will be used to develop the model for optimising the NSC Rail Freight Business. In applying a systems approach, the NSC-Rail System is considered as the System of Interest (SOI), while a Concept of Operations (CONOPS) for the NSC-Rail System addresses the questions; why, what, when, where, by whom and how the service is (or should be) delivered.

2 FORMULATION OF PROBLEM

2.1. Problem Statement

Freight traffic volumes on the NSC (road and rail) have increased from ca 10 mtpa in 1990 to ca 19 mtpa in 2016 (C-BRTA 2017) (an increase of 90%). During the same period the freight volumes transported by the NSC-Rail System declined from ca 3 mtpa in 1990 to ca 0,6 mtpa in 2016 (a decline of 80%) and the rail market share has dropped from ca 30% in 1990 to less than 10% in 2016, and further down to less than 5% in 2018 (C-BRTA 2018). What has caused this dramatic decline and what can be done to reverse the trend?

A sub-problem that this research will address is the perceived poor service delivered by the NSC-Rail System. The reported transit time of rail deliveries is 30 days from origin to destination (ACID, 2011), while the reported road transit time is 10 days (Wiggel, 2016). However, the target transit time for trains from origin to destination is only 8 days.

2.2. Research Background

The rail operators in the sovereign countries along the NSC-Rail System are all independent from each other and pass traffic on to the next operator when it reaches its geographical boundary. Each rail operating organisation within the NSC requires their own compliances, operates their independent train plans and charge prices based on their own business models. The customers however, want their freight transported between corridor origin and destination in a dependable seamless way, at minimum cost, in the shortest time and does not want to be challenged by interface complications between the parties acting across the rail corridor. The need is for a seamless service between origin and destination that will encourage clients to transport the large volumes of rail friendly freight, in both a northern and southern direction, by rail.

The southern connections of NSC is presented in Figure 2.1. It stretches from Kolwezi in the southern Democratic Republic of Congo (DRC) and Dar es Salaam in Tanzania to the ports of Maputo, Richards Bay, Durban. The ports of East London, Nqqura, Port Elizabeth and Cape Town are normally not included in the NSC references, although rail connections from Sentrarand in Gauteng to these ports do also service the NSC-Rail System and are included in this study for completeness. The railways associated with this multi-country corridor include the railway owners/operators within the DRC (SNCC), Tanzania (Tazara), Zambia (ZRL), Zimbabwe (NRZ and BBR), Botswana (BR), Swaziland (SR), Mozambique (CFM) and South Africa (Transnet and PRASA).

The typical north bound freight in the corridor is:

a. Coal/coke from Hwange to Zambia and DRC
b. Sulphur from Richards Bay to Zambia and DRC
c. Fuel from Gauteng to Zimbabwe, Zambia and DRC
d. Agri-produce from Gauteng to Zimbabwe, Zambia and DRC
e. Containerised goods from Gauteng and Mozambique to Zimbabwe, Zambia and DRC
f. General Freight from Gauteng to Zimbabwe, Zambia and DRC
g. Automotive from Gauteng to Zimbabwe, Zambia and DRC

The typical south bound freight in the corridor is:

a. Copper (cathode and concentrate) from DRC and Zambia to Mozambique and Durban/Richards Bay.
b. Sulphuric Acid from DRC and Zambia to ports
c. Maize from Lusaka to Zimbabwe
d. Cement from Lusaka to Zimbabwe
e. Sugar from Zambia and Zimbabwe to Durban
f. Coffee from Zambia and Zimbabwe to Durban

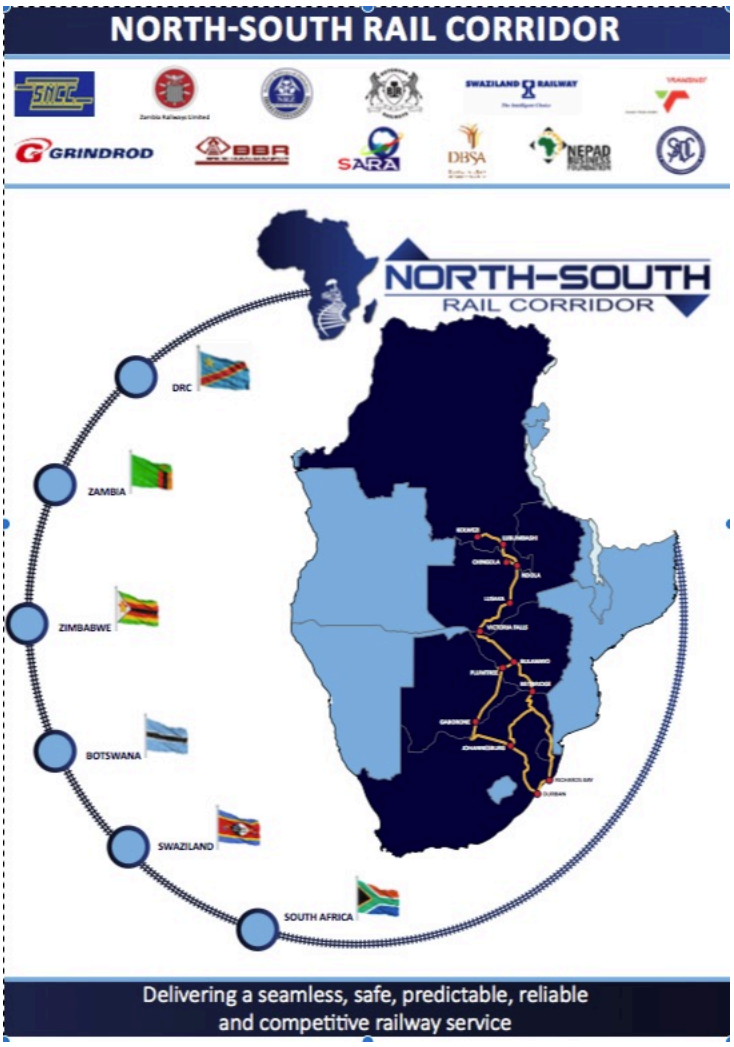


Figure 2.1: North-South Rail Corridor as the SOI

(NBF, NSC Brochure (December 2017))

The South African portion of the NSC starts/ends at the Beitbridge border post to Zimbabwe and or the connection to Botswana via Mafekeng and Lobatse. From Polokwane, alternative rail connection channels can be followed to the southern ports as indicated in figure 2.2. Here high-density line operations are shown in black and low-density line operations are shown in green. The rail system in South Africa is operated by an operating division of Transnet SOC, called Transnet Freight Rail (TFR).

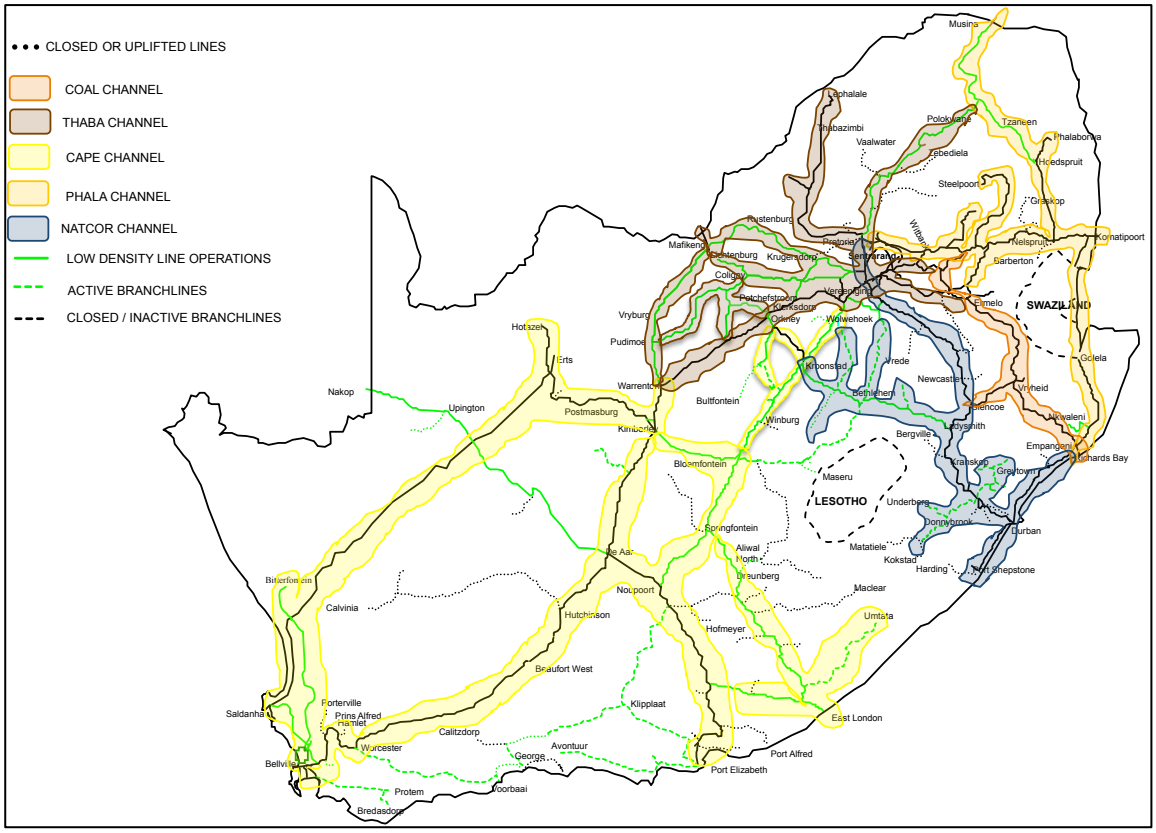


Figure 2.2: Graphical presentation of the South African portion of the NSC (TFR 2016)

Given the volume of bulk loads carried and long distances travelled, rail offers the obvious alternative to road, and should by its nature have a competitive advantage in this portion of the market. The realizable efficiencies of rail should outweigh the cost and speed of road haulage (Havenga, 2011). An action plan for an economically viable and financially profitable railway service on the NSC in the short, medium and long term is critically needed.

2.3. Specific Aims of the Study

The objectives of this research are to understand, conceptualise and structure the rail freight business model for the NSC-Rail System, this research thus interrogated the following:

a. The current stakeholders and operations of the NSC-Rail System.

b. The nature and volumes of trade (Demand and Supply) along the NSC.
c. The Supply Chain Services required to support the NSC.
d. Available Transportation Services (modes and infrastructure) serving the NSC.
e. Customers' views and expectations of the current and future NSC-Rail System.

3 LITERATURE REVIEW

Internationally the "second golden age of railroading highlights domestic intermodal transport as a growing industry." (Case 2009 as cited by Havenga 2011).
The NEPAD Business Foundation (2014) defines the strategic intent of the NSC project in Southern Africa as "To establish a seamless, efficient, competitive and integrated cross-border logistics and freight rail transportation corridor linking the DRC and South Africa with the purpose of promoting an attractive rail service offering."

3.1. Freight Transportation and Logistics Systems

Freight transportation systems and logistic systems are multi-disciplinary systems. Cloete-Hopkins (2011) presents the elements of these systems as adapted from Rodriques (2011) and a conceptual framework of freight transport and logistic systems (as adapted from Tavasszy 2008), that is presented in figure 3.1 below.

Cloete-Hopkins (2011) addresses the trends in freight transportation and logistics (the Big Picture) and key freight transportation policy issues and associated modelling needs. This leads to an architectural framework (based on Robinson 2008 & UK MOD 2011), which allows for viewpoint considerations. Using the two frameworks (conceptual- and architectural-) Cloete-Hopkins (2011) derives an operating concept description and further develops this to a high-level operating concept diagram.

3.2. Whole Systems Approach (System of Systems)

Considering the whole systems approach to the logistics challenge for an inland customer, Shaw (2016) has presented a typical marine container import supply chain, from the container vessel to the retail factory, as shown in figure 3.2.

Havenga (2011) concurred with such an end to end systems view in integrating and optimising logistics corridors, "Solutions need to be found that optimize (Southern) Africa's end-to-end supply chain, including integration of the rail, road, inland terminals and ports to complement one another as a whole, (competing) against other global supply chains."

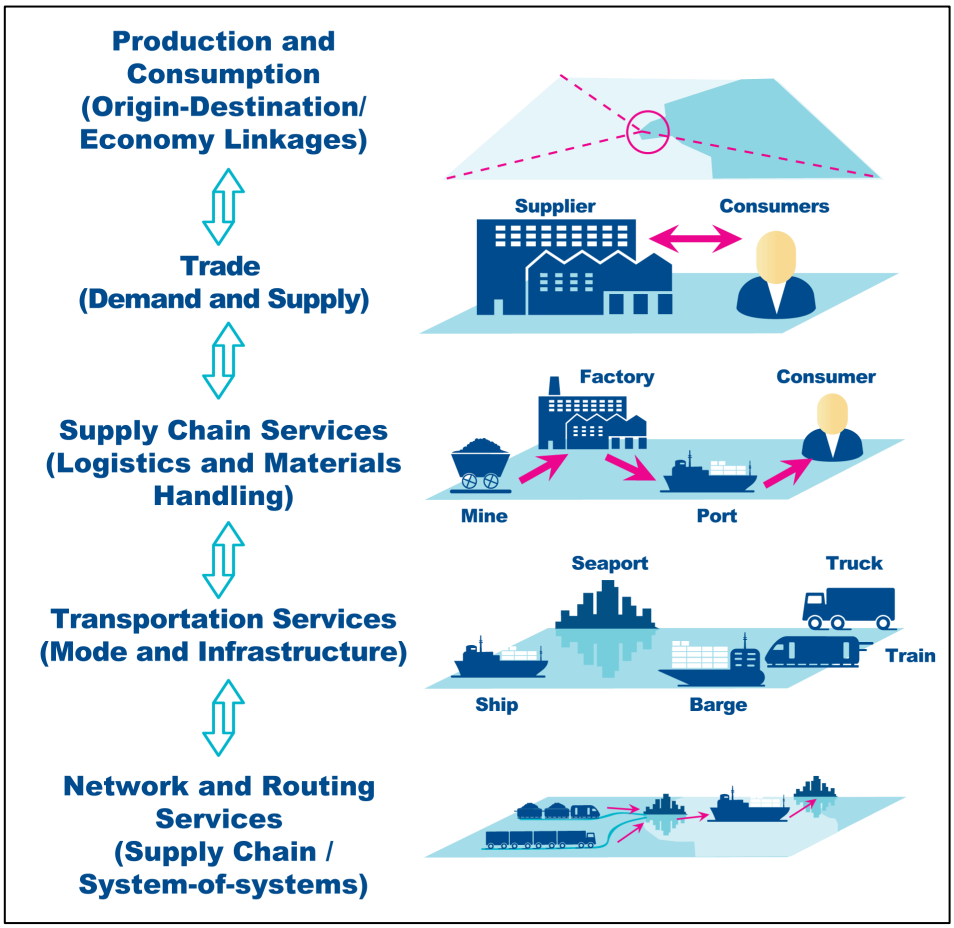


Figure 3.1: Conceptual Framework of Freight Transport & Logistic Systems (Cloete-Hopkins 2011)

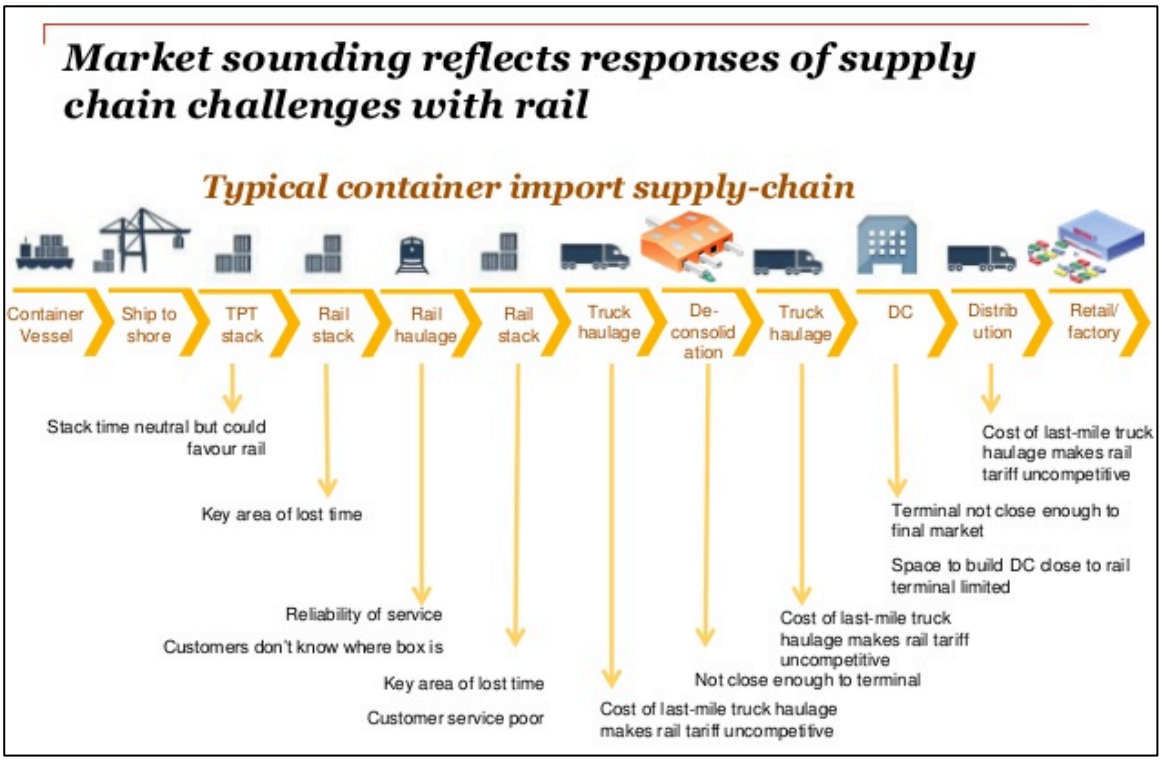


Figure 3.2: Typical marine container import supply chain (Shaw 2016)

Some of the goals of the research sponsored by the European Rail Research Advisory Council (ERRAC, 2014) focused on optimising the performance of multimodal logistic chains, and on increasing the efficiency of transport, and of infrastructure use, with information systems and market based incentives. ERRAC (2014) developed optimised business models, which could be used by the rail operators and the multi-modal service providers active in the European corridors.

ERRAC (2014) states that a "whole system" approach must be followed to address:

a. Capacity, performance and competitiveness
b. Energy and the environment
c. Safety (including certification) and security.

3.3. Systems Engineering

INCOSE (2015) defines Systems Engineering as follow; "Systems Engineering is an interdisciplinary approach and means to enable the realisation of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, registering requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. Systems engineering integrates all the disciplines and speciality groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality solution to meet the user needs." In this research, the NSC-Rail System was analysed as a system applying the elements of the INCOSE (2015) definition of Systems Engineering.

3.4. Rail Corridor Business Model Applications (Concept of Operations)

The published literature contains a few examples of recent rail corridor studies. In these studies the methodologies applied varies in line with the general context of the study.

Cloete-Hopkins (2011) developed a costing model for the proposed Mozambique coal export corridor. This 600km plus corridor was planned from the Moatize Coal Basin in Tete province to either the port of Beira or the port of Nacala. Heavy Haul technologies were used as the baseline for the costing in his study.

Woroniuk & Marinov (2013) modelled a Spanish branch line in order to optimize the viability of the line. Their modelling results showed that by increasing the freight mix on

the line and adding multimodal (containerised) freight, they drastically increased the viability of the line.

The EU CREAM Project (2012) addressed the mega Trans-European (Benelux to Turkey/Greece) rail corridor with a length of more than 3000 km. The project needed to address unfavourable framework conditions such as decrepit or missing infrastructure, obsolete rolling stock, limited co-ordination between the actors, and missing or uncommunicative IT systems.

The goal was seamless rail freight and intermodal rail / road and rail / short sea / road services. They managed to successfully integrate the system into an innovative corridor-related freight service concept. Rail performance features such as time-table, price, rate of punctuality and flexibility were all achieved.

3.5. Freight Transportation Requirements / Market Segmentation

Southern Africa's freight transportation requirements are forecasted to grow by 108% in tonne-km terms between 2009 & 2040 (Havenga 2011), whereas rail transport in Europe is expected to grow sustainable with freight volumes increasing by 80%, from the 2014 baseline to 2050 (ERRAC 2014), given that the business models of the service providers meet the changing future customer needs.

Havenga (2011) states that market segmentation is the first step in understanding demand or market opportunity. There is a shift in freight flow demand patterns from high stock levels to just-in-time delivery, and from low value/high volume to high value/low volume freight. "The *priori* reason for rail's decline in market share is poor understanding of shifting demand or an inability to adapt. This requires the implementation of intermodal freight transport solutions."

ERRAC (2014) states that European transport is at a crossroads; old challenges remain, but new ones have arisen. Each rail market segment has specific customer needs, mainly associated with the distance and purpose. The relevant market segments require specific design, construction, manufacture, operations and maintenance systems.

Rail resources are grouped in corridors, networks, management and three traffic segments:

1. Block trains – mode of choice for bulk commodities and heavy haul operations
2. Wagonload – individual or groups of wagons, used where industrial web is denser and in Sweden (where infrastructure charges are the lowest.)
3. Intermodal – rail to road or to water transfers and vice versa

Europe is committed to a revitalization of interoperable freight logistics, using integrated services. Quality-, safety- and security- management systems will be harmonised across Europe to keep to the promise of an interoperable European wide rail system.

Cloete-Hopkins (2011) showed that the main trading from Africa is to India, China, Japan and Europe. He has determined the key system requirements for logistics system from interviews with stakeholders as being; cost, schedule, proven-in-service, performance, safety, reliability, sustainability, inter-operability, future proofing and system capacity.

While road freight is dependent on imported fuel and is more damaging to the environment, rail solutions can utilise locally generated electricity (using coal or renewable energy sources) (Havenga 2011). Electrification is however only feasible on the higher density freight lines of South Africa and not viable to the NSC-Rail System north of the RSA border.

Railfuture (2016), a UK based rail promotion group, has published ten success factors for the rail industry to apply and government to support a level playing field for rail service providers. These ten success factors are Reliability, Capacity, Value for Money, Quicker journeys, Customer service, Modal Integration, Network connectivity, Organise for success, a Level playing field and Investment in rail systems.

3.6. Rail Economics

The freight-flow market spaces are described in terms of transport distance, cost and density. A future critical requirement is to determine how much freight and specifically which freight can switch to rail. The need is to identify the freight flows that will exploit rail's economic fundamentals. Rail economics principles indicate that freight flows with high density over longer distances are well suited to transportation by rail. (Havenga 2011)

A large proportion of rail costs is fixed (Pietrantonio & Pelkmans 2004 cited by Havenga). Rail infrastructure and rolling stock investments result in asset driven fixed costs for the rail system.

Due to the high level of fixed costs, the average cost per tonne/km and profitability are directly related to the degree of traffic density. It is essential to meet efficiency levels to be competitive.

A complication for rail in Southern Africa is that the region has a debilitating modal imbalance, where road hauliers are cross-subsidised by other road users (such as private

vehicles, etc. in carrying the costs of the road infrastructure. Dense corridors are however, ideal for rail- and intermodal transport. (Havenga 2011).

3.7. Transportation Modes

There is a critical density threshold, which implies that railways will only be competitive if the dense traffic flows exploit the **generic technologies** that distinguish railways from other transport modes. (Van der Meulen 2007 as cited by Havenga 2011)

*a. Railways have **only one degree of freedom** in propagation.*

b. Road transport, two degrees of freedom.

c. Air transport; three degrees of freedom.

The differentiating intrinsic technologies of rail are high axle loads, guidance (track which allows safe relative high speed of movement) and coupling (long trains with massive volumes) (van der Meulen, 2007).

These characteristics are ideal for **high volume-time** and **long-distance** solutions. Van der Meulen defines four international freight rail market spaces:

a. General Freight – slow moving light axle loads – not distance sensitive
b. Heavy Haul – high-density heavy axle loads preferable over distances exceeding 1000km.
c. Heavy Fast-Moving Consumer Goods (FMCG) – bimodal rail/road solutions, light axle loads, high value finished products, in the 200-500km space. Typical cargo includes containers, automotive, etc.
d. Heavy Intermodal – high containers heavy axle loads. The Southern African rail infrastructure is not suitable for this category due to the Cape gauge track.

Havenga (2011) concludes that freight transportation requires intermodal or multimodal solutions. He identifies clear opportunities for intermodal solutions benefitting both road and rail, but concedes that the intermodal systems which have successfully been implemented in the Americas, Europe and Australasia have unfortunately not been realised in Southern Africa.

3.8. Business Modelling

Rail is a "service business" orientated system (ERRAC 2014). Osterwalder and Pigneur (2009) applied new thinking to Business Model Generation in their handbook for practitioners striving to defy outmoded business models and design tomorrow's enterprises. They state, "A Business model describes the rationale of how an organisation

creates, delivers and captures value." This rationale is captured in their *Business Model Canvas*, presented in figure 3.3.

In his work to develop a Business Model for a rail freight service, Zhang (2010) identified the following important elements to understand:

a. Main cost drivers.
b. Pricing policies.
c. Price differentiation strategies.
d. Supposed weak position of service suppliers.
e. Business segments for the market.
f. Pricing principles for intermodal rail services.
g. Variable & fixed costs.
h. Time horizon for the service.
i. Cooperation between stakeholders on the service supply side.
j. Role of third party logistic (3PL) service providers.

The EU-CREAM Project (2012) delivered templates for road-competitive rail-based supply chains to be applied by all operators on the Trans-Europe corridor. These include:

a. Business model for railway undertakings.
b. Business model for intermodal operators.

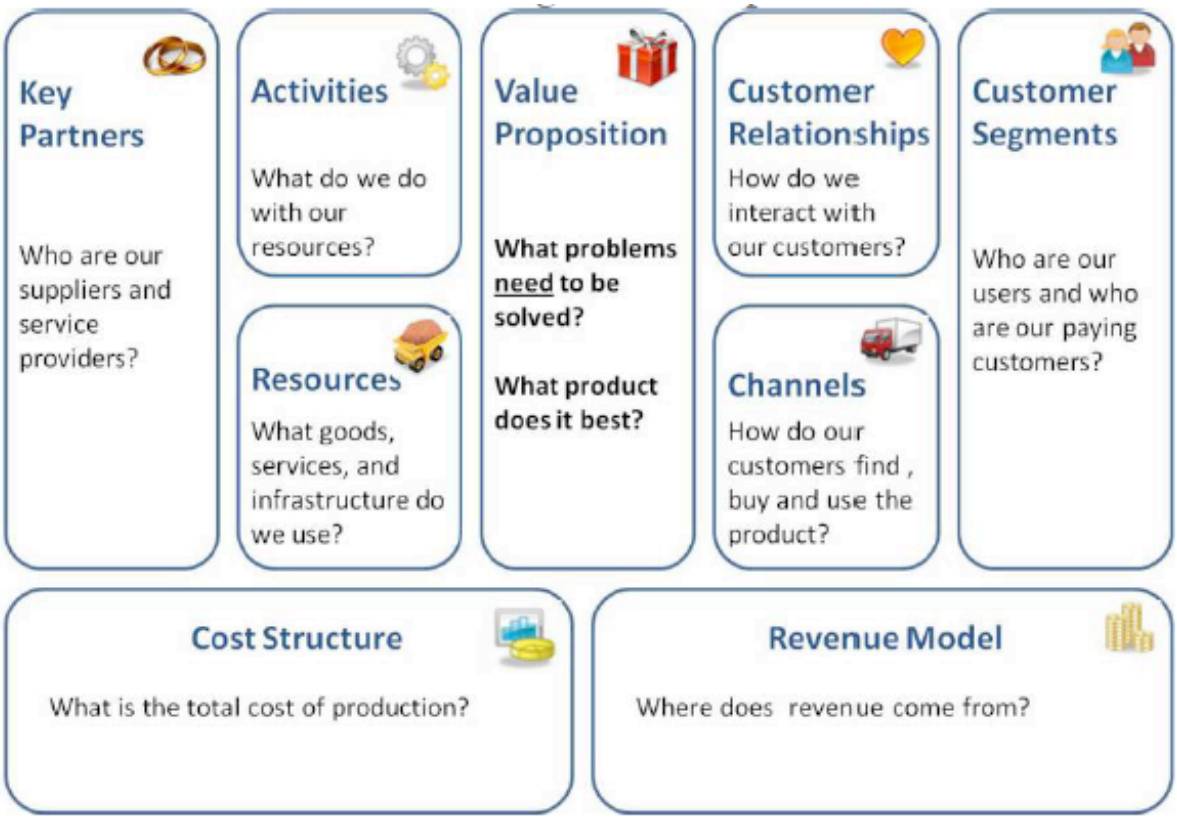


Figure 3.3: The Business Model Canvas (Osterwalder & Pigneur 2009)

Havenga (2011) states, “The case studies do not build a clear case for any specific model of rail reform.” It can however be concluded that rail reform must be driven by 1) reduce logistic costs, 2) sound business principles, and 3) sustainable macro-economic development principles.

3.9. Rail Freight Modelling / Operating Concept Description

Techniques for freight transport modelling have developed over time. During the 1980’s Multi-modal Networks techniques were used, then in the 1990’s Agent-Based Simulation models were used, whereas since the 2000’s Freight Network simulations are preferred. (Tavasszy 2008 as cited by Cloete-Hopkins)

In his study of a Scheduled Service Network Design for Integrated Planning of a Rail Freight Transportation system, Zhu (2011) modelled the rail-planning problem to a **service network design formulation**. This is a complex mixed-integer programming formulation. He applied a 3-layer time-space structure, where the time dimension provided for temporal impacts.

On their Spanish branch-line corridor, Woroniuk & Marinov (2013) assessed the level of utilization of the rail corridor using a series of simulation models. They applied a multi-method approach with discrete event based simulation models using Arena™ simulation software.

Havenga’s (2011) first step in analysing the SA freight-market space was to develop a comprehensive freight flow model. This model is complex and data intensive. It provides a view of supply and demand, modal market share, where on the network freight is moved and what (commodities/cargo) is moved. From the records of freight-flow data between defined origin and destination pairs, key flow patterns can be identified.

3.10. Stratified Systems Theory

Stratification is the layering of managerial accountability hierarchies into organisation strata. This is the core concept of Stratified Systems Theory defined by Elliot Jacques (1989). The way managers go about their work differs both quantitatively and qualitatively based on the levels of stratification in hierarchically structured bureaucratic organisations. In figure 3.4 the level of task complexity increases with organisation levels increasing from pure operational to pure strategic responsibilities are presented.

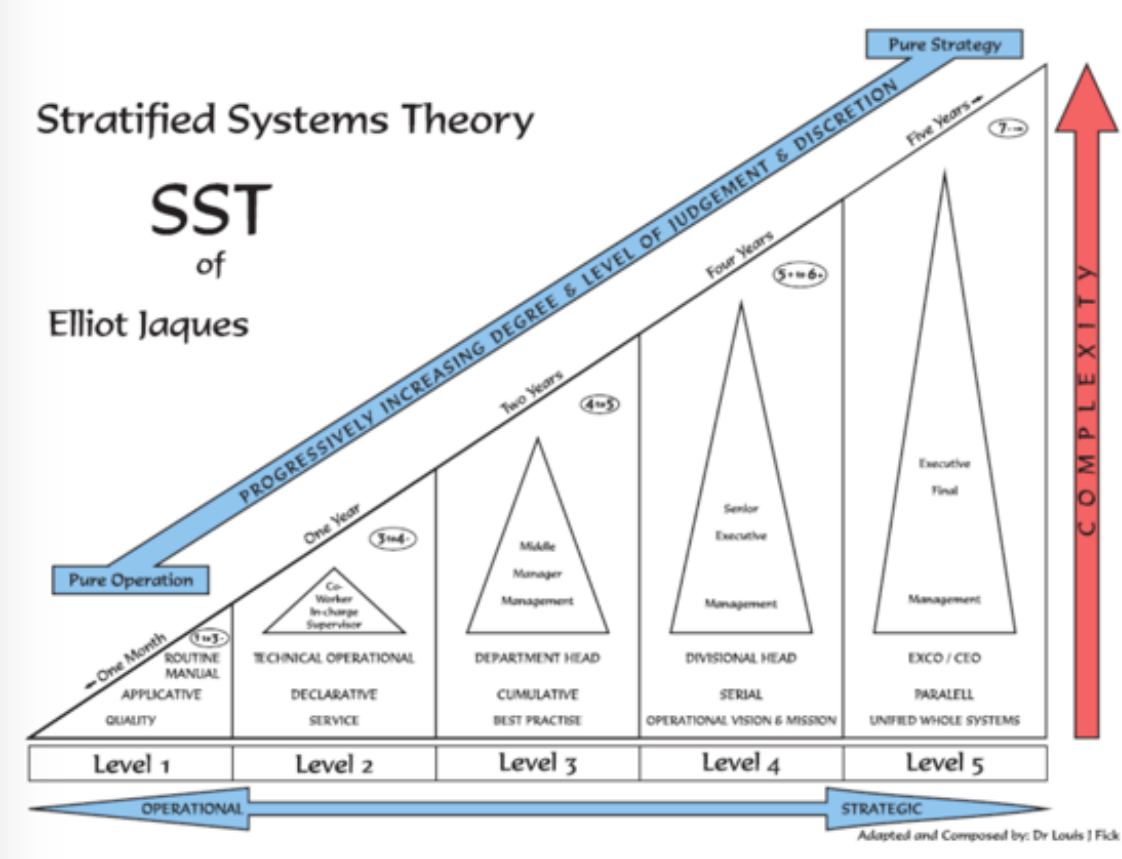


Figure 3.4: Stratified Systems Theory (Fick, LJ)

Stratified Systems Theory provides a multi-attribute framework for understanding both human capability for carrying responsibility for work and the structure of work in modern society, while recognising the duality of analytic/intuitive approaches to accomplish work. Work within these organisations consists of a complex mix of interactions involving individual mental effort, social relationships and the organisational structure. In Jacques's (1989) view all work is goal-directed and must be performed within prescribed limits of expense, quality and time. All work contains some level of discretion in which the person carrying out the work must exercise judgement and an intuitive sense about how to go about performing the assigned work. To have a Requisite Organisation the layers are based on the capability of thinking required at each level. This capability must handle ever increasing complexity, that spans across greater timeframes.

3.11. Viable Systems Model

Stafford Beer's (1972) Viable Systems Model describes the re-occurring five systems that naturally operate in all organisations. These 5 natural systems are presented in figure 3.5 below.

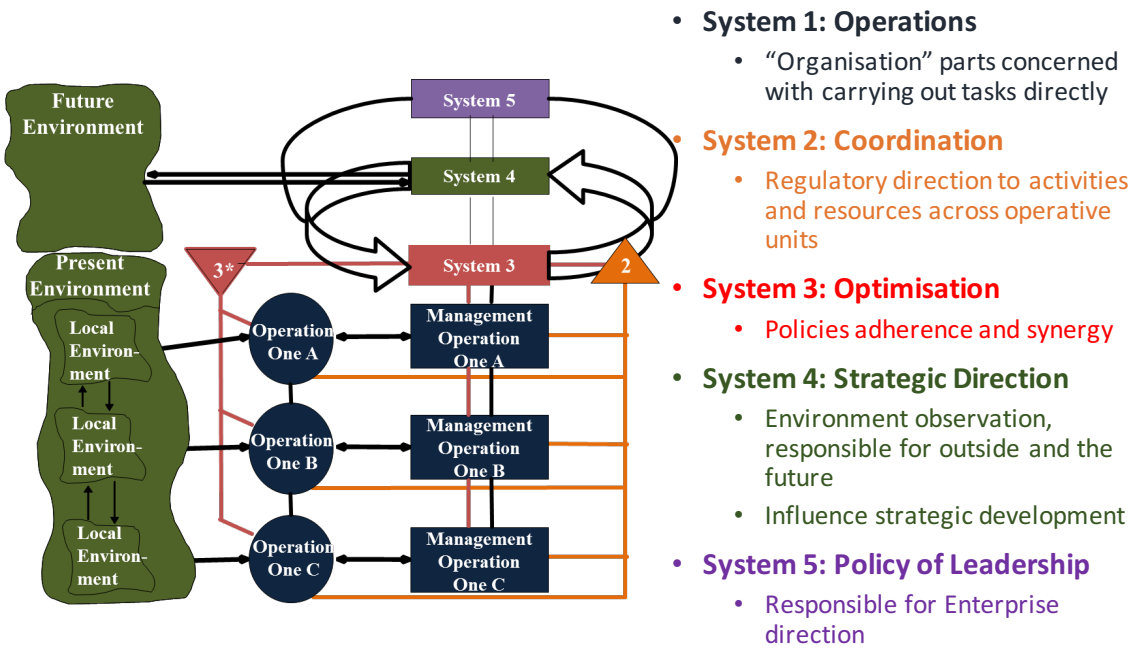


Figure 3.5: The Viable Systems Model (Stafford Beer 1972)

These reoccurring set of 5 systems are nested in a hierarchical structure where each ascending level has a broader mission and includes the level below. Of specific interest to the NSC-Rail System is System Level 2, Coordination between the independent operations units, and System Level 3, Optimisation of the integrated performance of all the independent operations units.

Problems occur when organisations lose their Vertical leverage. Instead of enabling leadership, the layers of an organisation then create bureaucracy. With effective Vertical leverage in the organisation, the focus is on enhancing Horizontal flow.

3.12. System Dynamics

System Dynamics is a field of study that includes a methodology for the constructing of computer simulation models to achieve better understanding of social and corporate systems. It draws on organisational studies, behavioural decision theory, and engineering to provide a theoretical and empirical base for structuring the relationships in complex systems.

Causal Loop Diagrams are diagrams consisting of arrows connecting variables (things that change over time) in a way that shows how one variable affects another. They map out core cause-effect relationships among system elements (Meadows and Behrens, 1974).

3.13. System Effectiveness

System Effectiveness is about ‘doing the rights things’. Rebentisch et al (2017) measures effectiveness as the “measures used to monitor the achievement of the mission or operational objectives of the system, or how well the solution achieves the intended purpose.” Mitter (2002) argues that system effectiveness is intimately tied to structure. The system can include technological as well as social and economic sub-systems. To be effective these sub-systems have to be coherent. Such coherence requires viewing the system as a “whole” which always has an environment and is measured against internal and external value systems. The system is observed by a multitude of external observers, with each observer possessing its own value system to measure the system effectiveness from their context. Forsberg (2005) states that cohesion is the degree of interactivity and interdependence among solution elements.

3.14. System Efficiency

System Efficiency is about ‘doing things right’. Efficiency is generally measured quantitatively as the ratio of outputs produced by the system against the inputs used by the system to transform these inputs into the produced outputs (Blanchard and Fabrycky, 2019). Efficiency is thus a measure of how optimally the system utilises its production and other resources, with a good efficiency rating indicating a system that minimises waste. In a system of systems, optimising efficiency in the individual sub-systems, may often lead to a sub-optimal performance of the system, as a whole.

3.15. Innovative- / Disruptive- / Emerging- Technologies

Innovative rail-based supply chains, including intelligent rail and multimodal operation models, are in the future of freight transportation. Additional customer services, such as, tracking and tracing information and intermediate storage of intermodal units will also be required (EU-CREAM Project 2012).

IVU Rail (2016) is a global company promoting an integrated commercially available rail management solution. It has been included in this literature study as an example of what integrated rail management systems can typically address. Innovation trends are based on the integration and convergence of technologies.

For Europe interoperable, international and intermodal transport at competitive cost is of utmost importance. This requires a highly reliable and low cost infrastructure. The Europe 2020 strategy is based on smart, sustainable and inclusive growth, but is also concerned

about environmental, security, social and economic implications. In addition, there is a drive to avoid transport pollution and congestion (EU-CREAM Project 2012).

Intermodal containerized transport is the fastest growing freight transport segment in Europe. "*The intermodal market segment is capable of extracting the maximum productivity from each transport mode according to the principle of co-modality.*" (ERRAC 2014)

The European rail corridors will allow **unhampered border-crossing for international traffic**, connect hubs for collecting and distributing goods and facilitate cost-efficient and high capacity rail service access. The rail services must be supported by intelligent processes and adaptive technology to serve an extended spectrum of logistic needs.

In his paper on the Southern African NSC Wiggel (2016) states that the NSC requires innovative disruptive technologies to serve sub-Saharan Africa's transportation needs.

3.16. Sub-Saharan NSC

In his article in Transport World Africa, Wiggel (2016) argues that the NSC from Durban (RSA) to Dar es Salaam in Tanzania is Southern Africa's most important trade route. He states that the road mode of the route is too heavily skewed in favour of SA exports and other imports to northern countries (north bound traffic), with much less southbound freight for the return trip.

Wiggel (2016) states that not enough containerized cargo is being moved in and out of the countries along this route.

The NSC's ca 3,000km plus journey with multiple stop-off points is primarily served by road transport (90% plus road and rail 10% minus). The further north from the RSA one goes, the less developed facilities become. Typical hazards to road hauliers are having to pay cash for fuel (US$ based pricing in Zimbabwe) and for border processing. The fallibility of GSM connectivity along the route is a further concern for tracking and communication with haulers.

The notoriously high transport costs on the NSC, compared to other major regions of the world, is a serious limitation on the economic development of the SADC region.

4 RESEARCH METHODOLOGY

The purpose of this chapter is to describe the research methodology used to address the research question; ***Why has the freight market share of the NSC-Rail System shown such dramatic decline in a fast growing market, what can the NSC-Rail System do to regain and grow its market share and what is an appropriate business model for the NSC-Rail System?*** The objectives of this research are to understand, conceptualise and structure the rail freight business model and concept of operation (CONOPS) for the NSC-Rail System, with this research interrogating the following:

a. The current stakeholders and operations of the NSC-Rail System.
b. The nature and volumes of trade (demand and supply) along the NSC-Rail System.
c. The Supply Chain Services required to support the NSC-Rail System.
d. Available Transportation Services (modes and infrastructure) serving the NSC-Rail System.
e. Which transport networks and routing options are available to customers and potential customers of the NSC-Rail System?

4.1. Research Approach

The research question drove the selection of the research approach. Both qualitative and quantitative views are important and these are combined in the pragmatic paradigm allowed by a mixed methods research approach. An **Exploratory Sequential Mixed Methods research approach** (Subedi, 2016) was used in this study to determine the driving factors in the NSC-Rail System, and to analyse the NSC-Rail System as a complex system. This research design allows a very practical and applied research philosophy (Subedi, 2016). Brannen (2005) suggests that in the current trend towards evidence-based practice and the systematic review of social science research, research that combines qualitative and quantitative methods is of importance.

4.1.1. Mixed Methods Research

Mixed methods research questions are concerned with unknown aspects of a phenomenon and are answered with information that is presented in both numerical and narrative forms. It may contain a single research question that is overarching in nature and incorporates both the qualitative and the quantitative sub questions (Teddlie and Tashakkori, 2009).

Brannen (2005) suggests that a distinction is made between the context of enquiry or the research design phase and the context of justification where data are analysed and interpreted.

Research challenges faced when using a mixed methods approach are how and when to connect the qualitative and the quantitative phases during the research process, and how to integrate the results of both phases of the study to answer the research questions. A further question on the research outcomes is whether the qualitative findings and quantitative results converge (Subedi, 2016).

4.1.2. Qualitative Research

The qualitative research portion was primarily exploratory and gave the researcher data which are rich in meaning. This data contribute to understanding the underlying perceptions, beliefs, opinions and insight to address a particular problem (Grosvenor, 2000). In this study, the problem is that the NSC-Rail System is losing rail friendly bulk freight traffic to road transport in a growing market. The trustworthiness of the qualitative findings were supported by using techniques such as triangulation and peer debriefing.

Osterwalder's (2009) Business Model Canvas Framework was selected as the most relevant theory for this research to develop a model for optimising the Business Model for a seamlessly integrated rail system within the NSC. In this chapter the framework is operationalised for the NSC-Rail System illustrating the various factors that influence the business model of the NSC-Rail System.

Paragraph 4.3.3 explains the research structure based on an adapted version of Osterwalder's (2009) Business Canvas Model Framework for the assessment of NSC-Rail System business and operational aspects.

4.1.3. Quantitative Research

The importance of including systems paradigms in the research of the NSC-Rail System was highlighted from the literature study in Chapter 3. The NSC-Rail System was analysed as an open system with the NSC-Rail System as the System of Interest (SOI). Stratified Systems Theory (SST) (Jaques, 1989) was used to provide a framework for presenting the business operations of the SOI and to link a Concept of Operations (CONOPS) to the NSC-Rail System. The identified poor service levels of the NSC-Rail System was analysed through Node Flow Mapping and through Value Stream Mapping.

4.2. Research design

A mixed-method approach (including both qualitative and quantitative elements) was adopted in this research. Data collection included:

- An analysis of NSC-Rail System related reports,
- A corridor routing analysis,
- A questionnaire to obtain unrestricted stakeholder viewpoints, and
- Inputs from corridor rail operator stakeholders work-sessions.

In the exploratory sequential design the researcher first collects qualitative data and then quantitative data. This research design evolved during the study and supported the researcher's assumption that the qualitative element will play a dominant part in the study. Brannen (2005) noted that ways in which the qualitative and quantitative research are combined is impacted by (a) the importance given to the qualitative and quantitative phases by the researcher and (b) by the time ordering or sequencing of the approaches. The third phase of the research process is the phase of interpretation and contextualization of the findings. "Contextualising is a critical part of a mixed-method strategy in creating and making sense of data" (Brannen, 2005, pp 182).

The **exploratory sequential mixed-methods research design** used in this research is presented in figure 4.1.

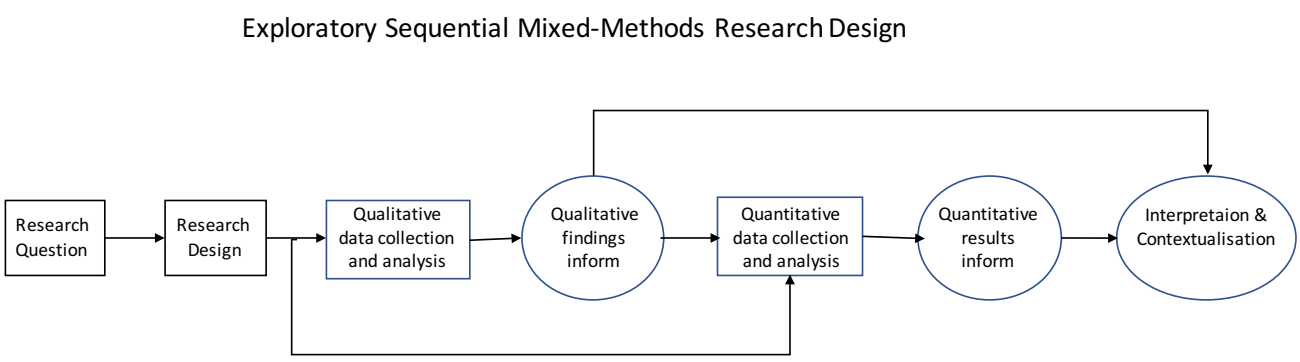


Figure 4.1: Exploratory Sequential Mixed-Methods Research Design (adapted from Subedi, 2016)

A questionnaire served as the central method of the qualitative research element. The core data from the questionnaire was compared to the data from the other methods. In contrast to quantitative research, which uses statistical analysis, qualitative research focusses on recording and describing events as they occur in order to establish a greater understanding of specific trends (Strangor, 2014). The qualitative element of this research sets out to explore the factors, reasons, and challenges impacting the NSC-Rail System that contribute

to the performance of the system and is thus reflected in the strategies and the business model for the system.

As applied in Systems Engineering, a systems diagram identifying the context in which the rail system operates and how the interdependent links are managed, by the multiple stakeholders in the corridor, adds huge value to understanding the interactions and conflicts in the system. Qualitative research is useful to go deeper into issues of interest and explore nuances related to the problem at hand. That is, *if the NSC-Rail System has been designed to handle freight volumes of 6 million ton per annum (mtpa) (10 times its current volumes), and the rail friendly bulk traffic volumes are growing, why then is this traffic favouring the road transport mode, and why is the rail system not competitive in a market-area where it should naturally have a competitive advantage?*

4.2.1. Qualitative Data Analysis

The aim of qualitative data analysis is to identify meanings and interpretations from a conceptual framework or model which is used as a reference for further analysis. In qualitative research, analysing records is largely subjective. This is due to the human element involved in choosing what data to analyse and how this information can be decomposed to uncover the participant's meanings. The researcher's role in qualitative research thus impacts the interpretations and the findings, as the researcher performs a fundamental part in the interpretation of the findings, and the researcher's background and experience can impact the interpretation of the data. Triangulation as discussed below, can to a level, contribute to limiting this bias effect from the researcher's own framework.

- ***Content Analysis*** is a qualitative technique used to analyse the data. Working through the contents of the open-ended responses to the questionnaire, the researcher noted specific statements reflecting the views, perceptions and experiences of the participants. The impact of these statements were reinforced by the number of times that different participants gave responses which together contributes to a research finding.
- ***Document analysis*** is another qualitative method. Document analysis is efficient in that it allows the researcher to obtain available data, thus requiring less time. The document analysis method also has some limitations, such as not necessarily producing sufficient detail needed to answer a research question.
- ***Triangulation*** is an approach used to improve the validity of the research outcomes. Triangulation compares the responses from independent different sources to validate

the findings or question discrepancies between them. In this study information collected from the responses to the questionnaires was therefore compared to the information in the document analysis and the same for the outcomes recorded from the stakeholder work-sessions and the views of informed specialists. Convergent results supported the research findings whereas divergent results required further exploration and explanation.

4.3. Operationalising a Business Model Framework for the NSC

4.3.1. Osterwalder's (2009) Business Model Canvas Framework

Osterwalder's (2009) Business Model Canvas Framework was discussed in Chapter 3 and describes the structural factors impacting the business model of the system. The nine elements identified in the Business Model Canvas are:

a. Deliver a proposed "Value Proposition" for the business. This will report on the problems to be solved and on the outcome of analysis of alternative ways to best solve the problems.
b. List the identified stakeholders ("Key Partners") in the business and record their roles and expectations of the business.
c. Report on "Customer Segments", who are the system users and who are the paying customers.
d. "Customer Relationships" will cover the interaction with customers of the business.
e. Address "Channels" through taking a systems approach on how freight is handled from source, through the origin- and the destination terminals and onto the end-users. The three flow items, i.e. freight (material), information and money must be included in the model.
f. Model the business Operation ("Activities") to support the recommendations on the optimised traffic mix and the proposed train planning for the NSC.
g. Recommend the capacities ("Resources") required from the rail network (infrastructure), freight wagons, locomotives and crews to deliver the service.
h. The "Revenue Model" will define where the revenue will come from and how it will be shared.
i. The "Cost Structure" will capture the total cost of delivering the NSC rail services.

4.3.2. Zhang (2010) Business Model for a Rail Freight Service

Zhang (2010) identified the following important elements for developing a Business Model for a rail freight service. This includes:

a. Main cost drivers.

b. Pricing policies.
c. Price differentiation strategies.
d. Supposed weak position of service suppliers.
e. Business segments for the market.
f. Pricing principles for intermodal rail services.
g. Variable & fixed costs.
h. Time horizon for the service.
i. Cooperation between stakeholders on the service supply side.
j. Role of third party logistic (3PL) service providers.

4.3.3. The Application of the Business Model Canvass to the NSC Rail System

The application of Osterwalder's (2009) Business Model Canvas (BMC) Framework to the NSC-Rail System is summarised in Table 4.1, which includes the contributing factors, based on Osterwalder's (2009) work, in the left column. The impact of each factor in the business model and the methods used to collect the data are explained in the middle and right columns respectively.

TABLE 4. 1 The NSC-Rail System Business Model Canvas (BMC) Framework

BMC Factors as defined in the model	Adapting the BMC factors to the NSC-Rail System	Data collection methods used to obtain the Qualitative & Quantitative data needed
Value Proposition What problem needs to be solved? What service offering does it best?	- The NSC-Rail System Value Proposition to its customers and other stakeholders will determine its success. This needs to be compared to the road transport mode offering.	-Published NSC-Rail Service offerings. - Responses to Questionnaire.
Customer Segments Who are the users and who are the paying customers?	-The viability of the system is dependent on servicing paying customers. -Other users may also benefit from the socio-economic contribution by the system.	-Published data on the NSC traffic volumes. - Economic development publications and forecasts from SADC. -Responses to Questionnaire.

BMC Factors as defined in the model	Adapting the BMC factors to the NSC-Rail System	Data collection methods used to obtain the Qualitative & Quantitative data needed
Customer Relationships How does the system interact with its customers?	-The marketing function is a key factor in system success. -How is this function currently performed? -How should it be performed in future?	-Reports from Work sessions with NSC stakeholders. - Responses to Questionnaire.
Channels How is the NSC rail service delivered to the customers? How do they access the system?	- The system should address the terminals at either end and along the corridor to provide customers access to the rail service. - Port facilities at the sea ports must be adequate to service the shipping lines. - Inland loading and unloading is also a focus area. This applies to bulk freight, agricultural produce, industrial equipment and containers.	- Economic development publications and forecasts from SADC. - Corridor Routing Analysis. - Responses to Questionnaire. - Feedback from Informed Specialists.
Activities How does the system operate?	-The operations of all the stakeholders forming part of the service delivery must be considered. -The activities in the system must be co-ordinated and integrated.	- Reports from Work sessions with NSC stakeholders. - Corridor Routing Analysis. - Responses to Questionnaire.
Resources What infrastructure, equipment & services do the system use to deliver the service? What are the capacity constraints? What is the availability of the resources?	Key resources to enable the system are; - the infrastructure, both the railways and the terminals. - equipment such as locomotives and wagons .- trained personnel - communication, planning and control systems - funding, both for operations, maintenance and rehabilitation where necessary.	- Published NSC-Rail System Reports. - Reports from Work sessions with NSC stakeholders. - Corridor Routing Analysis. - Responses to Questionnaire. - Feedback from Informed Specialists.

BMC Factors as defined in the model	Adapting the BMC factors to the NSC-Rail System	Data collection methods used to obtain the Qualitative & Quantitative data needed
Key Partners Who are the suppliers and service providers on which the system depends?	-Suppliers ensure the sustainability of the system -Service providers, such as freight forwarders, clearing agents, logistic service providers and consultants are necessary for the effective operation of the system.	- Published NSC-Rail System Reports. - Corridor Routing Analysis. - Responses to Questionnaire. - Feedback from Informed Specialists.
Cost Structure What is the total cost of providing the service? What are the cost-drivers? Who contributes what elements to the total cost?	- Delivering the service necessarily incurs costs which have to be paid. It is important to understand the costing of each activity to allow a fair allocation of costs and to make conscious decisions on cross subsidising occurrences.	- Published NSC-Rail System Reports. - Corridor Routing Analysis. - Responses to Questionnaire. - Feedback from Informed Specialists.
Revenue Model Where does the revenue come from? How is the revenue shared amongst the corridor stakeholders?	- From a Business Model point of view, earning a reliable revenue stream is a major contributor to the performance of the system. - Subsidies may also be obtained based on socio –economic considerations.	- Published NSC-Rail System Reports. - Reports from Work sessions with NSC stakeholders. - Corridor Routing Analysis. - Responses to Questionnaire. - Feedback from Informed Specialists.

The above table highlights the factors in the system, researched to develop a framework for a performing business model.

4.4. Data Collection Methodologies

4.4.1. Required Research Data

For the purposes of this study, the SOI is the NSC-Rail System inclusive of the inland terminals at producers/consumers and the shipping ports of Southern Africa. In order to contextualise Osterwalder's (2009) Framework to suit the NSC railway corridor context adjustments to the generic factors were necessary. As was explained in Chapter 2, there were a few difficulties in applying this model to a fragmented rail corridor where the priorities of stakeholders are seemingly not always aligned. In an integrated business entity the executive management will provide the strategic direction for the business, followed

by derived lower level business plans and projects driven by the operational managers, within the directed strategic framework.

In the NSC-Rail System, the stakeholders are primarily independent sovereign governments, regulators and operators, with customers and suppliers unrelated private sector entities. The priorities of these stakeholders may differ at any point in time and thus measuring a NSC-Rail System strategy will be the combined outcome of individual strategies of all these stakeholders. A further complication in the NSC-Rail System is the multiple border crossings and the varied customs regulations of the independent countries. This inevitably introduces the reality of successive delays for the trains heading both north and south.

The participants in the research were rail operators, freight forwarders, mining customers, logistic service providers and suppliers to the rail industry. This group of participants is further discussed in the Chapter 5. Some representatives of the sovereign governments, as the infrastructure owners, regulators, development financiers and strategic leaders declined to participate in this research. Some respondents questioned the "political will" of authorities to contribute to an integrated NSC-Rail System. Railway systems consultants contributed well informed views on the opportunities and challenges of the system.

An additional contribution was obtained from the members' association of all the rail operators in the SADC region, the Southern African Railways Association (SARA). SARA acts as a sub-committee of SADC and plays the important role of ***harmonising*** joint planning for the rail corridor. SARA has made positive strides in setting standards for technical and safety standardisation, but being only an ***association*** they have no mandate to assure alignment or integrated control of the corridor rail operations. Chapter 5 will expand on feedback received on the frustrations with slow implementation of accepted SARA resolutions, by the individual SARA members.

Customer opinion regarding NSC rail service was deemed an important factor to include in this research and is represented by way of freight forwarders, logistic service providers and mining clients. The role of customers is acknowledged as an external pressure that can force the system design and the service design, inclusive of required delivery times, benchmark pricing, security of goods and system safety. However, in this research the inclusion of the customers' viewpoints give more impetus to the concept of public-private-partnerships (PPP) in the infrastructure rehabilitation and future service offering of the rail system. Customers also indicated the factors which impact their decision to shift their traffic from rail to road mode and vice versa.

The importance of a reliable and cost-effective rail system for bulk freight transport in the socio-economic environment of Africa is accepted by all stakeholders. A further study analysing the relationship between such a desired rail system and economic development of the corridor/region has also been initiated at The University of the Witwatersrand (WITS). The historical context where the initial railway lines were built as part of the British colonial vision of a Cape to Cairo railway project was abandoned after the corridor countries obtained sovereign independence. After years of underinvestment and the deterioration of the rail infrastructure, Africa is now experiencing an economic revival and needs the developmental benefits to be harvested from a performing NSC-Rail System.

4.4.2. Data Collection

The approach to the different sources of data and methods applied to use these data is summarised in Figure 4.2.

1. Analysis of SADC & NSC-Rail System related reports

-To inform the interest in and developments taking place in the NSC-Rail System

-To confirm the perceived importance of the system in its socio-technical environment

2. Corridor Routing Analysis

-To appreciate the geographic routing of the NSC rail corridor

-To take note of the multiple independent countries linked in the corridor

-To get an understanding of the constraints, bottlenecks, border crossings and other flow challenges along the corridor

-To determine alternative rail routings based on available infrastructure options

3. Records of NSC stakeholder work sessions

-To acknowledge the concerns and current harmonisation efforts of stakeholders in the NSC

4. Questionnaires

-Approached representatives of all stakeholders in the NSC

-Stakeholder groupings to determine supporting or conflicting viewpoints on the performance of the system

Figure 4.2: Methods and sources of data used in this research

4.4.3. Analysis of SADC and NSC-Rail System related reports

The purpose of analysing the SADC and NSC-Rail System related reports was to determine what information on the past, current and future status, perceptions, expectations and planning with regards to the NSC-Rail System is publicly available.

4.4.3.1. Sourcing of Reports

SADC and NSC-Rail System related reports are published from different independent points of views and also represent different time periods. The reality that the NSC corridor links up to eight independent sovereign countries (when the Tazara line, Botswana, Swaziland and Mozambique are also included) was clearly reflected in the public reports. The loss of bulk traffic from rail to road mode has also been well covered in publications (e.g. Freight Weekly magazine, Africa Rail magazine, etc.).

In addition to the reporting of events related to the NSC, the type of information reported on is also important. For this research, validated factual information is needed in order to feed this information into a conceptual business model framework. The perceptions of poor safety, poor security and poor services are regularly posted as explanations for the poor performance of the NSC-Rail System, as discussed in Chapter 3. The information from the reports analysed was also used in the development of the research questionnaire.

The annual conferences held by SARA included papers and presentations on plans for the NSC and also addressed the initiatives by the NEPAD Business Foundation (NBF) and the DBSA with their focus on infrastructure development in SADC.

4.4.4. Corridor Routing Analysis

The purpose of the NSC Routing Analysis was to;

- Map the geographic routing of the NSC rail corridor.
- Identify the multiple independent sovereign countries connected in the corridor.
- Develop an understanding for the constraints, bottlenecks, border crossings and other flow challenges along the corridor.
- Determine alternative rail service and road offerings and available infrastructure options.

4.4.4.1. Information Sourcing

Published documents and regional maps served as sources of information to inform the researcher on the geographic routing of the NSC rail corridor. Through plotting the rail route on a map of the SADC region, the multiple independent sovereign countries connected in the corridor and their applicable border crossings were highlighted. More detailed analysis of the specific factors interacting on each successive portion of the railway corridor contributed to a better understanding of the constraints, bottlenecks, border crossings and other flow challenges along the corridor. This analysis also explored the

junctions and connections with other connecting and branch railway lines. Through this analysis the socio-economic considerations of the connected communities all along the corridor could also be noted.

4.4.4.2. Data analysis

The routing diagram for the NSC-rail corridor indicates the traffic flows and will be an input to the conceptual business model for the NSC-Rail System. The routing diagram is used to conceptualise the dynamic behaviour that can be expected of the system.

4.4.5. Records of NSC Stakeholder work-sessions

The purpose of consulting the unpublished records of the NSC Stakeholder work-sessions is to acknowledge the concerns and current harmonisation efforts of stakeholders in the NSC-Rail System and for the researcher to compare this information element with the information obtained through the other research methods used in this study.

4.4.5.1. Sourcing of Information

In line with their individual commitments to SARA, the rail operators in the NSC-Rail System are engaging in work sessions to jointly co-ordinate and harmonise the operations in the corridor. They have established the Joint Operations Committee to fulfil these tasks at operational planning and execution levels along the corridor. The SARA members are aware of shortcomings in the rail service offering and are addressing these. SARA has developed a five year strategic plan with the main objective to support the increase of freight market share of rail in SADC. For this plan SARA has secured funding from the DBSA (NEPAD, 2019). The SARA members are also contributing to the NBF study on the NSC. This NBF study addresses the rehabilitation of the infrastructure and explores means to resolve operational bottlenecks in the system.

4.4.6. Research Questionnaires

Research questionnaires with open-ended questions served as the central method used in the qualitative phase of the research. The questionnaires provided information from individuals based on their knowledge, thoughts, opinions, beliefs and experiences. Respondents provided specific feedback on their experiences in dealing with the NSC-Rail System, that were compared to the information collected from the published reports, the routing analysis and reports from the corridor work-sessions.

4.4.6.1. Sourcing of Responses

After obtaining University Ethics Approval (refer to Appendix C), a research questionnaire (refer to Appendix D) was directly distributed to forty (40) identified key stakeholders listed as participants and important role players in the NSC-Rail System.

Responses to the questionnaire were reasonable, with seventeen (17) out of the 40 key stakeholders participating in the research. Eleven individual members returned completed questionnaires and one comprehensively completed group response (representing 6 stakeholders) was received. This group response is discussed in the paragraph below. While it is acknowledged that questionnaires can elicit a poor response rate, it was positive to note that from those who did respond, their responses did represent all the important stakeholder categories.

During the period of this study, the NBF (Africa Infrastructure Desk), commissioned a study on the NSC rail operations and infrastructure rehabilitations required. A group of key stakeholders, including some operators, consulting engineers, logistics consultants and financiers indicated that their inputs have been consolidated in the comprehensive NBF response. The group response was treated as an equal status single response input by the researcher, thus *not* weighting it as more important relative to the other individual responses obtained.

The researcher followed up on the non-respondents and the reasons put forward by these stakeholders for not wanting to participate in this study, actually contributed an interesting view of the underlying sentiments in the NSC-Rail System. A few large consulting companies directly questioned why the university is conducting research on the NSC, where they have established commercial interests. Some NSC transport executives declined to participate in the research so as not to risk possible disclosure of their business strategies to other participants. Similarly, some executive stakeholders indicated that they could not get permission from their organisations to participate in this research. The limitations of using a questionnaire for which the response rate can be low, was addressed by using multiple approaches to obtain data in this research.

4.4.6.2. Data analysis

Qualitative studies involve two important stages: (a) data reduction and (b) data analysis. Data reduction involves breaking the information down (decomposing) and coding the information into different categories and themes. It is a process of selecting, focusing,

simplifying, abstracting, and processing data to where information is summarised, coded, and grouped based on the researcher's aims. Data analysis is a more complex and iterative process, where once the information is coded into themes, the data are then presented so that the information can be compared and understood, thus the qualitative findings can inform the research.

After all the responses were received, the feedback was recorded in tables. This information was used to populate a structure based on an adaption of Osterwalder's (2009) BMC framework. Categorised responses detailed any emergent and re-occurring themes emanating from the data.

A qualitative approach, using basic content analysis, was used in the analysis of all the responses. Relevant phrases, sentences and words were identified from the feedback which formed the basis of identifying what themes were shared views, perceptions and feedback from all the participants. The analysis also differentiated where opposing views were recorded by participants consisting of either customers and/or service providers, versus the views of the rail operators' participants.

Data management required labelling and sorting the data according to themes or concepts in preparation for a more interpretative analysis (Spencer et al., 2012). The data analysis of the questionnaire responses required working systematically through the written texts to learn what the respondents say relevant to the research questions in order to sort the responses. Identified topics emanating from the feedback were recorded. The topics were confirmed and the process repeated, until themes emerged from the data that addressed the overall research question.

Spencer et al. (2012) state that once the data have been managed, the researcher commences with the abstraction and interpretation process. Themes based on the structured questions, interpretations of responses, and views stated were noted. Logical sense of the patterns within the data were developed. Chapter 5 provides an analysis and discussion of the qualitative findings.

4.5. Ethical considerations

Since mixed methods research combines qualitative and quantitative research, ethical considerations need to attend to typical ethical issues that surface in both forms of inquiry (Subedi, 2016).

Conducting this research required obtaining permission from the University to approach target stakeholders, with the intent to obtain access to strategically sensitive and commercially confidential information through an open ended questionnaire (Appendix D). NSC Reports published in the public domain did not require any ethics clearance for it to be referenced during this research project.

Given that confidential information was provided in the documentation analysed and in the records of corridor work-sessions, and that human subjects were participating in the questionnaires, the researcher had to apply for University Ethics Approval. Approval was granted with the ethics protocol number H17/02/04. Ethics principles such as informed consent, anonymity, confidentiality, the right to withdraw and the provision of feedback were all included as part of the ethics submission. Appendix C details the ethics approval documentation.

4.6. Concluding remarks

A mixed-method approach (including both qualitative and quantitative elements) was adopted in this research. Data collection included:

- An analysis of NSC-Rail System related reports,
- A corridor routing analysis,
- A questionnaire to obtain unrestricted viewpoints from stakeholders, and
- Restricted minutes of corridor stakeholders work-sessions.

Qualitative techniques allowed the researcher to process the questionnaire responses received. Qualitative research is an iterative process of analysing and interpreting the data, and exploring relationships and interactions between the information collected. Triangulation of the questionnaire responses with document analysis outcomes and feedback from informed specialists was used to improve the validity and reliability of the qualitative phase of this research. The qualitative study provided the researcher with an understanding of the NSC-Rail System, its multiple interacting sub-systems and context elements. It also provided a means of conceptualising the factors impacting the business model and CONOPS of the system.

Quantitative analysis allowed the researcher to include systems paradigms in the research and analyse operational performance aspects of the system. Stratified Systems Theory (SST) was used to provide a framework for presenting the business operations of the SOI and to apply a CONOPS to the NSC-Rail System. The identified poor service levels of the NSC-Rail System were analysed through Node-Flow Mapping and Value Stream Mapping.

5 RESULTS OF THE STUDY

5.1. NSC-Rail System related reports.

NSC-Rail System related publications were studied to get acquainted with the applicable body of knowledge, appreciate the key system elements, learn of the various perspectives on similar challenges, appreciate the broader systems thinking in approaching such challenge and build the research on the science base of the subject system.

Appropriate data on the NSC-system and its environment were obtained in order to determine a suitable concept for modelling the NSC-Rail System. Data were primarily sourced from publications by SADC, SARA, Prof JH Havenga at the University of Stellenbosch, NEPAD Business Foundation and from publications by the African Union. Annual reports from operators such as Transnet (TFR division) and Grinrod (BBR-holding/parent company) provided insight into the NSC rail operations. A report from Ivanhoe Mines LLC on the development plans for two new copper mines in the southern DRC was also considered.

Typical data elements obtained from the reports are:

a. Socio-economic and political inputs.
b. Nature and volumes of trade (Demand and Supply) along the NSC.
c. NSC available Supply Chain Services.
d. Available Transportation Services (modes and infrastructure) serving the NSC.
e. Transport networks and routing options available to customers and potential customers of the NSC.

5.1.1. NEPAD Business Foundation

NEPAD Business Foundation (NBF) (NBF 2014) states that the NSC's strategic intent is to establish a seamless, efficient, competitive and integrated cross-border logistics and freight rail transportation corridor linking the DRC and South Africa (from Kolwezi to Durban or Richards Bay) with the purpose of promoting an attractive rail service offering.

The aim of the NBF project study on the NSC-Rail System is an "Integrated rail investment and operating strategy through the establishment of an integrated corridor development plan to meet existing and growing freight volumes" (NBF 2014).

5.1.1.1. Current traffic transported by the NSC-Rail System

Table 5.1 gives a view on the current freight traffic on the NSC.

TABLE 5. 1 Current freight traffic along the NSC

North Bound Rail Freight	South Bound Rail Freight
• Coal/coke from Hwange to Zambia	• Copper (cathode and concentrate) from Katanga (DRC) & Zambia to ports
• Sulphur from Gauteng to DRC & Zambia	• Sulphuric Acid from Zambia to ports
• Fuel from Gauteng to Botswana, Zimbabwe, Zambia & DRC	• Maize from Lusaka to Zimbabwe
• Agricultural-produce from Gauteng to Botswana, Zimbabwe, Zambia & DRC	• Cement from Lusaka to Zimbabwe
• Containerised goods from Gauteng and Mozambique to Botswana, Zimbabwe, Zambia & DRC	• Sugar from Zambia/Zimbabwe/Swaziland to ports
• General Freight from Gauteng to Botswana, Zimbabwe, Zambia & DRC	• Coffee from Zambia/Zimbabwe to ports
• Automotive from Gauteng to Botswana, Zimbabwe, Zambia & DRC	

5.1.1.2. NSC-Rail System Operators

The operators along the NSC-Rail corridor are primarily SOC's being SNCC (DRC), ZRL (Zambia), NRZ (Zimbabwe), BR (Botswana), TFR (South Africa), SR (SwaziRail) and CFM (Mozambique). The exception to this practice is BBR, a Grinrod controlled subsidiary, which operates the Bulawayo to Beit Bridge portion of the railways in Zimbabwe under a concession from the Zimbabwe government. This concession to a private company (a private–public-partnership (PPP)) brings a new dimension in the integration of the NSC-Rail System into consideration.

5.1.1.3. Recorded issues to be resolved

An action plan for an economically sustainable and financially profitable railway service on the NSC is critical for all stakeholders.

Currently the rail share on the NSC freight traffic is less than 10% (ca 0,6 mtpa) with an estimated transit time (from origin to destination) of ca 30 days, whereas the road transport mode manages an average of 10 days transit time. The rail service must reduce its transit time to less than 10 days (reduce the traffic transit time by 66,6%) to be comparable with the road service offering.

The history of Africa's economic developments created long export and import corridor requirements. The rail market share on these Southern African corridors compares poorly with the trend in the USA, where USA's rail corridor market share is in excess of 50% and on a growth trajectory (Havenga, 2012).

The implementation of the outcomes of the NBF NSC Rail Infrastructure investment and Operating Study, once available, will be cardinal for the future of the NSC-Rail System.

The NSC-Rail System must grow the rail freight volumes and reduce the cost of rail transportation to its customers through better price and integrated service strategies.

5.1.2. Grinrod Integrated Annual Report (2014)

Grinrod (2014) refers to the political and economic complexities associated with railway projects in Africa. They see locomotive leasing in the NSC rail corridor as a growing business opportunity (for Grinrod). Grinrod has also obtained a concession to build, operate and maintain the Zambian Northwest Railway, similar in principal to the operations of their subsidiary, Beitbridge-Bulawayo Rail (BBR). Grinrod (2014) states the rail freight along the NSC rail corridor includes automotive carriers, fuel transportation, containerized cargo, mining minerals and intermodal traffic. Their stated objectives are to continue to explore ways to increase its volumes on the NSC.

5.1.3. Transnet Freight Rail (TFR)

The Transnet SOC (Transnet) Market Demand Strategy (MDS) business plan addresses the predicted future gap between customers' demand and the rail system capacity offering.

The MDS also requires operational efficiency improvement coupled with capital investment to meet the future demand.

The MDS key strategies are:

1. Operational Planning & Efficiency.
2. Market Development (from 23 – 30% by 2018/19 with volumes of 350 mtpa) by improving their value proposition and service offering to customers.
3. Intense Innovative Investments.
4. Inspirational Leadership and Employee Development

5. Accountability – organisation model redesign.
6. Safety, Risk and Environment.

5.1.3.1. TFR Business Units

TFR is structured in focussed business units, in an effort to best serve the market segments in which it operates. These are:

1. Agriculture & Bulk liquids (ABL)
2. Containers & Automotive Business (CAB)
3. Coal Business
4. Iron Ore & Manganese (IOM)
5. Mineral Mining & Chrome (MMC)
6. Steel and Cement (SAC)
7. International Business (including the NSC-Rail System north of RSA borders)

At Transnet Group level, Transnet has created an over border business initiative called Transnet International Holdings (TIH), with a mandate to promote Transnet engineering, rail and port operations businesses beyond the RSA borders. TIH has an important focus on freight opportunities in Africa.

5.1.3.2. TFR National Command Centre (NCC) (for integrated rail operations)

The southern portion of the NSC-Rail System from the RSA border posts of Beitbridge and Mafekeng to the ports of Durban and Richards Bay are impacted by the TFR Rail Network operating rules. The NSC rail traffic mix will be impacted by TFR's categorisation of rail traffic, simplified and summarised as;

a. Category A Train: (Highest Priority) Bulk commodities (coal, iron ore, minerals, etc) transported in long, heavy unit-trains (heavy haul operations) running from the mine-pit to the shipping port.
b. Category B Train: (Second Priority) Scheduled unit-trains, typically trains transporting containers or automotive products, running from origin to destination without the need for shunting. Thus, for example, typically "container trains" running from either the container terminal at City Deep to a container terminal at a port (or vice versa); or an automotive train running between the Gauteng Automotive terminal and an automotive terminal at a port (or vice-versa). This is a service offering akin to a "scheduled bus-service".
c. Category C Train: (Lowest Priority) The so-called "Less than full trains" transporting "general freight" (inclusive of agricultural produce, bulk liquids, wood, etc.). These trains must support multiple origin-to-destination combinations for the freight being transported. This train service follows a hub

and satellite type operation, which must provide for shunting of trains at these origins, satellites, hubs and destinations. The service offering is akin to a "taxi-service" where service is called for when required by the customers.

The present situation is that NSC corridor traffic entering the TFR Rail Network is treated as Category C Trains. TFR's key operating performance measure is "tonne-km". An argument can be made that their key operational performance measurement should be profit earned or revenue earned, or maybe "Rand-tonne-km" to measure an optimised operation. This current "tonne-km" performance measurement obviously biases the Category A high volume heavy trains transporting relative low-value commodities.

On the TFR portion of the NSC-Rail System, Category A trains are prioritised in terms of routing, track occupations, wagons & locomotives allocated, and crew assignments. Second in priority is Category B trains, with the result that service levels provided for Category C trains offerings are often compromised.

Trains from operators on the NSC-Rail System also differ from TFR trains on technical specifications such as safety regulations, axle load restrictions, train lengths and brake systems amongst others.

5.1.3.3. Switching from road to rail

"Given the heavy loads carried and long distances travelled, rail offers the obvious alternative to road. The realizable efficiencies of rail simply outweigh the cost and speed of road haulage. (Havenga, 2011).

Switching from road to rail is however complex. The planning and regulations of the various rail systems differ in vision, content and implementation. The NSC-Rail System displays a lack of coordination among national railway systems in the region. This translates to a lack of reciprocal access rights amongst operators.

The NSC-Rail System presents a failure to coordinate operational planning. Standardised technical support is urgently needed. On the NSC-Rail System locomotives from one operator stop at border posts, for change-overs to locomotives from the next operator, to take the train further along the route. This changing of locomotives at the borders leads to long interchange delays at these points, which may be attributed to a lack of pre-emptive planning or a shortage of available serviceable locomotives or a shortage of crews when needed to operate the train through the next operator's region.

5.1.4. Africa Infrastructure Country Diagnostic Report (2011)

The Africa Infrastructure Country Diagnostic (AICD) Report in 2011 determined that the 3,000km plus trip from Kolwezi in DRC to Durban can take up to 38 days, of which 29 days were spent at borders due to delays. There are frequent delays of two or more days due to inefficiencies at the infamous Beitbridge border crossing between the RSA and Zimbabwe.

“Bribery and corruption by custom authorities is prevalent.” ”Things don’t seem to be getting better in Zimbabwe, with the 2015 Zimbabwe customs updates deemed an absolute shambles by the SA Association of Freight Forwarders (SAAFF)”. “Reducing the border-related delays will have a huge impact on the viability of rail for regional traffic.”(AICD 2011)

Existing rail networks in Africa are, generally, in poor condition and require upgrades to infrastructure (both track and signalling), stations and rolling stock, as well as road and rail network extensions, in order to adequately service passenger and freight demands of the communities along the corridor.

5.1.5. Ivanhoe Mines LLC, Development Plans

Railways Africa (Issue 1:2018, p38) reported that early in 2018 Ivanhoe Mines LLC submitted its report for the planned development of the new Kamoa-Kakula copper project located 25 km from Kolwezi in the DRC. This is a greenfields project of two new mines (Kamoa and Kakula) each with a projected copper output of 6 mtpa , thus 12 mtpa combined output.

For the first 5 years of production, copper concentrate will be transported by road to Ndola, or Kitwe, or Chingola in Zambia and then via the NSC-Rail System to the ports of either Richards Bay or Durban, as this is viewed as the current most attractive and reliable export corridor. The report assumes that rail should significantly reduce transport costs relative to using road transport down to the ports.

However, after 5 years of operation (ca 2025) it is expected that the SNCC Benguela line from Lubumbashi to the DRC-Angolan border will have been rehabilitated and connected to the Chinese built line from the Angolan port of Lobito, to the border town of Dilolo. The transport distance from Kolwezi to the port (Lobito) will thus be reduced from the ca 3,000 km of the NSC-Rail System to ca 2,000 km to the port of Lobito. This shorter transport distance is assumed to bring a material saving in transport cost and throughput time. The

upgraded Benguala line will be able to handle 20 mtpa. Another back-up alternative route available to the new mines is to use the Tazara corridor to Dar es Salaam.

Construction equipment for building the mine will be transported by road from South Africa. The report states that currently this could take up to three weeks and advises that it will be critical to implement an efficient logistics process flow with expediting and tracking systems to avoid construction delays.

Ivanhoe Mines LLC has also released plans for the development of the Kipushi Zinc Project near Lubumbashi. The projected output from the zinc project is 10,2 mtpa, further contributing to future demand on the NSC-Rail System (Orewin, 2019).

5.2. Routing Analysis of the NSC-Rail System

5.2.1. NSC-Rail System Routing Diagram

Grinrod (2016) has published a routing diagram of the NSC-Rail routing from Kolwezi to Durban. Their routing diagram, presented in figure 5.1, shows the many sovereign border crossings and the rail junctions connecting to the NSC main railway line.

The Grinrod diagram (figure 5.1) also shows the very important, current and planned, inland container handling terminals. Inland container handling capacity has been highlighted as a major constraint to the growth of container traffic on the NSC-Rail System.

The rail operators acting along the NSC-Rail System are:

a. SNCC (Kolwezi to Sakania) (DRC)
b. NWR (Kalumbila to Chingola)
c. Zambia Railways Limited (ZRL) (Ndola to Livingstone)
d. National Railway of Zimbabwe (NRZ) (Livingstone to Bulawayo) (Zimbabwe)
e. Botswana Rail (BR) (Plumtree to Mafekeng) (Botswana)
f. Bulawayo–Beitbridge Railway (BBR) (Grinrod subsidiary) (Bulawayo to Beitbridge) (Zimbabwe)
g. Transnet Freight Rail (TFR) (Beitbridge and/or Mafekeng to Durban, Richards Bay of other RSA port)
h. Swazi Rail (eSwatini, for connection to Richards Bay)
i. CFM (from Komatipoort to Maputo)

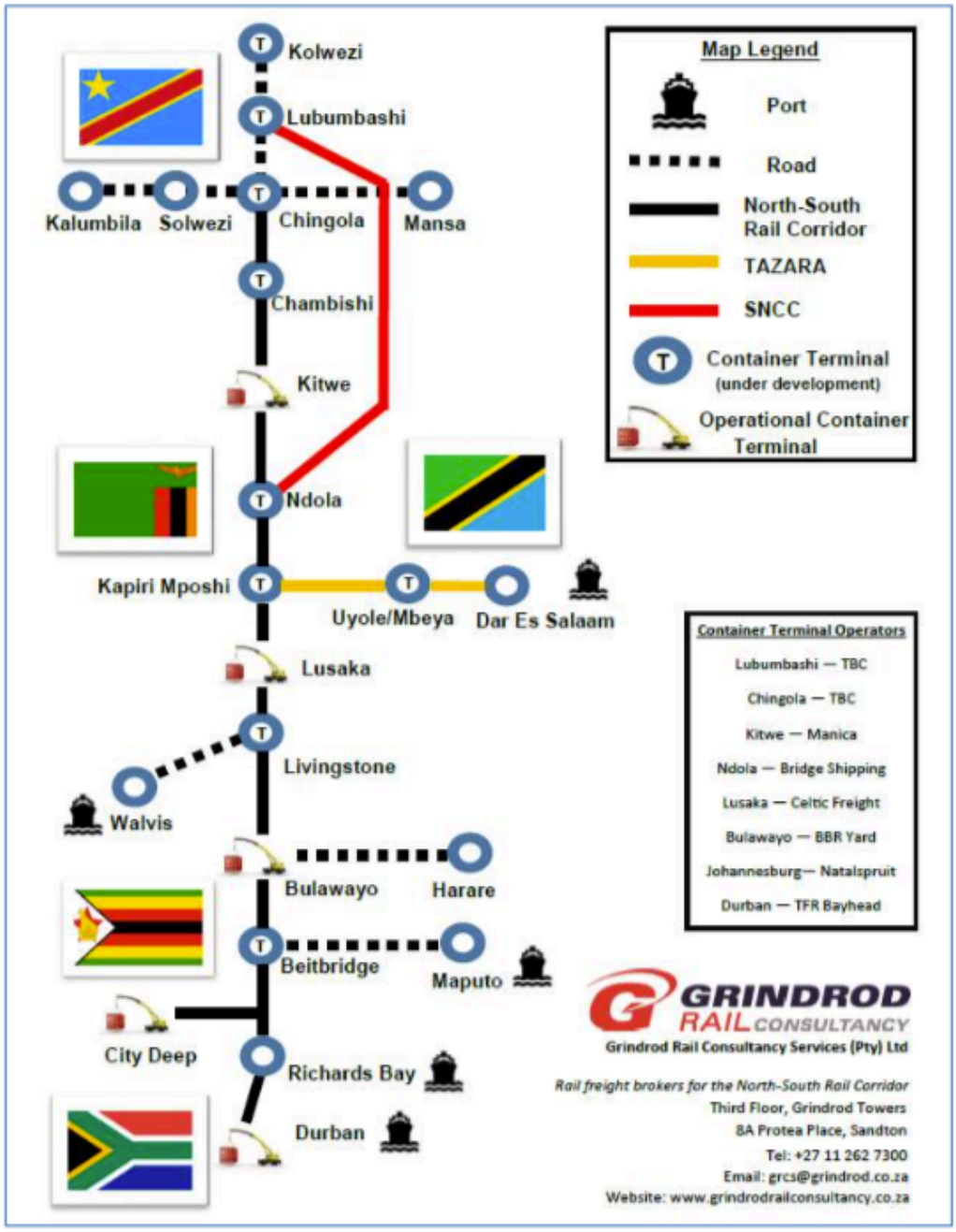


Figure 5 1: NSC-Rail Network Diagram (Grinrod (2016))

5.2.2. NSC-Rail System Eastern Route through RSA

The alternative route of the NSC-Rail System, follows the eastern route through the RSA, over Groenbult, Tzaneen, Hoedspruit and Komatipoort to Richards Bay and Durban.

The NSC trains operate as block trains, with an expected transit time of only 8 days from inland origin to port destination and this should result in a turn-around time of 16 days for rail wagons. Where full length trains in the Transnet network comprises 100 wagons, the maximum train length north of the RSA border is limited to 60 wagons and the maximum axle mass limited to 20 ton/axle. The 60 wagon trains are however broken up into two 30

wagon trains in Zimbabwe, and these 30 wagon trains are again broken up into two 15 wagon trains further up to the north.

Another listed constraint on the NSC corridor is the road-rail bridge over the Zambezi River at the Victoria Falls. This is also the Zimbabwe-Zambia border crossing. Scheduling for bridge crossings by road and/or rail traffic going in either north- or south-bound directions have proven to be a challenge, with the bridge considered to be a serious bottleneck on the NSC. The bridge has a single track and single lane for road traffic. Due to mass limitations trains and road vehicles may not cross the bridge at the same time. Very low speed restrictions over the bridge are enforced. A further complication is that the bridge is also used for tourist activities, with a sight-seeing tram traversing the bridge and getting preference in the crossing scheduling, as well as bungi activities launched from the bridge deck. Figures 5.2 and 5.3 show aerial views of this NSC bridge crossing the Zambezi river.

The routing analysis highlighted the discontinuities in the northern portion of the line and also showed up that the southern portion is not a line (or corridor as commonly referred to) but in fact an inter-connected network.

There is an observable step-change in the dynamics of the NSC rail traffic north versus south of the RSA border. The primarily linear corridor to the north enters the southern rail network with multiple connections to the alternative ports of South Africa. The network behaviour of the TFR network intuitively reminds of a hub and spoke distribution model. Figure 5.4 shows this linear portion and networked portions of the NSC-Rail System.



Figure 5.2: NSC Road & Rail bridge at Victoria Falls (*Vberger* – Transferred *from fr.wikipedia.org(2017*))



Figure 5.3: NSC-Road & Rail Bridge constraints (www.alamy.com (2017))

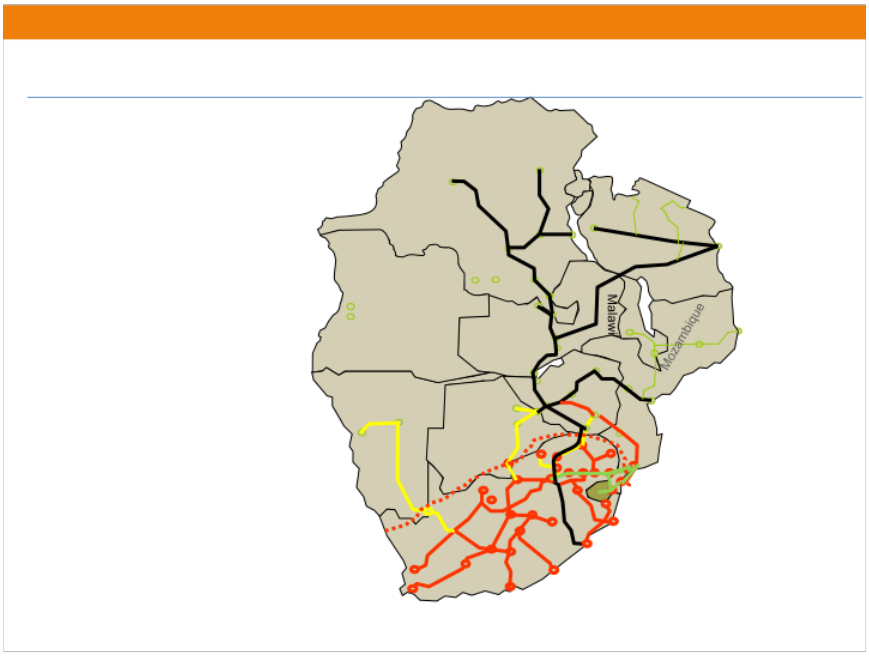


Figure 5.4: Northern NSC Rail Corridor (Black) and Southern TFR Rail Network (NBF (2012))

The 'arteries' of the TFR Rail Network in South Africa is presented in figure 5.5. When considered as a ring-fenced system the main channels for freight flow (the corridors) is not immediately visible. On entering the Gauteng freight hub, NSC originated freight becomes part of all the other TFR freight in the TFR Rail Network and will be scheduled for departure in accordance with the TFR network scheduling rules, preferably in 100 wagon 'full trains'.

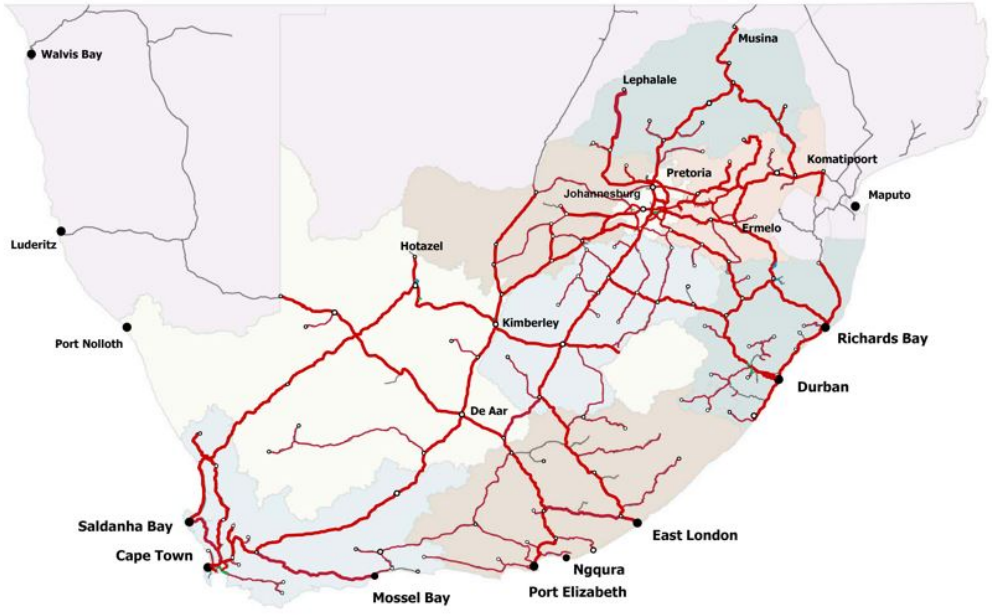


Figure 5.5: TFR Rail Network across South Africa (Gauteng Freight Data Bank (website) (2018))

5.2.3. System Diagram for the NSC-Rail System

Figure 5.6 below indicates the Systems Definition diagram with the NSC-Rail System as the SOI. The diagramme also shows the interfaces between the stakeholders in the NSC-Rail System and considers the political, economic, social and regulatory stakeholders in the NSC -Rail System.

The harmonising role of SARA as an organisation which have all the railway operators from the seven sovereign countries as members is recognised. External drivers of the NSC-Rail System is the ports visited by the major international shipping lines. At present Mearsk and MSC use the port of Durban and thus push and pull freight along the NSC between the Southern DRC and the port of Durban. The NSC Road corridor is the biggest competition of the NSC-Rail System and transports more than 90% of the freight along the NSC. The important decision making / influencing role of the freight forwarders and other 3rd Party Logistic (3PL) providers also needs to be acknowledged.

A routing model for the NSC-Rail System can be presented in a table as illustrated in figure 5.7. This model can be included in the framework for the NSC Business Model development and allows for the characterisation of the elements as they apply to the connected portions of the complete NSC-Rail System.

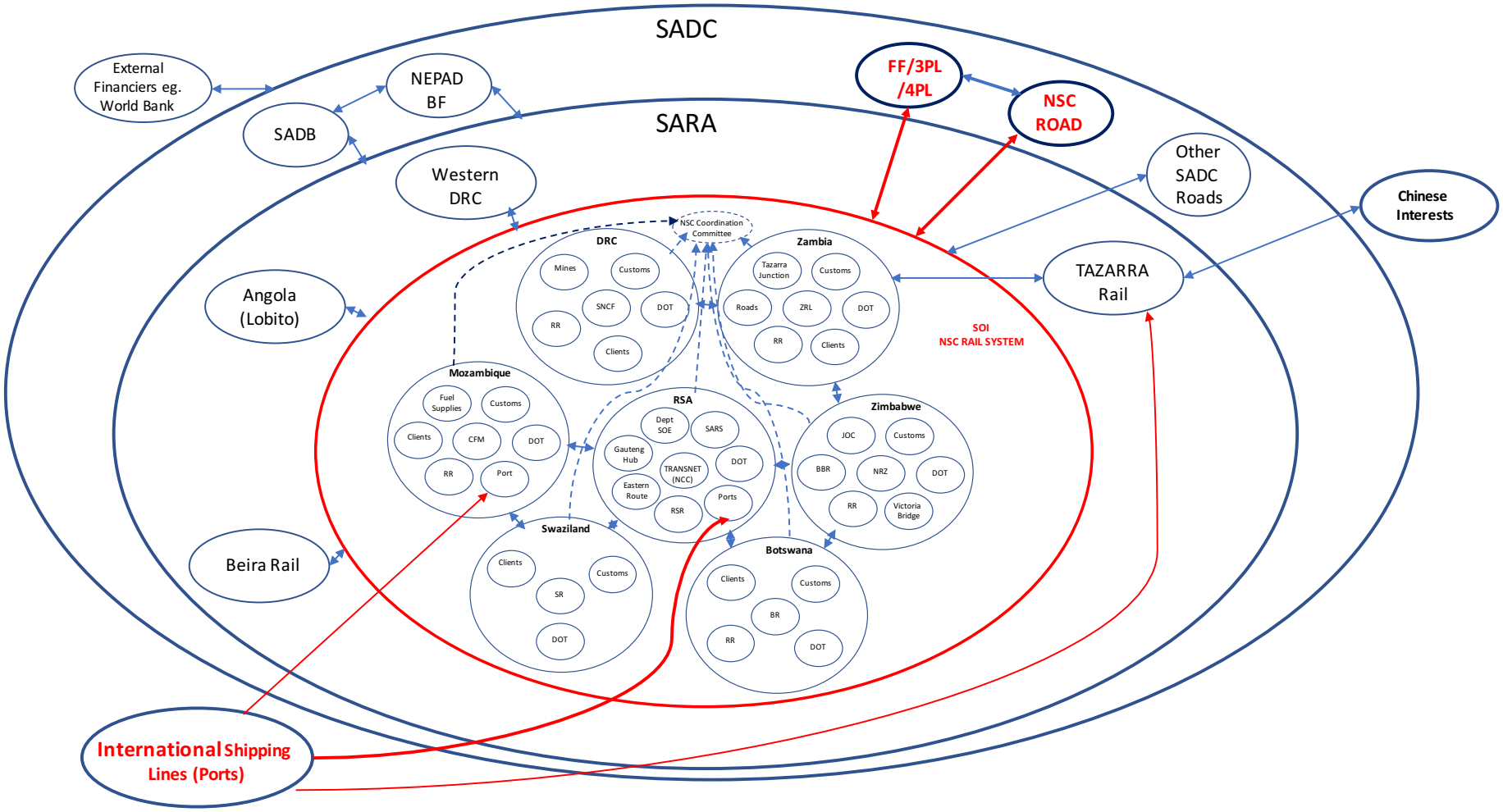


Figure 5.6: NSC-Rail System as System of Interest (SOI) within its contextual environment

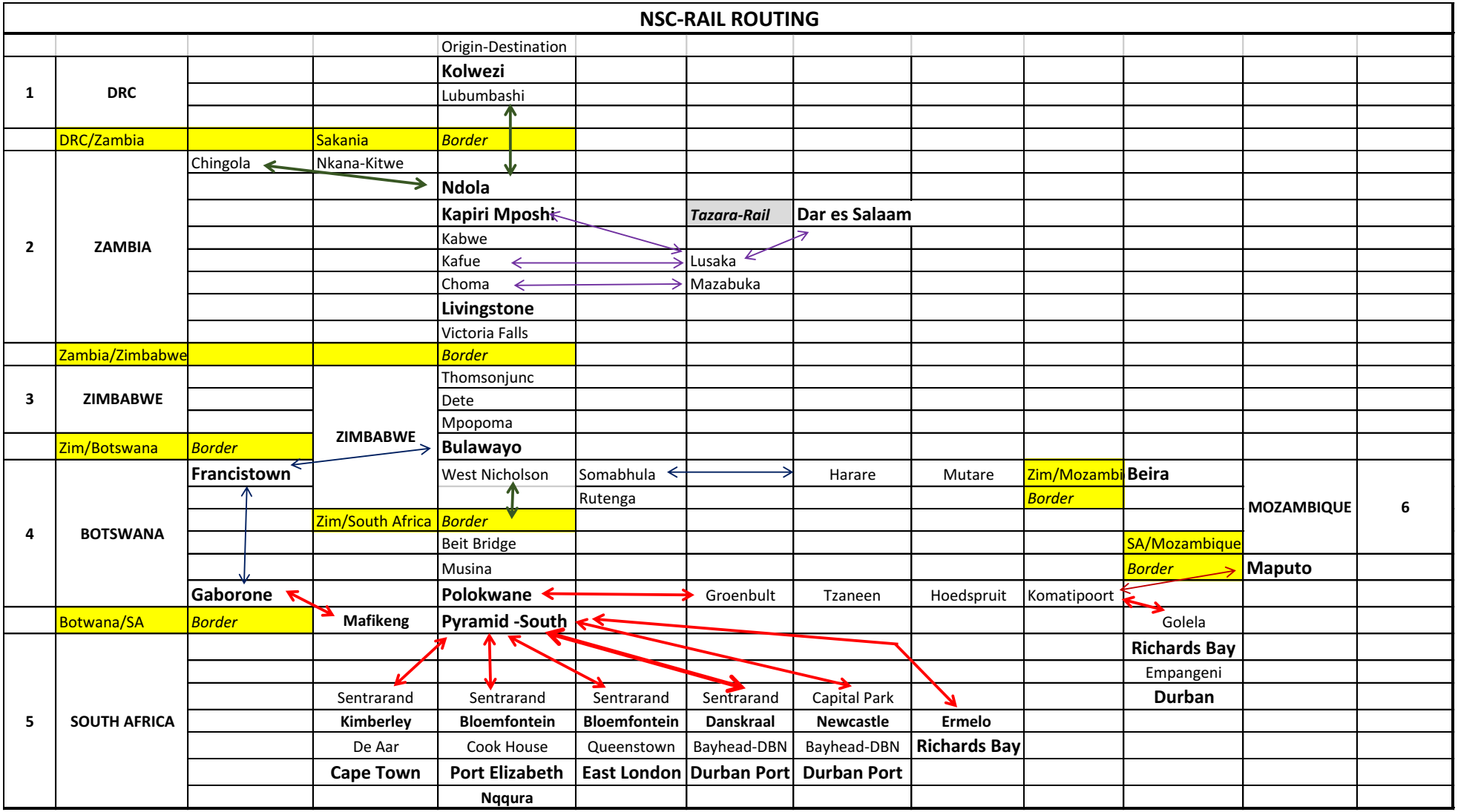


Figure 5.7: NSC-Rail System Routing Model

5.3. NSC-Rail System stakeholders work sessions

5.3.1. Purpose of stakeholder work sessions

The SARA member organisations have assigned representatives from their operations to conduct work sessions in order to determine the bottlenecks in the NSC-Rail System and to harmonise and improve the interconnected rail operations along the corridor. The participants in these work sessions are identified in the diagram in figure 5.8.

The author facilitated one of these work-sessions and proposed that the stakeholders consider taking a systems approach, with the NSC-Rail System as the SOI for analysis purposes. The individual sovereign operators need to acknowledge their role as sub-systems of the SOI and appreciate that their efforts should enhance the overall performance of the SOI. The participants in this work session decided to contribute to the development of a Concept of Operations for the NSC-Rail System.

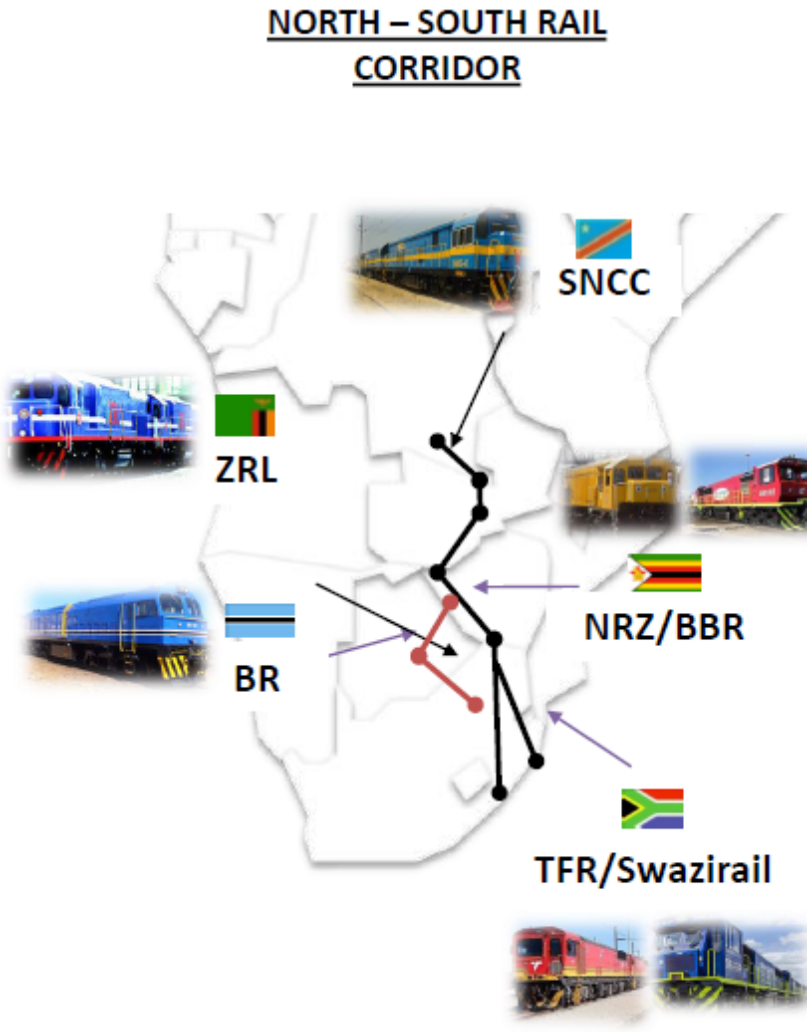


Figure 5.8: Participants in the NSC-Rail System stakeholder work sessions

5.3.2. Concept of Operations

A Concept of Operations (CONOPS) is a high-level conceptualisation of the strategy implementation that will lead to the desired system as an outcome. It is driven by the question 'Why?', and then continue to formalise, 'What needs to be done, When must it be done, Where will it be done, How will it be done and Who will do it.' (INCOSE SE Handbook, 2015)

The CONOPS is a deliverable in the early phases of a project which follows the Systems Engineering V-model for project life cycle planning (figure 5.9) and is an essential input for the elicitation of the system level requirements.

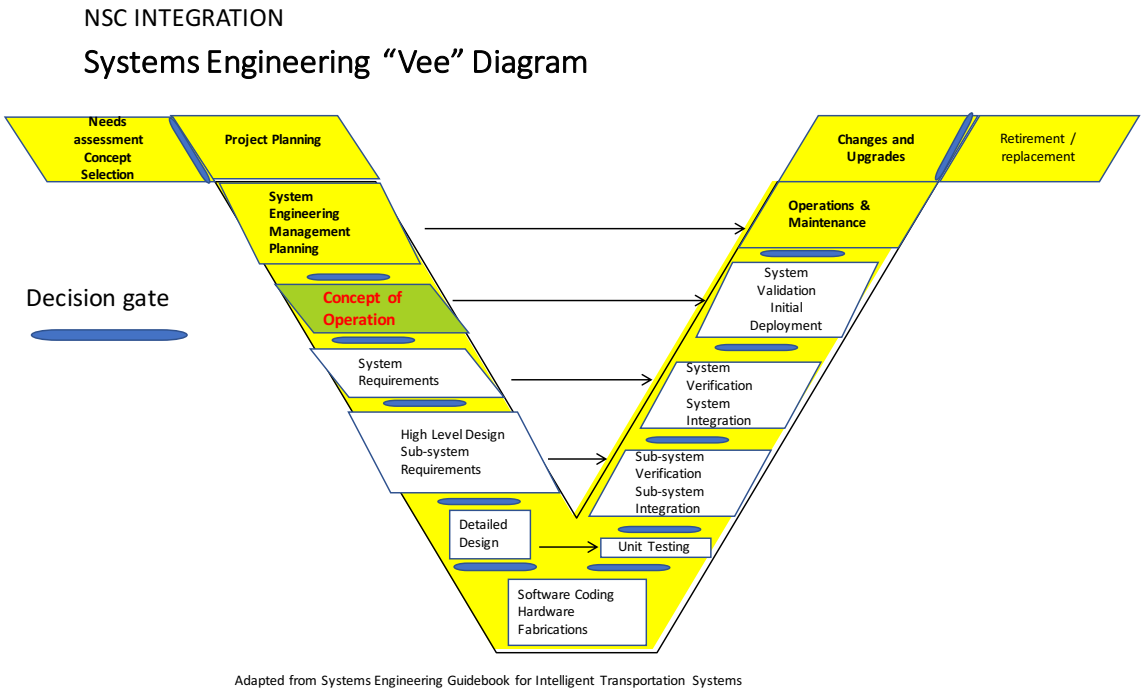


Figure 5.9: CONOPS place in the Systems Engineering V-Model (SE Guidebook for ITS (2015))

The questions asked by the stakeholders in their effort to define a CONOPS for the NSC-Rail System are presented in figure 5.10.

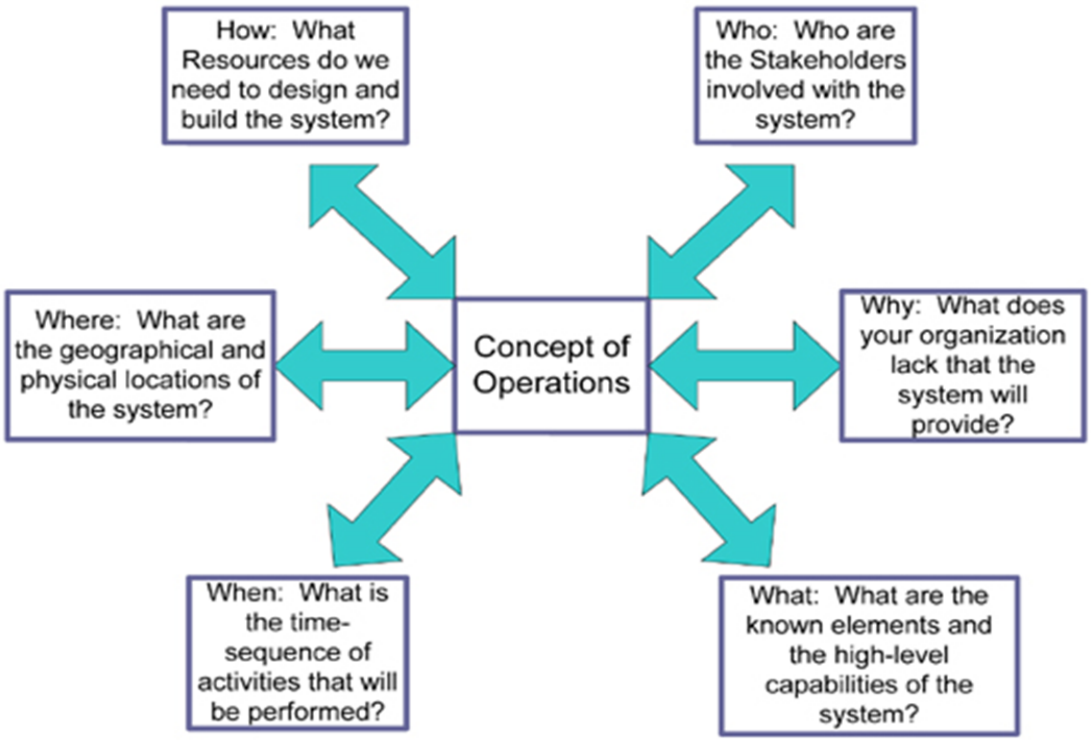


Figure 5.10: Questions pertaining to the development of a Concept of Operations (SE Handbook (2015))

The steps followed at the work session are presented in figure 5.11, with the outcomes of the work sessions summarised in figure 5.12.

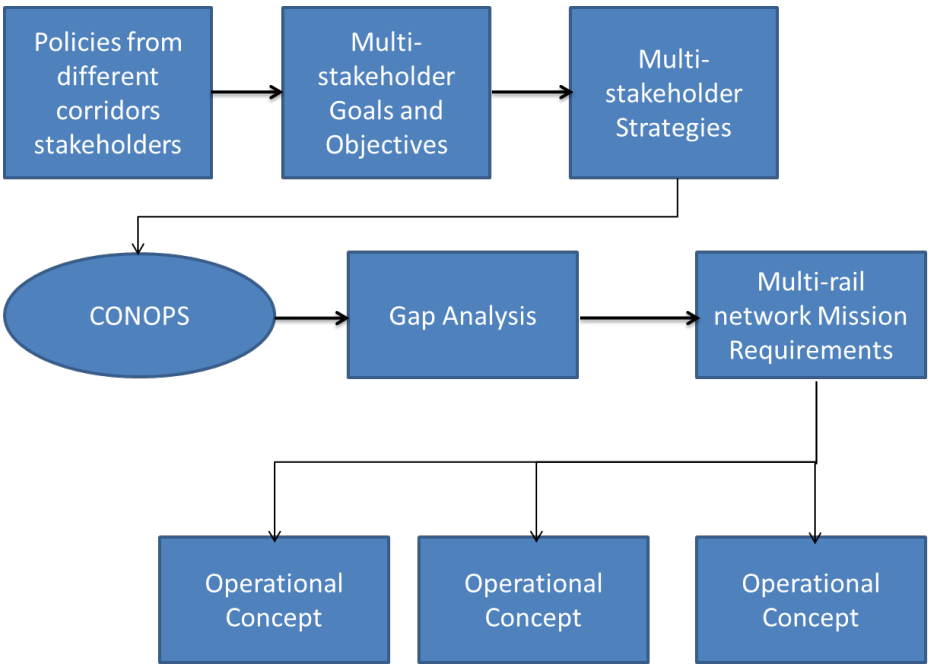


Figure 5.11: Process followed at NSC-Rail stakeholders work session

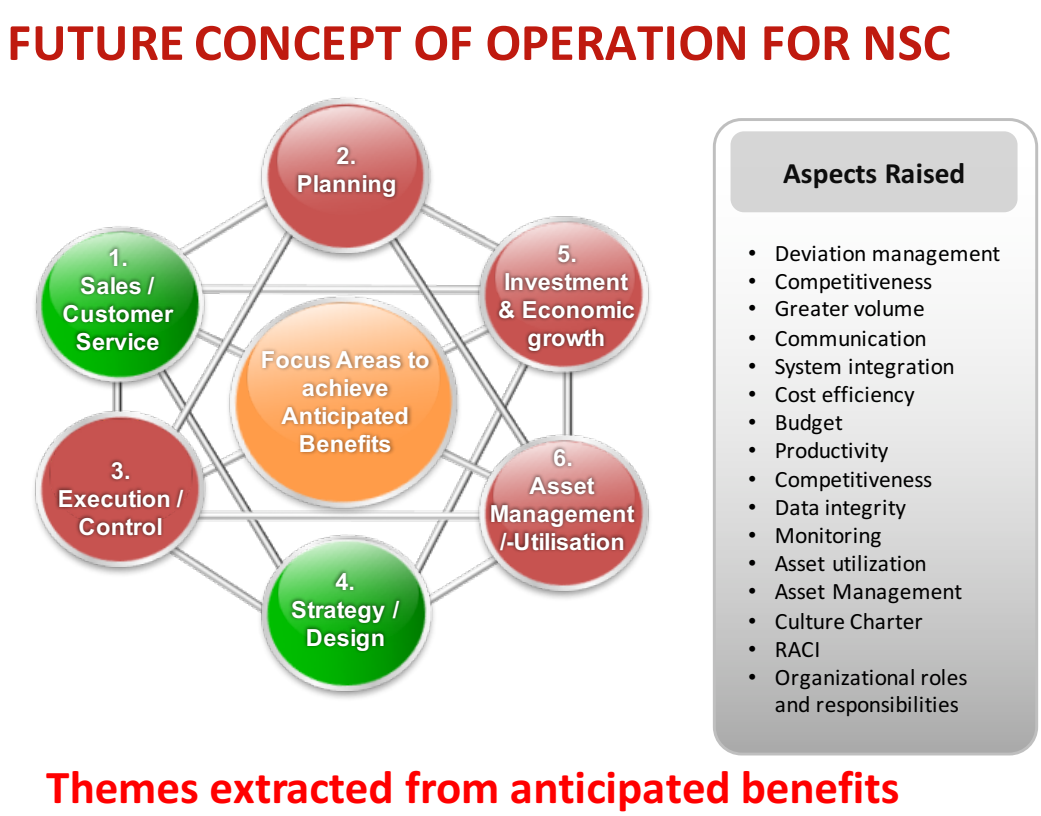


Figure 5.12: Summarised outcomes from NSC-Rail stakeholders work session (with priority areas indicated by the numbers in the circles with 1 being highest priority.

5.3.3. Joint Operations Centre

A current SARA strategic initiative has resulted in the establishment of a Joint Operations Centre (JOC) for the NSC-Rail System, located in Bulawayo. The JOC focusses on the operational level and is concerned with the harmonisation of planning and execution of rail traffic on the NSC rail corridor. Its further functions are to enhance efficiencies and to promote communication between stakeholders on the corridor. The operational role of the JOC is summarised in figure 5.13 below.

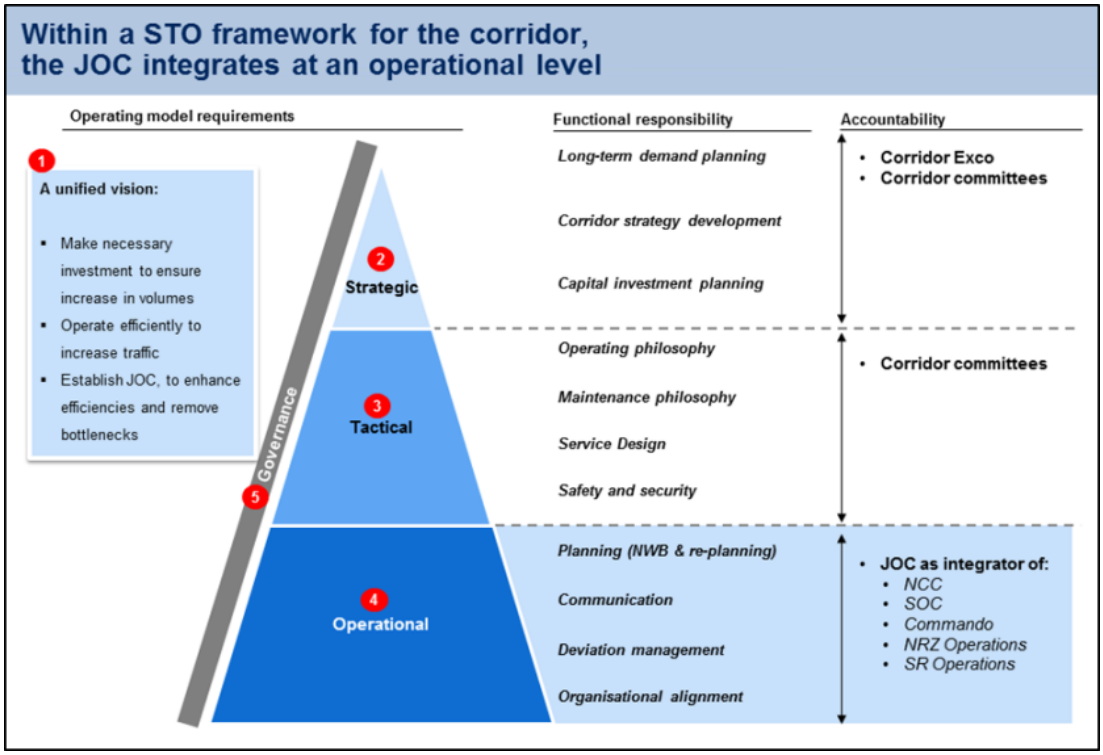


Figure 5.13: Role of the JOC within the Strategic, Tactical & Operational (STO) Framework of the NSC-Rail System (SARA 2017)

5.4. Responses to Research Questionnaires

5.4.1. Research Questionnaire

After obtaining WITS ethics approval, a research questionnaire was distributed to 40 key stakeholders, participants and role players in the NSC-Rail system. The data from the questionnaires were captured in tables and then summarised for each question grouping. These summaries are presented in Appendix A.

Participation in the research was acceptable, as described in section 4.6.4.1.

5.4.2. Analysis of Responses to Research Questions

5.4.2.1. Participation in the research

It was recorded that in profile most respondents are highly qualified and experienced members in their respective organisations. From the strategic nature of the questionnaire such participant profiles were expected.

5.4.2.2. Stakeholder representatives

The responses received covered most of the important stakeholder categories, as shown in Table 5.2 below and expanded on in Table A-2 in Appendix A. This enabled a systems analysis on the NSC-Rail System. The only stakeholder grouping not directly represented in the responses are the respective governments (transport ministries). However, the

responses from state owned rail operators have been taken as also representative of their government shareholders.

TABLE 5. 2 NSC-Rail Stakeholders participating in Research

Your Organisation	
Name of Organisation:	**Representative Stakeholder**
Type of Organisation (rail operator, regulator, customer, logistic services, financier, investor, labour, etc.):	Rail Operators (27%), Rail Associations (9%), Consultants (27%), Clients (18%), Rail Projects & Suppliers(19%).
Shareholders (government, private, etc.):	Goverments, SOCs, Registered Rail Operators, Asset Holding Companies, Private Investment Companies (Chinese in particular)
Primary business focus areas:	Rail, Dry-port, Corridors & Port Terminals Customs clearing, Freight Forwarding, Container Handling & Warehousing

The systems analysis of the NSC-Rail system must address all the elements of the required system which includes services such as; freight forwarding, warehousing, freight delivery, container handling, loading and unloading, customs clearing and collection, feeder transport, inland terminals, port terminals and rail transportation connections.

The identified products forming the market for the NSC-Rail service have been listed as; copper, coal, chrome, grain, cement, clinker, sugar, coffee, tea, granite blocks and containerised traffic. It was clear from the responses that the NSC-Rail is also expected to transport people (passengers).

Most rail operators in the NSC-Rail system are state owned and controlled by the respective sovereign governments. The exception being BBR which is privately owned. Research responses indicated that the state-owned rail operators are dependent on bank loans for their funding. Their balance sheets and operations, supported by state guaranties (in some cases), are the collateral for these loans. A respondent indicated that in his opinion private investment in the NSC-Rail system is urgently needed and expressed the hope that governments will see their way open to start promoting public-private partnerships (PPP's).

From a substantial number of participants in the research it was clear that they either have commercial interests in both SADC and in the Eastern African Community (EAC), or they consider the NSC and the Eastern (Tazara) route to Dar es Salaam as alternative channels for their business. When analysing the NSC-Rail system, the EAC solutions should thus be included in the context diagramme.

Some responses mentioned that the large Chinese equity interest in the African mining operations must be considered for impacting the NSC-Rail system.

5.4.2.3. Roles of the Stakeholder Organisations within the NSC-Rail System

The responding stakeholder's specific role within the NSC-Rail system will provide the perspective from which the stakeholder participated in the research. Table 5.3 summarises these responses to this questionnaire section, while this is expanded on in Appendix A Table A-3. The responses indicated that most parties focus on their specific role in NSC-Rail system only and reflected little appreciation for the perspectives of other parties.

Rail operators see their future opportunities primarily coming from mining, industrial and agricultural freight. The general feeling was that with rehabilitation of the rail system the bulk transport lost to road could easily be recaptured by rail.

Mining clients on the other hand indicated that they have moved their minerals to road transport due to the unreliable rail service, long delivery times and uncompetitive pricing from the NSC-Rail System in the past, and has lost interest in the rail offerings. A concern that was noted by these respondents is the remaining economic lives of the mines in Zambia and Southern DRC, stating only 4 to 10 years for some mines. Research into this falls outside the scope of this study, but should be undertaken before large capital investments are made in the rehabilitation of the rail system on the expectation of large mineral freight volumes to be transported to the ports.

TABLE 5.3 Stakeholder Roles in the NSC

Role of your Organisation in the NSC	
Define your organisation's role in the NSC:	Our role is to facilitate the movement of the goods within the NSC. We provide efficient handling and clearing procedures for customers' goods. Our copper is now transported by road.
Where do you see **your** opportunities for business development?	Mines and industry sector, agricultural sector, and movement of fuel and other products from the ports to inland countries such as Botswana, Zimbabwe, Zambia and the DRC. Rail can re-capture the bulk freight that has moved to road.
What Challenges and/or Constraints are you facing?	The challenges currently faced are shortage of wagons and locomotives and also the poor conditions of the railway network. Aging machiney [Locomotives and wagons], aging railway lines, **lack of capital** to revamp the aging systems and or revive the signaling systems for easy flow of trains. Poor rail service forces some of our clients to transport some of the containers by road after collecting them from the different ports like Beira or Durban.
In which areas of your business are you losing business or not making inroads in the market?	In Passenger Transport mainly because of old and outdated train coaches and also the inability to be on time most of the time. Container business; mainly because of lack of container handling facilities at source, Copper movement from Zambia to South Africa has moved to/remained on road transport. North bound traffic mainly going by road.

The prominent challenge/constraint identified by most participants is a lack of funding to rehabilitate the aging rail infrastructure, to invest in the serviceability of locomotives and wagons and for the necessary upgrading of the signalling systems. This negative spiral is re-enforcing in that the resultant unreliable service is leading to further loss of clients and even less revenues.

Rail operators defined their business strength lying in moving bulky commodities in large volumes and see their competitive advantage is in doing this at a lower cost than road transport. This may be true when considering flow in one direction only. However, as indicated by the clients, road transport is perceivably able to discount tariffs, based on two-way traffic, as they bring back containers or other cargo on the return trip.

Container rail traffic is rapidly growing worldwide, losing business in this area, as reported, will be fatal for the NSC-Rail system. The respondents attribute this decline in rail containerised business to a lack of container handling facilities at the inland terminals.

In the same vein, the current traffic on NSC-Rail system is extremely unbalanced with less traffic volumes flowing north. Containerised, automotive and general traffic from the major Gauteng freight node, as well as, through traffic from the ports of Durban, Maputo

and Beira, are predominantly going north by road. A freight forwarding respondent attributed their avoidance of using the north bound rail service to the loss of goods in the rail system, goods failing to reach its intended destination and goods being consumed in the wrong country. The latter comment may have been based on the respondent experiencing his rail consignments not reaching their intended destinations. They also noted their reported experiences of transit fraud in the NSC-Rail System.

Another area where the NSC-Rail system is losing business is in passenger transport. This is attributed to very old carriages, resulting in an unreliable and slow service offering. It is unlikely that the NSC-Rail system will be able to justify the investments required to provide a competitive passenger rail service on business merits alone. To cater for rail passengers within the South African borders, the Passenger Rail Agency of South Africa (PRASA) will also need to be included.

Many respondents reported on communication difficulties and cultural misunderstandings / misalignments between the railways of the different nations along the corridor. A lack of mutual trust amongst the operators was shining through the responses.

The Southern African Rail Association (SARA) is an outcome of SADC interactions. All the NSC rail operators are SARA members and SARA initiatives promote regional integration and harmonisation of rail operations in the SADC region. SARA has to date developed 10 joint standards for adoption by the NSC sovereign rail operators. Being only an association SARA is experiencing varying levels of commitments to SARA initiatives and slow adoption and implementation of these by some members. *Communication and cultural differences remain a major challenge in getting the NSC-Rail system to behave like an integrated system.*

5.4.2.4. Views on an Integrated and Harmonised NSC-Rail System

Participants were encouraged to share their views on how an Integrated and Harmonised NSC-Rail System should look and behave. This feedback is captured in Appendix A Table A-4 and summarised below in Table 5.4.

TABLE 5. **4 Stakeholders view on Integrated and Harmonised NSC**

Your view of an **Integrated and Harmonised NSC**	
Identify/list all the other role-players in the NSC.	SADC, SARA, DFIs, SADC Secretariat, COMESA. NSC Rail operators, Containers/inland ports operators, Freight Forwarders, Mining Houses, Private businesses, Government institutions, Port operators, Road Transport Operators, Air Transport. Mines, trading companies, customs, Governments (SADC), funders, consultants, NEPAD Business Foundation.
How would you define the competitive offering of the integrated, harmonised NSC?	**Price competitive**, safe, efficient, predictable and reliable end-to end supply solution for transportation of bulk heavy materials over long distances, with improved delivery times.
What are the challenges and/or constraints of the NSC in its current state?	Lack of coordination and cooperation amongst the different railway systems within the corridor. Poor communication resulting in NSC transport operators being considered a "black box" by customers. Infrastructure across the various Railway systems is in different states of wear and tear, and in the main requires rehabilitation and/or upgrading; cost structures also worlds apart
What are your expectations of the future of the NSC?	Rail should be the dominant player for long haul and bulk business. 1._Return to **system design capacity** in the short to medium term (***transportation of up to 6mtpa***), 2. Capture of up to 30 - 40% of surface transport market share in the long term.

This vision for the NSC-Rail system may be achieved by integrated planning, providing seamless services, pooling of resources, one stop client service centres, communication all round, information sharing, removal of institutional barriers and transit delays, common training, common operating language, common train planning and execution systems, common maintenance systems for networks and rolling stock, etc.

Participants defined the competitive advantage of an integrated, harmonised NSC-Rail System as being; "*Price competitive, safe, efficient, a predictable and reliable end-to end supply chain solution for transportation of bulk heavy materials over long distances, and with improved delivery times.*" Competitive pricing and short delivery times have surfaced as the key expectations of a future NSC-Rail system.

Part of the current challenges and frustrations experienced by clients is the complexity of dealing with multiple rail operators in the NSC-Rail System. Their experiences are that rail operations are not coordinated and that the rail operators are not cooperating with each other. Clients describe the rail operations as a 'black box' and criticise the rail operators of poor communications all round.

Responses list the areas where the NSC-Rail system is currently underperforming as:

1. Rail reliability is poor.
2. Too few well established dry ports.
3. Cargo security.
4. Complexities at border posts and customs.
5. Insufficient rail transport capacity to move rail friendly cargo.
6. Very little northbound business.
7. Different interchange and operational polices within the neighbouring railway systems.
8. Movement of passengers.

5.4.2.5. Views on Organisation's interactions with NSC

As presented in Table 5.5, a broader view of the NSC-Rail system external interfaces expands to the ports, shipping companies, trading partners, financiers and community interests. These research outcomes are presented in Appendix A Table A-5.

TABLE 5. 5 Stakeholder views on interactions with the NSC

Which other NSC role-players does your organisation directly interface with?	African Union, EAC, EU , World bank, Funding & Trading partners. Shipping lines; MSC, CMA-CGM, Portuguese International, Maersk
What is your view on current NSC information sharing?	Very poor, many perceptions. Piece meal, problem is the **language barrier** and distrust caused by **cultural differences**. Trading companies are keen to share information, operators not?
What is your view on current NSC commercial partnerships?	**Common view:** Individualistic (own priorities), not integrated, hidden agendas. Each Railway preserves rates information as confidential. **Opposed to**: We share rates and seek for customers as a team, the commercial partnerships are working well though there is room for improvement.
What is your view on the main elements of the NSC Cost Structures?	Road rates are relatively cheap (balanced up-and-down loads). Rail south is same price as rail north-bound. Traction costs; terminal costs; equipment costs and overheads. Warehousing and handling is competitive but has a security premium.
How would you describe the current NSC Revenue Streams and income sharing models?	**Revenue Sharing model agreed to at SARA level** is equitable. Variations are always negotiated. (view by rail operator who is getting a larger than fair share according to the other operators.) The revenue streams are based on the traffic tendered by customers and each member of the corridor charges its tariff based on the distance travelled over its own lines. Client invoicing is done by the operator from where traffic originates. Other operators invoices him for their share. The revenue sharing does not take into account the asset contribution of each railways. e.g the provider of the wagons is not rewarded for that contribution.

Noteworthy amongst these is that the port of choice for imports and exports is determined by the shipping lines. Where the NSC volumes are small compared to the TFR volumes, the NSC volumes contributing to shipping volumes are negligible. Thus NSC freight goes

where the shipping line docks and therefore shipping lines determine the port destination of freight along the corridor.

With regards to NSC Information Sharing, the questionnaire responses from Rail Operators, SARA & NBF differ from the common external perception of clients, freight forwarders and logistic service providers. The former mentioned key participants feel that information sharing is generally transparent. Currently (2017) all NSC Operators are committed to the process of sharing information in an encouraging manner that will allow the development of executable solutions for the rail corridor.

The view of Clients, Freight Forwarders, Consultants and Rail Suppliers is that Information Sharing amongst the parties is "Very poor" and mostly "Piece meal". These participants ascribe the problems to the language barriers and distrust caused by cultural differences between the nations on the corridor. These users and supporters of the NSC-Rail System hold the view that trading companies are keen to share information, but rail operators are not.

Similar to the above, the clients' views on commercial partnerships in the corridor are that these are generally good between the mines/clients and the road haulers, as opposed to them being indifferent on commercial partnerships with rail operators. A rail operator commented that there is a need for private participation in order to get the NSC-Rail system to grow.

In discussing the cost drivers, the lack of north-bound traffic on the NSC-Rail system was again highlighted. This predominantly one-way traffic contributes to making the NSC rail service uncompetitive versus road transport which has reportedly secured two-way traffic for its transporters. There is a large security premium on all elements of the NSC supply chain. Providing this required security may be more difficult for trains than for road transporters. This security challenge seems to be a major contributor to the lack of north bound traffic in the NSC-Rail system.

The current Revenue Sharing Model between the rail operators has been agreed to at SARA level. Some operators feel that this revenue sharing model allows for certain operators to get a larger portion of the revenue than is fair, while others feel that it is equitable. The operator where the freight originates deals with the customer, and the other operators then recover the charges for using their rail networks from the source operator. Responses indicated that no rewards are shared to the providers of the wagons used for the freight transport.

5.4.2.6. Contributions Expected from other NSC Stakeholders

The most pronounced contributions the respondents were expecting from other stakeholders in the NSC-Rail system were to contribute to finding innovative methods of financing the rehabilitation of the system. The need for the respective governments to support and make commitments to the rail system was expressed and views that individual operators should pool resources to ensure that sufficient capacity was available all along the corridor were shared. Table 5.6 summarises the responses to this section with the outputs contained in Appendix A Table A-6.

TABLE 5. 6 Contributions expected from other NSC stakeholders / role players

Contributions from other NSC stakeholders/role-players	
What contributions are you expecting from other role-players?	Contribute to socio-economic feasibility. From DFIs and other financial institutions we expect **innovative methods of finance, risk allocation and mitigation;** from governments we **expect sovereign support and commitment** to follow through on implementation of proposed projects. Operators to value safety of customers goods and quick responses to different needs of our customers. Actively generate additional business and back loads. NSC members to pool resources to ensure the required capacity in the corridor..
Comment on the framework providing for individual independent sovereign operators versus a joint co-operative NSC structure.	**The rail market is not mature enough for a joint NSC rail structure.** Road hauliers and integrators already provide a joint co-operative structure in the NSC, but this excludes rail. Railways are born out of Govt. Statutes, hence the **issues of sovereignty**. Due to differences in **working cultures**, **equipment** and other resources, a Joint co-operative NCS Structure may need a long time to set up. NSC rail operates through **individual independent sovereign operators**, some members of the corridor do not have **capacity** hence business can be lost through non availability of capacity. Considerations are; objectives of each State for its State owned entities and State assets; Fiscal implications and debt obligations.

Client expectations are that more 4th Party Logistics (4PL) players will start offering services on the NSC. They are expected to contribute to managing the integration of transport, materials handling, clearing and warehousing. (*Author: It is however more likely that these service providers will be 3PL providers in the short to medium term*.)

Responding to their own support role in the NSC-Rail system the respondents all reflected a spirit of willingness to share information amongst all NSC stakeholders, a desire for integrated operations and co-operation and achieving a harmonised service offering through participation in the Joint Operation Committees (JOC's).

The responses stating that some operators do not have sufficient capacity and hence business can be lost through non availability of capacity, may seem contradictory to the low utilisation on the rail corridor. It could however be interpreted as an indication of in-balances in the NSC-Rail System, where such operators may not have the available rolling stock or track serviceability to cater for the customers' freight.

The strong negative responses to the suggested alternative of a joint single NSC-Rail structure versus individual sovereign operators that pass the traffic on to each other along the corridor, were informative, and clearly relayed the individualism of all the operators along the corridor. Individual control in their sovereign regions is every operator's first priority.

This sensitivity to lose control to other players is also captured in the sensitive expressions adopted by SARA, "*harmonised operations*" and "*Joint Operations Committee (JOC)*" versus the needed '*integrated operations*' and joint operations '*Control*'.

A well informed non-operating respondent stated bluntly, "The rail organisations are not mature enough for a joint NSC rail structure, while road haulers and logistics integrators already provide a joint co-operative structure in the NSC. This however excludes rail."

It is however important to acknowledge that the NSC railways were all born out of government initiatives during the colonial period. They fall under the states' statutes and hence the issues of sovereignty, and the issues of state owned infrastructure and state financing (secured loans, etc.).

"It will require political will from all government stakeholders, for the sovereign operators to jointly collaborate effectively as one structure. Otherwise even the idea of a joint co-operative NSC structure will serve no valuable purpose", quoting another informed respondent.

A rail operator's view is that, "Individual sovereign operators may only need to take advantage of the advances in communication technology to work together by synchronizing their operation."

5.4.2.7. Harmonising the NSC Rail Operations

Respondents stated that the NSC-Rail Sales and Customer Services can be improved by better understanding of customer needs. The NSC-Rail operators must work together to create joint products over the whole NSC and these should be marketed through a joint marketing effort by all role-players. Table 5.7 summarises responses received on this

section while the complete outputs listing is presented in Appendix A (Appendix A Table 7).

TABLE 5. 7 Recommendations to Harmonise the NSC-Rail operations

Harmonising the NSC operations	
How can overall NSC sales and customer service be improved?	Through creation of a **joint marketing team** for the corridor to market the corridor to prospective customers and also to look at all the bottlenecks within the supply chain and how they can be eliminated, by sharing information processes and enabling one stop shop enquiry desks. information on rates, distances, mode of payments and any other related information should be readily available and accurate and uniform at all times. Transactions should be in international currency such as USD. Align the sales and customer service on an **online app**. Operations should provide for **online cargo tracking.**
How can coordinated and integrated planning for the NSC be achieved?	"**Political will**" is the key factor. Through Networking with the other stakeholders. Through setting up offices with representatives _from all corridor members. By formulating J**OCs [joint Operation Committees** and synchronizing our activities. Need to set up a joint operating/command centre. By **giving the JOC a stronger role to plan & execute**.
List the main considerations to take into account for the NSC System Design and NSC Service Design.	Infrastructure, Rolling stock, customer requirements, **port operations** and capacity, human factors, commodity type , tariffs etc Locomotives not changed at border. Wagons to flow over the whole network. **One operations centre** and concerned with delivery times. 1._environmental impact of operations. 2. safety considerations 3. cost effectiveness 4.profitability 5._rewarding employees 6. **Security of customer goods.**
In your opinion, which investment requirements should be prioritised for the NSC?	**First are soft operations and management issues**, then removal of Hot Spots (**Emergency perway rehabilitation**) along the NSC. Rolling stock & side door containers. Inland container parks/depots, Dry ports and terminals. Lastly is rehabilitation of infrastructure- which is a long term strategic investment.
State your view on the current utilisation of assets available to the NSC. _	Very poor, 30-60 days for a consignment to move up and down the corridor. Asset Utilisation is impacted by differences in assets available to individual players. Wagons are mainly loaded in southern direction and return empty, thus poor utilisation on the northen trip.
To what extent is standardisation of systems a concern and/or a constraint in the NSC?	Standardisation is a **main concern to customers**. They require things to move in line with modern technology. **Language and cultural barriers within the member states** were the main contributing factors to differing standards and equipment. For Rail Operators this is no longer a major issue. S**ome systems had already been harmonized though SARA especially on technical and safety aspects**. Biggest differences remain with locomotives and train authorisation systems.
Define the key metrics to measure NSC performance.	(1)Corridor Transit times (2) Net Tons Carried, Volume of key commodities. (3) Wagon Turnaround (4) Track availability (5) Locomotive Availability, (6) Locomotive km per month.

The biggest driver however is “Service Delivery Time” which must be improved from the reported current ca 30 days as stated by the questionnaire respondents (or up to 38 days as reported by AICD (2011), discussed in section 5.1.4), to no more than 10 days from origin to destination, for the NSC-Rail System to potentially compete with road.

Collaboration in planning, resource allocation and utilisation of capacity amongst the operators is necessary. The digital sharing of information will improve customer services and must allow for online cargo tracking by customers.

The operational mind-set is that rail services *need not focus on new customers*, but should first recoup the rail friendly traffic that has moved from rail mode to road transport mode, driven by the perceived better road service offering. The road/rail share of the bulk freight transport market is almost 90%/10% in favour of road transport in the NSC.

"*Political will*" is the key factor to achieve coordinated and integrated planning for the NSC-Rail System. This is hampered by the protectionist behaviour of the independent sovereign operators. The NSC JOC, referred to in paragraph 5.3.3, is only a ‘Harmonising Committee’, while the NSC-Rail System actually needs a mandated centralised Command Centre? The key role of SARA to align all NSC project efforts in line with SADC socio-economic drives was highlighted. The views of some respondents are that SARA should be tasked to integrate the efforts of all role players at regional, national and local operational spheres.

The biggest challenge for execution and control in the NSC-Rail System is that the individual railways work independently. Customers feel that the rail operators are slow to respond to commercial issues and very slow in the execution of their duties.

Informed respondents blame internal politics, hidden agendas and own priorities for independent operations being more important than the integrated NSC rail effort. The “Big Brother” in the corridor is also perceived to bring no benefit to other operators, whilst not all operators in the NSC-Rail System appreciates that the rail operations must be conducted on commercial principles to remain a viable business. *Author: It is assumed that the respondent’s use of the term “Big Brother” was a reference to TFR, which in size, dwarfs the other corridor operators. TFR has however recently leased eight locomotives and 600 wagons to ZRL to handle bulk cargo and has also committed to make locomotives and wagons available as part of the upgrade of the NRZ (NEPAD, 2019).*

The crucial need to address the multiple customs obstacles along the corridor was raised. A customer expressed the desire that ideally the stakeholders should agree on a single operator for the whole rail corridor as is the case for their dealings with road transport operators.

The global shipping lines servicing the Southern African ports are the primary drivers to consider in the NSC-Rail System Design and in the NSC-Rail Service Design. The security of customers' goods also featured. This security aspect supported an earlier view that one of the reasons for the perceived reluctance to use the rail system for traffic going north is the *perception* that goods will either not reach its destination or will be tampered with along the way.

For NSC-Rail System investment decisions we need to consider the complete NSC-Rail System, from client/producer to port/consumer. This systems view may determine the priorities of the system for investment, and does not only look at the confined rail operations elements. Research inputs identified the need for inland dry-terminals as a critical shortcoming of the NSC-Rail System. Communication-, tracking- and security systems also rated as a high priority, with specific rail-infrastructure bottlenecks also identified.

"The NSC-Rail System cannot compete as unit when it is so fragmented through independent sovereign operators, each at their own level of maturity." Beyond the scope of this study a systems maturity measurement can be performed on the NSC-Rail System as an integrated entity, as well as on each of the rail operators, using the CMMI (Capability Maturity Model Integration) method.

The general view of respondents is that asset utilisation along the NSC-Rail corridor is poor. The extra-long turnaround time for a trip has been repeatedly mentioned as unacceptable and represent the major measurable outcome and external show-piece of all that is internally wrong in the NSC Rail Service offering(s).

While customers rated the lack of standardisation, the use of different systems and the different ways of doing business by each rail operator as a big concern, the operators are positive that through the interactions of SARA standardisation is being achieved. An external view on the NSC is that SARA's impact on the NSC Rail needs to be mandated beyond an association forum and their role needs to grow beyond technical and safety standardisation.

An integrated and "harmonised" NSC-Rail System will still be confronted on how to address the language and the cultural barriers between the sovereign peoples, all being connected by the NSC value chain.

In proposing metrics to measure the NSC performance, it was clear that the underlying assumptions for these responses were that the rail friendly traffic is sufficient and can be transported profitably by the NSC-Rail System, it however comes down to fixing the NSC Rail Service offering.

5.4.2.8. General Comments and Inputs to the Research

The success of the NSC-Rail System is vital for the improvement of the economies of the member states along the NSC. Close co-operation and standardisation of processes are seen as key to the success of the NSC. This *requires a single NSC-Rail System Concept of Operations* that is adopted by all the independent stakeholders in the system.
The NSC Rail System requires an integrative approach, from the independent sovereign authorities whose constituents stand to gain immensely from a performing NSC-Rail System.

5.5. Summary Research Results

Research results were obtained from:

a. Analysing NSC-Rail System related reports.
b. A Routing Analysis of the NSC-Rail System.
c. Reports from NSC-Rail System stakeholder work sessions.
d. Responses received on the Research Questionnaire.

5.5.1. Summary NSC-Rail System related reports

NSC-Rail System related publications by NBF (2014), Grinrod (2014), Transnet (2016), Havenga (2011), AICD (2011) and Ivanhoe Mines (2018) were studied to get acquainted with the NSC-Rail System status, appreciate the key system elements and learn the various perspectives on the challenges.

The aim of the NBF project study on the NSC-Rail System is an "Integrated rail investment and operating strategy through the establishment of an integrated corridor development plan to meet existing and growing freight volumes" (NBF 2014). The Grinrod Annual Report (2014) states that locomotive leasing in the NSC rail corridor is a growing business opportunity for Grinrod. Transnet Freight Rail (TFR) categorise the

NSC corridor traffic entering the TFR Rail Network as Category C (lowest priority) trains in their network, with service levels provided for Category C trains often compromised.

The Africa Infrastructure Country Diagnostic (AICD) Report in 2011 determined that the 3,000km plus trip from Kolwezi in DRC to Durban can take up to 38 days, of which 29 days were spent at borders due to delays. “Reducing the border-related delays will have a huge impact on the viability of rail for regional traffic” (AICD 2011). Locomotives from one operator stop at border posts, for change-overs to locomotives from the next operator to take the train further, with resultant long interchange delays. Existing rail networks in Africa are, generally, in poor condition and require upgrades to infrastructure (both track and signalling), stations and rolling stock, as well as road and rail network extensions.

Ivanhoe Mines submitted a report for the planned development of 2 new mines in the Kamoa-Kakula copper project at Kolwezi in the DRC (Railways Africa Issue 1:2018, p38), with a combined output of 12 mtpa. For the first 5 years of production, copper concentrate will be transported by road to Zambia and then via the NSC-Rail System to the ports of either Richards Bay or Durban, as this is viewed as the current most attractive and reliable export corridor. The report assumes that rail should significantly reduce transport costs relative to using road transport down to the ports.

5.5.2. Summary Routing Analysis of the NSC-Rail System

The NSC-Rail routing diagram published by Grinrod (2016) shows the many sovereign border crossings and the rail junctions connecting to the NSC main railway line. It also shows the very important, current and planned, inland container handling terminals. Inland container handling capacity has been highlighted as a major constraint to the growth of container traffic on the NSC-Rail System.

The NBF (2014) routing diagram shows the NSC trains as block trains of 60 wagons and the maximum axle mass is stated as 20 ton/axle. The expected transit time from inland origin to port destination is stated as 8 days. The 60 wagon trains are however broken up into two 30 wagon trains in Zimbabwe, and these 30 wagon trains are again broken up into two 15 wagon trains further up to the north.

A listed bottleneck on the NSC corridor is the road-rail bridge over the Zambezi River at the Victoria Falls. This is also the Zimbabwe-Zambia border crossing. Scheduling for bridge crossings by road and/or rail traffic is a challenge, with long delays expected.

The routing analysis highlighted the discontinuities in the northern portion of the line and also showed up that the southern portion is not a line (or corridor as commonly referred

to) but in fact an inter-connected network. The primarily linear corridor to the north enters the southern rail network with multiple connections to the alternative ports of South Africa. The network behaviour of the TFR network intuitively reminds of a hub and spoke distribution model.

The NSC-Rail System was considered as the SOI in a systems analysis. The system diagram considers the political, economic, social and regulatory stakeholders in the NSC-Rail System. The harmonising role of SARA was recognised. The major international shipping lines, Mearsk, MSC, etc. use the port of Durban and thus push and pull freight along the NSC between the Southern DRC and the port of Durban.

5.5.3. Summary NSC-Rail System stakeholder work sessions

The SARA member organisations have assigned representatives from their operations to conduct work sessions to determine the bottlenecks in the NSC-Rail System and to harmonise and improve the interconnected rail operations along the corridor. The participants in this work sessions decided to contribute to the development of a Concept of Operations (CONOPS) for the NSC-Rail System.

The CONOPS is a deliverable in the early phases of a project which follows the Systems Engineering V-model for project life cycle planning and is an essential input for the elicitation of the system level requirements.

A current SARA strategic initiative has resulted in the establishment of a Joint Operations Centre (JOC) for the NSC-Rail System, located in Bulawayo. The JOC focusses on the operational level and is concerned with the harmonisation of planning and execution of rail traffic on the NSC rail corridor. Its further functions are to enhance efficiencies and to promote communication between stakeholders on the corridor.

5.5.4. Summary of Responses to Research Questionnaire

A research questionnaire was distributed to 40 key stakeholders, participants and role players in the NSC-Rail system. Participation in the research was acceptable, with 17 responses received. In profile, most respondents are highly qualified and experienced members in their respective organisations. The responses received covered most of the important stakeholder categories.

The systems analysis of the NSC-Rail system addressed all the elements of the required system which includes services such as; freight forwarding, warehousing, freight

delivery, container handling, loading and unloading, customs clearing and collection, feeder transport, inland terminals, port terminals and rail transportation connections.

Most rail operators in the NSC-Rail system are state owned and controlled by the respective sovereign governments. The exception being BBR which is privately owned.

From a substantial number of participants in the research it was clear that they either have commercial interests in both SADC and in the Eastern African Community (EAC), or they consider the NSC and the Eastern (Tazara) route to Dar es Salaam as alternative channels for their business. The large Chinese equity interest in the African mining operations must also be considered for impacting the NSC-Rail system.

The prominent challenge/constraint identified by most participants is a lack of funding to rehabilitate the aging rail infrastructure, to invest in the serviceability of locomotives and wagons and for the necessary upgrading of the signalling systems. This negative spiral is re-enforcing in that the resultant unreliable service is leading to further loss of clients and even less revenues.

Container rail traffic is rapidly growing worldwide, losing business in this area, as reported, will be fatal for the NSC-Rail system. The respondents attribute this decline in rail containerised business to a lack of container handling facilities at the inland terminals.

The lack of north-bound traffic on the NSC-Rail system was highlighted. This predominantly one-way traffic contributes to making the NSC rail service un-competitive versus road transport which has reportedly secured two-way traffic for its transporters. Containerised, automotive and FMCG traffic are predominantly going north by road. Respondents attributed their avoidance of using the north bound rail service to their perception that their goods will be lost in the rail system, goods failing to reach its intended destination and goods being tampered with in transit.

Many respondents reported on communication difficulties and cultural misunderstandings / misalignments between the railways of the different nations along the corridor. “Communication and cultural differences remain a major challenge in getting the NSC-Rail System to behave like an integrated system.” (Questionnaire respondent, 2017).“ It will require political will from all government stakeholders, for the sovereign operators to jointly collaborate effectively as one structure.

The business driver of the NSC-Rail System however is “Service Delivery Time” which must be improved from the reported current ca 30 days as stated by the questionnaire

respondents (or up to 38 days as reported by AICD (2011), to no more than 10 days from origin to destination, for the NSC-Rail System to potentially compete with road.

“The biggest challenge for execution and control in the NSC-Rail System is that the individual railways work independently. The rail system cannot compete as unit when it is so fragmented through independent sovereign operators, each at their own level of maturity” (questionnaire respondent, 2017). Collaboration in planning, resource allocation and utilisation of capacity amongst the operators is necessary. The digital sharing of information will improve customer services and must allow for online cargo tracking by customers.

The success of the NSC-Rail System is vital for the improvement of the economies of the member states along the NSC. Close co-operation and standardisation of processes are key to the success of the NSC. This requires a single *NSC-Rail System Concept of Operations* that is adopted by all the independent stakeholders in the system.

6 STRATIFIED SYSTEMS REVIEW FRAMEWORK

6.1. Node Flow Mapping of the NSC Rail System

The Stratified System Review Framework (SSRF) is derived from Stratified Systems Theory formulated by Elliot Jaques (Jaques 1989) in which he addresses complexity in organisations. He differentiates between the management roles at the successive management layers in an organisation.

Using node flow mapping the SSRF has been applied to the NSC-Rail System in the figures below, where the NSC-Rail Systems management layers are defined as SADC (strategic layer) (figure 6.1), SARA (executive layer) (figure 6.2), sovereign states (regulatory layer) (figure 6.3) and independent railway operators (operations layer) (figure 6.4).

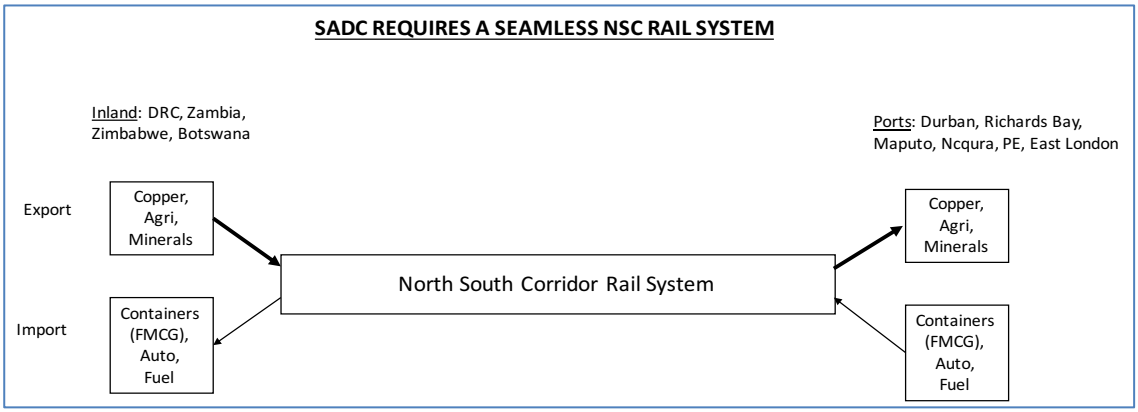


Figure 6. 1: SADC requirements for the NSC-Rail System

SADC requires a seamless NSC-Rail System to provide cost effective transport for heavy, high volume freight over long distances to enhance the competitiveness of the SADC community. The rail service should also promote intra-regional trade and provide efficient transport of people to enhance the mobility of the region's people.

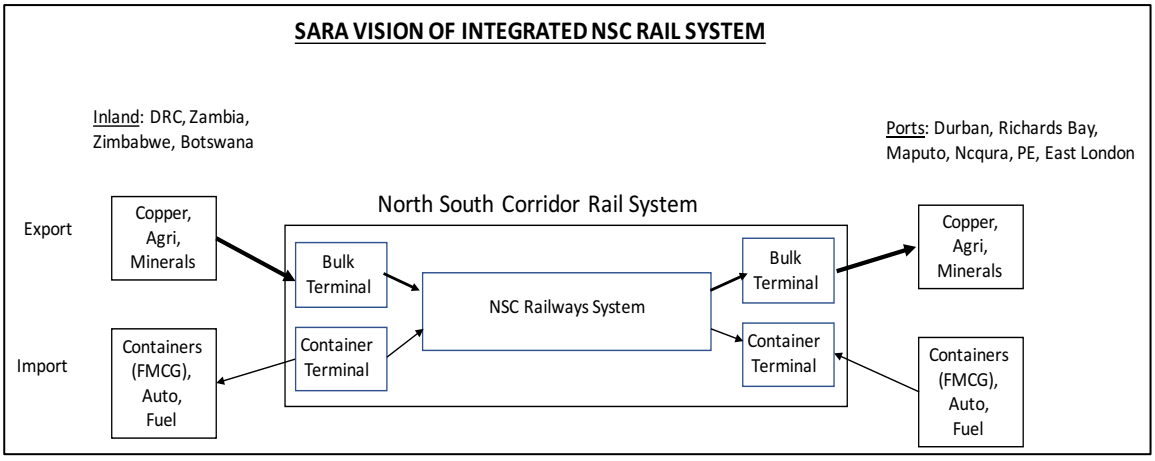


Figure 6. 2: SARA vision of an integrated NSC-Rail System

SARA is concerned with:

- Throughput capacity of the NSC Rail Corridor.
- Throughput time, determining service levels to customers and turnaround time for wagons.
- Bottlenecks and delays along the route.
- The limited number of inland terminals.
- Status/Condition of networks and rolling stock.
- Standards, safety, interoperability and 'harmonising' of services amongst the operators.
- Information sharing along the rail corridor.
- Obtaining a balanced loading regarding the south bound and the north bound traffic.

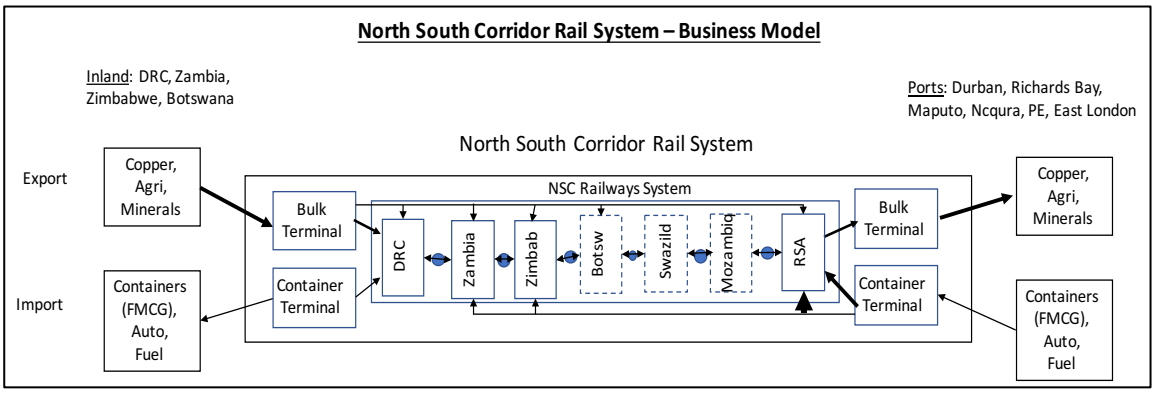


Figure 6.3: Business Model for the multi-country NSC-Rail System

The sovereign stakeholders, forming the value chain of the NSC-Rail System, impose their-own policies, rules and regulations on the operations of the NSC-Rail system in their geographical area. The following applies:

- The customer is owned by the rail operator in whose area the rail business originates.
- An agreed revenue sharing model based on ton-kms transported on each network portion.
- Wagons are shared by all, these are mostly provided by TFR.
- Each operator operates their own locomotives which is manned by their own crews.
- A procedure has been established for the handover of trains at the borders.
- Customs compliance is ensured at the border crossings.

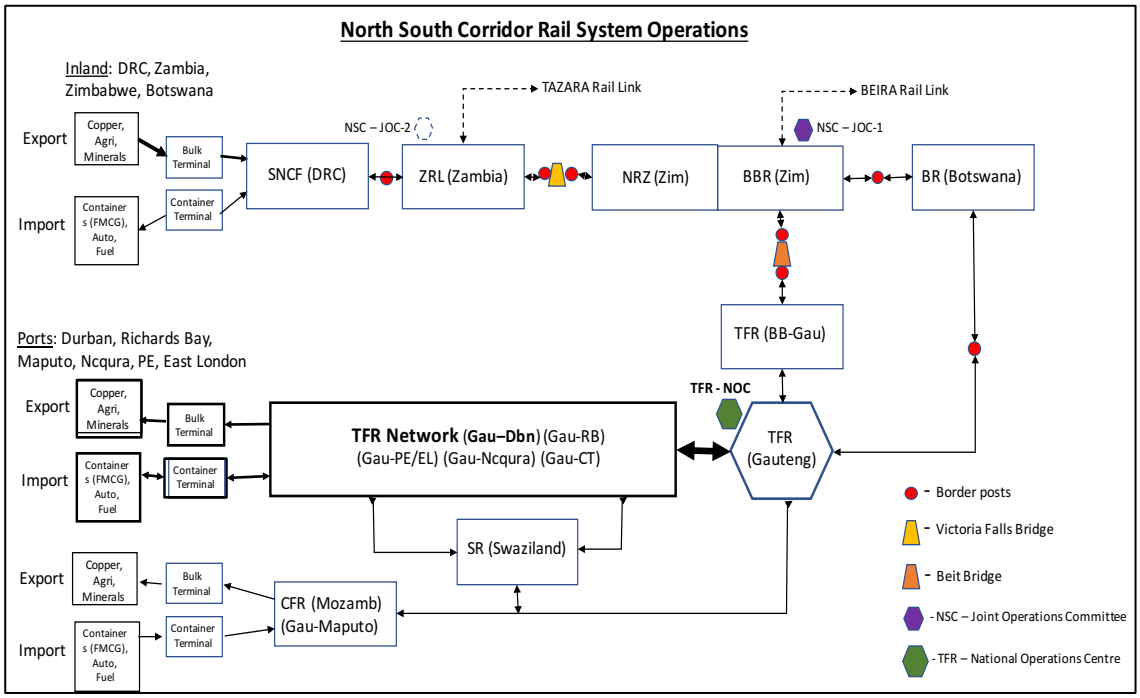


Figure 6.4: NSC-Rail System Operations

The function of the JOC, located in Zimbabwe, is to 'harmonise' operations between operators along the corridor. In particular, to arrange handovers in advance and to limit the delays at border crossings when a next operator will take over the train from the previous operator. Unfortunately, it has been recorded that operators wait until they have confirmation that the train has arrived at the border, before they mobilise their crew and locomotive to go and take over the train.

6.2. Viable Systems Model for the NSC Rail System

The Viable Systems Model (VSMd) from Stafford Beer (1972) describes the five systems that naturally operate in all organisations as discussed in the literature study (chapter 3) of this report. Applying the VSMd to the NSC-Rail System gives the following outcome:

- System 1: Operations; The NSC Rail System operations are represented by the independent railway operators which operate the rail services in their earmarked geographic areas along the NSC.

- System 2: Coordination; The purpose of the recently established JOC is to harmonise operations along the NSC rail corridor. However, the JOC is not mandated to provide the required regulatory direction to activities and resources across operative units. So, at System Level 2 the NSC-Rail System fails the VSMd

requirements.

- System 3: Optimisation; System optimisation is achieved through policy adherence and synergy, thus applying a synergistic concept of operations by all the operating units in the system. In case of the NSC-Rail System this means a shared rail service design, integrated planning and coordinated execution of the rail service plan for the corridor. This study indicated that optimisation does not happen where it counts, nor is any single person or organisation responsible for this level of system performance.
- System 4: Strategic Direction; SARA has taken on the role of providing strategic direction for the future of the NSC-Rail System. In this capacity SARA has scanned the external environment and has entered agreements to create future interventions and opportunities for the NSC-Rail System. Most notably of these are with the DBSA and the SAHHA.
- System 5: Policy and Leadership; The member states of SADC has defined the role that the NSC-Rail System must fulfil as a strategic transportation system, with a crucial role in the economic development and intra-regional trade of the SADC economic region.

6.3. Value Stream Mapping

One of the most powerful tools in the Lean Toolbox is the Value Steam Map. Value Stream Mapping (VSMp) breaks a core process down into the Value Adding (VA) elements and the Non-Value Adding (NVA) elements. By analysing the NVA elements the following concerns are highlighted:

- Bottlenecks and constraints.
- Long process cycle times.
- Poor uptimes.
- Excessive setup times.
- Poor quality / rework.

A Baseline VSMp analysis of the NSC-Rail system is presented in Table 6.1 below:

TABLE 6. 1 Baseline Value Stream Map for NSC Rail System

VSMp for NSC Rail System - (From Durban to Kolwesi)							
	Un-/Loading Tim	Distance	Travel Time	Dwell time	Clearance Time	Total Time	Total Time
	hrs	km	hrs	hrs	hrs	Hours	Days
DBN Port	24						
DBN Bayhead Yard				8,25			
		576	22,75				
Sentrrand				**2,75**			
		98	2,25				
Pyramid South				1,1			
		247	5,6				
Polokwane				2,6			
		201	9,8				
Mussina				2			
		27	0,6				
Beitbridge				6,75			
South Africa	**24**	**1149**	**41**	**23,45**		**64,45**	**2,7**
Beitbridge Border post					12,5	76,95	**3,2**
		141	*4,7*				
Rutenga				2,33			
		281	6,75				
Somabhula				7,1			
		130	3,67				
Bulawayo				**5**			
		12	0,75				
Mpopoma				1,25			
		292	6,5				
Dete				3,1			
		74	3				
Thomson Junction				3,5			
		99	2,75				
Victoria Fall Bridge				2,25			
Zimbabwe	**0**	**1029**	**28,12**	**24,53**	**12,5**	**129,6**	**5,4**
Vitoria Falls Border Poat					9,25	138,85	**5,8**
		18	1				
Livingstone				2			
		213	*7,10*				
Chroma				2			
		215	*7,17*				
Kafue				2			
		50	*1,67*				
Lusaka				2			
		142	*4,73*				
Kabwe				2			
		61	*2,03*				
Kapiri-Mposhi				3			
		117	*3,90*				
Ndola				**4**			
		66	*2,20*				
Nkana-Kitwe	**48**						
		94	*4,70*				
Zambia	**48**	**976**	**34,5**	**17**	**9,25**	**190,35**	**7,9**
Kasumbalesa Border Post					12	202,35	8,4
		100	*15*				
Lubumbasi				*4*			
		300	*30*				
Kolwezi							
DRC		*400*	*45*	*4*		*251,35*	***2,0***
	72,0	**3554,0**	**148,6**	**69,0**	**33,8**	**251,4**	**10,5**

From this analysis, based on service design information, it is derived that the rail throughput time on the NSC-Rail System should be 8 days as published. This provides for ca 4.4 days of actual transport time and ca 4 days cumulative time for changeovers of locomotives and crews and customs clearances at border posts. The transit times north of Chigongola or Nkana-Kitwe in Zambia is based on best assumptions, as the connections to Kolwezi are primarily through road transport.

Travelling from Durban to Kolwezi these unplanned delays can occur at the following change over points:

- Sentrarand – delays due to congestion of TFR traffic in the Gauteng freight ring and PRASA commuter services interfaces.
- Pyramid–South – delays due to locomotives and crew availabilities
- Beitbridge Border Post – customs clearance and train handover to BBR for further operation
- Somabhula, Bulawayo and Thomsons Junction in Zimbabwe – delays at changeovers and junctions along the Zimbabwean section of line.
- Victoria Bridge Border Post – customs clearances, waiting for opportunity to cross the bridge and train handover to ZRL for further operation.
- Lusaka and Kapiri–Mposhi– delays at Zambian changeovers and junctions.
- Ndola - train handover to SNCC for further operation.
- Sakania Border Post – customs clearance between Zambia and DRC.
- Lubumbasi – connections to Kolwezi.

A Best-Case Value Stream Map is presented in Table 6.2. In this table the dwell times at the various delay points in the rail corridor have been set at the minimum expected values. This optimistic analysis shows that in perfect conditions all-round, a best transit time through corridor can be reduced to 6 days.

TABLE 6. 2 Best Case Value Stream Map for NSC Rail System

Best Case VSMp for NSC Rail System - (From Durban to Kolwesi)								Comments
	Loading Time	Distance	Ave Speed	Travel Time	Dwell time	Clearance Time	Total Time	
	hrs	km	km/h	hrs	hrs	hrs	Days	
DBN Port	24							
DBN Bayhead Yard					4			Less time to assemble train 4 hours allowed
		576	25,3	22,75				
Sentrrand					1			No need for delyed stop
		98	43,6	2,25				
Pyramid South					1,1			Swop DC traction for AC and crew change
		247	44,1	5,6				
Polokwane					0,5			Crew change
		201	20,5	9,8				
Mussina					0,5			Crew change
		27	45,0	0,6				
Beitbridge					2			Swop AC traction for BBR diesels
South Africa	**24**	**1149**	**28,0**	**41**	**9,1**		**2,1**	
Beitbridge Border post						3	**2,2**	3 hour to clear at border post
		141	*30,0*	*4,7*				
Rutenga					1			Junctio and crew change
		281	41,6	6,75				
Somabhula					1			Junctio and crew change
		130	35,4	3,67				
Bulawayo					2			BBR to NRZ changeover
		12	16,0	0,75				
Mpopoma					1,25			Junction
		292	44,9	6,5				
Dete					0,5			Crew change
		74	24,7	3				
Thomson Junction					0,5			Junction
		99	36,0	2,75				
Victoria Fall Bridge					2,25			Delays to cross Victoria Falls Bridge
Zimbabwe	**0**	**1029**	**36,6**	**28,12**	**8,5**		**3,7**	
Vitoria Falls Border Poat						3	**3,9**	3 hour to clear at border post
		18	*18,0*	1				
Livingstone					2			NRZ change over to ZRL new crews, etc.
		213	*30,0*	*7,10*				
Chroma					0,5			Crew change
		215	*30,0*	*7,17*				
Kafue					1			Junction & crew change
		50	*30,0*	*1,67*				
Lusaka					1			Shorttne delyed stop
		142	*30,0*	*4,73*				
Kabwe					0,5			Crew change
		61	*30,0*	*2,03*				
Kapiri-Mposhi					3			Connection to Tazarra route
		117	*30,0*	*3,90*				
Ndola					4			Junction to SNCC line via Sakania, not operational
		66	*30,0*	*2,20*				
Nkana-Kitwe	**48**							**Last inland terminal on the NSC Rail System**
		94	*20,0*	*4,70*				
Zambia	**48**	**976**	**28,3**	**34,5**	**12**		**5,8**	
Kasumbalesa Border Post						3	5,9	
		100	*20,0*	*15*				
Lubumbasi					*4*			Truck stop to refuel and break for driver
		300	*20,0*	*30*				
Kolwezi								
DRC		*400*	*20,0*	*45*	*4*		*2,0*	
	2,0	3554,0	23,9	6,2	1,4	9,0	8,0	

From previous work done on trains running from Pyramid-South to Polokwane (on the NSC-Rail System), results were obtained on the reliability of the service. The planned travel time between these two points is 5 hours and 40 minutes. The actual time taken by 14 trains were recorded. The results of these are presented in Table B-1 in Appendix B. Only 6 out of the 14 trains completed the trip in the scheduled time, while 2 additional trains made it in less than 6 hours. The average duration of the trip for the 14 trains was 6 hours 18 minutes. The standard deviation was 39 minutes, while the slowest train took

7 hours 18 minutes, thus completing the trip within two standard deviations from the mean.

Applying the recorded variance of 2 standard deviations as an allowance in the NSC rail service design, to present a realistic service design, the outcome of such service design is presented in Table 6.3.

TABLE 6. 3 Value Stream Map for NSC Rail System within 2 standard deviations allowance **on travel time**

VSMp for NSC Rail System with 2 Standard Deviation allowance on Travel time - (From Durban to Kolwesi)								
	Loading Time	Distance	Ave Speed	Travel Time	plus 2SD	Dwell time	Clearance Time	Total Time
	hrs	km	km/h	hrs	Hrs	hrs	hrs	Days
DBN Port	24							
DBN Bayhead Yard						4		
		576	25,3	22,75				
Sentrrand						1		
		98	43,6	2,25				
Pyramid South						1,1		
		247	44,1	5,6				
Polokwane						0,5		
		201	20,5	9,8				
Mussina						0,5		
		27	45,0	0,6				
Beitbridge						2		
South Africa	**24**	**1149**	**28,0**	**41**	**49,46**	**9,1**		**2,4**
Beitbridge Border post							3	**2,6**
		141	*30,0*	*4,7*				
Rutenga						1		
		281	41,6	6,75				
Somabhula						1		
		130	35,4	3,67				
Bulawayo						2		
		12	16,0	0,75				
Mpopoma						1,25		
		292	44,9	6,5				
Dete						0,5		
		74	24,7	3				
Thomson Junction						0,5		
		99	36,0	2,75				
Victoria Fall Bridge						2,25		
Zimbabwe	**0**	**1029**	**36,6**	**28,12**	**33,92**	**8,5**		**4,3**
Vitoria Falls Border Poat							3	**4,5**
		18	*18,0*	1				
Livingstone						2		
		213	*30,0*	*7,10*				
Chroma						0,5		
		215	*30,0*	*7,17*				
Kafue						1		
		50	*30,0*	*1,67*				
Lusaka						1		
		142	*30,0*	*4,73*				
Kabwe						0,5		
		61	*30,0*	*2,03*				
Kapiri-Mposhi						3		
		117	*30,0*	*3,90*				
Ndola						4		
		66	*30,0*	*2,20*				
Nkana-Kitwe	**48**							
		94	***20,0***	***4,70***				
Zambia	**48**	**976**	**28,3**	**34,5**	**41,62**	**12**		**6,7**
Kasumbalesa Border Post							3	6,8
		100	*20,0*	*15*				
Lubumbasi						*4*		
		300	*20,0*	*30*				
Kolwezi								
DRC		*400*	*20,0*	*45*		*4*		***2,0***
	2,0	**3554,0**	**23,9**	**6,2**	**5,4**	**29,6**	**9,0**	**8,9**
				148,62	129,00			

This result indicates that although there is an amount of variance on the actual travelling time, ca 1 day within 2 standard deviations on the travel time for the total distance, it is not of such a random nature that multiple days will be lost in the travelling process. The VSMp in Table 6.3 supports the published throughput time of 8 days on the NSC Rail System.

Table 6.4 indicates that 3 days of excess dwell time and clearance time is provided for when a 10 days throughput time is scheduled.

TABLE 6. 4 Value Stream Map for NSC Rail System indicating excess dwell time provided for in 10-day transit schedule

VSMp for NSC Rail System - (From Durban to Kolwesi) - Excess dwell time provided in 10 day schedule									
	Loading Time	Distance	Travel Time	Dwell time Schedule	Clearance Time in Schedule	Minimum Dwell time	Minimum Clearance Time	Excess Dwell time in schedule	Excess Dwell time in schedule
	hrs	km	hrs	hrs	hrs	hrs	hrs	hrs	cumalative days
DBN Port	24								
DBN Bayhead Yard				8,25		4		4,25	
		576	22,75						
Sentrrand				**2,75**		1		1,75	
		98	2,25						
Pyramid South				1,1		1,1		0	
		247	5,6						
Polokwane				2,6		0,5		2,1	
		201	9,8						
Mussina				2		0,5		1,5	
		27	0,6						
Beitbridge				6,75		2		4,75	
South Africa	**24**	**1149**	**41**	**23,45**		**9,1**		**14,35**	**0,60**
Beitbridge Border post					12,5		3	9,5	0,99
		141	*4,7*						
Rutenga				2,33		1		1,33	
		281	6,75						
Somabhula				7,1		1		6,1	
		130	3,67						
Bulawayo				**5**		2		3	
		12	0,75						
Mpopoma				1,25		1,25		0	
		292	6,5						
Dete				3,1		0,5		2,6	
		74	3						
Thomson Junction				3,5		0,5		3	
		99	2,75						
Victoria Fall Bridge				2,25		2,25		0	
Zimbabwe	**0**	**1029**	**28,12**	**24,53**	**12,5**	**8,5**		**16,03**	**1,66**
Vitoria Falls Border Poat					9,25		3	6,25	1,92
		18	1						
Livingstone				2		2		0	
		213	*7,10*						
Chroma				2		0,5		1,5	
		215	*7,17*						
Kafue				2		1		1	
		50	*1,67*						
Lusaka				2		1		1	
		142	*4,73*						
Kabwe				2		0,5		1,5	
		61	*2,03*						
Kapiri-Mposhi				3		3		0	
		117	*3,90*						
Ndola				**4**		**4**		0	
		66	*2,20*						
Nkana-Kitwe	**48**							0	
		94	*4,70*						
Zambia	**48**	**976**	**34,5**	**17**	**9,25**	**12**		**5**	**2,13**
Kasumbalesa Border Post					10		3	7	2,42
		100	*5*						
Lubumbasi				*2*		*1*		**1**	
		300	*15*						
Kolwezi									
DRC		*400*	*20*	*2*	*10*	*1*	*3*	*1*	*2,46*
								60,13	
DAYS	2,0	3554,0	5,2	2,8	1,3	1,3	0,1	2,5	2,5
			123,62						

These excess dwell- and clearance times are about equally shared in the RSA, Zimbabwe and Zambian/DRC geographical territories.

The perceived throughput time of around 30 days, as stated by respondents to the questionnaire and studies such as the AICD (AICD, 2011) must include extra-long delays at the connections and handover points in the system, thus losing up to an additional 22 days on throughput time.

The reported total of 22 days lost in throughput time translates in more than 2 days of delays at each of these changeover points, on the assumption that they all contribute equally to the delay in throughput time. Research on where these extra-long delays occur in the NSC-Rail System, and what are the causes thereof, warrant further investigation.

6.3.1. NSC-Rail System Value Stream Mapping Summary

The outcomes of the NSC-Rail System Value Stream Mapping analysis captured in Tables 6.1 to 6.4 is summarised in Table 6.5 below. Table 6.5 shows that the current planning baseline for NSC rail throughput time, from Durban to Northern Zambia is 7,9 days and an additional 2,6 days are provided for the connections to Kolwezi. Should all dwell times along the corridor be reduced to the projected minimum then the delivery times to Kolwezi can be reduced to 8 days. The planning schedule thus includes cumulative excessive dwell time of 2,5 days.

Providing for real world variances, the actual travelling (running) time may vary with two standard deviations (2SD) from the planned travelling time. With provision for this 2SD allowance, the expected delivery times from Durban to Northern Zambia and Kolwezi are 6,7 days and 8,9 days respectively, assuming minimum dwell times along the corridor.

TABLE 6. 5 Expected Cumulative Delivery Times for the NSC-Rail System

	Cumulative Delivery Time for the NSC Rail System (DAYS)			Excessive dwell time in NSC schedule (cumulative days)
	Current Planning Baseline	Best Case min dwell time	Travel time Plus 2SD	
South Africa	2,7	2,1	2,4	0,6
Beitbridge Border Post	3,2	2,2	2,6	1,0
Zimbabwe	5,4	3,7	4,3	1,7
Victoria Falls Border Post	5,8	3,9	4,5	1,9
Zambia	**7,9**	**5,8**	**6,7**	2,1
Kasambulesa Border Post	8,4	5,9	6,8	2,4
DRC	10,5	8,0	8,9	**2,5**

6.4. Capacity Balancing in the NSC-Rail System

The capacity balancing and resource allocations in the rail transport system are subject to the dynamics illustrated in Figure 6.5, a diagram developed with inputs from the TFR Logistics Integration section.

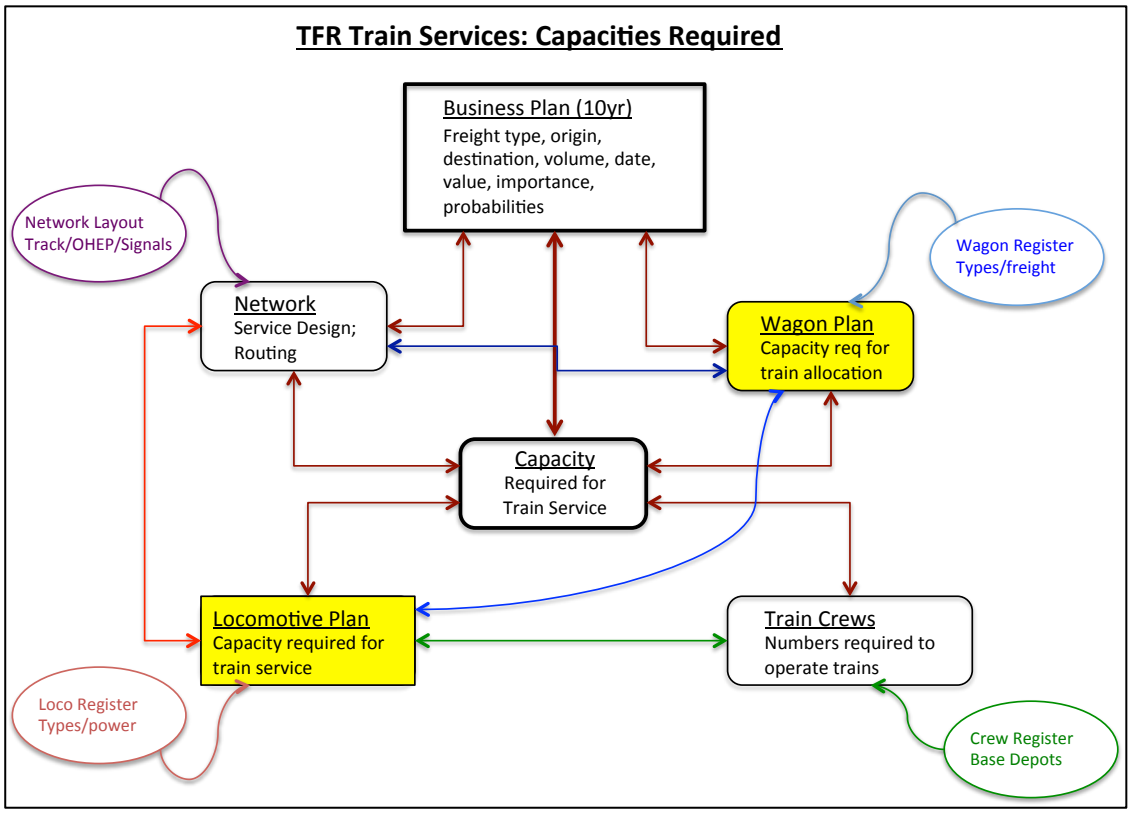


Figure 6.5: Capacities required to provide scheduled train service

The required capacity to perform the rail service formulated in the agreed business plan is determined by a number of factors, being:

- Service Design – based on the rail network capacity, typically in terms of track layout, routing, junctions, bridges, tunnels, stations, allowable axle mass, train lengths, loops, sidings, cross-over points, signalling systems, gradients, curves and speed restrictions.

- Wagon Plan – allocations of the correct types and numbers of wagons required for the scheduled trains at the origins, where and when required, to make up the scheduled trains.

- Locomotive Plans – assignment and dispatching of the correct types and numbers of serviceable locomotives to the scheduled trains by the interconnected rail operators. The locomotives need to be ready to take over the NSC trains on arrival at the border handover posts.

- Train Crews – the planning, assignment and readiness of the required crews to operate the assigned locomotives and trains through the corridor responsibility area of each successive individual railway operator in the NSC-Rail System

6.5. Stratified Systems Review Summary

The Node Flow Mapping of the NSC-Rail System highlighted the numerous discontinuities in what is required to be a 'seamless' NSC rail corridor. The regionally linked system is operated by 8 sovereign operators, each with their own politics, policies, business models, systems, equipment, cultures and ways of doing. It also showed the sharp contrast in the low traffic density linear corridor north of Pyramid South, and the high freight density integrated Transnet rail network south of Pyramid South.

The Viable Systems Model for the NSC-Rail System showed that the system fails at the Coordination (level 2) and Optimisation (level 3) levels of a viable system. This gap requires an accountable organisation at SADC/SARA level to manage the integrated NSC-Rail System.

The Value Stream Mapping identified the non-value adding delays caused by customs clearances at the multiple border crossings. Coordination by customs authorities can certainly phase out duplication of effort and reduce these unwanted delays. Further the VSMp identified the locomotive and crew change-over points as major causes of transit delays. These are between operators/countries and also at Pyramid South. Bottlenecks along the route were identified at Sentrarand/Gauteng and the crossing of the bridge at Victoria Falls between Zimbabwe and Zambia. The VSMp outcomes indicated that the rail transit time between Durban and DRC should be circa 8 days as presented in the rail service design. No reasonable explanation could be found why the respondents to the questionnaire, and other researchers recorded an actual transit time on the corridor of circa 30 days. These unplanned delays could be attributed to poor co-ordination between the service providers or lack of capacity to continue the train service as scheduled. On the South African side cross border trains may be delayed due to their Category C (low priority) status. To determine the causes leading to these delays in throughput time will require further investigation, which is beyond the scope of this research project.

Once the NSC-Rail System Service Design is applied in practice then capacity balancing through network capacity improvements, wagon and locomotive availability and train crew readiness should be addressed.

7 SUMMARY AND CONCLUSIONS

7.1. Summary Research Outputs

The outputs from this research are covered under the headings of:

a. Research questionnaire outputs summary.
b. BMC Outcomes for the NSC-Rail System.
c. Summary of systems analysis and opportunities.

7.1.1. Research Questionnaire Outputs Summary

The key outcomes from the questionnaire are listed below:

- **Rail operations**. Rail operations are expected to be seamless, cost-effective, safe and reliable with delivery times that should be better than that achieved by road transport, as the operators have control over their infrastructure and can optimally schedule their services. The NSC-Rail System however, suffers from the discontinuities of hand-overs between multiple operators along the corridor and similarly multiple border crossings (repeated customs clearances).
- **Independent operators**. The biggest challenge for execution and control in the NSC-Rail System is that the individual railways work independently. Customers feel that the rail operators are slow to respond to commercial issues and very slow in the execution of their duties. A customer expressed the desire that ideally the stakeholders should agree on a single operator for the whole rail corridor.
- **Communication difficulties**. Many respondents reported on communication difficulties and cultural misunderstandings / misalignments between the railways of the different nations along the corridor. A lack of mutual trust amongst the operators was shining through the responses.
- **Multiple customs clearances**. The need to address the multiple customs obstacles along the corridor was raised and questioned why the customs officials from the stakeholder countries could not work together in having a single clearance accepted by all relevant customs.
- **Concept of Operations**. The rail solution requires a single NSC-Rail System Concept of Operations that is adopted by all the independent stakeholders in the system. This will ensure one offering to the market and standardisation of operations at all levels of the system.

7.1.2. BMC for the NSC-Rail System

Table 7.1 presents the BMC framework outcomes for the NSC-Rail System.

Table 7.1 BMC for NSC-Rail System

BMC Outcomes for the NSC-Rail System	
Value Proposition	Seamless movement of bulk freight (minerals , agricultural inputs and products, containers, fuels, automotive and related products) to and from the sea ports and within the respective countries. Price competitive, safe, efficient, predictable and reliable end-to end supply solution for transportation of bulk heavy materials over long distances, with guaranteed
Customer Segments	Increased trade volumes in the region and along the corridor; expansion of industrial, argricultural and commercial sectors reliant on an efficient rail solution (e.g copper mines), development of industrial hubs linked to an efficient rail solution,
Cusomer Relationships	The NSC-Rail System must have a co-ordinated marketing and customer relations effort. A seamless service from origin to destination should be offered. Local relationships with local customers must be maintained within the bigger joint NSC-Rail service offering. Communcation on progress and the tracking of freight is a requirement.
Channels for Services	Most customers use the services of 3PL freight forwardes and clearing agents. They impact the transport decision. Marine-ports, Loading docks, and in-land dry-ports are the required facilities at the rail service terminals. Feeder transport providing connections to the rail service is essential.
Activities to be Performed	Seamless' cross border train services in accordance with the NSC Service Design. Consistently meet the transit time of 8 days as per the Service Design. Increased regional integration, reduced carbon emissions, reduced external interfaces. Ensure a safe, secure and reliable service. Perform scheduled and on-condition maintenance. Perform training at all levels within the system.
Resources Required	Dependable rail infrastructure, well maintained track and control systems, sufficient wagons of the right types, reliable locomotives, well trained crews and other operating personnel. Funding is required to enable operations, ensure maintenance and invest in the rehabilitation and capacity upgrades of the system. The standarsdisation of systems and equipment in the NSC-Rail System is important.
Key partners to support Offering	The integration of rail services along the NSC rail corridor is cardinal. The independent operators within the sovereign countries must agree to integrate their services along the corridor. Support from the respective government structures, rail safety regulators, SARA and SADC is key. The support from major shipping lines servicing the Southern African ports contributes to the viability of the NSC.
Cost Structure	The major cost driver is the fixed infrastructure, systems, equipment and personnel costs, both in terms of capital investment and maintenance and training. Traction costs; wagon costs, terminal costs; control costs and conumables add to the variable costs. The need to secure the systems and the freight transported on the NSC requires a security premium which is not present on other global rail services. The high rate of in-efficiency in the NSC-Rail System contributes to under utilisation of the expensive infrastructure and much higher costs.
Revenue Model	Rail is a 'price-taker' from road, where road rates are relatively cheap based on balanced up-and-down loads. Customers wants to pay one price for the complete service and prefers this to be in a stable currency (e.g. USD) as this is also the currency that they trade their produce in. The revenue streams are based on the traffic tendered by customers and each member of the corridor charges its tariff based on the distance travelled over its own lines. Client invoicing is done by the operator from where traffic originates. Other operators invoices him for their share. For an integrated system revenue management may be centralised.

7.1.3. Summary Systems Analysis and Opportunities

The key outcomes from the systems analysis are listed below:

- **Corridor versus Network architecture**. During the systems analysis it became clear that when modelling the NSC-Rail System, the accepted general definition of the 'pit-to-port corridor', running from Kolwezi in the Southern DRC down to the ports of Southern Africa, will not suffice. The actual bi-directional 'corridor' runs from Kolwezi to the Transnet Gauteng Freight node connection at Pyramid-South in the Gauteng Province of South Africa. At Pyramid-South the NSC train enters the Transnet Gauteng Freight node and is further routed via the Transnet Rail 'network' with separate/alternative connections to the respective ports of Durban, Richards Bay, Maputo, Nqqura, East London and Cape Town.
- **Traffic Density**. On entering the Gauteng Freight node the traffic density intensifies multiple times (ca 100x) and the modelling constructs used for the linear corridor do not continue to apply in the Transnet network with multiple connections and distributed flows. The 'corridor-dynamics' north of Pyramid–South is now replaced by the 'network-dynamics' of the Transnet rail system. The latter system is similar to a typical communications network, or power distribution network or logistics packet distribution network and should be modelled using such concepts (typically agent based modelling), whereas for the line north of Gauteng, optimisation of a linear system would be appropriate.
- **System Design and Service Design**. The dynamic behaviour differentiation (corridor vs network) impacts on the System Design and Service Design of the NSC-Rail System. In future modelling work it will be required to connect the two different dynamic models, being the NSC northern line and the Transnet Rail Network branching out from the Gauteng Freight Node to the Southern African ports. The model will need to represent a system with connected sub-systems, with different dynamics at play in each of these sub-systems.
- **Value-Add**. By treating the NSC-Rail System as an integrated system and by introducing the concept of *value-add* into the planning of the NSC operations, the optimised business model for this rail corridor may lead to a new way of managing this business.
- **Viable Systems Model.** The Viable Systems Model for the NSC-Rail System showed that the system fails at the Coordination (level 2) and Optimisation (level

3) levels of a viable system. This gap requires an accountable organisation at SADC/SARA level to manage the integrated NSC-Rail System.

- **Value Stream Mapping.** The Value Stream Mapping of the NSC-Rail System determined that the throughput time from Durban to Kolwezi (and vice versa) should be 8 days as stated in the service design for the NSC-Rail System. This outcome then requires an explanation of the experienced 30 days throughput time reported by questionnaire respondents, as well as publications such as the AICD (2011). The 22 days (30 days minus 8 days) lost in throughput time, can rather be attributed to long border clearance delays, discontinuity in train handovers between successive operators and waiting time for locomotive change overs. These delays point to a failure in the co-ordinated execution of the integrated train plans for the NSC-Rail System. This study should be extended to focus on the causes of these dwell times in the system, and to address ways of eliminating the excessive time lost at border crossings and train hand-overs between the successive rail operators.
- **Benefits from research findings**. For customers to return their freight to the NSC-Rail System they require a cost-effective seamless solution from origin to destination. They do not want to interface with all the operators and other stakeholders along the corridor, but want to be informed on the progress of their cargo, which they expect to be reliably delivered at the destination within 8 days. Implementing the findings of this research will make a big contribution to improving the performance of the NSC-Rail System.

7.2. Conclusions

The rail service on the NSC must be improved to provide a better service in delivering bulk freight and containerised traffic to and from the central (landlocked) areas of Southern Africa. The operations of the multi-country rail operators must be aligned and optimised to contribute to the value adding performance of the complete system. Rail passenger transport has been declining and has not been included in the work presented here.

It can be concluded that:

- **Inland dry-terminals** have been identified by the questionnaire respondents as a key success factor for the NSC, and investment in the rehabilitation of the rail network only, without also establishing this crucial element of the complete NSC-Rail System will result in sub-optimal returns.

- **Security of Freight**. A freight forwarding respondent attributed their avoidance of using the north bound rail service to the loss of goods in the rail system, goods failing to reach its intended destination and goods being consumed in the wrong country. The security of customers' goods also featured. This security aspect supported an earlier view that one of the reasons for the perceived reluctance to use the rail system for traffic going north is the *perception* that goods will either not reach its destination or will be tampered with along the way.
- **System Effectiveness and Operational Efficiency**. The study identified that the essential challenge on the NSC-Rail System is system effectiveness and operational efficiency above all else. Infrastructure degradation has certainly contributed some margin to the decline in rail service levels. However, the identified communication difficulties and cultural misunderstandings, -misalignments and distrusts between the railways and the peoples of the different nations along the corridor are a serious challenge to seamless operations.
- **Competitive Advantage**. Participants defined the competitive advantage of an integrated, harmonised NSC-Rail System as being; "*Price competitive, safe, efficient, a predictable and reliable end-to end supply chain solution for transportation of bulk heavy materials over long distances, and with dependable delivery times.*"
- **Competitive pricing and short delivery times** have surfaced as the key expectations of a future viable NSC-Rail system. An optimised business model for the NSC-Rail system must deliver on these expectations.
- **Business model.** The framework for a business model for NSC-Rail System must address all the elements of the required system which include services such as; freight forwarding, warehousing, freight delivery, container handling, loading and unloading, customs clearing and collection, feeder transport, inland terminals, port terminals and rail transportation connections.

7.2.1. Recent interventions on the NSC-Rail System

After completion of the body of this research, during October 2017, the following developments on the NSC-Rail System are noteworthy;

a. The NEPAD Business Foundation Infrastructure Study has been completed, but the report on this study has not yet been released into the public domain.
b. A further JOC to complement the one in Bulawayo is being planned for Ndola in Zambia.

c. Transnet SOC has been awarded a contract to perform the rehabilitation of the Zimbabwe rail infrastructure.
d. New inland container handling facilities are being planned for key points along the NSC, the primary new ones being Lubumbashi, Ndola and Kapiri Mposhi.
e. SARA has signed a MOU with the DBSA to enable the DBSA to fund infrastructure rehabilitation projects on the SARA rail corridors in Southern Africa.
f. SARA has also signed a MOU with the SA Heavy Haul Association, with a view of translating the application of heavy haul best practices also to the lighter rail corridors overseen by SARA.
g. Zambia has promulgated a law that requires at least 30% of identified bulk freight to be transported by rail. This law was driven by the need to protect the country's investment in its road infrastructure from the damage caused by heavy bulk freight loads.

7.2.2. Improving Effectiveness

All these current improvement efforts are focussed on improving the efficiency of the NSC-Rail system. A critical problem, contributing to the lack of effectiveness of the NSC-Rail system, uncovered by this research through the views of Clients, Freight Forwarders, Consultants and Rail Suppliers, is that 'Information Sharing amongst the parties is "Very poor" and mostly "Piece meal". These research participants ascribe the problems to the language barriers, misunderstandings and distrust caused by cultural differences between the peoples of the nations along the corridor. A standard NSC-Rail System wide programme addressing applied training, change-management-, goal alignment and a common vocabulary is recommended to address this underlying problem of unity in the NSC-Rail System.

7.2.3. Interventions not addressed in this study

Interventions on the NSC previously studied, but not addressed in this research include alternative legislative policies, organisational reform, unconventional asset ownership schemes, innovative funding and financing vehicles and technological improvements.

8 RECOMMENDATIONS FOR FUTURE WORK

A concern that was noted by the respondents, is the remaining economic lives of the mines in Zambia and Southern DRC, stating only 4 to 10 years for some mines. Research into this falls outside the scope of this study, but should be undertaken before large capital

investments is made in the rehabilitation of the rail system on the expectation of large mineral freight volumes to be transported to the ports. Similarly, the feasibility of establishing the much shorter rail link from the DRC to the port of Lobito should also be considered, as such an alternative solution will have a major impact on the future viability of the NSC-Rail System.

The Value Stream analysis concluded that a more in-depth analysis on why a 30 days transit time is the reported performance level, while the expectation is an 8 day transit time. An analysis of all the sources of dwell time in the NSC-Rail System listed below, is required:

- Sentrarand – delays due to congestion of TFR traffic in the Gauteng freight ring and PRASA commuter services interfaces.
- Pyramid–South – delays due to locomotives and crew availabilities
- Beitbridge Border Post – customs clearance and train handover to BBR for further operation.
- Somabhula, Bulawayo and Thomsons Junction in Zimbabwe – delays at changeovers and junctions along the Zimbabwean section of line.
- Victoria Bridge Border Post – customs clearances, waiting for opportunity to cross the bridge and train handover to ZRL for further operation.
- Lusaka and Kapiri–Mposhi - delays at Zambian changeovers and junctions.
- Ndola – train handover to SNCC for further operation.
- Sakania Border Post – customs clearance between Zambia and DRC.
- Lubumbasi – connections to Kolwezi.

A detailed analysis of the reported scheduling problems to cross the Zambezi river at the Victoria Falls bridge is also recommended.

An integrated NSC-Rail System will still be confronted with the challenge on how to address the socio-technical problems along the multi-country corridor, with underlying language, cultural and trust barriers between the sovereign peoples, all being connected by the NSC value chain. Future studies on how to solve these traditional differences and prejudices can make a major contribution to the future operations of the NSC-Rail System, and also have a wider impact in better co-operation throughout the whole SADC region.

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APPENDIX A LISTING OF RESEARCH FEEDBACK

After obtaining Wits ethics approval, a research questionnaire was distributed to as a many as possible stakeholders, participants and role players in the NSC-Rail system. The researcher also identified 40 key stakeholders which were directly approached to participate in the research.

Respondents (Table A-1)

Responses to the research questionnaire were poor, with only 17 members returning completed questionnaires. On the positive side these responses did cover all the important stakeholder categories. Table A-1 below summarises the respondents.

TABLE A-1 Respondents

TABLE 1: RESPONDENTS					
NSC-RAIL SYSTEM RESEARCH PROJECT					
QUESTIONAIRRE FEEDBACK					December 2017
		Minimum	Mean	Maximum	Responses / Feedback
Question No	Question				
1	**Personal Details**				
a.	Name:				Representatives of Rail Operators, SARA, Logistic Consultants, Customs/Tax Consultants, Freight forwarders, Mining Clients, NEPAD ID & Rail Suppliers.
b.	Formal qualifications:	Log Dipl	Post grad	MSc, MBA, M	Highly qualified respondents, Mostly financial or business
c.	Work experience:	9	**22**	35	Experienced respondents
d.	Job Title / Position:	Snr manager	Executives	Directors	
e.	Position you report to:	Chief Traffic Offic	Board Levels	CEO's	
f.	Duration in your current position:	1	**7**	17	Experienced respondents in current positions for a reasonable time
g.	Previous position title:	Senior Clerks	Snr Managers	GM's	
h.	Duration in previous position:	3	**8**	25	Respondents has progressed through the ranks spending a reasonable time in their previous positions.

Representative Stakeholders (Table A-2)

The responses received covered most of the important stakeholder categories, as shown in Table A-2, and thus enables a systems analysis on the NSC-Rail System. The only stakeholder grouping not directly represented in the responses are government. However, the responses from state owned rail operators will be taken as also representative of their government shareholders.

TABLE A-2 Representative NSC-Rail System Stakeholders

TABLE 2: REPRESENTATIVE NSC-RAIL SYSTEM STAKEHOLDERS		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
		Responses / Feedback
Question No	Question	
2	Your Organisation	
a.	Name of Organisation:	Representative Stakeholder
b.	Type of Organisation (rail operator, regulator, customer, logistic services, financier, investor, labour, etc.):	Rail Operators (27%), Rail Associations (9%), Consultants (27%), Clients (18%), Rail Projects & Suppliers(19%).
c.	Shareholders (government, private, etc.):	Goverments, SOCs, Registered Rail Operators, Asset Holding Companies, Private Investment Companies (Chinese in particular)
d.	Source of Funding (capital & operational):	Rail operators funded through bank loans.
e.	Type of Business:	Rail operations - freight & people
f.	Primary business focus areas:	Rail, Dry-port, Corridors & Port Terminals Customs clearing, Freight Forwarding, Container Handling & Warehousing
g.	Main business strategy:	NSC Rail to provide Cost-effective, safe & reliable Bulk Transport
h.	Geographical operating area:	SADC & EAC
i.	Service offering/products:	**Services:** Freight Forwarding, warehousing, delivery, container handling, customs clearing and collection. **Products**; coal, chrome , grain, cement, clinker, sugar, coffee, tea, granaite blocks, containersed traffic and passengers

Roles of the Stakeholder Organisations within the NSC-Rail System (Table A-3)

The responding stakeholder's specific role within the NSC-Rail system will provide the perspective from which the stakeholder participated in the research. Table A-3 summarises these responses to this questionnaire section. The responses indicated that most parties focus on their specific role in NSC-Rail system only and reflected little appreciation for the perspectives of other parties.

TABLE A-3 Role of Stakeholders within the NSC-Rail System

TABLE 3: ROLE OF STAKEHOLDER WITHIN THE NSC-RAIL SYSTEM (PERSPECTIVES)		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
		Responses / Feedback
Question No	Question	
3	**Role of your Organisation in the NSC**	
a.	Define your organisation's role in the NSC:	Our role is to facilitate the movement of the goods within the NSC. We provide efficient handling and clearing procedures for customers' goods. Our copper is now transported by road.
b.	Where do you see **your** opportunities for business development?	Mines and industry sector, agricultural sector, and movement of fuel and other products from the ports to inland countries such as Botswana, Zimbabwe, Zambia and the DRC. Rail can re-capture the bulk freight that has moved to road.
c.	What Challenges and/or Constraints are you facing?	The challenges currently faced are shortage of wagons and locomotives and also the poor conditions of the railway network. Aging machiney [Locomotives and wagons], aging railway lines, **lack of capital** to revamp the aging systems and or revive the signaling systems for easy flow of trains. Poor rail service forces some of our clients to transport some of the containers by road after collecting them from the different ports like Beira or Durban.
d.	How would you describe your organisation's strengths, your established business areas and your competitive advantage?	Our strength is in moving bulky commodities in large volumes and our competitive advantage is in doing this at a lower cost than our main competitor [road transport].
e.	In which areas of your business are you losing business or not making inroads in the market?	In Passenger Transport mainly because of old and outdated train coaches and also the inability to be on time most of the time. Container business; mainly because of lack of container handling facilities at source, Copper movement from Zambia to South Africa has moved to/remained on road transport. North bound traffic mainly going by road.
f.	Describe any operational problems you are dealing with.	Currently dealing with challenge of establishing a reliable and sustainable system of trains working. Slowness in implementing SARA initiative by SARA members. Communication & cultural challenges.

Views on an Integrated and Harmonised NSC-Rail System (Table A-4)

Participants were encouraged to share their views on how an Integrated and Harmonised NSC-Rail system should look and behave. This feedback is captured in Table A-4.

TABLE A-4 Views of an Integrated and Harmonised NSC-Rail System

TABLE 4: VIEWS OF AN INTEGRATED AND HARMONISED NSC-RAIL SYSTEM		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
		Responses / Feedback
Question No	Question	
4	Your view of an **Integrated and Harmonised NSC**	
a.	Identify/list all the other role-players in the NSC.	SADC, SARA, DFIs, SADC Secretariat, COMESA. NSC Rail operators, Containers/inland ports operators, Freight Forwarders, Mining Houses, Private businesses, Government institutions, Port operators, Road Transport Operators, Air Transport. Mines, trading companies, customs, Governments (SADC), funders, consultants, NEPAD Business Foundation.
b.	What future opportunities do you foresee for an integrated, harmonised NSC?	Seamless movement of minerals , agricultural inputs and products, Fuels and related products to and from the sea ports and within the respective countries. Increased trade volumes in the region; expansion of industrial & commercial sectors reliant on an efficient rail solution (e.g copper mines), development of industrial hubs linked to an efficient rail solution, increased regional integration, reduced carbon emissions, reduced externalities. **Mining target customers**: Nchanga mine, Glencore , Konkola deep mine, Sentinel/Kalumbila mine, Chibuluma mine and the Mutanda mine, beneficiation : Kansanshi, Nchanga and the Mufulira smelters, retail
c.	How would you define the competitive offering of the integrated, harmonised NSC?	**Price competitive**, safe, efficient, predictable and reliable end-to end supply solution for transportation of bulk heavy materials over long distances, with improved delivery times.
d.	Define the major advantages and/or strengths of the integrated, harmonised NSC.	REDUCED TRANSPORT COSTS Lower logistics costs, improved efficiency and improved delivery times IMPROVED REGIONAL INTEGRATION AND COLLABORATION REDUCED EXTERNALITIES
e.	What are the challenges and/or constraints of the NSC in its current state?	Lack of coordination and cooperation amongst the different railway systems within the corridor. Poor communication resulting in NSC transport operators being considered a "black box" by customers. Infrastructure across the various Railway systems is in different states of wear and tear, and in the main requires rehabilitation and/or upgrading; cost structures also worlds apart
f.	State areas where the NSC may be currently underperforming and/or failing to achieve its potential.	Rail reliability is poor. Few well established dry ports. Cargo security. Border posts and customs. Insufficient rail transport capacity to move rail friendly cargo. Very little northbound business. Different interchange and operational polices within the neighbouring railway systems. Movement of passengers.
g.	What are your expectations of the future of the NSC?	Rail should be the dominant player for long haul and bulk business. 1._Return to **system design capacity** in the short to medium term (***transportation of up to 6mtpa***), 2. Capture of up to 30 - 40% of surface transport market share in the long term.

Views on Organisation's interactions with NSC (Table A-5)

As presented in Table A-5, a broader view of the NSC-Rail system external interfaces expands to the ports, shipping companies, trading partners, financiers and community interests. Noteworthy amongst these is that the port of choice for imports and exports is determined by the shipping lines. Where the NSC volumes are small compared to the TFR volumes, the NSC volumes contributing to shipping volumes are minute. Thus NSC freight goes where the shipping line docks and therefor determines the port destination of freight along the corridor.

TABLE A-5 View's of Organisations's Interactions with the NSC-Rail System

TABLE 5: VIEWS OF ORGANISATION'S INTERACTIONS WITH THE NSC-RAIL SYSTEM		
5	**View of your organisation's interaction with the NSC**	
a.	Which other NSC role-players does your organisation directly interface with?	African Union, EAC, EU , World bank, Funding & Trading partners. Shipping lines; MSC, CMA-CGM, Portuguese International, Maersk
b.	What is the nature of these interfaces?	Bilateral and corridor meetings Face to face and advocacy, transact business and also share information. Facilitation and coordination, information gathering and analysis, alignment on proposed corridor solutions.
c.	What is your view on current NSC information sharing?	Very poor, many perceptions. Piece meal, problem is the **language barrier** and distrust caused by **cultural differences**. Trading companies are keen to share information, operators not?
d.	What is your view on current NSC commercial partnerships?	**Common view:** Individualistic (own priorities), not integrated, hidden agendas. Each Railway preserves rates information as confidential. **Opposed to**: We share rates and seek for customers as a team, the commercial partnerships are working well though there is room for improvement.
e.	What is your view on the main elements of the NSC Cost Structures?	Road rates are relatively cheap (balanced up-and-down loads). Rail south is same price as rail north-bound. Traction costs; terminal costs; equipment costs and overheads. Warehousing and handling is competitive but has a security premium.
f.	How would you describe the current NSC Revenue Streams and income sharing models?	**Revenue Sharing model agreed to at SARA level** is equitable. Variations are always negotiated. (view by rail operator who is getting a larger than fair share according to the other operators.) The revenue streams are based on the traffic tendered by customers and each member of the corridor charges its tariff based on the distance travelled over its own lines. Client invoicing is done by the operator from where traffic originates. Other operators invoices him for their share. The revenue sharing does not take into account the asset contribution of each railways. e.g the provider of the wagons is not rewarded for that contribution.

Contributions Expected from other NSC Stakeholders (Table A-6)

Question 6, summarised in Table A-6, explored what contributions the respondents were expecting from other stakeholders in the NSC-Rail system. Most pronounced of these was to **find innovative methods of financing** the rehabilitation of the system.

Responding to their own support role in the NSC-Rail system the respondents all reflected a spirit of willingness to share information amongst all NSC stakeholders, a desire for integrated operations and co-operation and achieving a ***harmonised service offering through participation in the Joint Operation Committees (JOC's).***

TABLE A-6 Contributions Expected from other NSC Stakeholders

TABLE 6: CONTRIBUTIONS EXPECTED FROM OTHER NSC STAKEHOLDERS		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
Question No	Question	Responses / Feedback
6	**Contributions from other NSC stakeholders/role-players**	
a.	What contributions are you expecting from other role-players?	Contribute to socio-economic feasibility. From DFIs and other financial institutions we expect **innovative methods of finance, risk allocation and mitigation;** from governments we **expect sovereign support and commitment** to follow through on implementation of proposed projects. Operators to value safety of customers goods and quick responses to different needs of our customers. Actively generate additional business and back loads. NSC members to pool resources to ensure the required capacity in the corridor..
b.	How can you support the other role-players in the NSC?	Through applying **integration models**, cooperation and responsiveness, through pooling resources together and also through harmonized training for operatives. Interacting and sharing ideas through meetings and formation of joint operation committees, ensuring information sharing at the appropriate levels.
c.	Comment on the framework providing for individual independent sovereign operators versus a joint co-operative NSC structure.	**The rail organisations is not mature enough for a joint NSC rail structure.** Road hauliers and integrators already provide a joint co-operative structure in the NSC, but this excludes rail. Railways are born out of Govt. Statutes, hence the **issues of sovereignty**. Due to differences in **working cultures**, **equipment** and other resources, a Joint co-operative NCS Structure may need a long time to set up. NSC rail operates through **individual independent sovereign operators**, some members of the corridor do not have **capacity** hence business can be lost through non availability of capacity. Considerations are; objectives of each State for its State owned entities and State assets; Fiscal implications and debt obligations.

Harmonising the NSC Rail Operations (Table A-7)

NSC-Rail Sales and Customer Services can be improved by better understanding of customer needs. The NSC-RAIL operators must work together to create joint products over the whole NSC and these should be marketed through a joint marketing effort by all role-players.

TABLE 7: HARMONISING THE NSC-RAIL OPERATIONS		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
Question No	Question	Responses / Feedback
7	**Harmonising the NSC operations**	
a.	How can overall NSC sales and customer service be improved?	Through creation of a **joint marketing team** for the corridor to market the corridor to prospective customers and also to look at all the bottlenecks within the supply chain and how they can be eliminated, by sharing information processes and enabling one stop shop enquiry desks. information on rates, distances, mode of payments and any other related information should be readily available and accurate and uniform at all times. Transactions should be in international currency such as USD. Align the sales and customer service on an **online app**. Operations should provide for **online cargo tracking.**
b.	Define typical future customers who should be targeted by the NSC.	Customers are already there. They have just taken their business from rail mode of transport to road mode. **Customers**: Mining outputs (copper, cobalt & chrome). Imports for mines (lime, sulpher, etc.) Agro processed traders (tea, coffee, sugar, etc.) Containerised freight.
c.	How can coordinated and integrated planning for the NSC be achieved?	"**Political will**" is the key factor. Through Networking with the other stakeholders. Through setting up offices with representatives _from all corridor members. By formulating J**OCs [joint Operation Committees** and synchronizing our activities. Need to set up a joint operating/command centre. By **giving the JOC a stronger role to plan & execute**.
d.	What current problems is your organisation experiencing with regards to execution and control in the NSC?	The **individual railways work independently.** Slow response to commercial issues and slow in execution of duties. Non return of rolling stock to owners. Pilferage of cargo. Individualistic approach by operators_, with some wanting to " Play Big Brother" to no benefit or at the expense of the overall NSC strategy. Politics of member states also affects smooth operations of the NSC.
e.	Propose considerations for an integrated strategy for the NSC.	**Political will and commitments** at states level. Transparency, Investor friendly socio-economic policies with long term commitments. **One operator over the whole network**. Wholesale price for rail.
f.	List the main considerations to take into account for the NSC System Design and NSC Service Design.	Infrastructure, Rolling stock, customer requirements, **port operations** and capacity, human factors, commodity type , tariffs etc Locomotives not changed at border. Wagons to flow over the whole network. **One operations centre** and concerned with delivery times. 1._environmental impact of operations. 2. safety considerations 3. cost effectiveness 4.profitability 5._rewarding employees 6. **Security of customer goods.**
g.	In your opinion, which investment requirements should be prioritised for the NSC?	***First are soft operations and management issues*** , then removal of Hot Spots (**Emergency perway rehabilitation**) along the NSC. Rolling stock & side door containers. Inland container parks/depots, Dry ports and terminals. Lastly is rehabilitation of infrastructure- which is a long term strategic investment.
h.	State your view on the current Asset Management practices applied in the NSC.	**Each operators manages and maintains own assets** , except for cross border rolling stock. Maintenance is weak. Not enough parts for on-going maintenance, leads to a general shortage of wagons and locomotives amongst NSC Rail operators.
i.	State your view on the current utilisation of assets available to the NSC. _	Very poor, 30-60 days for a consignment to move up and down the corridor. Asset Utilisation is impacted by differences in assets available to individual players. Wagons are mainly loaded in southern direction and return empty, thus poor utilisation on the northen trip.
j.	To what extent is standardisation of systems a concern and/or a constraint in the NSC?	Standardisation is a **main concern to customers**. They require things to move in line with modern technology. ***Language and cultural barriers within the member states*** were the main contributing factors to differing standards and equipment. For Rail Operators this is no longer a major issue. S**ome systems had already been harmonized though SARA especially on technical and safety aspects**. Biggest differences remain with locomotives and train authorisation systems.
k.	Define the key metrics to measure NSC performance.	(1)Corridor Transit times (2) Net Tons Carried, Volume of key commodities. (3) Wagon Turnaround (4) Track availability (5) Locomotive Availability, (6) Locomotive km per month.

The biggest driver however is "Service Delivery Time". This MUST be improved from the current ca 30 days to no more than 10 days from origin to destination, for the NSC-Rail system to become successful.

Collaboration in planning, resource allocation and utilisation of capacity amongst the operators is necessary. The digital sharing of Information will improve customer services and must allow for online cargo tracking by customers.

For modelling purposes, it became clear that the North–South Rail "***Corridor***" actually ends at Pyramid-South where the south traffic enters the Transnet Gauteng freight node and north traffic departs from the Transnet Gauteng freight node. From the Transnet Gauteng freight node traffic is within the Transnet rail ***network*** with connections to Maputo, Richards Bay, Durban, Port Elizabeth, Ncqura, East London and Cape Town. The "***corridor-dynamics***" north of Pyramid–South is now replaced by the "***network-dynamics***" of the Transnet rail system. The latter system is similar to a typical communications network, or power distribution network or logistics packet distribution network and should be modelled using such concepts, whereas for the line north of Gauteng, optimisation of a linear system (such a line-balancing) would be appropriate.

This dynamic behaviour differentiation (corridor vs network) impacts on the System Design and Service Design of the NSC-Rail system. In our future modelling effort we need to connect the two different dynamic models, being the NSC northern line and the Transnet Rail Network branching out from the Gauteng Freight Node to the Southern African ports. The model will need to represent a system with connected sub-systems, with different dynamics at play in each of these sub-systems.

General Comments and Inputs to the Research (Table A-8)

The success of the NSC-Rail system is truly vital for the improvement of the economies of the member states and close co-operation and standardisation of processes is key to the success of the NSC.

The NSC Rail System requires an integrated approach, from the independent sovereign authorities whose constituents stand to gain immensely from a performing NSC-Rail system. General comments to the research is presented in Table A-8.

TABLE A-8 General Comments and Inputs to the Research

TABLE 8: GENERAL COMMENTS AND INPUTS TO THE RESEARCH		
NSC-RAIL SYSTEM RESEARCH PROJECT		
QUESTIONAIRRE FEEDBACK		December 2017
Question No	Question	Responses / Feedback
8	General comments/inputs for the study.	The success of the NSC is truly vital for the improvement of the economies of the member states and close co-operation and standardization of processes is key to the success of the NSC. It is critical to gain the respective Governments' support for the required investments in the NSC Rail to materialize concurrently, because of the sovereignty issues around most Rail operators. Strong lobbying is therefore necessary, through the various Ministries of Transport, so that one or more Railways in the link do not become a hindrance to the attainment of overall objectives.

APPENDIX B RESULTS OF TRAVEL TIME BETWEEN PYRAMID-SOUTH AND POLOKWANE

The scheduled travel time between Pyramid-South and Polokwane on the NSC-Rail corridor is 5 hours and 40 minutes. The actual time taken by 14 trains were recorded. The results of these trips are presented in a Table B-1. Only 6 out of the 14 trains completed the trip in the scheduled time, while 2 additional trains made it in less than 6 hours. The average duration of the trip for the 14 trains were 6 hours 18 minutes. The standard deviation was 39 minutes, while the slowest train took 7 hours 18 minutes, thus completing the trip within two standard deviations from the mean

Table B-1 Results of travel time between Pyramid-South and Polokwane

	Sign On (Time)	Sign Off (Time)	Total Shift Time (Hours)	Total Driving Time (Hours)	Percentage of Driving Time / Total Shift time (%)
1	14:25:00 PM	22:08:00 PM	07:43:00	06:12:00	80.35
2	21:26:00 PM	03:58:00 AM	06:32:00	05:45:00	88.01
3	06:00:00 AM	15:46:00 PM	09:46:00	06:41:00	68.43
4	14:02:00 PM	19:48:00 PM	05:46:00	05:30:00	95.38
5	13:42:00 PM	00:30:00 AM	10:48:00	07:18:00	67.59
6	21:05:00 PM	03:35:00 AM	06:30:00	05:52:00	90.26
7	15:41:00 PM	21:40:00 PM	05:59:00	05:42:00	95.26
8	16:40:00 PM	22:30:00 PM	05:50:00	05:31:00	94.57
9	15:36:00 PM	22:58:00 PM	07:22:00	06:24:00	86.88
10	20:20:00 PM	03:30:00 AM	07:10:00	05:36:00	78.14
11	12:29:00 PM	20:29:00 PM	08:00:00	06:51:00	85.63
12	12:20:00 PM	20:38:00 PM	08:18:00	07:12:00	86.75
13	17:20:00 PM	00:46:00 AM	07:26:00	06:41:00	89.91
14	20:56:00 PM	04:19:00 AM	07:23:00	07:02:00	95.26
		Min	05:46:00	05:30:00	67.59
		Max	10:48:00	07:18:00	95.38
		Mean	07:28:04	06:18:21	85.89
		SD	01:26:39	00:39:14	9.25

APPENDIX C UNIVERSITY ETHICS CLEARANCE

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Bester

CLEARANCE CERTIFICATE	PROTOCOL NUMBER: H17/02/04
PROJECT TITLE	A conceptual framework for optimising the business model of the North-South Rail Corridor (NSC) in Southern Africa
INVESTIGATOR(S)	Mr P Bester
SCHOOL/DEPARTMENT	MIA Engineering/
DATE CONSIDERED	17 February 2017
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	18 May 2020
DATE 19 May 2017	pp CHAIRPERSON Director (Professor J Knight)

cc: Supervisor : Dr I Campbell

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature

22/05/2017
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

APPENDIX D RESEARCH QUESTIONNAIRE

RESEARCH PROJECT

A CONCEPT FOR THE OPTIMISING OF THE BUSINESS MODEL FOR THE NORTH SOUTH RAIL CORRIDOR FOR SOUTHERN AFRICA

QUESTIONNAIRE

The rail North South Corridor (NSC) in Sub-Saharan Africa is defined as the rail corridor stretching from the southern DRC, through Zambia, Zimbabwe, and Botswana to the ports of Mozambique and South Africa. There are multiple role players in this corridor and the rail services provide for both freight and passengers. The corridor crosses the borders of the sovereigns and has a key role to contribute in the economic development of this sub-continent.

1. Personal Details
   a. Name:_____
   _____
   b. Formal qualifications:_____
   ____
   c. Work experience:_____
   _____
   d. Job Title / Position:_____
   __
   e. Position you report to:_____
   f. Duration in your current position:_____
   g. Previous position title:_____
   h. Duration in previous position:_____

2. Your Organisation

a. Name of Organisation:_____

___

_____

_____

b. Type of Organisation (rail operator, regulator, customer, logistic services, financier, investor, labour, etc.): _____

_____

_____

c. Shareholders (government, private, etc.):

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d. Source of Funding (capital & operational):

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e. Type of Business:

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f. Primary business focus areas:

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g. Main business strategy:

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h. Geographical operating area:

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i. Service offering/products:

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3. **Role of your Organisation** in the NSC

a. Define your organisation's role in the NSC:

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b. Where do you see **your** opportunities for business development?

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c. What Challenges and/or Constraints are you facing?

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d. How would you describe your organisation's strengths, your established business areas and your competitive advantage?

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e. In which areas of your business are you losing business or not making inroads in the market?

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f. Describe any operational problems you are dealing with. _____
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4. Your view of an **Integrated and Harmonised NSC**

a. Identify/list all the other role-players in the NSC.

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b. What future opportunities do you foresee for an integrated, harmonised NSC?

c. How would you define the competitive offering of the integrated, harmonised NSC?

d. Define the major advantages and/or strengths of the integrated, harmonised NSC.

e. What are the challenges and/or constraints of the NSC in its current state?

_____

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f. State areas where the NSC may be currently underperforming and/or failing to achieve its potential.

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g. What are your expectations of the future of the NSC?

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5. View of **your organisation's interaction** with the NSC

a. Which other NSC role-players does your organisation directly interface with?

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b. What is the nature of these interfaces?

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c. What is your view on current NSC information sharing? _____

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d. What is your view on current NSC commercial partnerships?

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e. What is your view on the main elements of the NSC Cost Structures?

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f. How would you describe the current NSC Revenue Streams and income sharing models?

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6. Contributions from **other NSC stakeholders/role-players**

   a. What contributions are you expecting from other role-players?

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   b. How can you support the other role-players in the NSC? _____

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   c. Comment on the framework providing for individual independent sovereign operators versus a joint co-operative NSC structure.

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7. Harmonising the NSC operations

a. How can overall NSC sales and customer service be improved?

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b. Define typical future customers who should be targeted by the NSC.

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c. How can coordinated and integrated planning for the NSC be achieved?

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d. What current problems is your organisation experiencing with regards to execution and control in the NSC?

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e. Propose considerations for an integrated strategy for the NSC. _____

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f. List the main considerations to take into account for the NSC System Design and NSC Service Design.

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g. In your opinion, which investment requirements should be prioritised for the NSC?

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h. State your view on the current Asset Management practices applied in the NSC.

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i. State your view on the current utilisation of assets available to the NSC.

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j. To what extent is standardisation of systems a concern and/or a constraint in the NSC?

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k. Define the key metrics to measure NSC performance.

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8. General comments/inputs for the study.

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