A systems-based comparative assessment of corridor bottlenecks: the case of Beira Corridor

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DEDICATION

This thesis is dedicated to the people most special in my life. They were like the waters of the sea around a ship, as they all kept me buoyant throughout my academic voyage. Despite the turbulence of striving to balance my work, social life and academic work, they stood steadfast, anchoring me with their support and love like an anchor securing a ship from rough tides of the ocean. These are my late wife, Violet and my children, Kudzai, Tendai and Ruvimbo. I will forever treasure their unconditional love. Their inexplicable tolerance to my emotional absence during the time of my academic journey towards a doctoral degree qualification is priceless. I will continue being indebted to them beyond my time. Lastly, my late mother's support and that of my two sisters was equally unparalleled.

"*Just as ships are kept afloat offshore by the waters around them, so are we by the people around us".* Author.

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ABSTRACT AND EXECUTIVE SUMMARY

The existence of alternative routes to serve landlocked countries within the Southern African Development Community (SADC) and the resulting competition between corridors provides the backdrop to this comparative study. Historical research compares corridors in terms of both direct costs and time delays, but without translating time delays and variability in time delays into the economic costs experienced by corridor users. As cargo owners form part of global Just-in-Time value chains, unpredictable time delays can have a devastating impact on their competitive situation within the global economy. Against this background this study takes a systems approach to compare the performance of the Beira Corridor with two other competing corridors, serving the same landlocked SADC countries served by the Beira Corridor: Dar es Salaam and North-South (Durban) corridors.

The motivation for the research is the paradox that, while Beira port is much closer to the landlocked countries served by these corridors compared to Durban and Dar es Salaam, it attracts much less cargo compared to the other two corridors. The study compares the attractiveness of each corridor based on Total Economic Cost (TEC) from the perspective of the combined set of stakeholders, including transporters, retailers, and manufacturers. The TEC model includes not only direct costs but also the impact of logistics delays and variability in delays. It furthermore quantifies the relative contributions of ports, border posts and road travel to TEC.

The study found that while the Beira corridor has the lowest direct cost to the hinterland if only average travel time is considered, the North-South corridor proves to be the most competitive corridor when the variability in time delays is also considered. Port's efficiency proved to be the biggest differentiator between these corridors, followed by border posts and road links. This explains why the North-South corridors enjoys the largest share of cargo transported between the coast and the landlocked hinterland. Based on the results, the thesis recommends the use of modern ICT solutions by ports and customs authorities to streamline both the physical processing of cargo as well as the enforcement of compliance, as this has proven to be critical elements to achieve the levels of efficiency observed for corridors operated on other continents. Secondly the study recommends that transport policy, as implemented by the governments of the countries through which the corridors run, must support a higher level of competition regarding the provision of logistics services, as this has proven to increase the quality of service on corridors serving developed economies. Thirdly, for Beira corridor to be competitive, it is recommended that the identified physical and non-physical bottlenecks need to be addressed.

This includes construction of a RORO berth to cater for motor vehicle imports and to establish reefer services for reefer containers for fruits and vegetables exports both of which products feature as having a significant untapped import potential for the four LLCs.

The study recommends that corridor development and assessment efforts must consider all elements constituting a corridor, not in isolation, as is seen in most studies and initiatives concerned with corridor performance assessment and development. The study has confirmed that the absence of formal governance, poor regulatory processes, poor infrastructure conditions, modal capacity constraints and uncompetitive logistics activities, all create a host of bottlenecks that reduce the efficiency of the Beira Corridor. Through the application of a systems approach, the performance of the corridor can be assessed, incorporating all the impediments from the various sub-systems to allow for appropriate improvements and performance enhancement. This is confirmed by the comparative assessment performed in this study, to determine the performance of the Beira Corridor which was put in the context of competing corridors, instead of assessing it in isolation.

Lastly the study recommends that efforts to understand corridor bottlenecks should not focus on one element such as physical infrastructure alone, but consider other factors, such as transport modes, logistics activities and regulatory processes. The dry port should be considered part of the solution, where it serves as an extension of the port to address the problem of congestion. It should play the role of an intermodal facility, which will lower logistics costs for users as rail is more competitive than road at distances 300km and above. This supports the systems thinking argument, that corridor performance is a function of a host of factors emanating from the various elements constituting a corridor. Since these elements are interrelated, they all generate different forms of bottlenecks that affect the efficiency of the corridor and can only be understood if a systems approach is adopted in the assessment of corridor bottlenecks and in the development and management of corridors in general.

Keywords: transport corridor bottlenecks, performance, total economic cost, landlocked countries, systems thinking.

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ACRONYMS

AFREXIMBANK	African Export–Import Bank
CFM	Portos e Caminhos-de-Ferro de Mocambidue
DFID	Department for International Development
DRC	Democratic Republic of Congo
EAC	East African Community
GMS	Green Motor Services
GPS	geographical positioning system
ICT	Information and communication technologies
ITC	International Trade Centre
LLDCs	Landlocked countries
NWU	North West University
OSBP	One-Stop-Border Post
PwC	Pricewaterhouse Coopers
SADC	Southern African Development Community
TCs	Transit Countries
TEC	Total Economic Cost
TEU	Twenty-foot equivalent unit
USAID	United State Agency for International
USD	United States Dollar
VOC	Vehicle operating cost

CHAPTER 1 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

The Beira Corridor connects Zimbabwe, Malawi, Zambia, and DRC to the gateway of the Port of Beira, situated on the eastern coast of the Indian Ocean, at the mouth of the Pungwe River, in Mozambique. This study compares the performance of three competing corridors serving the above landlocked Southern African Development Community (SADC) and East African Community (EAC) countries: The Beira, Dar es Salaam and North-South (Durban) corridors. These three corridors are listed in the AFREXIMBANK report produced by Nathan, (2020), as primary routes that dominate cargo flows to and from the hinterland.

Transport corridors as part of the transport system play an important role in linking landlocked countries to global markets, through various regional ports and inland hubs. This is true for the Beira corridor which is critical for imports and exports for Malawi, Zimbabwe, Zambia and the eastern Democratic Republic of the Congo (DRC), all regarded as landlocked countries, albeit DRC being semi-landlocked (PricewaterhouseCoopers (PwC), 2018). The Beira Corridor has been a subject of interest among international donors who have funded studies such as DFID (2016) and USAID (2018) all of which were aimed at identifying bottlenecks affecting the performance of both Nacala and Beira corridors. The Beira corridor needs to address its bottlenecks in order to be competitive with corridors competing for cargo to and from the same hinterland as illustrated in Figure 1.

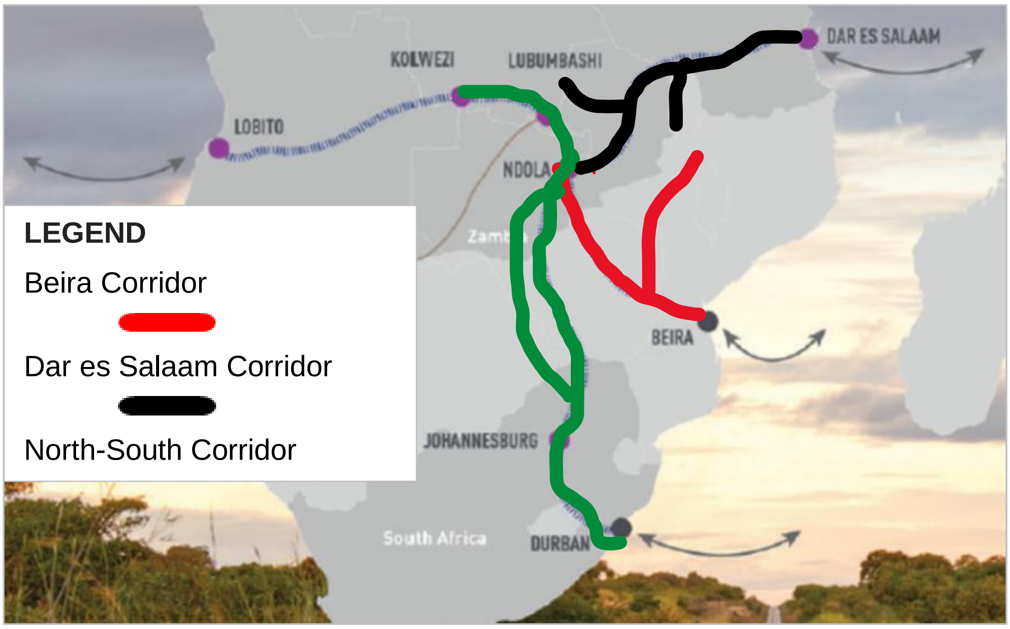

Figure 1 The three main corridors serving SADC landlocked countries

Source: Adapted from Tanzania Ports Authority Handbook (2019-20)

The map in Figure 1 shows three corridors that serve the same the same market, namely the Beira, Dar es Salaam, and Durban (North-South) corridors; the latter two are direct competitors and threats to the existence of the Beira corridor. They are all on the Indian Ocean and target the same hinterland as the Beira Corridor. Goods and services are transported across the world via global supply chains to satisfy demand. According to PwC (2018) seaports process 80% of trade by volume and 70% in terms of value. Therefore, it is important that bottlenecks at ports are addressed, as the corridors linking these ports to the hinterland need to be rid of the various bottlenecks to perform effectively. According to Japan International Cooperation Agency (2010) the performance of the region's ports has been poor, mainly due to congestion since cargo-handling capacity cannot cope with growing demand. Import and export procedures require considerable time, and the detention of goods at ports has become a major obstacle to efficient distribution.

The deterioration of regional railways over the years, partly due to very little investment, has not spared the Beira Corridor. The collapse of the railway service on the Machipanda line created a bottleneck as all the traffic was forced onto the road network. According to Japan International Cooperation Agency (2010) the privatisation of railways has not helped the situation, rather there has been an increase in waiting times at ports before cargo can be loaded onto trains, hence causing extremely low productivity.

Since transport corridors transcend national borders in the port hinterland, border posts have been shown to pose as another source of bottlenecks in the form of lengthy clearance processes which increase logistics cost. Transporters in most parts of the region cross several borders between ports and landlocked destinations. According to Southern African Development Community (2013) initiatives to implement One-Stop Border Posts (OSBP) have been gaining momentum across the region to enhance administrative processes, including one on the Beira Corridor implemented in 2009 at Chirundu, between Zambia and Zimbabwe.

The other source of bottlenecks on the Beira Corridor is regulatory issues, which also contribute to delays and long transit times along the corridor. According to USAID (2018) these include transport regulations, such as mandatory use of certain termini, checkpoint regulations and customs regulations at border posts. The lack of storage facilities at or near the port, as well as near production centres across the corridor is a bottleneck linked to regulatory issues. It is stated that necessary regulations are not sufficiently enforced, especially axle load limits on roads. This not only reduces the life expectancy of roads but is also to the detriment of modal competitiveness of road viz a viz rail, and of transport service quality.

This chapter presents the background, research problem statement, research questions and motivation of the study. The conceptual framework for the study is presented as well as the expected contribution of the research. The research methodology and design for the study are briefly explained and issues of validity and ethics considered. The Chapter closes with an outline of the thesis Chapters and a concluding summary.

The landlocked countries of the South African Development Community (SADC), comprising the Eastern Democratic Republic of Congo (DRC), Malawi, Zambia, and Zimbabwe, are served by three intermodal corridors. These countries have the option of using either the Beira Corridor, Dar es Salaam Corridor or North-South Corridor (with Durban as port). When choosing between routes users consider time efficiency and cost-effectiveness of the corridor as of paramount importance. According to Hanaoka et al (2019) many landlocked developing countries (LLDCs) encounter difficulties importing and exporting goods because cargo must pass through land borders and lengthy roads or railways to access seaports located in transit countries (TCs). They argue that difficulties arise due to the poor condition of transport infrastructure and border facilities, which forces LLDCs to endure higher logistics costs and longer transit times compared with TCs, making them less competitive in the global context.

Various studies have reviewed the development of multinational transport corridors and assessed their performance (Goldmann & Wessel, 2020) (Hanaoka, et al., 2019). However, not many studies have focused on transport corridors in SADC. Although there have been concerted recent efforts to develop international highways and railways in SADC, there are many road sections and railway lines that have deteriorated, with the Beira Corridor the most affected of the three corridors (USAID, 2018). Additional barriers to cross-border movement still exist in the region because of nonphysical constraints (e.g., lengthy customs procedures). These inefficiencies in the transport system have an adverse impact on the economic development of LLDCs (Hoffman, et al., 2013).

The study furthermore employed descriptive research complemented by interpretive research to explain the quantitative results, including a SWOT analysis using secondary and primary data. Literature relating to similar studies was reviewed to appreciate the various approaches employed in assessing corridor performance. While Hanaoka et al (Hanaoka, et al., 2019) evaluated corridor performance from the perspective of infrastructure owners (ports, roads, and railways), this study conducts the evaluation from the perspective of the cargo owner, more specifically the retailer or manufacturer importing goods as part of business operations. To arrive at a model that includes all relevant costs the study assesses the physical infrastructure including ports, maritime transport, railways, roads, border crossing facilities and intermodal transfer points, as well as non-physical measures such as the border crossings and customs clearance processes as a system. The three corridors are then evaluated in terms of the cost impact of both total transportation time and variability in time delays. The main source of long and variable transit turnaround times at border posts and ports is the lack of suitable ICT support, causing inefficiencies such as intrusive inspection methods.

Previous research (Hanaoka, et al., 2019) (Goldmann & Wessel, 2020) mainly considered the cost of infrastructure and direct transport costs and incorporated other factors like infrastructure and regulations only by way of qualitative discussions. These studies furthermore compared time delays but without converting time delay and variability of time delay into their respective economic impacts on corridor users.

1.2 The Beira Corridor

The Beira corridor consists of several routes that connect the Democratic Republic of Congo (DRC), Malawi, Zambia and Zimbabwe to the port of Beira.   For these inland countries, which rely on foreign trade, it is important to secure access to alternative corridors. The configuration of the Beira and Nacala Corridors consisting of the main routes (road and rail), are illustrated in Figure 2.

Figure 2 Map of major routes constituting Beira and Nacala corridors

Source: Google maps

The Beira Corridor serves road transport along the following routes:

- the Beira–Mutare–Harare–Chirundu–Lusaka Route, which overlaps with the Harare–Chirundu–Lusaka section of the North-South Corridor,
- the Beira–Tete–Blantyre Route, the so-called Tete Route, and
- the Beira–Nhamilabue–Nsanje–Blantyre Route, the so-called Sena Route, as the shortest route to the sea for inland countries including Malawi, Zambia, and Zimbabwe,

all of which are also served by the Dar es Salaam and North-South Corridors. The Beira Harare transport corridor was developed as Zimbabwe's prime international trade route but was affected by the regional conflict situation from the mid-1960's to the mid-1990's. Both the road and rail links were kept operational throughout the Mozambique civil war, while the route to Nacala and the links between Beira and Malawi were disrupted. The current condition of roads sections along the Tete and Sena Routes are however not good. While rehabilitation is ongoing on some sections, financing has not been available for the development of most sections.

The port of Beira is the gateway for the Beira Corridor, which imports and exports for several landlocked countries as indicated above. According to Pricewaterhouse Coopers (2018) the port of Beira is the second largest port in Mozambique and has consistently handled imports and exports for Malawi, Zimbabwe, Zambia and the DRC. The port of Beira links to its hinterland via roads, railways and a pipeline. The port of Beira over the years suffered from lack of investment and operational efficiency. In addition, the shallow draughts at berths as well as on the access channel make it impossible for bigger vessels to call at the port. Even with the further dredging that has continued to happen, the port still has challenges with sedimentation and a shallow channel, both of which pose as a bottleneck for the accommodation of larger vessels. The continuous dredging of the port adds to the operational costs of the port affecting the port's competiveness with other Mozambican ports on the same coastline of the Indian Ocean such as Nacala and Maputo.

The 'Beira Port Transport System' received international donor support of about $450 million in the period 1985 to 1996, which was focused on the port and Beira Harare Corridor (Perez-Niño, 2015). It included dredging of the port and access channel to its design depth (which could not be maintained for more than few years), and the construction of a new container terminal and a new oil terminal. However, the port of Beira continued to have challenges including the perennial siltation according to PWC (2018).

In 1998 the government of Mozambique awarded a twenty-five-year concession to a private company, Cornelder de Mocambique, to operate the container and general cargo terminals, a policy decision aimed at improving the operations of the port and to encourage investments. The company is a partnership between the state-owned rail and ports authority Portos e Caminhos-de-Ferro de

Mocambidue (CFM) and Cornelder Holland. The concession has been operational since October 1998 and was due to end in 2023 but has since been extended for a further 10 years.

Through Cornelder, the port of Beira has witnessed many improvements that have led to increased throughput over the years. For instance, the container and general cargo terminals have received significant improvements. According to PWC (2018) there are plans to construct a new coal terminal for vessels up to 125 000 dwt as well as a new bulk terminal for fertiliser, sugar and cereals. This would also include the deepening of the shallow access channel to cater for larger vessels and a dedicated warehouse for breakbulk cargo and tobacco.

In the next section the developments that have been already implemented at the port of Beira are discussed. These include the container and the general cargo terminals.

1.2.1 Port related improvements

Since the operation of port of Beira has been transferred from the government of Mozambique to Cornelder, several projects have been implemented to improve the port. The various terminals have been upgraded which have led to the revamping and expansion of the port terminals. Figure 3 shows various terminals at Beira port, namely fuel, coal, general cargo, bulk grain and container terminals. In addition, many projects have been implemented where physical infrastructure upgrades have been made. For example, the various dredging projects at the port increased draft at the various quays and berths to accommodate bigger vessels. There were also upgrades on the fuel, container, coal and general cargo terminals.

Figure 3 Beira port layout

Source: Cornelder (2018)

Before the completion of the physical infrastructure projects, port statistics show that in 2010 the performance was very low, whereby the port was achieving 300 moves per day, with truck turnaround time of more than 4 hours and vessel productivity of 15 moves per hour and container dwell time of approximately 20 days according to USAID (2018). However, the DFID (2016) report established that, while most trucks left within 12 hours, some spent 20 to 34 hours within the port. Hence, there is still need for improvement in terms of processing of cargo and vehicles.

According to Cornelder (2018) in 2017 the performance of the port doubled following the continued investments in physical and non-physical infrastructure. On the physical infrastructure side, the terminal was expanded with additional capacity created to accommodate 200 000 TEUs instead of the original design of 100 000 TEUs. In order to support these increased volumes, there was significant investment in handling equipment, which included 4 x STS Gantry Cranes, 2 x 65-tonne Twin cranes, 21 reach stackers, 35 terminal tractors/trailers. There was also the expansion of the empty yard as well as the expansion of the full yard.

On the non-physical side, new systems were implemented including increased automation and employment of modern logistics and cargo handling techniques. There was also a strong drive to train and retrain the workforce to be able to respond to modern logistics challenges and increased demand at the port. Thus, performance in terms of productivity doubled to 600 moves per day and truck turnaround times reduced by more than 5 times to a record 45 minutes in 2017, according to Cornelder (2018). Vessel productivity more than doubled from 15 moves to more than 40 plus moves per hour with container dwell times reduced by more than 100% from 20 days to less than 10 days. While these represent productivity improvements, 10 days is still high as some ports like Durban achieve dwell times of 2 or 3 days. The handling of cargo therefore remains a bottleneck even though from a space perspective the capacity more than doubled.

1.2.2 General Cargo Terminal

Figure 4 below illustrates the volumes of general cargo handled from 1998 to 2017. There has been almost 200% growth in capacity between 1998 and 2017 as a result of the various investments in infrastructure and logistics processes improvements over the years.

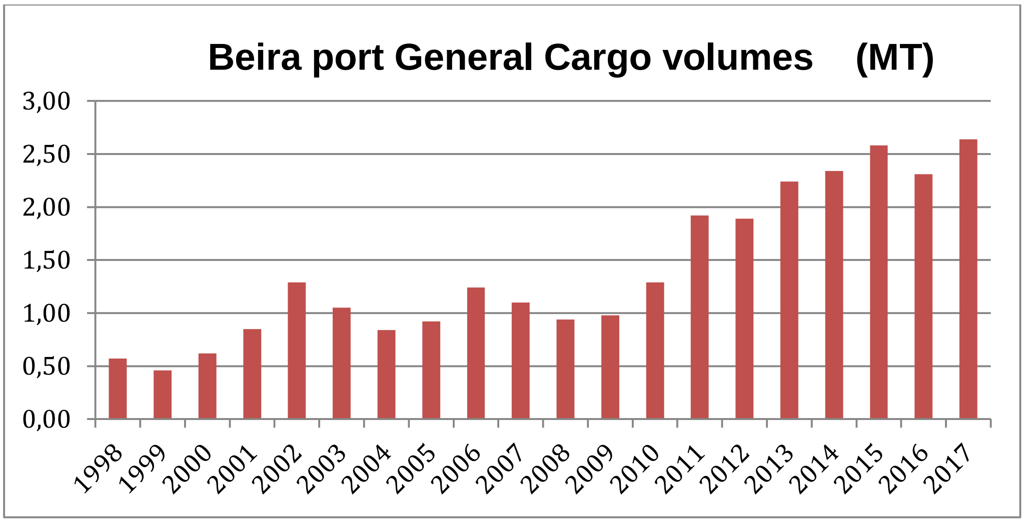

Figure 4 General cargo handled at Beira port between 1998-2017

Source: Cornelder (2018)

Figure 5 below shows the trend of the TEUs handled at the terminal from the time of concessioning, 1998 to 2017. The trend line shows a progressive increase in volumes handled over the years as a result of the infrastructure projects implemented and the various logistics improvement initiatives implemented by the concessionaire. According to Cornelder (2018), there are several initiatives that were undertaken to achieve this exponential growth. The company attributed this to investment in infrastructure and systems, training of staff, implementation of better procedures and rules as well as collaboration with stakeholders.

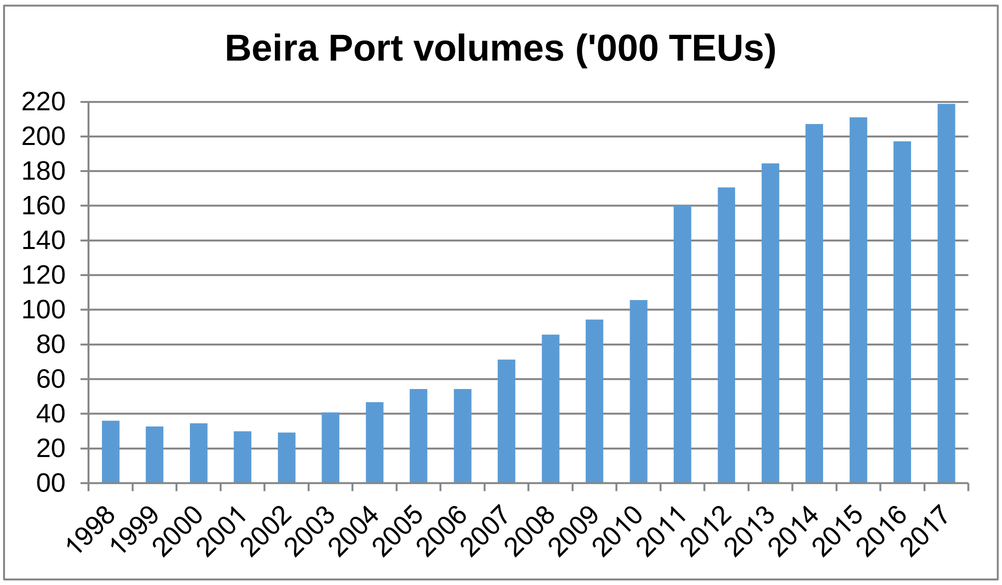

Figure 5 Container traffic volume handled at Beira port between 1998-2017

Source: Cornelder (2018) Container traffic 1998-2017

In terms of physical infrastructure, the general cargo terminal now has a capacity comprising 680m of quays. The facility has a capacity of 15.000m^2 covered storage, 150.000m^2 open storage and 50.000t bulk cereals storage. Given the annual turnover of containers through the port, this will allow containers a maximum dwell times in the port of between 10 and 20 days before the storage yard becomes congested. Storage space is therefore not a significant bottleneck that constrains port capacity. In terms of equipment, the general cargo terminal has three-50t forklifts, bagging machines/hoppers/grabs and two mobile port cranes. Heavy lift cranes are hired from private operators in the city of Beira. While this increase in capacity means more space available to accommodate and handle cargo, it needs to be complemented by increased truck loading capacity. At the moment trucks still spend between two and three days at the port which is a bottleneck.

The port still has a significant amount of work to be done despite the improvements discussed above. For instance, the container terminal still requires the upgrade of the quay and yard capacity. Accessibility into the port remains a challenge which needs to be upgraded in terms of infrastructure and systems. According to Cornelder (2018) these upgrades would increase the container terminal significantly to 700 000 TEUs per annum. According to Cornelder, it will implement the upgrades in three phases, with the first phase already completed, as indicated above and this has contributed to the increase in cargo volumes handled as displayed in Figure 5. These improvements mean that more volumes will be handled by the port in future and would require increased capacity for other elements of the Beira Corridor such as rail, road, border posts dry port as well as processing capacity in terms offloading and reloading after physical inspections.

While the port capacity has been largely improved, the link of the port with the hinterland is fraught with challenges including the collapse of the Machipanda railway line which connects with Zimbabwe. Equally, the major road linking the port with its hinterland, the EN6 has also deteriorated over the years due to lack of maintenance. Despite the significant investments that have happened at the port, road and rail infrastructure has not enjoyed the same levels of investments. Due to lack of funding the EN6 has not been maintained for a long time to the extent that it became completely run down, thus becoming a major bottleneck. The deterioration was further compounded by the shift of all traffic to road due to the collapse of rail on the Beira Corridor has exerted pressure on the road rendering it poor in condition, leading to reduced travel speeds, long transit times and high vehicle operating cost (VOC).

Besides the physical infrastructure challenges, there are also several non-physical obstacles including regulatory issues that have continued to affect the Beira Corridor. These tend to have the same effect as physical infrastructure issues in terms of contributing to delays, long transit times and the overall logistics costs. While over the years efforts have been made to address some bottlenecks, there still remain challenges, which continue to limit the performance of the freight transport nodes and indirectly hamper the development of the entire corridor (USAID SPEED+ Project, 2018). This motivates the need to identify the still existing bottlenecks affecting the Beira corridor as a system and quantify the improvements that will be achieved if these bottlenecks are eliminated. This will form the basis for motivating policy direction and the allocation of funds and management efforts towards the objective of corridor bottlenecks reduction and increased competitiveness.

1.3 Purpose of the study and research problem statement

From an economic cost perspective, it would be expected that the proximity of competing ports to the hinterland should determine the share of cargo moving on each corridor between the hinterland and the Indian ocean seaboard. As demonstrated in this study, this is however not the case: while Beira Port is by far the closest to the primary economic hubs of the landlocked SADC countries, it also enjoys the smallest share of imports and exports. For instance the AFREXIMBANK report, (Nathan, 2020) ranks Beira Corridor 1st in terms of road distance, Dar es Salaam 3rd and North-South Corridor 7th, yet Beira carries a significantly small share. In terms of the most important corridor for each transit markets in 2016, for regional flows, the report states the following made several observations in terms of the competitiveness of each corridor with respect to the hinterland market share. It states that for the DRC Copperbelt market the Dar es Salaam Corridor dominates with 73% market share, followed by the North-South Corridor, with 21% of the market. In terms of the Zambian market the North-South Corridor dominates with 51% market share, followed by the Dar es Salaam Corridor with 39% of the market. Equally, the Zimbabwean market is dominated by the North-South Corridor, with 94% market share, followed by the Beira Corridor with 6% of the market. The report then ranked the most important regional transport corridor for regional flows for the period 2016 as follows:

1. North-South Corridor with 11.791 million tons;
2. Dar es Salaam Corridor with 3.839 million tons;
3. Walvis Bay Corridor with 0.651 million tons;
4. Nacala Corridor with 0.438 million tons; and,
5. Beira Corridor with 0.471 million tons.

The number 1 ranking of Beira Corridor in terms of distance to the market does not translate favourably to the share of regional flows handled by the corridor paradoxically. Instead, the North-South Corridor ranking number 7 in terms of distance carries more ten times the share of Beira.

Previous approaches to assess corridors based on distance and direct cost, for example Regmi & Hanaoka, (2012) and Yang et al (2018), cannot explain the above paradox, as both the cost required to provide and operate infrastructure as well as the direct transportation cost is the lowest for Beira Corridor. This study therefore aims to quantify the hidden costs from the perspective of cargo owners, mostly resulting from variability in time delays, to arrive at a Total Economic Cost (TEC), by Hoffman (2019) model that can explain the reasons for the observed share of cargo that each corridor enjoys.

The use of the TEC model provides evidence that the choices of corridor made by cargo owners and their logistics service providers are indeed rational and based on maximising economic value for corridor users. The lack of providing for the impact of variability in time delays is thus proven to be a severe limitation in previous work that compared corridor performance. It is furthermore important to notice that the TEC model incorporates all the factors impacting corridor performance, including policy, regulations, infrastructure, direct and indirect costs, since the total delays experienced by cargo transported along a corridor reflect the impact of all these factors.

Given the above background and problems, the study compares the performance of three competing corridors, namely the Beira, Dar es Salaam and North-South (Durban) corridors using a systems approach. According to Blanchard & Fabrycky (2014) a system refers to a combination of functionally related elements forming a unitary whole such as a transportation system. They argue that systems comprise components, attributes as well as relationships. It is based on the foregoing definition that this study considers a corridor as system or a set of transport systems and routes, whose challenges can only be adequately addressed if the various elements are considered as one whole and not in isolation. A systems approach will ensure that bottlenecks emanating from all elements of the corridor are considered and addressed within their proper context, as part of efforts aimed at improving corridor efficiency and reducing logistics costs.

The most recent studies by DFID (2016) and USAID (2018) as well as PWC (2018) confirm that there still remain a significant number of bottlenecks on the Beira Corridor affecting its competitiveness. The two studies by DFID and USAID focussed more on the Nacala Corridor and referred to the Beira Corridor on aspects of comparative and competitive advantage with no in-depth study of the Beira Corridor bottlenecks. This study will improve upon these historic studies by embracing a holistic perspective in assessing the bottlenecks that remain through the application of systems thinking.

The various elements of the corridor in terms of physical infrastructure and non-physical attributes form the basis for the assessment of bottlenecks.

On the other hand, the non-physical bottlenecks of the corridor are those associated with the conceptual system aspects comprising logistics activities, regulatory issues, customs processes, cargo handling and checkpoints along the corridor.

The systems approach is used to assess all the bottlenecks affecting the Beira Corridor, in comparison with competing corridors, and to estimate the benefits to the regional economy that could be achieved, should road infrastructure and regulatory processes be improved to the same level as the available port infrastructure.

Therefore, the purpose of this study is to compare the attractiveness of each corridor based on Total Economic Cost (TEC), incorporating all factors contributing to cost from the perspective of the combined set of stakeholders, including transporters, retailers, and manufacturers. Against this background the research questions for this study are as follows:

Main Question:

1. *What role can a systems perspective play in solving the bottlenecks that currently affect the performance of the Beira corridor?*

Sub-questions:

2. *What are the bottlenecks affecting the performance of the Beira corridor?*
3. *What is the economic impact of bottlenecks to corridor users?*
4. *How does the Beira corridor compare with competing corridors?*
5. *By how much can traffic on the Beira Corridor be increased through improvements on the corridor?*

The aim of this study is therefore to assess the bottlenecks that still exit on the Beira Corridor, and to recommend possible improvements to address the bottlenecks, thereby reducing logistics costs. The study analyses the Beira corridor in terms of physical infrastructure (roads, railways, border posts, port and dry port) and non-physical bottlenecks such logistics activities and regulatory bottlenecks. The objectives are stated as follows:

- *i. To determine the bottlenecks affecting the performance of Beira Corridor*
- *ii. To compare the attractiveness of each of the three corridors;*
- *iii. To analyse the effect of bottlenecks on corridor performance;*
- *iv. To assess the economic impact of the bottlenecks to corridor users using the TEC model;*
- *v. To estimate the increase in traffic on the Beira Corridor after improvements on the corridor; and*
- *vi. To make recommendations on how to address the problem of bottlenecks.*

1.4 Conceptual framework

The conceptual framework for the study is depicted in in Figure 6. It visualises the integration between the different elements and the multiple dimensions of the corridor where bottlenecks or chokepoints emanate. In this way, it becomes possible to shift between different elements and dimensions in accordance with other proponents' conceptualisations including Chapman et al (2003), Larkham & Dickins (2003), (Romein et al (2003) and andPremius & Zonneveld (2003). The conceptuaal framework seeks to embrace systems thinking as an alternative to solve problems as proposed by Blanchard & Fabrycky (2014). This approach is similar to the integrated approach to corridor development and management proposed by Witte (2014).

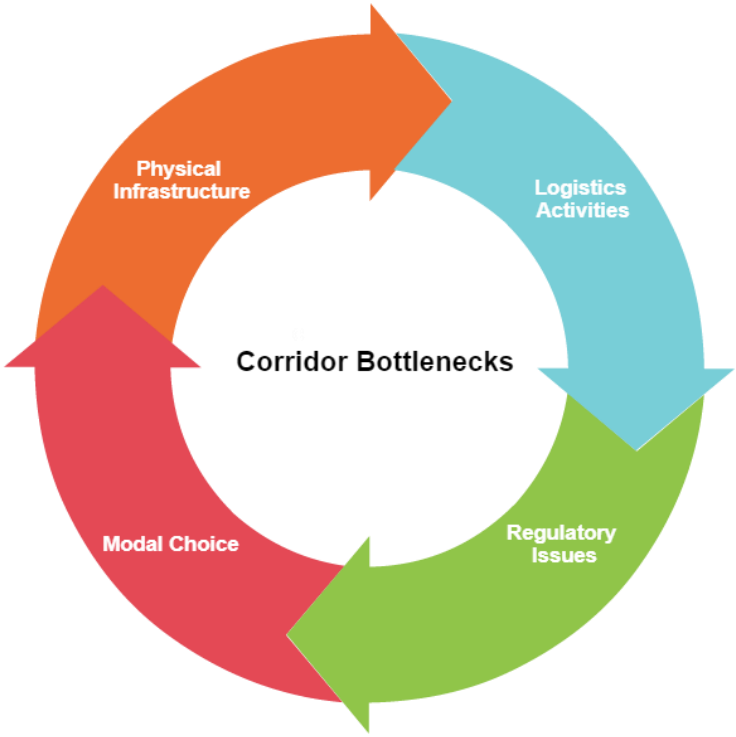

Figure 6 Conceptual framework for corridor bottleneck assessment

Source: Developed by author for the study

This dissertation adds to the existing body of knowledge and to several theoretical and empirical insights on corridor development by Rodrigue et al (2016), Premius & Zonneveld (2003) and Witte (2014). The conceptual framework places the corridor bottlenecks into four dimensions, namely physical infrastructure, logistics activities, regulatory issues and mode choice as shown in Figure 1. This dissertation furthermore proposes Total Economic Cost as a new explanation for the choices made by cargo owners and logistics service providers when deciding which of a number of alternative corridors to use.

1.5 Research design

This section outlines the research design, including the themes, theories, and methods used in undertaking this study (Chapters 2–4).

The study method employed for this study is a combination of qualitative and quantitative methods, and a case study design is used (Creswell (2014). With recent calls for expanding the scope and rigor of engineering education research, the use of qualitative methods to answer research questions that cannot be answered through quantitative methods is taking on increasing significance (Ljungberg & Douglas, 2008). The study sampling strategy is discussed in the methodology chapter together with the overall data collection and recording procedures.

The data analysis steps, the methods used for validating, presenting and interpreting the data and indicating the potential outcomes of the study are explained in the methodology chapter as well. Furthermore, comments are provided to justify the specific type of qualitative strategy used and about the nature of the final written product.

1.5.1 The Case Study Research Design

The proposed study employs a case study research design because the intent is to explore, in detail, the bottlenecks affecting the Beira Corridor performance.

1.5.2 Scope of the study

The study is based on a case study of the Beira Corridor, one of the key corridors in the SADC region, serving three landlocked countries. In order to establish performance benchmarks, comparisons are made with other SADC corridors, to gain an understanding of the role of infrastructure issues affecting the performance of corridors. The focus is a case study of the Beira Corridor, to explore the extent to which infrastructure and other bottlenecks affect the efficiency of the transport corridor.

1.5.3 Sample

For the quantitative part of the study cargo and vehicle movement data were collected from road transport operators and freight agents using the three competing corridors mentioned above. This data comprised of the movements of several thousand trucks, including almost 100,000 cargo trips, as well as freight movements for several hundred thousand cargo consignments processed through the customs and ports systems serving these corridors. The data covered the period 2014 – 2017.

For the qualitative part of the study data was collected from officials employed by the most prominent players in the various transport corridors in the region through face-to-face interviews, similar to the approach used by (Jeevan et al. 2015). The interviewees included customs, clearing agents, truck drivers, terminal operators, and relevant government ministries. The target population is public and private organisations and agencies involved in regional transport operations and development, all of which constitute key stakeholders of the Beira trade and transport corridor.

1.5.4 Ethical Considerations

Ethics clearance was obtained from the NWU Engineering Research Ethics Committee with ethics number (NWU-01688-19-A1). According to (Oxford, 2018) ethics concerns the moral principles and values that govern the way an individual or a group conducts its activities. Ethics applies to all situations where there can be potential harm of any kind, including in research. For this reason, anonymity was maintained, and respondents were requested to sign an informed consent form. Participants were also given the option to withdraw if they wished to do so in the process of responding to either the interview or questions. Each interview or response was treated with strict confidentiality and above all, the information and data collected in the study was used solely for research and academic purposes.

1.5.5 Data Collection Strategies

Quantitative data was collected using geographical positioning system (GPS) techniques, obtained from fleet operator serving the Beira, Dar es Salaam and Durban corridors, as well as port, customs and freight agent transactions, while qualitative data was collected through personal interviews and a review of reports and records obtained from the respondents, audio recording, study reports and physical observations along the Beira Corridor.

1.5.6 Data Analysis Procedures

The data was captured on spreadsheets to calculate transit times and waiting times and the outcomes systematically organised and presentation in terms of bar charts, histograms and tables. Pictures of infrastructure condition taken were analysed to support the findings from the data analysis. The data analysis procedure is described in detail in Chapter 5, which describes and justifies the mixed method of quantitative and qualitative research paradigm and the cases study design.

1.5.7 Verification

A critical requirement for any research is that it accurately measures what it purports to measure; stated results should be valid and reliable. In ensuring internal validity, the following strategies were employed:

- Triangulation of data – data was collected through multiple sources to include interviews, observations and document analysis, and the use of quantitative data in the results.
- Member checking – the informants, especially the dry port officials and clearing agent representatives served as checks telephonically throughout the analysis process.
- An ongoing dialogue regarding interpretations of the informants' reality and meanings ensured the truth-value of the data.

- Lengthy and repeated observations at the research site – regular and repeated observations of similar phenomena and settings occurred on-site over a long period of time as the researcher was involved in research studies on the corridor since 1994.
- Peer examination – an article based on the thesis outcomes was submitted to a scientific journal for peer review and for publication.
- Participatory modes of research – the informants were involved in most phases of this study, from the design of the project to checking interpretations and conclusions.

Finally, the primary strategy utilised in this project to ensure external validity is the provision of rich, thick, detailed descriptions so that anyone interested in transferability will have a solid framework for comparison (Creswell, 2014).

1.5.8 Reporting the findings

Yin (2011) states that although data collection and analysis strategies are similar across qualitative methods, the way the findings are reported is diverse. Creswell (2014) addresses the importance of creating a data display and suggests that narrative text has been the most frequent form of display for qualitative data. This is a naturalistic study. According to Yin (2011) this refers to a study where one observes and notes a phenomenon, in its natural setting while without interfering with the phenomena. For this study, the results are presented in a combination of descriptive narrative, graphs, tables, and pictures. Thick description is the vehicle for communicating a holistic picture of the performance of a corridor. The final product is a construction of the respondents' experiences and the meanings they attach to them. This allows readers to vicariously experience the challenges encountered and provide a lens through which readers can view the corridor performance subject's world.

1.5.9 Structure of the thesis

The thesis consists of seven chapters, where Chapter 1 provides the introduction and background to the study. Chapter 2 deals with a critical review of the literature on the corridor concept, with specific emphasis on the impact of bottlenecks on the performance of the Beira Corridor. The origin of the corridor concept is discussed, and it is shown how the concept has become popular in regional economic development and transport network performance enhancement initiatives globally. Chapter 3 discusses logistics activities form a systems perspective considering all components of the corridor, physical and non-physical, comprising gateways, inland terminals (dry ports), linkages, modes of transport, and regulatory process as sources of bottlenecks that impact on the performance of the three transport corridors. The characteristics of the various modes and choice thereof are discussed, highlighting how availability and condition of physical and non-physical infrastructure affect modal performance.

The methodological paradigm and the methods employed in assessing and comparing the Beira Corridor with the other two corridors are discussed in detail in Chapter 4. The case study research design which has been used for the study is explained and discussed in detail. Data collection methods used in the study are also explained in detail in the methodology chapter. Furthermore, the process of analysing the collected data is explained in detail. Results of the case study are interpreted, discussed and reported in Chapter 5. Chapter 6 deals with a detailed comparison of the Beira corridor with Dar es Salaam and North-South Corridors. Finally, the conclusions and recommendations of the study are reported in Chapter 7, together with suggestions on directions for future research on corridor performance analysis and enhancement.

1.6 Conclusion

This Chapter has presented the background to the study, outlining the problem statement and the issues to be addressed. The purpose and scope of the study were explained, and the possible practical and academic contributions of the study stated. The main research question and sub-questions to be addressed by the study have been presented. The corridor bottlenecks conceptual framework developed for the study has also been discussed and explained.

The constructivist qualitative paradigm and deductive quantitative paradigm have been combined into a pragmatic mixed method paradigm. This paradigm, chosen together with a case study, was selected as the appropriate research design because of the need to explore in detail, the phenomenon being studied – the impact of bottlenecks on the performance of the Beira Corridor. The sample and the data collection methods used have been briefly explained. Finally, the structure of the thesis is outlined together with the contents of each chapter. In the next chapter relevant literature is reviewed in order to appreciate existing work on corridor bottlenecks and their impact on corridor performance which knowledge is used in the comparative assessment of the Beira Corridor and the two corridors serving the same hinterland, the Dar es Salaam and the North-South Corridor.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to review literature on the concept of a transport corridor and transport corridor bottlenecks. In doing so, this study is placed in the context of contributing to the body of knowledge dealing with finding solutions to the problem of transport corridors, in this case bottlenecks that increase logistics costs. Different approaches used in existing literature are explored also to give context for this study. By reviewing existing literature, the study will use this knowledge to address the objectives and research questions presented in Chapter 1. It is for this reason that the review looks at a wide range of issues including the various elements that constitute a corridor and the associated bottlenecks that affect corridor performance. Bottlenecks related to physical infrastructure, regulatory processes, information and communication technology (ICT), logistics services and transport modes are discussed in line with the conceptual framework depicted in Chapter 1. Literature on transport corridors from both the developed and developing regions is reviewed in order to appreciate corridor development trends and the challenges encountered in various parts of the world and how various scholars have attempted to address these challenges.

Examples from North America, Europe, Asia and Sub-Saharan Africa are explored. The salient observations derived from the review of existing knowledge on corridor performance and associated challenges are discussed and then summarised in the conclusion of the chapter. The aim is to use existing literature to contextualise the bottlenecks affecting the Beira Corridor and to compare the corridor's performance with competing corridors so that the challenges can be addressed and the competitiveness of the Beira Corridor can be enhanced as it is currently regarded as poor. In the next sections a number of aspects are dealt with, including, the concept of a transport corridor, bottlenecks, systems perspective of a corridor, and corridor performance assessment. The last part features a discussion of the two corridors being compared with the Beira Corridor to provide context.

2.2 The concept of a transport corridor

The concept of a transport corridor has been studied extensively with a considerable body of knowledge having been generated, e.g. (Douma & Kriz, 2003); (Hesse & Rodrigue, 2004); (Regmi & Hanaoka, 2012) and Hanaoka 2012; (Stoumann, Kvist, & Light, 2012); (Witte, Van Oort, Wiegmans, & Spit, 2013). Regmi & Hanaoka, 2012 argue that the continuing trend of trade growth needs a new paradigm to improve efficiency and cost-effectiveness of the transportation system. In their view one of the emerging transportation concepts is the development of intermodal transport corridors that encompass various modes, logistics services and transport processes. There are several examples of empirical applications, including in Europe – TEN–T Priority Axes (Witte P. , van Oort, Wiegmans, & Spit, 2014); North America – Canamex (Rodrigue & Notteboom, 2013); East Africa – Northern and Central Corridors (Regmi & Hanaoka, 2012); and Southern Africa – Trans

Kalahari and Maputo Corridors (Fraser & Notteboom, 2014) where the development of intermodal transport corridors links the transport nodes of gateways and the hinterland. Therefore, this study assesses the transport bottlenecks occurring on transport corridors at both micro and macro levels, just like these cited previous studies.

According to Premius & Zonneveld (2003) the corridor is a planning concept that emerged about a century ago for linear city models, presented as alternatives for the densely populated, concentric industrial city. They argue that the concept has a long history in spatial and urban planning. Chapman, Pratt, Larkham, & Dickins (2003) support this assertion, observing that in planning history, there is a lengthy tradition of concepts of urban structure taking the form of linear belts that could have a strong link with the emerging concept of the corridor. According to (Chapman, Pratt, Larkham, & Dickins, 2003), the first such linear plan was envisaged by the Spanish engineer Soriay Mata in the early 1880s. Premius & Zonneveld (2003) maintain that the mega-corridor or euro-corridor concept, proposed in the context of the discussion on European territorial development, strives to integrate policies on infrastructure, urbanisation and economic development. Thus, in their view, the corridor concept can count on a hostile reception from spatial planners. As an analytical concept, the corridor can hardly be denied its legitimacy and popularity. Several urgent policy issues can be attached to corridor developments, which together require improved coordination between policy domains at different spatial levels, which culminate in a comprehensive governance regime that transcends national jurisdictions as witnessed with the emergence of several international corridors across many regions of the world.

There are two major types of corridors that researchers continue to study extensively, namely transport and economic corridors. These are mutually interdependent for the obvious reason that transport demand is derived from socio-economic activities. Because transport demand is inherently derived (Rodrigue J. P., 2016), the development of an economic corridor creates demand for the movement of freight and passengers, which consequently leads to the emergence of a transport corridor that serves for the connection of the various economic nodes of production and consumption, to inland hubs and gateways.

The meaning of gateways and hubs can vary according to the transport mode as. each mode has its own technical characteristics, economies of scale and commercial relations. Transport corridors are commonly linking gateways to their hinterland. Gateways tend to have a temporal stability as they commonly emerged at the convergence of inland transport systems and through the long-term accumulation of infrastructure and investments. The importance of a hub can change depending on the commercial strategies of its users. For instance, a transport company (e.g. maritime shipping or air carrier) may decide to switch from one hub to another to improve its operations or commercial opportunities. Flows, origins, destination and the modes used can therefore change. In this context, a hub can lose a share of its connectivity as the network it is part of is reorganised. The functions of gateway or hub are not mutually exclusive since a location can assume both functions if it fits the commercial strategies of carriers.

Port competitiveness is increasingly influenced by the process of developing trade corridors. The goal is to integrate the port system into a multimodal transportation network in order to improve market access, fluidity of trade and the integration into an industrial network. In this context, a port must have interfaces between major oceanic maritime trade and economic activities of ports and inland terminals that provide intermodal structures and connections between the forelands and hinterlands (Klink and Geerke, 1998, Notteboom and Rodrigue, 2005). Obviously, business transactions require an adaptation to hinterland means. Conversely, the amplification capacity of transport modes may allow the expansion of trade. These bonds of mutual causality are now present in the traffic of port cities. The quality and capacity of hinterland modalities, roads and relays as part of the corridor are essential to any expansion of trade.

The concept of infrastructure corridors was thus quickly perceived as a useful network structure in freight transportation (Hesse & Rodrigue, 2004). Today the corridor concept is regarded as one of the most popular approaches of addressing transport systems efficiency for both the developed and developing world, to support global trade. Nevertheless, transport corridors are not without their own challenges as an element of a transport system. They are characterised by numerous bottlenecks that impose delays and restrictions in the normal flow of transportation due to inefficiency (Rodrigue, Comtois, & Slack, 2016). Depending on each corridor's uniqueness these vary from infrastructure, regulatory processes or governance as well as bottlenecks related to logistics activities.

2.3 The transport corridor defined

There is a plethora of definitions for a transport corridor, including: infrastructure axis, urbanisation axis, economic development axis etc. e.g. (Douma & Kriz, 2003); (Premius & Zonneveld, 2003); (Arnold, 2006); (Stoumann, Kvist, & Light, 2012); (Witte, Van Oort, Wiegmans, & Spit, 2013), (Rodrigue, Comtois, & Slack, The Geography of Transport Systems, 2013). Several scholars have contributed to the definition of a corridor, each one with an inclination in accordance with their speciality. Some of the many definitions for a corridor include:

- an accumulation of flows and infrastructures of various modes with their development linked with economic, infrastructural and technological processes (Rodrigue J. P., 2016);
- a linear orientation of one or more transport routes and flows connecting important locations acting as origins, destinations or points of trans-shipment. The development of intermodal transport corridors is essential to serve the existing trade flow (Regmi & Hanaoka, 2012);

- a bundle of infrastructure that links two or more urban areas concerning connections that use different transport modes such as road, rail, maritime and air, carrying both passenger and freight transport (Premius & Zonneveld, 2003);
- a specified route, ideally intermodal, that can expedite the movements of goods and people across international borders by connecting key points in different countries (Chowdhury & Erdenebileg, 2006);
- a geographical area between two points, linking multiple centres, and moving people and freight (Douma & Kriz, 2003); and
- the concentration of freight/passenger traffic between major hubs along main lines and by relatively long distances of transport (Witte, Van Oort, Wiegmans, & Spit, 2013).

Witte, Van Oort, Wiegmans, & Spit (2013) argue that transport corridors are concerned with connections of transport nodes that use different modes such as road, rail, barge or intermodal and include both passenger and freight transports. Their conceptualisation of a corridor is illustrated in Figure 7. They contend that for a corridor to emerge, there must be infrastructure and transport systems as well as enough demand for transport within a given area. They also concede that a corridor includes a political and institutional level, a view shared by (Rodrigue, Comtois, & Slack, 2013). The two levels interact to cause the development of a corridor and determine the planning and implementation of physical infrastructures, such as roads and railways, as well as the coordination and regulation of traffic and transport flows. This includes setting the more general framework for the corridor in terms of regulation. Political authorities and institutions can in addition play a role in the development within a corridor, by providing specific innovation programmes and supportive knowledge and educational institutions.

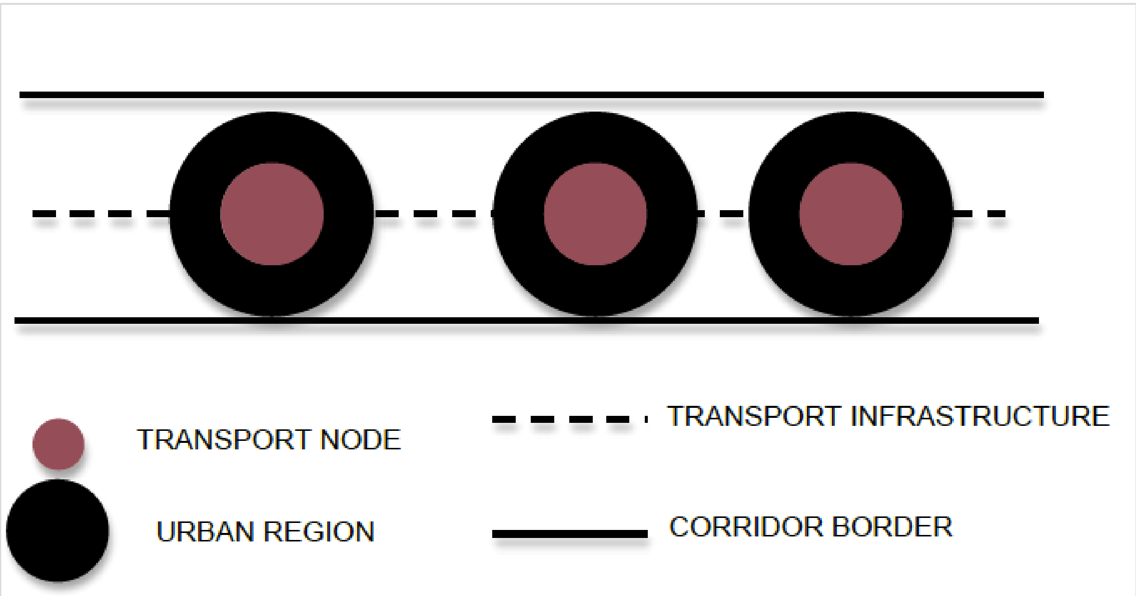

Figure 7 Conceptualisation of a transport corridor

Source: Adapted from (Witte, van Oort, & Spit, 2012)

The physical perspective conceptualises a corridor as a collection of routes constructed from the transport networks of adjoining countries and bounded by gateways (Arnold, 2006). Hence, they argue that corridors are complex as they are usually multi-modal and include multiple border crossings. They also acknowledge that corridors have an economic perspective, with the function promoting both internal and external trade by providing more efficient transport and logistics services. Arnold (2006) argues that the major reason for designating routes as part of a corridor is to focus attention on improving both these routes and the quality of transport and other logistics services in the corridor. Quality determines the performance of the corridor and is measured in terms of the transit time, cost for shipment of goods along the corridor, the reliability of the services in terms of transit time and the flexibility provided in terms of diversity of services offered on multimodal routes.

Designating a specific set of routes as a corridor is a government endeavour, to focus its efforts on improving the quality of transport services to specific routes. Hence, it is important to create a single point of coordination, given the diversity of stakeholders and many government agencies that oversee the different activities within a corridor. Coordination requires a public-private partnership in order to address a range of problems, including investment in infrastructure, regulation of transport and trade, as well as facilitating improvement in private sector transport and logistics services (Arnold, 2006).

After considering the many corridor definitions, by various authors such as Rodrigue (2016) ; Regmi & Hanaoka (2012) Witte et al (2013) and Premius & Zonneveld (2003), a definition is proposed for this thesis where a corridor is conceived to be a system of interrelated elements, comprising physical infrastructural links, nodes, regulatory and governance processes, logistics activities and economic hubs, that generate transport demand for different types of products and for at least one mode of transport. This definition resonates with the conceptual framework presented in Chapter 1, where the corridor is depicted to comprise certain elements that may also become a source of bottlenecks if they do not function properly. The various conceptualisations and definitions depict a corridor as a complex system comprising many sub-systems that work together in linking regions in terms of economic productive zones and markets. For this study, viewing a corridor as a system emanates from an appreciation of the interrelatedness of the components constituting a corridor such as seaport, dry ports, highways, railroads, ITC platforms and the regulatory regimes governing trade and transportation of goods. The argument is that the only way to address challenges affecting performance of a transport corridor is to incorporate all elements and or components that constitute the corridor formation, ensuring that each of the components operate optimally for the corridor to be efficient. In this study the systems thinking perspective of a corridor is premised on view that the performance of a corridor is dependent on the mutual interaction of the various elements of the corridor conceptual framework. Therefore, each element is indispensable and plays an important role in determining corridor performance.

Intermodal transport refers to the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes. In contrast the carriage of goods by two or more modes of transport is referred to as multimodal transport (Regmi & Hanaoka, 2012). Intermodal transport enables cargo to be consolidated into economically large units (containers, bulk grain railcars, etc.) by optimising the use of specialised intermodal handling equipment to effect high-speed cargo transfer among ships, barges, railcars, and truck chassis, using the least labour to increase logistic flexibility, reduce delivery times, and minimise operating costs. The development of intermodal transport corridors encompassing various modes, logistics services and transport processes is an emerging transportation concept critical to dealing with transport systems efficiency.

As noted above, according to Rodrigue, et al (2016) a transport corridor is a linear orientation of one or more transport routes and flows connecting important locations that act as origins, destinations, or points of transhipment. On the other hand, Yang, et al. (2018) views a corridor as an international intermodal transport route that can expedite the movements of goods and people across international borders by connecting key freight transport points in different countries. Development of intermodal transport corridors is essential to serve international trade, especially for landlocked countries, as intermodalism improves connectivity to inland hubs, seaports, markets, and production centres (Sakalys & Batarliene, 2017). The development of integrated intermodal transport in SADC is one of the main components of the transport program adopted for the region. Rodrigue (2020) argued that intermodal freight transport corridors that use both road and rail are more competitive alternatives than road only freight transport for medium to long-distance transportation hauls. Unfortunately, rail has continued to decline on most SADC corridors which has impacted negatively on corridor performance (USAID, 2018).

A common phenomenon with landlocked countries is their remoteness from seaports, which presents them with additional challenges associated with high transportation cost and time. International cooperation is essential to provide transit access and efficient transportation systems for landlocked countries (Regmi & Hanaoka, 2012). Transport corridors can provide an answer to LLDCs' poor accessibility to resources and markets via maritime transport. Hanaoka, et al (2019) contend that cross-border corridors with proper conditions, facilities and institutions are one solution for reducing transport costs and times for landlocked developing countries. They believe that as stakeholders of cross-border corridors such as roads, railways, and ports, manage their own infrastructure, stakeholders may desire to gain more benefit by obtaining more cargo from and to the hinterland countries.

Table 1 shows a list of some of the major corridors in Africa. The Eastern DRC, Malawi, Zambia and Zimbabwe are four SADC landlocked countries linked to global trade via the Beira, Dar es Salaam and North-South corridors.

Table 1 Some Major African Corridors

Source: (Peterson, 2015)

CORRIDOR	DISTANCE	TRANSPORT MODE
Central Africa		
Douala Corridor: Port Douala, Cameroon, to the Central African Republic to Chad	1800 km	Road some rail
Lobito Corridor: Port of Lobito, Angola, to Lubumbashi, Democratic Republic of the Congo (DRC), to Lusaka, Zambia	1345 km	Road, some rail
Southern Africa		
North-South Corridor: Port of Durban, South Africa to Zimbabwe, Zambia and Eastern DRC	2700 km	Road, some rail
Dar es Salaam Corridor: Port of Dar es Salaam, Tanzania to Lusaka, Zambia, DRC and Malawi,	2 396 km	Road, some rail
Beira Corridor: Port of Beira, Mozambique to Malawi, Zimbabwe, Zambia and Eastern DRC	1600 km	Road
Walvis Bay Corridors: (1) Port of Walvis Bay, Namibia to Lusaka, Zambia, to DRC and (2) Port of Walvis Bay to Botswana, to DRC	(1) 2 100 km (2) 1 800 km	Road
West Africa		
Port Abidjan, Cote d' Ivoire, to Burkina Faso to Mali	1 200 km	Road some rail
Lagos to Niger	1 500 km	Road
East Africa		
Central Corridor: Port of Dar es Salaam, Tanzania, to Rwanda, Burundi, Uganda and DRC	1 600 km	Road, rail, inland waterways
Northern Corridor: Port of Mombasa, Kenya, to Uganda, Rwanda and DRC	2 000 km	Road, rail, inland waterways

2.4 The transport corridor as a system

The transport corridor is a complex formation which is better analysed in terms its various components of links and nodes. Therefore, applying a systems theoretical approach provides for a holistic perspective that helps one to better understand the interdependence of nodes and links and the bottlenecks generated by each one of them. Viewing the corridor as a system allows one to appreciate the interactions of all the components of the corridor and how they are interdependent. This is very important because it helps with ensuring that investments meant at improving the corridor are correctly allocated.

According to Blanchard (2014) the science of systems is called systemology and derives from the realisation of the existence of interdisciplines. He maintains that humanity can benefit from systemology and systems thinking in resolving complex problems. Mobus (2018) defines systems thinking as the ability to perceive wholeness of a thing, perceiving the connections between it and other things with which it interacts, perceiving the internal composition of sub-things, interconnected and interacting to constitute itself. Frank (2012) asserts that systems thinking is what makes systems engineering differ from other kinds of engineering. He maintains that it is the underpinning skill required to do systems engineering. In his view Engineering Systems Thinking is conceived as a high-order thinking skill that allows one to successfully perform systems engineering tasks. Figure 8 illustrates the structure of systems science, at the heart of which is systems theory. The model shows that systems analysis, design and development are derived from systems theory. Management science, programme management and product life cycle management are believed to derive from this theory too.

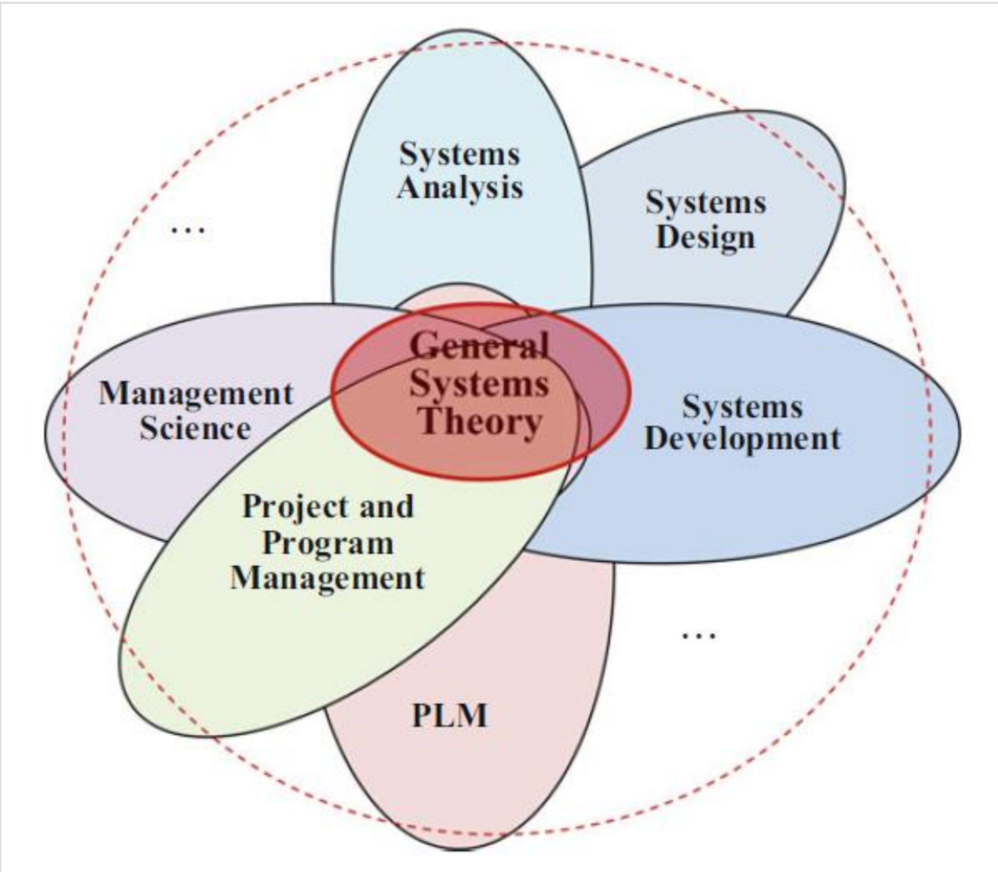

Figure 8 Structure and composition of systems science

Source: Novikov (2016)

Novikov (2016) says the systems approach is a direction in the methodology of scientific cognition and social practice, that treats objects as systems in terms of the integral set of elements in the aggregate of their relations and connections. According to Blanchard (2014) the concept of interdisciplines emerged in the middle of the last century and brought about evolutionary knowledge synthesis. He argues that the system age is about putting things together, not separating them. Hence, he maintains that analytic thinking is outside-in and that synthetic thinking is inside-out thinking. The synthetic mode of thinking, when applied to systems problems, is what is referred to as systems thinking or the systems approach, and is based on systems theory principles.

According to Novikov (2016) systems theory is an interdisciplinary theory, that deals with the forms of complex systems in nature, society, and science, and is a framework which one can use to investigate and/or describe any group of objects that work together, such as the elements of a corridor, to produce some result. He argues that the systems approach facilitates adequate problem formulation in concrete sciences and provides effective strategies of their study. In his view, the systems approach is a general way of activity organisation, which embraces any type of activity, and reveals regularities and interconnections, for their efficient usage. Blanchard (2014) maintains that, the approach derives from the observation that, when each part of a system performs as well as possible, the system may not perform as well as possible. This follows from the fact that, the sum of the functioning of the parts is seldom equal to the functioning of the whole. These arguments are applicable to the functioning of a component of a corridor such as a port, whose improvement in isolation does not necessarily equal the better functioning of the corridor. Hence the synthetic mode seeks to overcome the predisposition to perfect details, while ignoring system outcomes.

For this study, the corridor as a system, would be the interaction of roads, railway links, the port, dry ports, border posts, modes, type of products and the regulatory processes involved. Akhtar et al (2018) argue, that decision makers need to develop systems thinking capabilities, so that they can understand the complexities involved in the systems around them. They argue that systems thinking considers a panoramic view of interactions, creating a broader understanding of the picture. Mobus (2018) argues that the understanding of systems thinking allows one to be able to see systems in the world and how those systems are connected more broadly. Furthermore, one can see how the systems are organised for specific purposes and how, if they fail to serve those purposes, they will not be able to persist as systems. In his view, the knowledge of systems allows one to reason about the future states of the world, based on those systems' behaviours. By embracing this approach in the assessment of the corridor, the various dimensions that may generate bottlenecks would be better understood than if they were separated. The various frameworks on corridor bottlenecks display the existence of aspects within the corridor, that are interrelated such as physical infrastructure, regulatory or governance processes and institutions as well as other supporting dimensions. The interaction of these components determines corridor performance in terms of effectiveness. In the next section some corridor bottleneck frameworks are discussed as part of the review of bottlenecks.

2.5 Conceptual frameworks of corridor bottlenecks

Witte P. A., Wiegmans, van Oort, & Spit, (2012) conceptualise transport system bottlenecks as consisting of four common distinctive perspectives (see Figure 9). Firstly, there is infrastructure, comprising the physical and organisational dimensions. Secondly, there is spatial structure, comprising functional and morphological dimensions. Thirdly, there is governance structure, dealing with the political and institutional dimensions. The fourth one is economic structure, comprising market conditions and financial aspects dimensions. Within each perspective (Witte, Van Oort, Wiegmans, & Spit, 2013) identifies bottlenecks depicted in the framework.

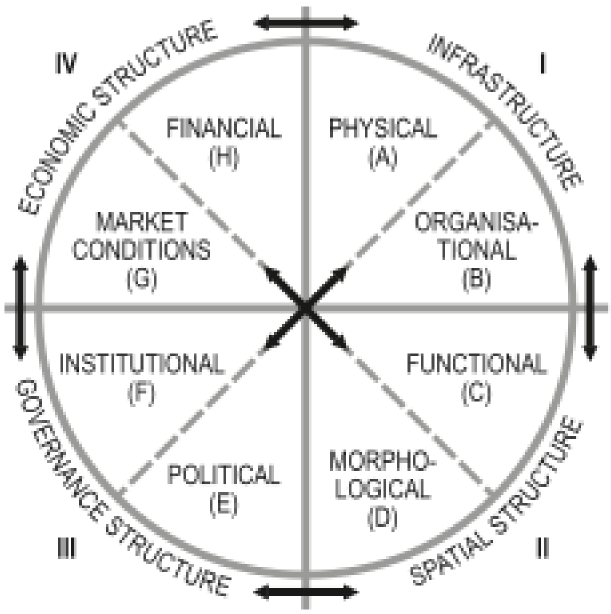

Figure 9 Conceptual framework for corridor bottlenecks

Source: Witte, et. al. (2012)

An alternative framework for corridor bottleneck is presented by (Prentice, Duncan, & Sokol, 2004) and (Rodrigue & Notteboom, 2013), who conceptualise corridor bottlenecks as comprising three general categories: infrastructure related bottlenecks, regulatory bottlenecks and bottlenecks that develop because of supply chain disruptions. Their conceptual framework is illustrated in Figure 10. The infrastructure bottlenecks are easiest to understand. They fall into two categories: chronic constraints that are predictable and temporary constraints that are more random. Climate is a chronic constraint where for some environmental reason a facility is unavailable for part of the year. The Port of Beira, for example, suffers a capacity constraint each year because of siltation. To a lesser extent, the EN6 road has the same sort of climate barrier, because trucks cannot transit the Pungwe flats during flooding.

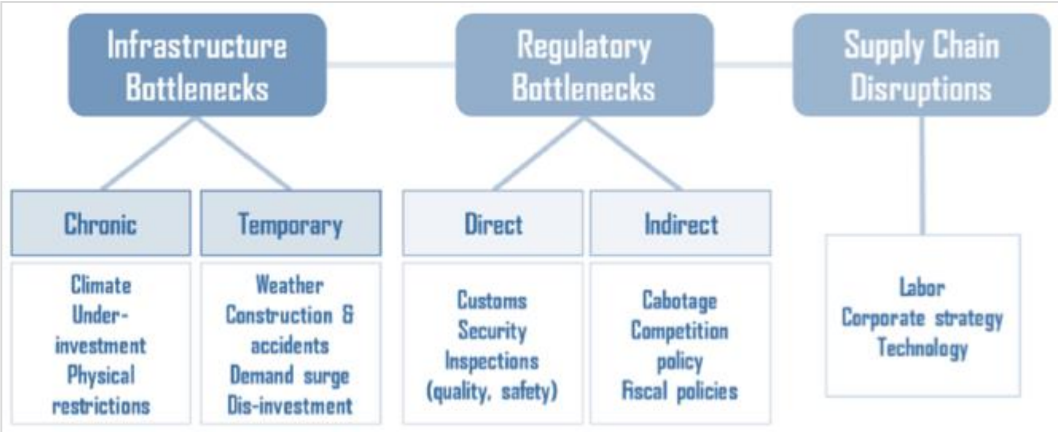

Figure 10 Framework for transportation bottlenecks

Source: (Rodrigue & Notteboom, 2013)

2.5.1 Infrastructure bottlenecks

Infrastructure bottlenecks can be the outcome of chronic or temporary conditions (Rodrigue, Comtois, & Slack, 2013). Evidently, climate change can be a factor altering conditions that could damage the transport infrastructure and shorten its useful life. Physical restrictions can form bottlenecks as traffic expands. For instance, despite the increase in traffic on the EN6 due to the upgrades at the port of Beira the bridge at the Pungwe River had not been upgraded to increase its capacity to cater for the surge in traffic volumes. Its approaches get submerged during the rainy season making it impassable due to floods. Under-investment in infrastructure can produce chronic bottlenecks when rapid economic growth takes place, implying that the capacity is insufficient to keep up with the demand. This is evident with the shallow access channel of the Beira port whose draught limits the size of ships calling at the port, hence constraining the port's capacity to handle more traffic, which usually results in ships having to call at competing ports such as Nacala and Maputo for consignments that would have been otherwise destined for Beira port.

Equally, temporary transportation bottlenecks can be caused by natural or market forces. Weather disruptions, such as a storm, are among the most prominent, as well as construction, accidents and labour conflicts (industrial action). These events are usually expected but cannot be predicted. At the same time a surge in demand can also create a bottleneck as infrastructures are designed to convey a constant level of service. Disinvestment, often through lack of maintenance, can cause temporary bottlenecks as the case with the EN6 highway connecting the Port of Beira to the border with Zimbabwe.

2.5.2 Regulatory processes bottlenecks

Regulations that delay goods movements for security or safety inspections by traffic inspectors sometimes create bottlenecks as a direct consequence. If international movements are concerned, customs procedures for passengers and freight are a common source of delays. Even if the intention is not to convey delays, regulations inevitably cause delays and disruptions. There is also corruption, imposing uncertainty and a burden on transport operations.

Three sources of bottlenecks created by the indirect effects of regulation are cabotage restrictions, competition policies and fiscal policies. Cabotage restrictions prevent foreign carriers for carrying freight within a country; their capacity is thus not available. Competition policies can create bottlenecks either by supporting a monopoly where the operator engages in rent-seeking strategies or by complete deregulation where many carriers will compete for similar transport segments. Fiscal policies can deter investments through taxation and create bottlenecks due to lack of available capacity.

2.5.3 Logistics activities bottlenecks

Logistics bottlenecks relate to specific tasks and procedures in supply chain management that trigger bottlenecks. For instance, labour availability, such as work shifts, may impose time-dependent capacity shortages. Even so, some companies may create bottlenecks on purpose as a rent-seeking strategy since they control key elements of the supply chain. Usually, tasks and sequences along a supply chain are not properly coordinated, which can create bottlenecks. Lastly, technology can also be a problem as different information exchange protocols can create delays in information processing leading to delays in shipments or trans-shipments on a corridor (Rodrigue, Comtois, & Slack, 2013).

2.5.4 Information and communication technology (ICT) bottlenecks

Rodrigue (2020) identifies five main areas of the application of information technologies in corridor development and management which he refers to as the key drivers in freight distribution. The five key ICT drivers include freight visibility, asset management, efficiency, freight information exchange and regulatory compliance.

Regmi & Hanaoka (2012) have noted contributions of emerging ICT technology for efficient intermodal transport operations and freight transport in Europe and the United States. In their view the potential use of ICT to improve the efficiency of transportation along intermodal transport corridors should be explored. Rodrigue (2020) recommends the use of ICT, Radio Frequency Identification (RFID) and satellite positioning systems to facilitate the movement of goods across borders. He argues that the use of ICT reduces cargo processing time and border clearance as well as transportation cost. In his view ICT further helps with real time information assessment in terms of freight location along a corridor. Electronic sealing and cargo tracking systems are being extensively used to secure and track the movement of containers along corridors in the SADC region. Figure 11 illustrates the five key areas in which ICT can enhance transportation efficiency along corridors. Each of the key areas is explained in terms of specific context of application in the system. Unfortunately, the application of ICT in the SADC region is still very limited, which has affected the performance of corridors.

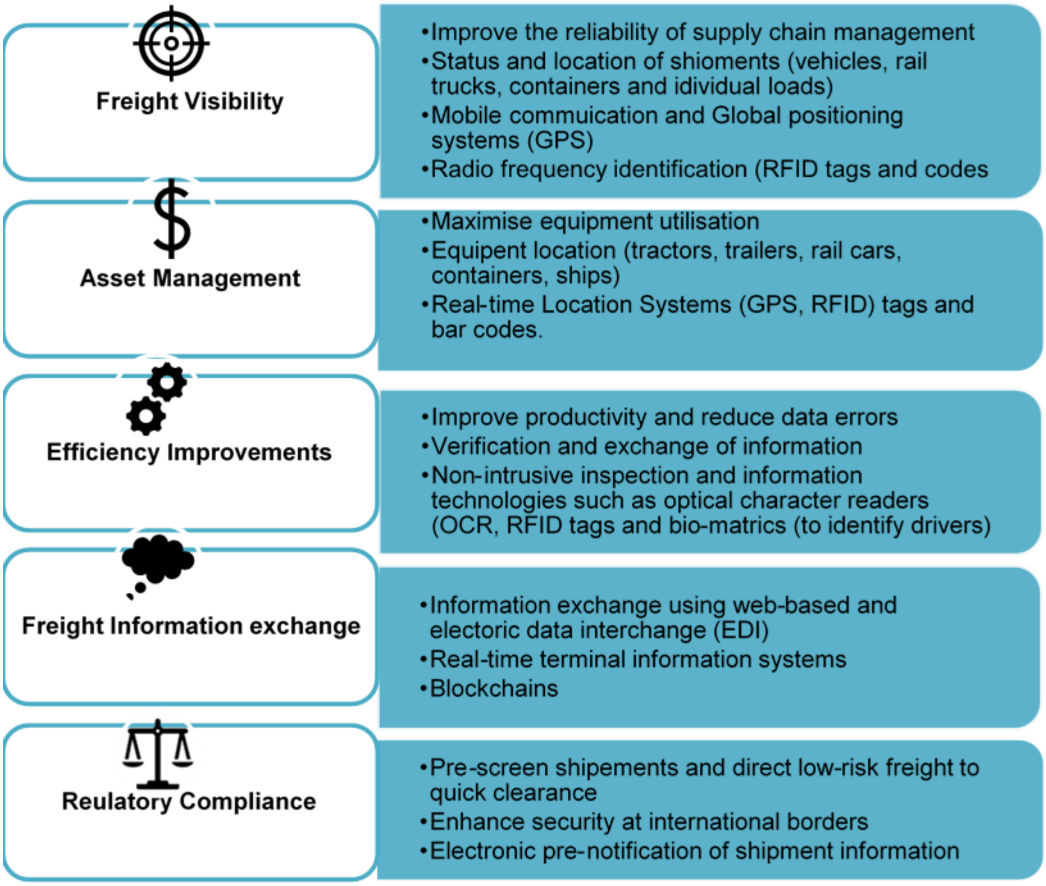

Figure 11 The five ICT key drivers for freight distribution on a corridor

Source: Adapted from Rodrigue (2020)

Cargo visibility is a vital consideration in the development of a corridor as it provides shippers with valuable information to plan and serve their customers effectively. Secondly, transport operators and shipping lines need to manage their transportation assets such as vehicles and containers for them to remain in business. Thirdly efficiency in the corridor is guaranteed through the quality of freight information being exchanged as well as the capability to remotely monitor transport conditions. The ability of the system to provide easily accessible and real-time freight information systems allows the logistics service providers and consumers of transport services to interact.

Lastly compliance with regulations, such as customs requirements, in a more efficient and cost-effective manner is very vital as it also can lead to unnecessary bottlenecks. Delays exist if there is no mechanism for pre-screening of consignments to allow for prompt clearance of low-risk shipments. Intrusive methods of cargo inspections through physical examination of cargo contribute to very long delays at ports, dry ports and border posts and continue to be cited one of the many bottlenecks existing. The paperwork related bottlenecks in clearing cargo at border posts can be removed through the emerging concept of paperless trade. Regmi & Hanaoka (2012) believed that if paperless trade is adopted at the border posts along corridors this would reduce total transportation cost and time.

Lack or low application of ICT in cargo processing creates bottlenecks in the corridor due to delays, leading to low asset utilisation which increases logistics costs. Where it is implemented there is the issue of reliability as ICT systems are often down either due to malfunctioning or power outages. The other problem is lack of coordination between adjourning countries where the ICT systems used vary. For instance, one country could be operating on ASYCUDA World while the other is still on ASYCUDA++ as is the case between Zimbabwe and Zambia respectively at Chirundu OSBP. The application of ICT platforms on the Beira Corridor and most SADC corridors still lags behind, compared to corridors in other parts of the world such as North America, Asia, and Europe. The improvement of ICT applications is therefore one area that needs to be considered a vital component in the planning and development of corridors in the SADC region if logistics costs are to be reduced at all.

2.5.5 Impact of bottlenecks

Hanaoka et al (2019) argue that corridors with proper conditions, facilities and institutions reduce transport costs and times for landlocked developing countries. They maintain that since corridor stakeholders of roads, railways and ports manage their own infrastructure, they want to benefit through moving more goods in terms of exports and imports from and to hinterland countries respectively. They developed a model to evaluate the performance of multiple stakeholders to determine how stakeholders determine required investment for transport infrastructure on the Central and Northern Corridors in East Africa. The results showed that with railway expansion, the road capacity also increased marginally compared with the case when there was no rail investment. This led to the rise in volumes for all the stakeholders. They also noted that with progressive investment and organisational restructuring, the highest regional net surplus is achieved with the net surplus of landlocked countries also increasing significantly.

While the corridor concept suggests that performance is determined by several bottlenecks, literature seems to elevate infrastructure-related bottlenecks as having far-reaching consequences on corridor performance (Monios & Wimsmeier, 2013). Moreover, differences exist between those related to links and those related to ports and inland terminals. In the cases extant in the literature, the best performing corridors appear to be those with good infrastructure in terms of port linkages and inland terminals. Poorly performing ports occur when the port authority is not in a position to achieve such operational "extended gate" (port inland hub connectivity) integration, thus limiting the potential for successful inland terminal developments by port authorities (Monios & Wimsmeier, 2013). This implies that an enlarged institutional capacity may be an increasingly important source of competitive advantage in the port industry.

Prentice, Duncan, & Sokol, (2004) contends that the speed of traffic flow is determined by the worst bottleneck. Even if goods move quickly to this bottleneck, it must wait to process through the bottleneck, a view supported by this study. Traffic cannot move faster than the worst constraint and goods will back up in a queue if they arrive faster than they can be processed. As the speed of traffic is reduced, the fixed costs of transportation and logistics start to rise because of lower equipment utilisation and greater in-transit inventories. An individual bottleneck is a problem, but it can also have a cascading effect. Evidence of this is visible on the Mississippi River locks, and possibly on the St. Lawrence Seaway. Problems at one lock can cascade through the whole system. Even once the bottleneck is cleared up, evidence of its impact is visible for some time (Prentice, Duncan, & Sokol, 2004). A relevant example is the recent blocking of the Suez Canal by a container ship, which almost brought the global economy to a standstill (Anon., 2021).

Figure 12 is a conceptual model that illustrates the impacts of bottlenecks. Costs would be minimised if there were no bottlenecks to interrupt the free flow of traffic. Obviously, the more traffic that is processed through a system, the better is the utilization of infrastructure and equipment. Consequently, costs per unit should fall continuously with greater throughput. As bottlenecks appear, traffic slows down, and average costs of logistics and transportation start to rise.

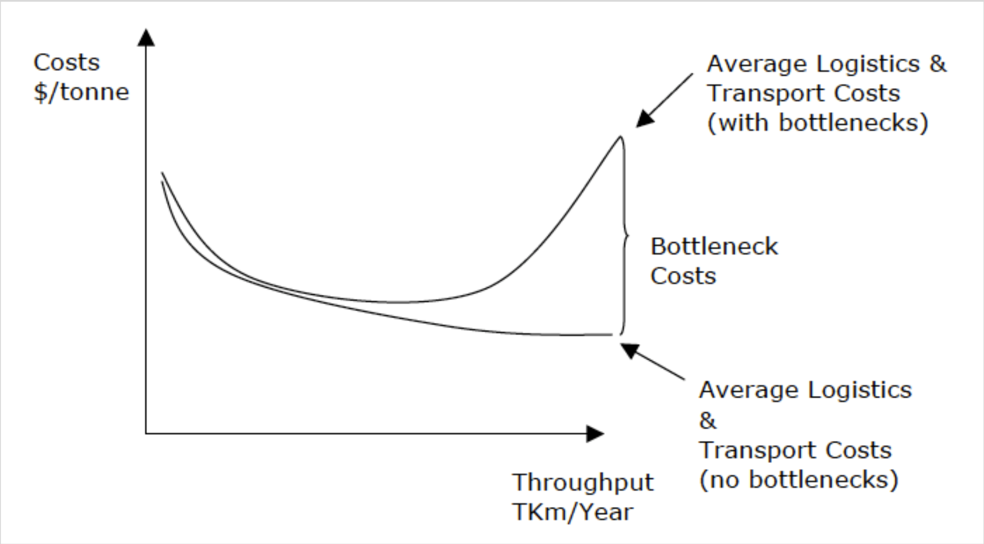

Figure 12 Conceptual model for the economic impact of corridor bottlenecks

Source: (Prentice, Duncan, & Sokol, 2004)

2.6 The corridor and the global perspective

Rodrigue, Comtois & Slack (2013) envisage a perspective of the main elements structuring the organisation of space at the local, regional and global levels as depicted in Figure 13. In their view, while the major nodes structuring spatial organisation at the global level are gateways supported by port, airport and telecommunication activities, at the local level, employment and commercial activities, which tend to be agglomerated, are the main structuring elements. Figure 13 shows each of these scales as also characterised by specific links and relations ranging from locally based commuting to global trade flows. It is these scales that culminate in a range of transport networks that contribute to the development of corridors.

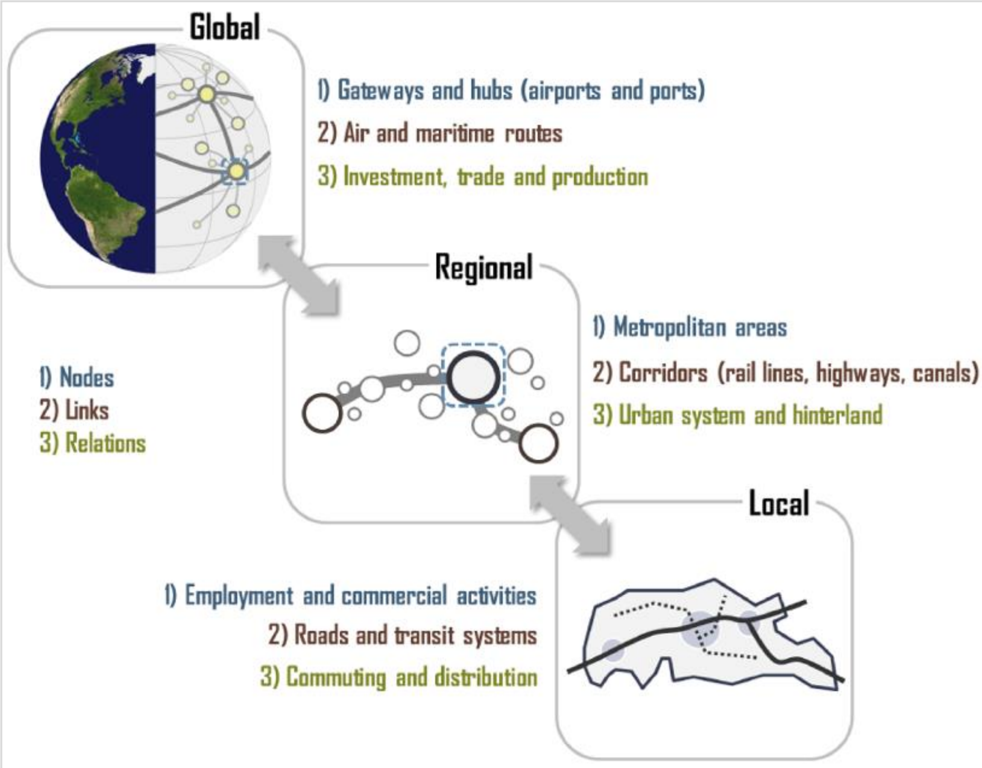

Figure 13 Conceptualisation of the global perspective of transportation

Source: (Rodrigue J. P., 2016)

Premius & Zonneveld (2003) observe that the development of corridors over the course of time has reflected technological advances in transport modes, and the construction legacy of different varieties of infrastructure. They further note that new generations of infrastructure are usually located close to older systems and occasionally on top of older systems. This is to confirm that the development of corridors is strongly path dependent, the core of Whebell's theory of corridors (Whebell, 1969) in (Prentice, Duncan, & Sokol, 2004). In most parts of the world, cities were initially linked over land only by road. Wagons, carts and coaches were drawn over these roads by horses and other animals, and roadhouses, inns and markets sprung up along the way. In areas rich in water, rivers and other water routes were important conduits for sailboats and barges.

The advent of industrialisation saw the emergence of the personal car and the lorry, and finally also the highway. Curves were straightened out; roads were paved, and average speeds increased. (Rodrigue, Comtois, & Slack, 2013) maintain that while industrialisation brought motorboats and steamboats as well, increase in traffic over water was not as dramatic as that on land. They further observe that road networks became increasingly elaborate, while waterway networks remained much more basic, being expanded only in exceptional circumstances. Ultimately, the industrialisation era brought trains and trams, which according to Rodrigue et al (2013) saw a completely new rail-based infrastructure being laid out. Regmi & Hanaoka (2012), noted that in recent times some corridors have been developed based on political vision rather than economic necessity. This was the case for the Dar es Salaam multimodal corridor comprising of railway, road, pipeline and port linking Zambia to the port of Dar es Salaam in Tanzania where TAZARA moved most of the cargo but was less functional of late compared to the early years of development. Most of the cargo has moved to road since then, like in the case of Beira and the North-South corridors.

Rodrigue, Comtois, & Slack (2013) argue that the development of transportation networks commonly leads to the formation of corridors through the spatial concentration of flows along an axis. They adopt the corridor development model, developed by Taaffe, Morrill and Gould (1963), to explain this process in the Western African context. They assert that the model can be applied elsewhere to other regions such as in North America. However, they concede that the timing of the phases might vary substantially by region. Their model identifies six distinctive phases as discussed in the next paragraphs. In the first phase it is stated that a set of small trade ports is established along a coastline. These would be connected to a wider network of trade and provide access to locally supplied resources. According to the proponents of the model the process can take place over centuries, as was the case for the global port system prior to the industrial revolution. The second phase entails the construction of trade lines accessing the hinterland, permitting the development of new resources and/or markets. The ports to which they are connected grow in proportion to the new traffic generated. The authors of the model observe that this would be typical of the early stages of the industrial revolution where the first canal and rail connections were established.

In the third phase, the hinterland of penetrating lines is further expanded by the development of feeders. This is said to represent the early stages of rail corridor developments. This is followed by the fourth phase whereby transport networks that would have been developing independently gradually become interconnected. It is argued that intermediate centres also start to emerge along with the first road systems, with the setting of rail corridors peaking. The fifth phase is said to be the outcome of increased connectivity where traffic tends to concentrate on the most connected ports (often corresponding to the largest cities), implying that several less well-connected ports decline or disappear. According to Rodrigue et al (2013) this phase is associated with rapid construction of highway systems supporting existing rail corridors as well as the setting of air connections between large city-pairs. Finally, in the sixth phase economies of scale are said to favour the concentration of the traffic along the most efficient links, supporting the emergence of transport corridors. It is at this stage where links having lower volumes can even be closed or naturally disappear. According to Rodrigue et al (2013), the regional transport system consequently would have reached maturity and the network structure would be unlikely to change, unless under circumstances of significant economic or technological developments.

Arnold (2006) acknowledges that corridors are usually developed to support regional economic development. However, he claims that there are nuances to this objective that have a big impact on the way the corridor is developed. He observes that some corridors have been developed to promote economic activity along the corridor as was the case with the Maputo corridor, developed as part of a spatial development initiative. The route had earlier served as the outlet for the import/export trade of the industrial region around Johannesburg. When the route was closed due to civil war, trade is said to have diverted to Durban and Richards Bay. The same happened on the Beira Corridor during the RENAMO civil war in the early 1990s. As a result, the economy along the route declined. The restoration of the corridor was intended to help rebuild this economic activity. Arnold (2006) argues that while the Maputo Corridor was successful in achieving its objective, this outcome contrasted with the lack of success of other economic corridors developed under the same initiative.

He maintains that a corridor might be developed to provide an international gateway for one or more landlocked countries. The Beira Corridor is a good example of such, which serves landlocked SADC countries including Malawi, Zambia, Zimbabwe and the DRC as noted in chapter one. According to Arnold (2006) while there is usually substantial trade between the landlocked country and its neighbours, trade with third countries must often be conducted through intermediaries in neighbouring countries that have access to the sea. Thus, corridors are developed to allow the importers and exporters of landlocked countries to interact directly with the markets in which they trade and thereby reduce transaction costs. This was the rationale for the development of corridors such as the Northern Corridor in Eastern Africa, Beira Corridor in Southern Africa, the West Bengal Corridor in India and various corridors leading to and from Laos.

Other corridors such as the TKC were developed to increase activity at the international gateway at the end of the corridor, according to Arnold (2006). The objective was largely to increase the use of the Port of Walvis Bay as the principal gateway for the customs union of Botswana, Namibia and South Africa. On the other hand, in the United States, the Alameda corridor was developed to provide a high-density rail connection between the ports on San Pedro Bay and the transcontinental rail network. There have been cases where corridors have been created simply to channel funds for infrastructure development to specific routes and to promote reforms of the regulations and procedures that restrict movement of goods along these routes. By the same token there are corridors that have been developed as part of a broader effort to develop an economic union. Good examples include corridors in the Greater Mekong Sub-region, and the Mercosur region. The same objective may be extended to expanding an existing economic union, typically the case for the extension of the TEN networks to Eastern Europe through TRACECA in support of the enlargement of the EU (Emerson & Vinokurov, 2009).

2.7 Corridor performance assessment

Lessons from earlier corridor development studies indicate that, as the planning and development of intermodal transport corridors requires careful consideration, their evaluation and assessment must consider aspects of corridor operation in addition to cost and time. (Arnold, 2005) considered reliability and flexibility, while (Raballand, et al., 2012) considered the infrastructure and service perspective.

According to Regmi and Hanaoka (2012) the time-cost-distance approach is extensively used by the Economic and Social Commission for Asia and the Pacific (ESCAP) and Asian Development Bank (ADB) for the assessment of transport operations. Regmi & Hanaoka (2012) applied the time-cost-distance approach to assess the performance and operational status of two important intermodal transport corridors linking North-East and Central Asia namely: Korea–China–Central Asia; and Korea–China–Mongolia–Russian Federation. These corridors use maritime, road and rail modes for the transportation of goods. They made policy recommendations to improve physical infrastructure and minimise non-physical barriers in order to enhance operational efficiency of the intermodal transport corridors, which can be useful for other countries and regions.

Several other studies, especially Athukorala & Narayanan (2018), Yang et al (2018), Hanaoka, et al (2019) and Goldmann & Wessel (2020), combined the evaluation of international transport processes with trade and transport facilitation measures. Jiang (2019) used a simple time-cost-distance approach to evaluate intermodal transport corridors in North-East and Central Asia and identified time and cost related barriers.

Athukorala & Narayanan (2018) conducted an in-depth study of the design, implementation, and the developmental impact of the Northern Corridor Economic Region (NCER) in Malaysia. They examined prerequisites for a successful economic corridor development program in a country with a federal system of government. Their analysis suggested that the NCER has the potential to leverage the core strengths of the state, including global connectivity, mature business eco-system with a strong presence of multinational enterprises, and sizeable talent pool. However, so far, the achievements have not matched the expectations primarily because of an inherent institutional limitation of the program: failure to constitute the Northern Corridor Implementation Authority (NCIA) with adequate power and operational flexibility to achieve the overarching goal of shared growth while ensuring compliance from all stakeholders.

Hanaoka, et al (2019) developed a simulation model to evaluate the performance of multiple stakeholders to understand how stakeholders determined their investment into transport infrastructure in cross-border corridors. The model was applied to a case study of East Africa including four landlocked countries, encompassing the Northern Corridor and Central Corridor. They concluded that the highest regional net surplus is achieved in the case of progressive investment of the organisational restructuring scenario, involving the establishment of a corridor institution with the necessary authority to harmonise regulations along the corridor across country boundaries, that markedly increased the net surplus of landlocked countries.

In the case of the Trans-European Transport Network (TEN-T) the European Union coordinates and co-finances supra-national transport infrastructure investments consisting of road, rail, airport, and port infrastructure. Goldmann & Wessel (2020) quantified the direct and indirect economic growth effects of newly created TEN-T core corridor roads in Eastern European countries. Through a combination of panel data and spatial analyses their results showed that regional GDP growth at the NUTS3 level is between 0.5 and 2.0 percentage points higher if a region has direct access to a newly built road. The analyses with a Durbin model (SDM) showed that the new construction of a TEN-T core road also causes positive spill over effects on other regions that have direct access to the corridor network, as well as on regions that are not directly connected to the corridors. The results thus indicate that the TEN-T policy, which aims to alleviate transport bottlenecks, can increase cohesion between central and peripheral regions and consequently enhance regional welfare in Eastern Europe.

Yang, et al (2018) investigated the attitude of relevant stakeholders towards the performance of the Traditional Sea-Land Line (TSLL) alongside the two emerging container routes forming part of the Belt and Road (B&R) initiative. Under this initiative, two new emerging trade corridors connecting the Far East to Europe have been built. These are the China-Europe Sea-Land Express Line (CESEL) and the New Eurasian Land Bridge (NELB). They built a performance evaluation model to understand the relative performance of these trade routes, performing surveys among both government and industry stakeholders. They found that economic indicators obtained much higher model weights in the government group than in the industry group, whereas commodity nature and geopolitical stability have higher weights in the industry group. In their view this may be attributed to the different concerns and expectations between government policymakers and industry practitioners on the development of the new routes. This distinct variance is generated due to unique "trajectory activity" in the multiple-level institutional system of China.

A study conducted in China, where the central government dominates the process as the principal institutional entrepreneur, established a strong preference among stakeholders that economic factors, such as trip frequency, freight rate and trip time, take precedence over other factors (Bersenev, et al., 2020). On the other hand, geopolitical stability is also heavily weighted, which indicates the concern of relevant stakeholders towards the political stability of the nations along the transport route. These factors are very important for Beira Corridor given its history of civil war involving RENAMO and the Mozambican government.

2.7.1 Physical infrastructure

The standard and quality of infrastructure, underdevelopment of logistics infrastructure and services, limited availability of multi-modal transport services and relatively high costs of international transport services for small cargo are often seen as barriers for the growth of intermodal transport (Regmi & Hanaoka, 2012). Development of modern intermodal logistics centres as well as improvement in operations could consolidate freight for the international market in sufficient volumes and allocate them to the most efficient transportation mode. A decision support tool, including a cost model, was developed to assist logistics service providers to select optimum multimodal routes, in the process optimizing transportation routing within GMS countries (Kengpol, et al., 2012).

The level of development of the logistics industry in a country also has much bearing on the overall efficiency of transport processes. In the studies of (Regmi & Hanaoka, 2012) and (Yang, et al., 2018) the logistic performance index (LPI) among the countries along the case study corridors shows a wide variation. The Republic of Korea (3.64) and China (3.49) have high LPI, while Kazakhstan (2.83), Mongolia (2.25) and the Russian Federation (2.61) have low LPI (Arvis, Mustra, Panzer, Ojala, & Naul, 2010). This indicates that much improvement of logistics infrastructure and services to facilitate international trade are required in Kazakhstan, Mongolia and the Russian Federation.

According to the 2018 LPI scores, among the four SADC LLCs along the case study corridors, Malawi (2.59) and Zambia (2.53) have higher LPI compared to their two counterparts, DRC (2.43) and Zimbabwe (2.12). Although the condition of infrastructure along some intermodal transport corridors in SADC has improved, there is much to be done to improve the efficiency of corridor operations, especially for the Beira Corridor. Among the countries operating the respective ports, South Africa has the highest LPI of 3.38, with Tanzania at 2.91 and Mozambique at 2.24. This provides an indication of the condition of infrastructure, procedural impediments and intermodal transport operation and management along the respective corridors.

2.7.2 Modal choice

Freight is predominantly carried by road transport in the SADC region which is more energy intensive than other modes. Regmi & Hanaoka (2012) suggest that one way to reduce environmental impacts and emissions from transport operations is modal shift from road to other transport modes such as railway. Improved logistics organisation, coordination, and corridor route planning is believed to be able to reduce CO2 emissions by as much as 10–20% worldwide (OECD, 2010). The development and use of intermodal transport corridors for transportation of goods can therefore help to reduce emissions of pollutants and environmental impact.

Many studies consider the environmental aspect of intermodal corridors and logistics (Rodrigue, 2020). Shippers of goods usually consider using a combination of modes and exploit opportunities for modal shifts that minimise environmental impact from transport operations along the corridors. In the case of the corridors considered in this study the absence of continuous rail networks however results in road being the dominant mode for land-based transport. The subject of modal choice is also discussed in the next chapter as part of logistics activities.

2.7.3 Customs clearance and border crossing

Several studies have cited problems related to customs clearance and delays at border posts as a major bottleneck in the transport process along most corridors. The World Bank (2005) found that on the Almaty-Europe corridor more than 50% of transit time is lost in downtime at borders. In a similar study Walker et al (2004) identified bottlenecks restricting the use of intermodal freight transport linking Western Europe with Central and Eastern Europe and analysed various policies and prioritised those for reducing bottlenecks. (Raballand, et al., 2012) claimed that the increase in logistics cost and transit time and border-crossing problems are some of the reasons for trade imbalance and low trade volumes between Central Asia and Europe. Islam, et al., (2006) assessed impediments to the development of efficient multimodal transport in Bangladesh and recommended the reform of customs procedures and provision of door-to-door services by shippers as essential to improve operational efficiency on corridors.

Even though international and transit trucks can cross borders in the SADC region, there are different procedures to gain entry and exit permits for crossing borders and various unofficial charges are required to accelerate the border crossing and clearance process. In the region, as per the SADC Protocol on Communication and Meteorology, there are cases of reciprocal charges levied on trucks originating from member countries. This makes time required to cross borders in the SADC region unpredictable and unofficial payments are oftentimes cited as one of the reasons for increasing transportation cost (Anon., 2012).

2.7.4 Coordination and cooperation among stakeholders

The development and operation of intermodal transport corridors is a complex issue as it involves different sectors and government agencies. There is a challenge to ensure efficient collaboration among various stakeholders to manage and operate intermodal transport corridors within a country as well as those crossing one or more borders. While infrastructure development is usually led by the public sector, its operation involves both public and private sectors. It is found that railway is operated by the public sector while road transportation is operated by the private sector in most countries. There is a perceived belief that transport operations that are handled and managed by the private sector are more efficient and competitive than that managed by the public sector.

De Vries and Priemus (2003) recommended that improved coordination and cooperation between the public and private sectors, coordination between central and local governments and improvement of border crossing arrangements are essential to improve the performance of corridors. Collaboration among stakeholders and developing collaborative hub networks can help to reduce logistics cost and maintain logistics services by selecting appropriate modes that ensure economies of scale (Groothedde, Ruijgrok, & Tavasszy, 2005. Caris, Macharis, and Janssens (2008) argued that increased levels of coordination and cooperation between stakeholders in the intermodal transport chain is required to improve the performance of intermodal freight transport and indicated that further research is needed in this area.

Lehtinen and Bask (2012) analysed four business models considering manufacturers, trading companies, transport companies and 3PL companies. Their study sought to understand these companies' perspectives of transport corridors that employed road, rail and short sea modes. They concluded that while theoretical studies indicated a particular corridor as being favoured, this was not the case in practice. In fact, the indication was that the coordination of manufacturers and trading companies was an important issue that needed to be further explored.

Chapman, et al., (2003) stated the difficulty in integrating policies and defining scope of London–West Midland Corridor. Others argued that the improved governance and management of corridors was an important aspect (Priemus & Zonneveld, 2003). The responsibility to manage various parts of the transport corridors lies with the national governments. It was concluded that corridor-based management and coordination was needed to improve corridor operation through the sub-regional programs. Generally recent approaches to corridor management have tended to incline towards a focus, either infrastructure and facilities or infrastructure and regulatory procedures (Arnold, 2006). A few examples are TEN and Can-Mex (infrastructure and facilities) and Maputo, Trans-Kalahari and Northern Corridor (infrastructure and regulatory procedures). In the next sections competing corridors are discussed in terms of bottlenecks affect their market share of the hinterland cargo. This is meant to give context to the comparison of the Dar es Salaam Corridor and North-South Corridor with Beira corridor.

2.8 Competing Corridors

The corridors that compete directly with the Beira Corridor for key transit markets of DRC (Copperbelt), Malawi, Zambia and Zimbabwe was are Dar es Salaam and North-South corridors. This is confirmed in the AFREXIBANK report, Nathan (2020) which lists these two corridors to be among those competing for the four transit markets in 2016, for regional flows. It observed that the DRC market was dominated by the Dar es Salaam Corridor, with 73% market share, followed by the North-South Corridor, with 21%. For the Zambian market, the dominant was the North-South

Corridor, with 51% market share, followed by the Dar es Salaam Corridor with 39%. In terms of the Zimbabwean market, this was again dominated by the North-South Corridor, with 94% market share, followed by the Beira Corridor with only 6% of the market. Lastly, the Malawian market was dominated by Nacala and North-South Corridor, each with 39% of the market share. It is clear from these statistics, that the Dar es Salaam and the North-South corridors are competing directly with the Beira Corridor. The study compares these two corridors with the Beira Corridor in order to understand the paradox as described in the Problem Statement above. In the next sections the Dar es Salaam and the North-South corridors are discussed.

2.8.1 Dar es Salaam Corridor

The Dar es Salaam multimodal corridor illustrated in Figure 14 is a system that links SADC landlocked countries, including Malawi, Zambia and southern Democratic Republic of Congo and of late Zimbabwe, to the port of Dar es Salaam, which makes it a direct competitor of the Beira Corridor. The routes on the corridor cover a total distance of 5, 400 km and comprise road, rail and a pipeline, with some inland waterways also included according to Cardno (2020). The Dar es Salaam port is managed by the Tanzania Ports Authority, a government agency established in April 2005.

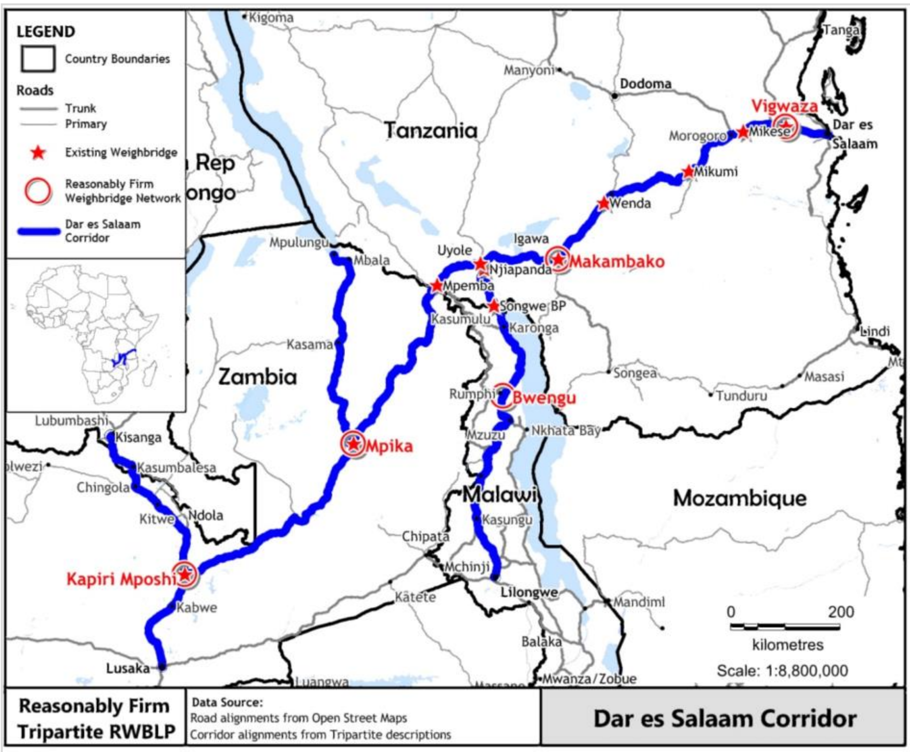

Figure 14 Configuration of the Dar es Salaam corridor

Source: Tripartite Transport & Transit Facilitation Programme (TTTFP)

The corridor, just the same as Beira, has many bottlenecks for goods and services according to Cardno (2020). The cited bottlenecks include customs and or police checks downtime and long truck turnaround times, which have a negative economic impact on the SADC region. The port of Dar es Salaam and the entrance channel is shown in Figure 15. The port serves SADC and EAC landlocked countries including Malawi, Zimbabwe, Zambia, the DRC, Burundi, Rwanda and Uganda respectively.

Figure 15 Layout of the Dar es Salaam port showing the entrance channel

Source: Tanzania Ports Authority Handbook (2019-20)

Figure 16 Photo of Dar es Salaam port viewed from the eastern direction

Source: TPA (2020)

Figure 16 illustrates a photo of the port of Dar es Salaam viewed from the eastern direction facing the entrance channel. Dar es Salaam is one of East Africa's leading freight gateways – a growing entry and exit of goods for local markets and to many landlocked countries across East and Central Africa. The port is the Indian ocean entry point of a complex logistics network stretching across much of central Africa. The port handles about 95% of Tanzania International trade across 11 deep-water berths. Tanzania Port Authority (TPA) operates seven berths while four are under consortium with Tanzania International Container Terminal Services (TICTS) (TPA Handbook, 2016).

The port is accessible via 3-5km entrance channel that can allow vessels of up to 234 meters LOA and 140 metres breadth with a depth of 10.5 meters at Chart Datum, a bottleneck that restricts passage of larger vessels, the same problem suffered by Beira port. The port has a total quay length of 2.6 km with 11 Berths at Main Quay plus a Single Buoy Mooring (SBM) and a dedicated berthing area for coastal vessels at the lighterage Quay. Berths number 1 to 7 has a depth between 8.7 and 10.5 meters for general cargo vessels. Berths No. 8 to 11 have an average depth of 11.0 meters and are mainly dedicated to liner vessels (TPA, 2020). The port also has Grain Terminal facility (silos with storage capacity of 30,000 mt). TPA is implementing several major projects including the Dar es Salaam Maritime Gateway Project (DMGP) which will allow the reception of larger vessels. Port modernisation projects include strengthening and deepening of berths 1-7 and Roll on, Roll-off (RORO) terminal, dredging of entrance channel, turning circle and harbour basin, strengthening and deepening 8-11, and construction of a new terminal jet.

The activities of the Dar es Salaam Corridor are coordinated by the Dar es Salaam Corridor Committee (DCC). The DCC is a forum established to foster regional cooperation on cross border transport policy formulation, regulation and operation. It comprises both public and private institutions from member countries. The DCC which was established in 2003, under auspices of the Southern Africa Development Community (SADC), serves to facilitate and promote trade in and among member states using the Dar es Salaam corridor. It facilitates the reduction of total transit times on the corridor and total transport cost for corridor traffic.

As part of dealing with addressing bottlenecks of the corridor, DCC, through World Bank support, has allocated funds for the development of a CPMS which will allow it to fulfil its responsibilities and accurately monitor the corridor performance. The purpose of the system being developed is to capture data from such stakeholders as Tanzania Ports Authority (TPA), freight truck operators, railway utilities, clearing and forwarding agents, traffic police, and more, from all member countries. This will provide Corridor Performance Benchmarking that measures Key Performance Indicators (KPIs) such as turnaround times for major routes or profitability of routes per cargo type.

Through the quality data and reports produced by the CPMS, the DCC aims to pinpoint where improvements and interventions can be made along the corridor in order to improve its efficiency.

The data generated will provide evidence to support suggestions and recommendations for future projects to be actioned along the corridor, ultimately improving the overall efficiency and effectiveness of the corridor and subsequently increasing trade and travel along the road network and surrounding areas. This will result in large scale economic growth and improved connectivity in the regions which in turn will help the populations, both rural and urban, in all four countries, and likely beyond. The implementation of OSBP at Nakonde-Tunduma on the corridor is one of the initiatives that has seen a reduction in turnaround times on the corridor.

The Nakonde - Tunduma One Stop Border Post (OSBP) between the United Republic of Tanzania and Zambia was officially opened on the 5th of October 2019 by the Presidents of the two countries. The Tunduma – Nakonde OSBP handles traffic to and from the Tanzanian port of Dar es Salaam for Zambia and DR Congo and also Zimbabwe. The implementation of the OSBP is expected to improve freight trucks' turnaround times and enhance operational efficiency of the border agencies of the two adjoining countries. This is expected to result in faster clearing times and reduction of waiting times at the border, lowering the cost of trade Between the Tunduma Mbeya district of Tanzania and Nakonde, Zambia. The border is 925 km from the port and the truck travel time is about 20 hours. Figure 17 shows a photo of the new facility at Tunduma on the Tanzanian side of the border.

Figure 17 Tunduma-Nakonde OSBP building (Tanzania side)

Source trendsnafrica.com (2019/10/11)

tanzaniainvest.com (2020) reports that Tunduma is the busiest transit and entry point in Tanzania linking transit trade destined for the Democratic Republic of Congo, Malawi, Zambia, and Zimbabwe. On average trucks leaving Tanzania take about 2.5 days to cross the Tunduma border into Zambia.

Delays in cross border clearance are due to duplication of handling procedures on either side of the border, poor institutional arrangements and cargo management systems, inadequate physical infrastructures and services and immigration management. The OSBP will boost trade by cutting the time taken to clear goods between the two nations by at least a third, thus contributing to a reduction in transport cost, whilst increasing volumes of trans-shipment cargo through the Dar es salaam Corridor.

The implementation of the OSBP at Nakonde-Tunduma border post is expected to reduce the time spent from 2.5 days to 1 day. The average daily volume of traffic is between 300 and 400 freight trucks crossing the border at Tunduma (ddcustomslaw.com, 2020). In addition, a considerable number of private vehicles and pedestrians are transiting via the border crossing. The border crossing agents give priority to tankers, private vehicles, and cargo trucks respectively. The route to reach and cross the border is a bottleneck due to narrowness and it causes congestion. Generally, trucks take at least one day to process through customs.

Usual documents are required for the custom clearance including invoice, packing list, permits, and the contract signed between the customer and the clearance agent, if any. The truck driver must present his passport to the authority. Note that the goods could be subject to examination upon entering country. The fees vary in function of the origin, destination, and the number of axles. For small vehicles, the fees are mainly based on the longer of the journey in Tanzania.

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A comprehensive programme aimed at finalising the legal (extra territorial legislation), operational and institutional arrangements necessary for the efficient operation of the OSBP will be implemented.

The institutional structure responsible for the oversight of the establishment of the Nakonde/Tunduma OSBP will comprise the following:

- a Ministerial Committee to provide overall political leadership, guidance and direction for the OSBP implementation;
- a Steering Committee made up of senior officials at the level of Permanent Secretary or Heads of Department to deal with policy and overall programme leadership and direction, as well as including monitoring and evaluation,
- Technical Committees/Technical Working Groups to support the Steering Committee and to execute the work programme and all technical activities (each specialised for competence area, such as: legal, procedures, ICT and infrastructure and physical facilities); and finally
- a Joint Border Operations Committee made up of representatives of border agencies at the Nakonde/Tunduma OSBP, that meets regularly to deal with day-to-day operational issues

affecting both countries, not only limited to the OSBP, but to regular operations and functions at the border.

The OSBP was funded by DFID through TradeMark East Africa, an organisation that aims to improve trade competitiveness in East Africa by reducing transit time and logistics costs and improving trade. The $6 million investment is expected to boost trade between member states of SADC and East African Community (EAC).

2.8.2 North-South Corridor

The North-South Corridor (NSC) illustrated in Figure 18, is arguably the busiest of all the SADC region corridors, serving all the landlocked countries in the region. It converges with the Beira Corridor in Harare, Zimbabwe making it a direct competitor of the Beira corridor in terms of target market served. The port of Durban situated on the Indian Ocean handles imports and exports for the NSC and is in the South African province of Kwazulu Natal (KZN) to the south eastern part of South Africa.

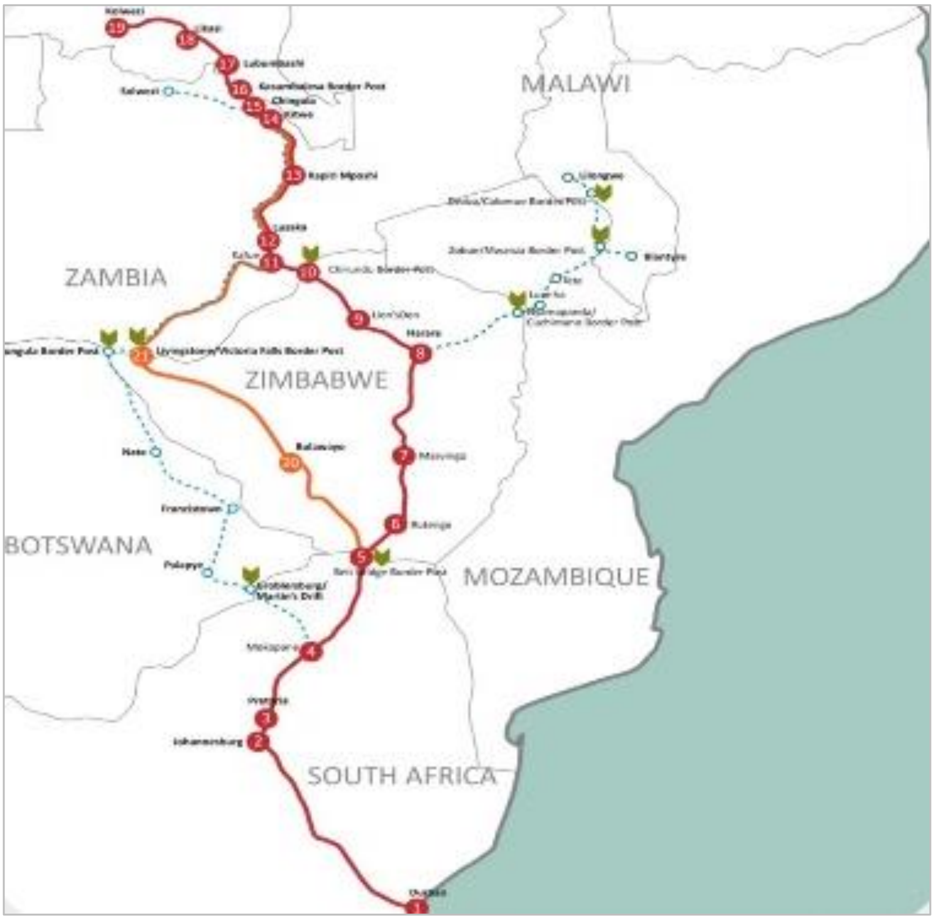

Figure 18 North-South Corridor (Beitbridge-Chirundu route)

Source: www.researchgate.net (2020)

Arguably one of the busiest ports in Africa, Durban is one of the largest cargo ports in Southern Africa with 59 berths, excluding maintenance ones. The port continues to expand and develop new areas, to cater for increased demand that it faces from year to year. This area is linked to important industrial areas which makes it perfect for exporters. According to Transnet (2020) the port has two major floating docks, one of which controlled by the NPA (National Ports Authority). The lifting capacity of the latter is 4500 tonnes while the second dock has a capacity of more than 8500 tonnes. Durban accommodates large ships with capacities of up to 230,000 dwt (Deadweight tonnage), but ship sizes vary every day. There are even larger ships (post Panamax) that entered Durban port over its history. Over 800 ships use this port on a monthly basis, excluding non-commercial and private. The port of Durban handles the largest volume of sea-going traffic of any ports in southern Africa (Anon., n.d.). In the cargo side of the port are traded oil and petroleum imports and exports as well as other large quantities of goods.

The port of Durban is owned by the South African National Ports Authority (NPA) and operated by Transnet Port Terminals (TPT), one of five operating divisions of Transnet SOC Limited, South Africa's state-owned freight transport and handling company (Transnet, 2020). TPT is responsible for commercial handling services of sea-route freight across imports, exports and trans-shipments in containers, bulk, break-bulk and automotive. TPT operates terminals in seven South African commercial ports namely Richards Bay, Durban, East London, Port Elizabeth, Ngqura, Cape Town and Saldanha. Operations cover import and export operations across the following cargo sectors: Containers, Mineral Bulk and the Agricultural Bulk and Ro-Ro (roll on/roll off). The operational model divides the country into three geographical regions namely Eastern Cape, Western Cape and KwaZulu Natal. Users of the NSC have a wide option in terms of ports given the diversity of the Transnet port system footprint.

Krogman et al (2018) acknowledge that land borders in the SADC region are critical zones for unlocking economic development, regional value chains and trade. They note the importance of Beitbridge and Chirundu border posts, as links in the North–South Corridor are vital in regional development and multilateral initiatives. The two borders still have many issues related to regional integration due to physical and non-physical bottlenecks. Understanding the major bottlenecks affecting the competitiveness of trade and undermining trade facilitation initiatives is therefore essential and cannot be over emphasised. Failure to improve border efficiency can similarly undermine the trade for most of the SADC landlocked countries depending on the corridor to access global markets. If the North-South Corridor offers more value to shippers than the Beira Corridor, it would pose as a threat to the existence and viability of the Beira despite it being the closest to Malawi, Zambia, Zimbabwe and the DRC. In choosing a route or corridor, shippers consider the efficiency, predictability and generalised logistics costs more than the distance. Thus, the more cost effective, efficient and reliable a corridor is the more competitive and favourable it is.

2.9 Conclusion

In this chapter, literature pertaining to the corridor concept and corridor bottlenecks was reviewed in order to appreciate the diverse views of scholars on the subject matter of corridors. Systems thinking was explained in terms providing a holistic perspective in the assessment of a corridor. The chapter explored the various elements that constitute a corridor, such as inland terminals, ports, roads and railway lines together with the different types of bottlenecks that affect corridor performance. For instance, bottlenecks related to physical infrastructure, regulatory process, logistics services and transport modes are discussed in line with the conceptual framework depicted in Chapter 1.

Furthermore, a review of literature on transport corridors from both the developed and developing regions was performed in order to appreciate corridor development trends and the challenges encountered in various parts of the world. Examples explored are from North American, Europe, Asia and Sub-Saharan Africa, especially the Dar es Salaam and North-South Corridors which directly compete with the Beira Corridor, to provide context. The observations derived from the review of existing knowledge on corridor performance and associated challenges were appreciated in order to develop a perspective with which to approach the assessment of the Beira Corridor bottlenecks. The aim was to assess the bottlenecks affecting transport corridors to draw lessons that could assist in the assessment of the bottlenecks affecting the Beira Corridor and its competitors. The idea was to perform a comparative analysis with other corridors, hence this chapter provides information and conceptualisations of corridors that are useful for the assessment of the Beira Corridor bottlenecks. In the next chapter logistics activities are discussed with regards to their role in corridor performance.

CHAPTER 3 CORRIDOR LOGISTICS ACTIVITIES

3.1 INTRODUCTION

In the previous chapter literature on the concept of a corridor as well as the challenges of bottlenecks were reviewed, together with the systems concept. Following the systems approach, this chapter proceeds to explore the theoretical underpinnings of the role of dry ports as a component of the corridor. This is explored in terms of how this theory applies to the Beira Corridor in respect of addressing some of the bottlenecks adding to the costs incurred by users.

Stopford (2009) has defined logistics as the science that deals with complex transport problems. He maintains that the term *logistics* is derived from the Greek word *logistikos,* meaning 'calculatory' or 'rational', which was adopted by the military to describe the science of planning the supply chain which supports combat troops. The term logistics is now used by commercial organisations to describe the process of rationalising supply chains to support their commercial operations. Typically, logistics involves integrating transport modes, storage facilities, cargo-handling facilities, information management and performance measurement and monitoring. Therefore, logistics is a very important component of the corridor, especially with respect to performance measurement and monitoring of the corridor. In this study, logistics costs are regarded as one of the indicators of corridor performance, hence the need to discuss the subject of logistics activities in detail.

Firstly, the role of dry ports and inland terminals as extensions of the port, is discussed to show the inter-relationship between the two and the role they play in supporting the port, both of which are sub-systems of the corridor. This is followed by a discussion on the dry port in the context of port/terminal regionalism and market connectivity and corridor performance. Thirdly government policy and regulation of inland terminals is discussed to give context of corridor bottlenecks. The fourth aspect is a discussion on the role of transport mode in the system and the cost implication to the corridor users. Lastly, the Beira Corridor modes choice is discussed to explain how these could have impacted the performance of the corridor, where availability or otherwise might affect the costs incurred. This then is followed by the conclusion to the chapter.

3.2 The role of Dry Ports in addressing bottlenecks

According to Rodrigue (2013) a dry port is an inland terminal linked to a maritime terminal that has a level of integration with the seaport terminal and that supports efficient access to the inland market for both imports and exports. The Beira Corridor comprises various logistics activities: dry ports/inland hubs, the maritime port and modes of transport serving the corridor, in combination constituting the corridor system. In trying to foster the role of the systems approach in addressing corridor bottlenecks, the role of dry ports is assessed in terms of a sub-system and how they can contribute to addressing corridor bottlenecks in the case of the Beira Corridor. Logistics activities such as dry ports play a very important role in determining the cost of logistics in general, as dry ports contribute significantly to the handling of cargo to and from the port as extensions of the seaport.

Each dry port remains the outcome of modal availability and efficiency, market function and intensity as well as the regulatory framework and governance. The geographical characteristics linked with modal availability and the capacity of regional inland accesses have an important role to play in shaping the emergence and development of dry ports. Each inland market has its own potential requiring different transport services. Therefore, there is no single strategy for a dry port in terms of modal preferences, as the regional effect remains fundamental. The setting of global supply chains and the strategy of Pacific Asian countries around the export-oriented paradigm have been powerful forces shaping contemporary freight distribution. Indirectly, this has forced players in the freight transport industry (shipping companies, terminal operators, logistics service providers) to examine supply chains as a whole and to identify legs where capacity and reliability are an issue.

While developing economies have attracted a lot of attention from scholars in recent years, a comparative study on developed economies (such as North America and Europe) have remained relevant. Hence, it allows analysing the underlying converging and diverging trends in (rail-based) dry port settings and operations in more mature economies that are pioneers in the application of the dry port concept. Rodrigue and Notteboom analysed the setting and development of rail-based dry ports in North America and Europe (Rodrigue & Notteboom, 2012). They argue that rail-induced dry port development, or alternatively dry port induced rail development, comes in many forms and shapes as a function of the regional and local governance and regulatory settings. These include strategies of stakeholders involved, the spatial and functional relations with adjacent and or distant gateway ports, dynamics in logistics network configurations, and the specific competitive setting, that is competition with trucking and barges.

In the case of the Beira Corridor, the gateway is the port of Beira and for this reason dry ports and other elements such as roads and railways are discussed in the context of modal choice on the various routes linking the port with its hinterland. According to Rodrigue & Notteboom (2010) ports represent the fundamental interface structure between regional and global transport systems; in this case Beira port provides that interface for the land locked countries mentioned in Chapter 1. Rodrigue (2020) describes gateways and hubs as locations where freight flows converge and that mark the first point of global connectivity. The difference between the two is the nature of connectivity, where a hub is central location in the transport system with several inbound and outbound connections of the same mode, while a gateway signifies a transfer from one mode to the other, e.g. from maritime to land and vice versa. Hence, a gateway performs an intermodal function, whereas a hub serves as trans-modal node. Figure 19 illustrates the difference in function between a gateway and a hub according to Rodrigue (2020).

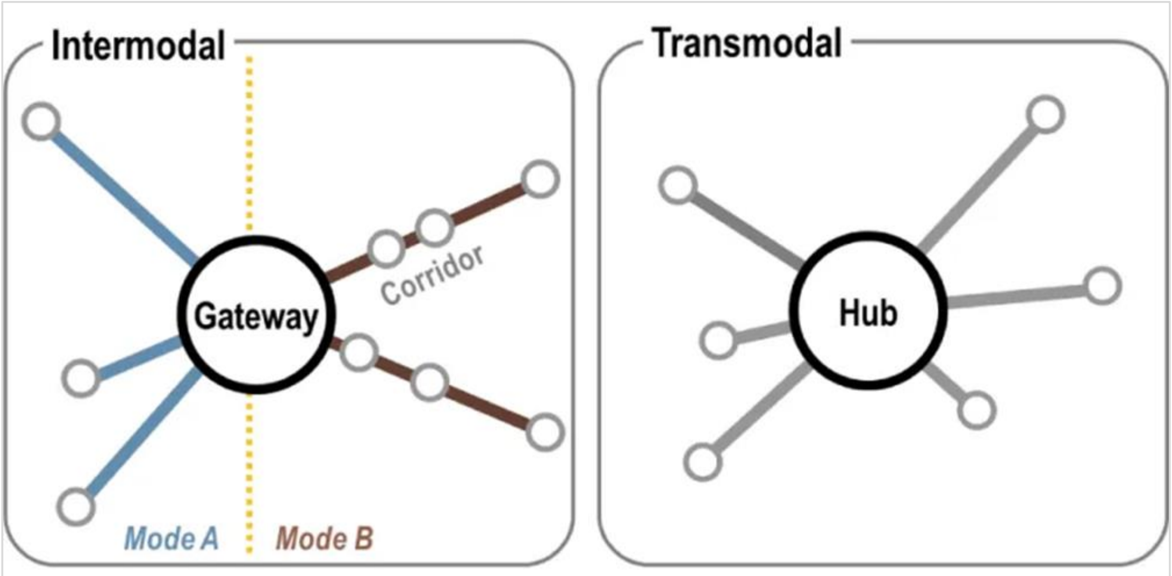

Figure 19 Gateway and hub as components of the corridor

S**ource: Rodrigue (2020)**

The next section discusses the role of the dry port as a component of the corridor and the various services that are found. The reason for discussing the logistics activities found in the dry port is that some bottlenecks on the corridor can be found at the dry port, whether related to physical or non-physical infrastructure.

Literature suggests that dry ports play a significant role of being an integral part of port development as they address bottlenecks associated with port congestion due to increased traffic volumes. For instance, Rodrigue (2020) contends that a high capacity and frequently serviced intermodal corridor that has an efficient rail terminal reduces transportation costs and maintains reliable services to the benefit of the users, especially logistics activities. The improvements at the port of Beira resulted in a huge growth in traffic along the Beira Corridor. This has led to congesting around the port area as trucks queue for long hours, sometimes days waiting to be loaded.

While a dry port provides a range of related logistical activities linked with the terminal, including customs services, distribution centres, containers depots and logistical service providers, it is a buffer to the port. It can free the port of space required to process vessels docking do deliver cargo. The Mutare Dry Port, formerly Green Motor Services (GMS) dry port in Zimbabwe, is 279 km from Beira, strategic to provide that solution for the port of Beira. The Dry port is a typical rail-based dry port terminal supposed to be served by rail and road modes. The collapse of rail service on the Machipanda line to this dry port has rendered it a road-based dry port used mainly for the physical inspection of trucks by customs. With the right improvements, it is ideal to serve as an extension of the port of Beira because it is operated by the Beira port concessionaire, Cornelder. The use of dry ports around Beira and along the corridor could alleviate the congestion problem and improve port productivity, thereby improving the performance of the Beira Corridor.

Typically, a rail-based dry port such as the Mutare Dry Port that is supposed to serve as an intermodal terminal, caters for logistics activities and acts as gateway to a corridor. Economies of scale and economies of agglomeration should ensure multiplying effects. Currently, the GMS facility does not meet these criteria as it has been reduced to a road-based dry port which increases costs to the contrary of the paradox that rail terminals should reduce costs. It is argued that co-location provides additional value to an inland port as it minimises drayage. This is believed to involve the setting of a real estate base that can either be sold or leased to freight distribution activities. In its current state the GMS dry port cannot accommodate these other services because of its limited land space, unless if it secures a more spacious site than the current one. Dry ports elsewhere cover several hectares of footprint catering for a diverse range of logistics activities, including stuffing, de-stuffing, consolidation and distribution among other activities.

The issue of capacity, particularly the inclusion of rail service, is important if the dry port is to achieve this kind of service role. This is echoed by Notteboom and Rodrigue (2005) who assert that the complexity of modern freight logistics, the increased focus on intermodal and co-modal transport solutions and capacity issues appear to be the main drivers. They argue that while trucking tends to be sufficient in the initial phase of the development of inland freight distribution systems, at some level of activity, diminishing returns such as congestion, energy consumption and empty movements become strong incentives for the establishment of inland terminals as the next step in regional freight planning. They believe that the densification of flows in networks, through a concentration of cargo on a limited set of ports of call and associated trunk lines to the hinterland, creates the right condition for nodes to appear along and at the end of these trunk lines. Thus, dry ports development is in line with the port regionalisation process. This phenomenon is the latest stage of port system development, characterised by improved hinterland accessibility through market strategies and policies. The Beira Corridor's competitiveness can be enhanced if this philosophy is embraced. This could address the capacity constraint posed by limited space at the port and the congestion associated with many trucks having to battle to enter the port. This would be enhanced through the revival of the Machipanda line rail services linking the Mutare Dry Port with the port of Beira.

Rodrigue & Notteboom (2012) argue that there is also a significant distance/cost dichotomy between forelands and hinterlands since, depending if space (distance) or cost is considered, the relative importance of the hinterland significantly changes. Maritime transport has achieved remarkable economies of scale, underlining its ability to transport cargo over long distances and at a low unit cost (Stopford, 2009). Notteboom & Rodrigue (2009) argue that economies of scale are much more difficult to achieve over the hinterland and that as traffic increases, transport networks near ports get increasingly congested. The unit costs per TEU-km underline this situation. For example, the shipping price on the Asia–North Europe trade ranges between 0.05 and 0.19 euro per TEU-km, according to Rodrigue & Notteboom (2012). The price for inland haulage per truck from north European ports usually ranges from 1.5 to 4 euro per TEU-km depending on distance and weight. By barge, the price ranges between 0.5 and 1.5 euro per TEU-km (excluding handling costs and pre- and end haul by truck) according to Notteboom & Rodrigue (2009). As the cost burden has shifted from the seaside to the landside, inland freight distribution remains the most salient issue in long-distance freight distribution logistics.

The evolution of inland freight logistics is a cycle in the ongoing developments of containerisation and intermodal transportation, yet for the Beira Corridor it is the opposite, due to the collapse of rail, hence the conversion of the Mutare Dry Port to a road-based inland terminal used only for customs physical inspections, adding to costs through inspection fees charged to trucks. According to Rodrigue and Notteboom (2012) the geographical characteristics linked with modal availability, capacity and reliability of regional inland access have an important role to play in shaping this development. They contend that as maritime shipping networks and port terminal activities become better integrated, particularly through the symbiotic relationship between maritime shipping and port operations, the focus shifted to inland transportation and inland terminal facilities and dry ports as fundamental components of this strategy. In their view, after a phase that relied on the development of port terminals and maritime shipping networks, the integration of maritime and inland freight distribution systems has favoured the setting up of dry ports. This argument was true at the inception of the establishment of the Mutare Dry Port, where cargo would be transported by rail to the GMS dry port for transhipment to trucks for the last mile. The collapse of rail operations has limited the ability of the terminal to contribute to the reduction of logistics costs creating a huge bottleneck for the Beira Corridor.

It is important that rail services are revitalised for the dry port to serve its purpose as defined in literature. Rail accessibility to gateway seaports is at the heart of the functioning and development of dry ports around the world. Even on the North-South Corridor, City Deep is an inland terminal almost 500km from the port of Durban linking bay rail through Kings Rest rail terminal where block trains move huge volumes of cargo for transhipment at City Deep. Equally, on the Dar es Salaam Corridor, inland dry ports served by rail help reduce costs as some legs are by rail.

Once maritime shipping networks and port terminal activities have been better integrated, particularly through the symbiotic relationship between maritime shipping and port operations, inland transportation becomes the obvious focus and the inland terminal a fundamental component of this strategy. This is true for the Beira Corridor where the improvements saw the handling of liner ships and other big vessels leading a surge in traffic volumes demanding high capacity transport to serve the hinterland. This can be explained by a huge number of trucks plying the route which has put pressure on the road infrastructure as well as congestion around the port. Once rail transport has improved, the Mutare Dry Port and other I land terminals along the Beira Corridor would play an important role in reducing bottlenecks associated with lack of space in and around the port.

This mainly took place in North America and Western Europe, which tended to be at the receiving end of many containerised supply chains where inbound logistics dominate (Rodrigue & Notteboom, 2012). However, focus has shifted to also considering inland terminals for the early stages of global outbound logistics – locations with an export-oriented function.

Elsewhere, inland terminals have evolved from simple intermodal locations to their incorporation within logistic zones. Inland terminals (particularly rail) have always been present since they are locations from which specific market coverage is achieved. Containerization has impacted this coverage through the selection of terminals that were servicing a wider market area. This spatial change also came with a functional change as intermodal terminals began to experience a specialization of roles not only based on their geographical location but also based on their 'location' within supply chains. Dry ports in many cases have witnessed a clustering of logistics sites in the vicinity, leading to a process of logistics polarization and the creation of logistic zones. They have become excellent locations for consolidating a range of ancillary activities and logistics companies (Rodrigue & Notteboom, 2012).

In addition to standard capacity and accessibility issues in the hinterland, a dry port is a location actively integrated or in many cases striving to be integrated within supply chain management practices. Actions to achieve this goal take many forms such as the agglomeration of freight distribution centres, customs clearance, container depots and third-party logistical services. The dry port can also become a buffer in supply chains, acting as a temporary warehousing facility often closely connected to the warehouse planning systems of nearby distribution centres (Notteboom & Rodrigue, 2009). Purchasers can even be advantaged by such a strategy since they are not paying for their orders until the container leaves the terminal, delaying settlement even if the inventory is nearby and available.

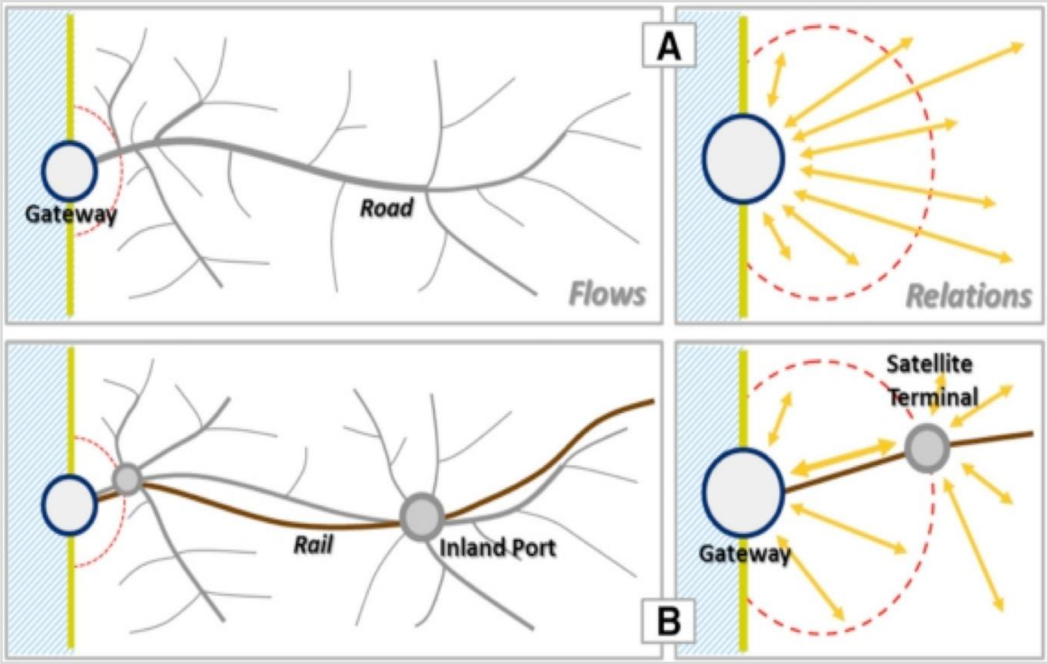

Figure 20 A perspective of gateway/dry port relationship

Source: (Rodrigue & Notteboom, 2012)

The emergence of dry ports in some cases underlines some deficiency in conventional inland freight distribution that needed to be mitigated (Figure 20). First, when a deep-sea terminal facility has limited land available for expansion, the intensification of activities at the main terminal triggers a search of lower land value locations supporting less intensive freight activities. Second, capacity problems in seaport areas appear to be one of the main drivers of dry port development since a system of inland terminals increases the intermodal capacity of inland freight distribution. Third, through long-distance transport corridors, dry ports confer a higher level of accessibility because of lower distribution costs and improved capacity. These high-capacity inland transport corridors allow ports to penetrate the local hinterland of competing ports and thus to extend their cargo base.

A functional and added value hierarchy has emerged for dry ports. In many instances, freight transport terminals fit within a hierarchy with a functionally integrated inland transport system of gateways and their corridors, where they serve three major functions (Figure 21): satellite terminals (A), load centres (B) and trans-shipment centres (C). These functions are not exclusive, implying that inland terminals can serve several functions at once. For inbound or outbound freight flows, the inland terminal is the first tier of a functional hierarchy that defines its fundamental (activities it directly services) and extended (activities it indirectly services) hinterlands.

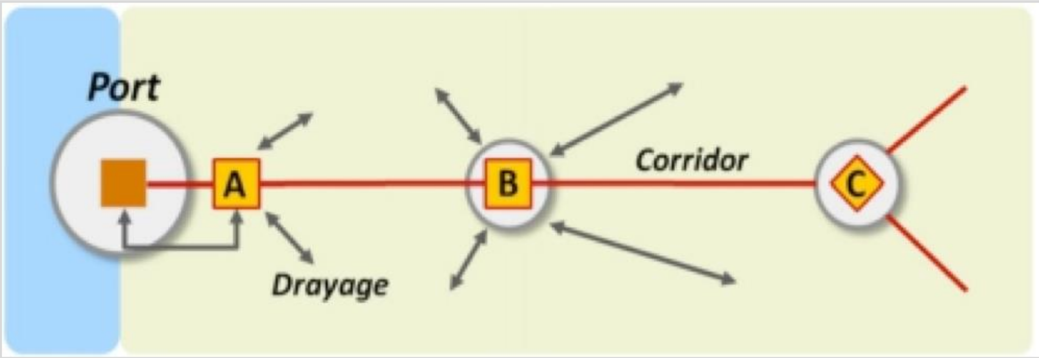

Figure 21 The corridor function of a dry port

Source: (Rodrigue & Notteboom, 2012)

Satellite terminals (A) tend to be close to a port facility, but mainly at the periphery of its metropolitan area (often less than 100 km), since they mainly assume a service function to the seaport facilities (Slack, 1999). They accommodate additional traffic and serve functions that either has become too expensive at the port such as warehousing and empty container depots or are less bound to a location near a deep-sea quay. A few satellite terminals only have a transport function transhipping cargo from rail/barge to trucks and vice versa. Satellite terminals can also serve as load centres for local or regional markets, particularly if economic density is high, in which case they form a multi-terminal cluster with the main port they are connected to through regular rail or barge shuttle services. For gateways having a strong import component, a satellite terminal can also serve a significant trans-loading function where the contents of maritime containers are de-stuffed into domestic containers or truckloads.

Freight distribution clusters (load centres; B) are major intermodal facilities granting access to well defined regional markets that include production and consumption functions. It commonly corresponds to a metropolitan area where a variety of terminals serve concomitantly intermodal, warehousing, distribution and logistics functions. These tend to take place in logistics parks and free trade zones (or foreign trade zones). The inland terminal is thus the point of collection or distribution of a regional market. The more extensive and diversified the market, the more important is the load centre. If the load centre has a good intermediary location, such as being along a major rail corridor, then freight distribution activities servicing an extended market will be present.

Trans-loading facilities (C) link large systems of freight circulation either through the same mode (e.g. rail-to-rail) or through intermodalism (rail-to-truck, or even rail-to-barge). In the latter case, the inland terminal assumes the role of a load centre. The origin or the destination of the freight handled is outside the terminal's market area, a function like that of trans-shipment hubs in maritime shipping networks. Such trans-shipment terminals are often found near country borders in view of combining administrative processes linked to cross-border traffic to value-added logistics activities. Although this function remains marginal in most parts of the world, where the scale and scope of intermodal services are increasing, ongoing developments in inland freight distribution are indicative that trans-shipment services are bound to become more prominent.

3.3 Terminals and regionalism

According to Rodrigue and Notteboom (2010) port/terminal regionalism refers to a phenomenon whereby global maritime networks and hubs emerge, connecting regional and global systems thereby creating functional regions on the maritime foreland through inland terminals. They note that regionalism of gateways and terminals leads to maritime / land interfaces, with gateways becoming significant logistical clusters with the accumulation of terminal infrastructures, such as ports, rail terminals and freight distribution centres. Although gateways are the fundamental structure of the maritime – land interface, terminals are the physical infrastructures through which functional regionalism is shaped. Notteboom and Rodrigue (2005) assert that port regionalisation is the result of the emergence of new relations between port terminals and their hinterland with the setting up of dry ports and distribution services. They note that port terminals' connections with the hinterland is influenced by regional characteristics such as density, economic function, the physical performance of terminal facilities, the capacity and the available modes of inland connections as well as of dry ports. These attributes are currently not fulfilled by the Mutare Dry Port, in terms of availability of modes. Once rail is revived, the role of the dry port in Mutare would be to be an integral part of the Beira port, as an extension of the port. Relieving the port of the congestion pressure. Through rail service, the bulk of the cargo would be shipped direct to the dry port for transhipment to trucks in Mutare.

There are very few new ports in North America with the exception of Prince Rupert, exploiting a niche market of shorter Trans-Pacific distances and long-distance rail access to the Chicago hub, and the Mexican Pacific coast that has seen the setting up of new terminal facilities such as in Lazero et al (2008). Infrastructure investments tend to reinforce the existing efficiency of the inland transport system where long distance is dominated by rail and where limited if any, inland barge services are possible. Rodrigue and Notteboom (2010) observe that the new heartland corridor linking the terminals of Norfolk to the Chicago hub is a salient example. The benefits of double stacking are expanded with double (or triple) tracking and the setting of inland load centres servicing their respective market areas. This also permitted the setting of large-scale intermodal rail terminals because such economies of scale were feasible. Thus, North American inland terminals tend to service large market areas. In Europe, there is a multiplication of terminals in new ports to cover the expansion of the EU as well as to take advantage of better hinterland accessibility. A prime example is the new eastern gateway of Constantza in the Black Sea. This implies the setting of entirely new distribution practices, such as inland barges and short sea shipping to complement and substitute trucking which has the dominant share. However, for rail terminals economies of scale are difficult to achieve because of the unavailability of double stacking and of shorter unit trains (up to 95 TEU per shuttle train).

Barge services are less impaired by such limitations with ongoing economies of scale where the draft is permissible (Notteboom & Konings, 2004). While the European hinterland for a long time was marked by a temporal stability, the impacts of European integration and changes in hinterland access are having large impacts on the distribution of freight flows. According to Notteboom and Konings (2004), the enlargement of the European Union from 15 members in the 1990s to 27 members today reinforced trading links with countries in East and Central Europe. It has, however, also led some manufacturing activities to move from Western Europe towards the low-cost regions in Eastern Europe, with ever-larger bi-directional East-West flows within the European Union of raw materials and consumer products. The East-West flows are giving impetus to the creation of extensive infrastructures including corridors and terminals.

Germany, the Czech Republic, Poland, Slovenia and Hungary have strong rail networks while road networks in the East European countries are less well developed. The Danube and the Elbe are emerging as new barge corridors, although total barge volumes remain small compared to the Rhine River and its tributaries and the North-South axis (the Netherlands, Belgium and Northern France). Northern ports like Hamburg, have benefited the most from EU enlargement, whereas new development opportunities might arise for secondary port systems in the Adriatic and the Baltic Sea. The developments in East Europe are complemented by a strong development of trade flows in the Baltic area and the Latin arc (stretching along the coastline from southern Spain to northern Italy). At a policy level, the above developments have fuelled an intense discussion on distributional equity in the European port system. While market-related dynamics such as maritime and intermodal connectivity and scale considerations favour a concentration of European cargo flows on trunk lines between major (mostly North-European) container ports and the hinterland regions, some political forces at the European Union level advocate a more evenly distributed system with a larger participation of South- and East European ports in freight distribution systems.

This tension between centralization and a decentralised port system is a key input for future inland infrastructure development in Europe via the TEN-T program (Trans-European Network – Transport). The possibility of economies of scale at terminals, linked with operational (e.g. double stacking, unit train size, maximal truckload unit) and land availability constraints, is imposing a notable differentiation between North American and European inland terminals. While in both cases gateway systems tend to be similar, it is on their respective hinterlands that differentiation is taking shape. In a European setting, a larger number of inland terminals are required to handle a similar volume than their North American counterparts. North America and Europe follow different paths when it comes to the inclusion of intermediary port terminals in maritime networks. The geography of the Mediterranean Sea and the Baltic Sea offered the right conditions for the emergence of trans-shipment terminals.

In the Mediterranean, extensive hub-feeder container systems and short sea shipping networks emerged since the mid-1990s to cope with the increasing volumes and to connect to other European port regions. Quite a few shipping lines rely on a hub-and-spoke configuration in the Med with hub terminals located close to the main navigation route linking the Suez Canal with the Straits of Gibraltar. Major ‘‘pure" trans-shipment ports in the region are Algeciras, Taranto, Cagliari, Marsaxlokk and Gioia Tauro. Northern Europe does not count any pure trans-shipment hub. Hamburg, the North-European leader in terms of the sea–sea flows (mainly in relation to the Baltic), has a trans-shipment incidence of about 45%, far below the elevated trans-shipment shares in the main south European trans-shipment hubs according to Notteboom & Rodrigue (2009) and Brooks & Black (2009). A third major trans-shipment market has emerged on the link between the UK and the mainland. Many of the load centres along the southeast coast of the United Kingdom faced capacity shortages in recent years. Some shipping lines, therefore, opted for the transhipment of UK flows in mainland European ports (mainly Rotterdam, Zeebrugge, Antwerp and Le Havre) instead of calling at UK ports directly.

It is evident from the discussion that dry ports and or inland terminals have continued to play a very important role in enhancing the performance of global transportation systems, especially the enhancement of port-hinterland connectivity. Therefore, identifying and addressing chokepoints and or bottlenecks in terms of physical infrastructure, regulatory issues or logistics activities is vital because bottlenecks increase freight logistics costs and affect the performance of the corridor. This trend is not only limited to Europe and America, but the world over including in the developing world, such as in SADC. The following section addresses issues relating to terminal regulations and governance. The following section discusses the role of policy and regulation of inland terminals.

3.4 Policy and regulation of inland terminal

Government policy and regulations play an important role in shaping the dry ports development landscape. Through a wide range of development strategies, land use policy and financial incentives by port authorities and economic development agencies can lead to the development of inland ports. This can be supported by policies related to foreign trade zones and customs procedures, enabling a transfer of functions that were previously taking place at the port (customs port of entry) to an inland location. This is commonly a significant hurdle since many national trade regulations only enable containers to be cleared for imports or exports at a port. A similar trend applies to cargo safety and security procedures where the inland port becomes a component of a chain of cargo integrity.

The geographical characteristics linked with modal availability and the capacity of regional inland access have an important role to play in shaping the emergence and development of inland ports. Each inland market has its own potential requiring different transport services. Thus, there is no single strategy for an inland port in terms of modal preferences as the regional effect remains fundamental. In developed countries, namely North America and Europe, which tended to be at the receiving end of many containerised supply chains, a few inland ports have been developed with a focus on inbound logistics.

Rodrigue (2016) notes the convergence between North America and Europe in terms of the regulatory framework. He argues that through liberalisation, lowering barriers of entry in modal and intermodal activities and privatisation, where the ownership structure is transferred to the private sector, have occurred across modes and regions both in Europe and North America. However, he acknowledges that there is a significant variation in policy implementation between the two regions. For instance, the North American approach is said to be a paradigm shift where after the enactment of new policies, changes are sudden and profound, but reflect the anticipation and participation of major market players. This is different from the European approach, where policy development is more incremental as a compromise must be reached between the various Member States that naturally tend to put their respective interests first.

The division of powers between the EU-level and the national level is guided by the subsidiarity principle as defined in Article 5 of the Treaty of Maastricht. It is the principle whereby the European Union does not act (except in the areas which fall within its exclusive competence) unless it is more effective than action taken at national, regional or local levels. The action by the EU must bring added value over and above what could be achieved by an individual or member-state government action alone (the benefit criterion). The European Union, however, has a call for an ever-closer union, which could eventually lead to major constitutional clashes. Europe has a tradition of national and regional policy where various public actors are shaping the outcome, which is less present in North America as many regulations fall within federal jurisdiction.

3.5 The role of transport mode in the system

In the previous chapter it was noted that transport corridors are served by one or more modes and this tends to affect the competitiveness of the corridor in terms of alternative options of mode. Modes of transport as a sub-system are the means by which conveyance of goods is achieved. Each different transport mode has a unique set of technical, operational and or commercial characteristics favouring certain types of cargo and suited for certain distance thresholds as indicated in Figure 24.

The lack of capacity and the unsuitability of a mode as well as the quality of the infrastructure to support such a mode can be a source of bottlenecks. Because of their operational characteristics, freight transportation modes have different capacities and levels of efficiency Rodrigue (2016).

The truck is the mode with the least capacity, yet it has the advantage of flexibility, speed and door-to-door services compared to rail and maritime modes. However, there is now the realisation of the benefits of intermodality whereby modes are integrated to maximise the comparative advantage of each mode. Rodrigue (2020) states that there is a tendency towards intermodality and linking the modes ever more closely into production and distribution activities. He argues that the integration includes the integration of ports and inland hubs and/or dry ports where the latter is now complementing the seaport from a capacity point of view. Rodrigue (2020) presents a modal choice and transport cost model in Figure 22, that compares the competitiveness of each mode based on distance involved.

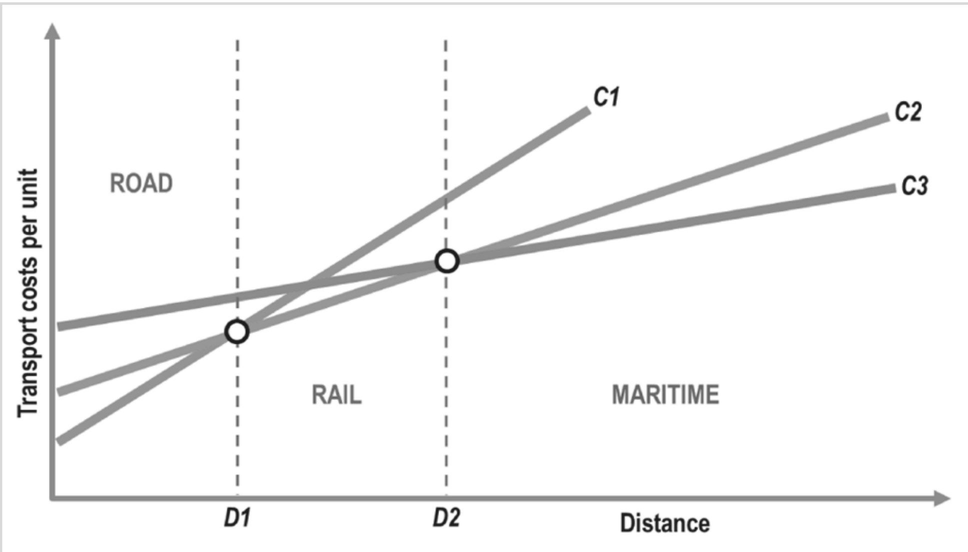

Figure 22 Modal choice cost implication

Source: Rodrigue (2020)

C1 – Road transport cost function
C2 – Rail transport cost function
C3 – Maritime transport cost functionD1 – Road transport break-even distance
D2 – Rail break-even distance

It is notable from the model that the three modes, road rail and maritime, offer unique cost functions and tariff structures in accordance with the distance involved. The model uses a linear distance effect; road, rail, and maritime transport have respectively cost functions C1, C2, and C3. The model shows that road transport has a lower cost for short distances below 500 km, but this increases faster than rail and maritime costs. Thus, at a distance D1, rail transport becomes more competitive than road transport. From distance D2, maritime transport becomes more advantageous than road and rail modes. According to Rodrigue these threshold points are referred to as break-even distances. The model sets point D1 between 500 and 750 km of the point of origin, whereas D2 is approximately close to 1,500 km. While this relation among these modes seems straightforward, this is not the case due to several factors or reasons, including modal choice option availability.

The first point is that the model assumes that modal options are interchangeable, which is not always the case. For many origins and destinations, options of modes such as rail and or maritime may not exist at all, meaning they cannot be considered as options regardless of their suitability. In such instances, a modal option with a higher cost will be used, a typical case with most landlocked countries in the SADC region. Since rail and maritime transportation are discrete networks only accessible through terminals, most locations will involve a road transportation segment, which changes the cost structure. In the SADC region road transport is chosen for distances way above 1500 km, a distance suited for maritime according to Rodrigue's model. Such scenarios make transport costs excessively high.

Rodrigue (2020) points out the issue of regional differences that impacts the break-even distance. Where there are higher market densities, such as in Europe, the break-even distance (D2) is said to be in in the range of 1 050 km, compared to the United States where it is said to be around 1 200 km. In the USA, about 5% of the intermodal rail traffic concerns distances of less than 1 200 kms showing the clear dominance of trucking for such a service range. The average rail haul length is believed to be in the range of more than 3 050 km, with around 65% involving distances of more than 3 200 km.

Modal competition arises when there is an overlap in geography, transport markets, and level of service. Cost is one of the most important considerations in modal choice. Rodrigue & Notteboom, (2012) contend that since each mode has its price/performance profile, competition between the modes depends primarily upon the distance travelled, the quantities shipped, and their value. While maritime transport might offer the lowest variable costs, road transport on the other hand is the most competitive over short distances and for small consignments. It is vital to note that the terminal cost structure for each mode is critical, where the costs and delays during loading and offloading a unit (truck/train/ship) impose fixed costs that are incurred independent of the distance travelled, hence the bottlenecks concern

Nevertheless, modern times transport demand is affected by integrated transportation systems that dictate the need for flexibility insofar as the use of a mode is concerned. It is for this reason that modal competition exists to various extents and assumes several forms. Thus modes can either compete or complement one another in terms of cost, speed, accessibility, frequency, safety, comfort, etc. There are conditions that ensure that some modes are complementing one another such as different geographical markets and different levels of service. The is true for road and rail in the case of the SADC region where investment in rail is still very low to the extent that road carries 90% of the freight and in some cases 100% for some corridors where a rail service is not available at all.

However, Rodrigue (2020) acknowledges that in different markets situations, modes can complement each other, for purposes of continuity in the system, particularly at different spatial scales such as national and international transportation. In such instances an interconnection is required, as a gateway, where transfer from one mode to the other can occur. Credit has been given to intermodal transportation for improving the complementarity and connectivity of different geographical markets. Also, different service levels are vital where for a similar market and accessibility, two modes that offer a different level of service will tend to complement another with niche services. The most prevailing complementarity concerns costs versus time. Figure 23 depicts possible scenarios on a corridor in terms modal competition, complementarity and possible shift.

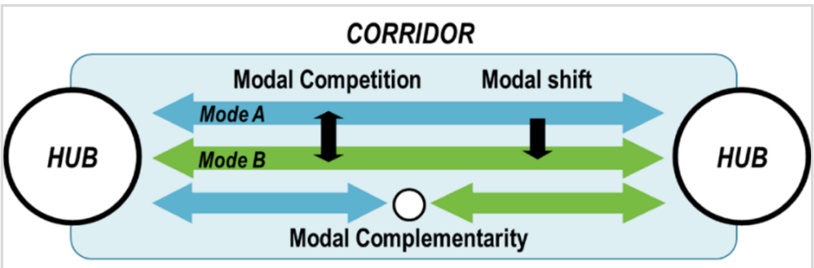

Figure 23 Complementarity of modes on the corridor

Source: Rodrigue (2020)

The transport industry aims at adapting transport infrastructures to growing needs and requirements. When a transport mode becomes more advantageous than another over the same route or market, a modal shift is likely to take place. A modal shift involves the growth in the demand of a transport mode at the expense of another, although a modal shift can involve an absolute growth in both concerned modes. The comparative advantages behind a modal shift can be in terms of costs, convenience, speed or reliability. For freight, this has implied a shift to faster and more flexible modes when possible and cost-effective, namely trucking and air freight. A modal shift can further be nuanced by time shift, for which the use of the same mode takes place at another time period, likely when there is less congestion. In a situation of congestion, it is thus likely that time shifts will be preferred to modal shifts, particularly if the time shift is relatively marginal. In the next section the modal choice phenomenon for the Beira Corridor is discussed in the context of the theoretical imperatives discussed above to determine the performance of the corridor in that respect.

3.6 Application of corridor logistics concepts to the Beira Corridor

The port of Beira links to its hinterland, including roads, railways and a pipeline. Due to poor rail infrastructure almost all cargo is transported by road on the Machipanda route of the Beira Corridor. Even when operational, the single-track-railway line on the Mozambique–Zimbabwe route limits the capacity of the Beira corridor. It is for this reason that any increase in freight volumes results in congestion of the port and the road as rail fails to cope with increased volumes. The absence of electricity infrastructure, with no plans yet to electrify the Beira–Machipanda corridor, with only diesel trains operable on the corridor, reduces capacity and performance of the corridor. For sections of the line still in operation, there are speed restrictions as low as 10km/hour, due to the poor state of the line which lower service levels. Apart from the under-rail infrastructure challenges, there is also a rolling stock problem of insufficient wagons and containers on the part of both the Zimbabwe and Mozambique, causing delays on the dispatch of goods and congestion of the port.

The exact numbers in terms of fleet requirements are not known, but CFM is believed to have acquired a newer fleet of wagons.

For railway operations to improve along the corridor, there is need for provision of sufficient locomotives, wagons and containers. There is further need to improve locomotive traction through electrification of rail lines, improving technology and speed enhancement. Operationally, the improvement of border crossing infrastructure and transhipment facilities as well as modernisation of intermodal transfer facilities, especially the port, inland container depots and dry port in Mutare are essential. Estimates based on NRZ feasibility study indicate that up to one hundred million US$ could be required to upgrade the section of the Machipanda railway line.

As indicated above, there are thresholds for the competitive of each type of mode in terms of distances suitable for the use of a particular mode and for Beira Corridor this would be road versus rail. This also applies to type of commodity, whereby bulk high volume low value commodities are more suitable for transportation by rail instead of by road. Due to the challenged stated above, all cargo is transported by road to and from DRC, Zambia and Zimbabwe on the Beira Corridor contributing to high logistics costs.

In the past, prior to year 2000 and the commencement of the railway concession process, freight along the Beira-Harare route of the Beira Corridor was mainly transported by rail. This has now exclusively shifted to the road, including granite exports where loads are too heavy for the road. Rail transport has suffered from poor reliability, long transit times and higher costs than the road, particularly on the Mozambique section of corridor, although there are efforts by CFM, to address the problem (Giersing, van Zyl, & Howard, 2013). Table 2 and Figure 24, below show the cargo split for the two modes, where over time more and more cargo shifted to road from rail. It is for this reason data on rail traffic was only available up to 2011. Since then cargo has been transported by road leading to high logistics costs particularly where commodities ideal for rail have all shifted to road. The data on modal split was only available for the period shown which in itself was a shortcoming as there is no cpmarative data.

Table 2 Mode split of cargo between road and rail

Year	Rail	Road
2005	27%	73%
2006	27%	73%
2007	20%	80%
2008	27%	73%
2009	13%	87%
2010	13%	86%
2011	10%	90%

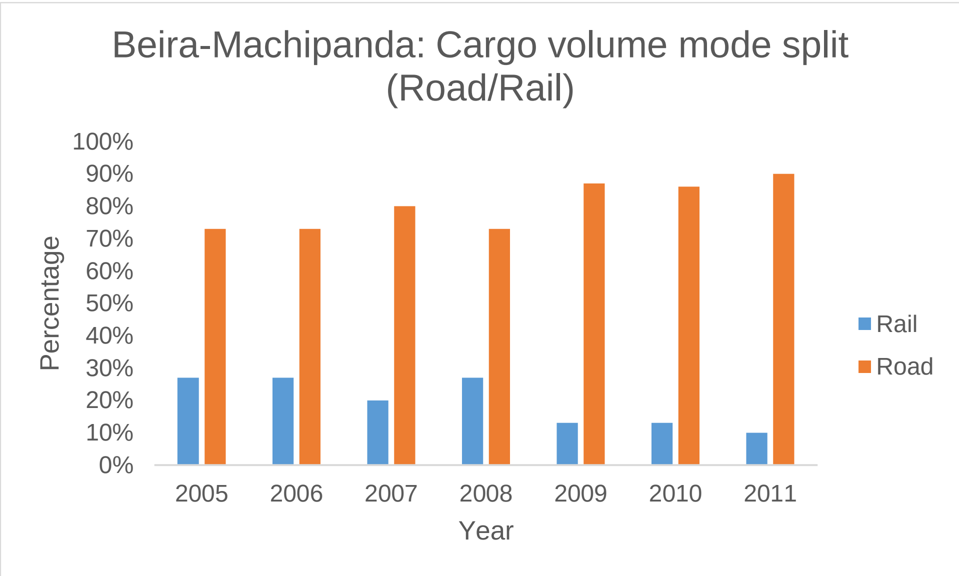

Figure 24 Beira Corridor road/rail cargo split

Before the ongoing rehabilitation and expansion, the Nacala port and railway were mainly used to transport Mozambican imports and exports, whereas the Beira port was dominated by international transit cargo to/from Zimbabwe, Zambia and Malawi.

While the Beira Corridor is composed of three modes, road rail and pipeline, its performance is compromised due to the non-performance of the latter modes. For instance, rail is carrying less than 10% of the traffic along the corridor. The rail service has deteriorated significantly; as a result, most traffic has shifted to the road. The downward trend has continued since 2005 and continues to date. Statistics obtained from Cornelder confirms this, showing that rail traffic has gone down from more than 20% in 2005 to about 10% in 2011 (see Figure 26). It would have been ideal if data could be obtained for the current conditions. There is a possibility that the percentage of road vs rail could be in the range 95% to 5% in favour of road, with the 5% coming from the operational section between Dondo and the port of Beira, and 100% road for the rest of the section to Zimbabwe on the EN6. The dominance of road transport as the main mode supporting the corridor is evident by the many trucks now passing through the corridor. This development is a major bottleneck that impacts the Beira Corridor which could be addressed by the revitalisation of rail to cater increasing cargo volumes.

3.7 Conclusion

This chapter discussed logistics activities, exploring the integration of gateways and inland terminals in the hinterland as a means to improve the performance of the corridor. It is noted that logistics gateways evolve continuously due to globalisation and exploration of new markets. Furthermore, logistics outsourcing and integration, containerisation and advances in information technologies have also contributed to the changes that have happened in global logistics. At the same time service expectations of customers have tended to move towards higher flexibility and reliability.

Modal choice has also become an issue as customers seek cost effective methods for the delivery of cargo for both imports and exports. This is an area that would require addressing on the part of the Beira Corridor, failure to do so would see many users opting to corridors that offer mode alternatives as they seek to reduce logistics costs. International supply chains have become complex and the pressure on gateway logistics is increasing, not just in terms of infrastructure and capacity, but also in more efficient regional freight distribution strategies. Most market players have responded by providing new value-added services in an integrated package, through a vertical integration along the supply chain. Entire freight distribution systems including gateways, corridors and inland centres are adapting to the new realities. Despite powerful converging forces, namely containerisation, information technologies and globalisation, geographical, political and cultural characteristics convey regionalism elements to freight distribution.

In many fields, regionalism is expressed by different logistical practices relying on various modes and terminals to provide added value. It has become highly relevant to assess the extent to which existing practices in different regions are converging, or alternatively, diverging. However, although there is a convergence in terms of the establishment of hinterland logistics based on a higher level of integration between gateways and inland ports, gateway logistics will remain significantly differentiated by regionalism. Among the most significant elements of this regionalism, the function and operation of freight corridors are salient. In the developing world, rail densities through double stack and multiple tracks and governance (ownership of the right of way and terminals) are unlikely to be achieved. For SADC the priority is addressing the backlog in terms rail investment and revival. The next Chapter presents and discusses the research methodology and research design as well as the paradigm used for this study.

CHAPTER 4 METHODOLOGY AND RESEARCH DESIGN

4.1 INTRODUCTION

To address the aims and objectives as well as research questions presented in Chapter one a mixed method approach was adopted for this study. The purpose of this Chapter is to explain the in-detail approach and methods used in assessing the impact of transport corridor bottlenecks affecting the competiveness of the Beira Corridor compared with the other two corridors competing for the same hinterland cargo. Given the existence of both qualitative and quantitative data and also the need to adopt a systems approach in addressing the objectives of the study, the most appropriate paradigm would be pragmatism, hence the use of mixed methods. In order to study the transport corridor phenomenon, it was also decided that a multiple case study comprising three corridors was most appropriate as it would allow not only a detail study of the case, but also the comparison of the three corridors in terms of performance. The mixed method approach was used to further refine the theoretical framework developed from the literature in Chapter 2 to ensure that the research questions and objectives are addressed adequately.

The chapter begins with an outline of the qualitative and quantitative research to explain why the approach was adopted for this study and to justify the use of a case study as an exploratory research method appropriate for this research and the complementarity of the two methods in strengthening research results. The case study is compared with other qualitative and quantitative methodologies that can be used for exploratory research. The comparison is followed by a detailed description of the case study design and how data was collected, analysed and interpreted for this research. The strengths and limitations of the case study techniques are explored, followed by an examination of the validity and reliability of the case study research design.

Boblin et al (2013), in keeping with a post-positivist orientation, and (Yin, 2011) has advocated the use of a formal conceptual framework – which is presented in Chapter 1 – and propositions that are tested and accepted or refuted as data are collected and analysed. Stake (1995), again compliant with the constructivist orientation, concurs with the view that researchers can use a conceptual framework to guide the study, but this is not a required necessity. With Stake’s approach, issue statements might be developed by the researcher, but this is also not necessary. Consideration was made whether a conceptual framework as would constrain the collection and data analysis and whether Stake’s recommendation of a flexible conceptual framework would be overly lacking in structure.

Consequently, the question of which framework to use, if any, and how to use it was a significant design decision encountered. The focus was on a conceptual framework, rather than uncovering previously unknown elements of the phenomenon which would limit the richness of data collected.

The persuasion was to follow Stake's recommendations, beginning with a flexible, relatively unstructured conceptual framework. The experiences as the study unfolded, provided substantiation for the soundness of the decision. This was complemented by the systems theory framework discussed in the literature chapter which deals with science of whole to address complex phenomena such as transport corridor bottlenecks.

4.2 Plan for the research

Creswell and Creswell (2018) have described research approaches as plans and procedures for research that range from broad assumptions to detailed data collection, analysis and interpretation. The general strategy for resolving a research problem is called a research design (Leedy & Ormrod, 2015). It provides the overall structure for the procedures the researcher follows, the data the researcher collects, and the data analysis the researcher conducts. In other words, research design is planning. Leedy & Ormrod (2015) observe that planning the overall design carefully helps the research effort to be successful. They argue that the efficiency and effectiveness of the research are achieved through the upfront identification of resources, procedures and data – always with a resolute goal of solving the research problem. Clearly, the research plan covers the strategic decisions about the choice of data collection methods to be used to solve the problem. Figure 25 illustrates a framework for research as envisaged by Creswell and Creswell (2018). The study adopts pragmatism, case study and mixed methods as the philosophical worldview, design and approach respectively.

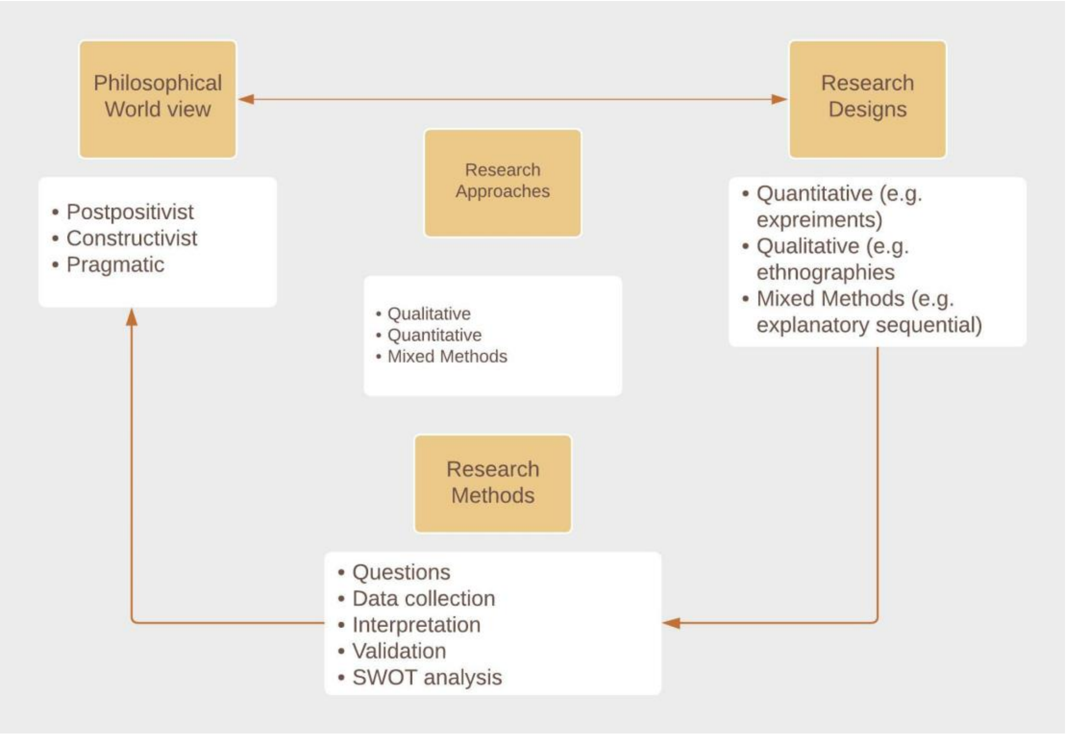

Figure 25 The research framework for the study

Adapted from Creswell and Creswell (2018) for this study

The methodology used for a research problem must always consider the nature of the data to be collected to resolve the research problem. Creswell (2014) identifies two basic categories of research approaches or philosophies, namely quantitative (explanatory) and qualitative (exploratory). This research takes a pragmatic worldview and applies a mixed method approach, which draws from both qualitative and quantitative assumptions according to Cresswell and Creswell (2018).

4.2.1 Exploratory versus explanatory research

Leedy and Ormrod (2015) contend that exploratory research seeks to provide a tentative understanding of a research problem and provides input for further research. In this research, exploratory research included a critical review of relevant literature (Chapter 2) and case study convergent interviews (Chapter 5) to gain insights into the research problem and to discover the most important issues in relation to the effect of bottlenecks on the performance of the Beira Corridor.

On the contrary, the explanatory research seeks to provide evidence of cause and effect relationships (Yin, 2011). This research approach entails manipulation of independent variables of interest and control, for the influence of other variables (Yin, 2011) and (Creswell, 2014). While this is true, a quantitative approach can be employed in a case study design in order to improve on the research outcomes, which is why this thesis uses this approach together with the qualitative approach.

4.2.2 Qualitative and Quantitative methods

Leedy & Ormrod (2015) assert that quantitative researchers seek explanations and deductions that will generalise to other persons and places. The intent is to establish, confirm, or validate relationships and to develop generalisations that contribute to theory. On the other hand, qualitative researchers seek a better understanding of complex situations. Their work is often exploratory in nature, and they may use their observations to build theory from the ground up, which theory could be tested using quantitative approaches.

Because quantitative studies represent the mainstream approach for research, carefully structured guidelines exist for conducting them. Concepts, variables, hypotheses, and methods of measurement tend to be defined before the study begins and remain the same throughout. According to Yin (2011), quantitative researchers choose methods that allow them to objectively measure the variable(s) of interest. They also try to remain detached from the research participants so that they draw unbiased conclusions.

The qualitative research process is more holistic and “emergent,” with the specific focus, design, measurement instruments (e.g., interviews), and interpretations developing and possibly changing along the way. Researchers enter the setting with open minds, prepared to immerse themselves in the complexity of the situation and interact with their participants. Categories (variables) emerge from the data, leading to "context-bound" information, patterns, and/or theories that help to explain the phenomenon under study.

In view of the fact that both qualitative and quantitative data was collected, the study used the pragmatism paradigm which involves the use of mixed methods to incorporate the strength of each approach. Thus, in order to appropriately address the research problem, which pertains to corridor bottlenecks, the study employed constructivism paradigm in accordance with Saunders et al (2007) and Tuli (2010). On the other hand, in order to improve on the validity of findings and the use of statistical and quantitative data, the study also employed a quantitative paradigm. According to Atieno (2009), the word paradigm can be used to mean either an approach or design. Tuli (2010) observes that the selection of research methodology depends on the paradigm that guides the research activity, more specifically, beliefs about the nature of reality and humanity (ontology), the theory of knowledge that informs the research (epistemology), and how that knowledge may be gained (methodology).

Saunders et al (2007) define a paradigm as a set of theories and linked assumptions shared amongst a community of researchers. Still, Creswell (2014) defines it as a worldview, which includes and spans across ontology, epistemology, and methodology, which researchers or scientists use as common benchmarks in designing research as well as reporting findings. Essentially, ontology is a reality, whereas epistemology is the relationship between that reality and the researcher – how the researcher views the world, and methodology refers to a set of techniques employed by the researcher in investigating such a reality or the world (Creswell, 2014).

According to Atieno (2009) constructivism is better suited in the study of current and pre-paradigmatic phenomena using inductive techniques when existing paradigms are clearly inadequate in relation to the research problem. Evidently, corridor performance paradigms as applied have been unable to achieve anticipated objectives determining factors affecting transport corridor performance as observed by Witte et al (2014). Shortcomings of the present corridor performance-measuring regime are evident and objective realities remain a challenge. However, perceptions of this situation appear to be subjective and unobservable. Positivism cannot be used in this case because it looks at observable phenomena using cause-effect research designs, according to Saunders et al (2007).

The nature of some of the aspects of this study are interpretive and descriptive according to Creswell (2014), where constructs are the values and interests of persons, which are not purely quantifiable (Yin, 2011). Justifiably, this study also employs qualitative techniques to gain an understanding of the phenomenon – corridor bottlenecks – using qualitative methods of data collection that include hermeneutical and dialectical methods (Saunders, et al., 2007) and (Creswell,2014). On the other hand, quantitative analysis was required in order to improve on the validity of the findings, using quantitative data, hence the use of mixed methods. For instance Hoffman, et al. (2021) also used quantitative analysis to quantify the contribution of customs, trade and ports to cargo time delays.

In another study on comparative performance assessment of Beira and Nacala Corridors Van Zyl & Hoffman (2016) used both quantitative and qaulitative data. This study in contributing to the debate adds a further dimension of a systems perspective in assessing the impact of corridor bottlenecks on the Beira Corridor to cater for the complexity of corridor configuration comprising sub-systems such as ports, road networks, railways, dry ports, border posts, ICT systems, regulatory processes and a regime of multiple stakeholders, both public and private. The system perspective is extended to the hinterland to include additional two corridors competing with the Beira Corridor because their competitiveness impact on Beira Corridor traffic as cargo shifts to the better performing corridor(s).

4.3 Applying a systems-based approach to corridor assessment

In chapter 2 the systems approach is recognised as a direction in the methodology of scientific cognition and social practice, that treats objects as systems in terms of the integral set of elements in the aggregate of their relations and connections according to Novikov (2016). It is also regarded as a concept of interdisciplines which has brought evolutionary knowledge synthesis according to Blanchard (2014). The systems age is about putting things together (synthetic thinking is inside-out thinking), not separating them (analytic thinking) outside-in. The study applies the synthetic mode of the corridor bottlenecks problems. This is referred to as systems thinking or the systems approach which is based on systems theory principles according to Novikov (2016).

This study recognises the complexity of the corridor formation, as depicted in the corridor theory and therefore applies systems thinking to better analyse the Beira Corridor not only in terms of the various components of links and nodes, but also in terms of its place in the regional context of a system of corridors serving the same hinterland. Applying a systems theoretical approach provides for a holistic perspective that helps one to better understand the interdependence of nodes and links and the bottlenecks generated by each one of them. Viewing the corridor as a system allows one to appreciate the interactions of all the components of the corridor and how they are interdependent. For instance, increased capacity and removal of bottlenecks does not necessarily translate to the improvement of the entire corridor. Such improvement may exert pressure on other subsystems of the corridor, such as road and rail capacity of dry port/inland terminals. This means each component of the corridor would need to be optimised in relation to the other components of the corridor.

Equally, the performance of the Beira cannot be assessed in isolation of the other corridors competing for the same cargo to and from the regional hinterland. While there are many studies that have dealt with the economic impact of corridor bottlenecks, the tendency has been to deal with certain aspects not all and also limited to one or two sources of bottlenecks, in most cases physical infrastructure. Attending to physical infrastructure alone will not resolve all the bottlenecks of the corridor as some of them may be non-physical bottlenecks related to for instance cumbersome customs processes, harmonised regulatory process, poor logistics activities or lack of ICT applications. Figure 28 below shows the conceptualisation of the system perspective as applied in this study.

The Beira Corridor is placed at the centre as the focal case, whose performance is dependent on sub-systems comprising, nodes (port, border posts, dry ports), regulatory processes (permits, health, agriculture, security etc.), ICT (customs data processing, inspection, tracking) and links (roads, railways and pipelines). Figure 28 shows two levels of the systems approach, the first one being the Beira Corridor and its sub-systems: nodes, links and processes. The second level being where the Beira Corridor is assessed in the context of the market served compared with the other corridors, whose performance is also based on the same typical sub-systems of nodes, links and processes. The performance of the Beira Corridor is compared with the other corridors (the bigger system) based on the bottlenecks impact, which will be reduced by addressing the bottlenecks identified.

Figure 26 Application of the systems perspective to the assessment of Beira Corridor bottlenecks

Source: Developed by author for this study

Using the systems perspective, it can be seen that the sub-system complement has the potential of generating bottlenecks that can affect the performance of the corridor as its formation is a function of the interaction of the sub-systems depicted in Figure 26. In the case of the Beira Corridor and the other two corridors, the sources of bottlenecks could be links related, in terms of physical infrastructure such as poor road condition or poor railway condition. On the other hand, the source of bottlenecks could be non-physical related, such as slow processes at ports, dry ports or border posts and also lack of ICT applications to speed up the processing of cargo or traffic. These bottlenecks have a negative impact on the performance of the corridor, rendering it uncompetitive due to high total economic costs. Thus, the study also takes a holistic (systems) perspective in analysing the economic cost through the application of the Total Economic Cost model explained in section 4.8 below. To enable the assessment a set of quantitative and qualitative data was collected and analysed. The study data collection processes and sampling are discussed in the next section.

4.4 Data collection and sampling

In this section the primary method for this study is explained in detail and how the quantitative data from GPS tracking systems was collected and prepared for analysis. The survey data obtained through questionnaires only complemented this to verify if the conclusions extracted from the GPS tracking data is supported by the views obtained from the surveys. The samples of data provided by participants in respect of the Beira Corridor is presented. Furthermore, the data fields that were extracted, as well the description of how the data was interpreted, to allow similar performance measures to be extracted for data received in different formats from different participants is outlined. Quantitative data was mainly obtained from freight agents and road transport operators. Table 3 below provides an overview of the data that was made available to this study.

Table 3: Overview of the data contributed to this study

No	Participant	Type of Data	Number of Consignments	Start Date	End Date	Parameters Extracted
1	Transporter 1	Trip plans	105 582	2014-01-01	2016-05-20	Road travel times origin to destination from and to Beira
2	Transporter 1	GPS tracking data	20 000	2014-01-01	2016-05-20	Road travel time per road segments and delays at waypoints from and to Beira
3	Freight agent 1	Tobacco container movements to Beira	577	2015-07-01	2015-12-31	Number Days Tete – Beira Number Days Fumigation – Port Number Days Port – SOB
4	Freight agent 2	Rail cargo from Nacala to Blantyre	57	2015-11-01	2016-04-22	Time delays for the following set of processes: • Arrived by ship – CUSTOMS • CUSTOMS IN – OUT • TIME TO LOAD ON WAGONS • LOAD - DEPART BY RAIL • DEPART - ARRIVE IN BLANTYRE
5	Freight agent 3	Consignments arriving at Beira by sea	180	2015-12-30	2016-05-17	Time delays for the following set of processes: • CUSTMSBROKER/IN & OUT • CORNELDER STAMP & PAY • Stamp to load
6	Freight agent 4	Consignments arriving by sea at Nacala and moving to Blantyre	4 213	2010-11-17	2016-05-31	Time delays for the following set of processes at Nacala: • Arrived by ship – loaded • Loaded on road transport – destination
7	Freight agent 4	Consignments arriving by sea at Beira and moving to Blantyre	3 906	2010-11-25	2016-06-04	Time delays for the following set of processes at Beira: • Arrived by ship - cleared by customs • Cleared by customs - Loaded on road transport • Loaded on road transport – destination

For the purpose of the corridor bottlenecks assessment, the approach to measure performance was adapted to be suitable for the amount of data that could be collected from participants during the limited time period available. All assessments were made in terms of quantitative data rather than relying on subjective opinions of participants. A small number of participants were selected who supplied either documentary data (records of processed consignments) or telematics (GPS tracking) data.

In this section we show samples of the kind of data provided by participants, identify the data fields that were extracted and describe how the data was interpreted to allow similar performance measures to be extracted for data received in different formats from different participants. Creswell, (2014) advises in favour of the selection of a small sample within a small geographic area, to allow intensive analysis. This view is also shared by Yin (2011) and Hyett et al (2014). They all agree that although case studies require intensive analysis, they also depend on extensive and in-depth data collection from small samples. For this reason, the Beira case was chosen as primary, but extended through comparison with competing corridors of Dar es Salaam and North-South. The methods used to collect and process the data depended on the nature of the type of data that was required and the corresponding size of identical sources of data.

4.4.1 Freight Forwarder Data

The data provided by freight agents mainly consisted of line items per consignment showing the critical steps in the processing of a freight consignment either from an arriving ship through the port, customs and land transport up to the point of arrival in the interior, or vice versa from origin to ship. Dates were typically provided for each step in the process, allowing the extraction of process times. The accuracy was limited to a granularity of 1 day; by however taking averages across many consignments a somewhat more accurate indication is obtained of the average times. Tables 4 to 6 below provides samples of the kind of data that was obtained.

Table 4: Sample of data obtained from Freight Agent 1 – Road to Beira

SI No.	Final despatch Tete date	Final stuffing date	Container No.	Aeration sealed date	Date Arrived in Beira	Date Arrived in port	Date Vessel booked	Actual SOB date	Documents sent by DHL
MLT282/15	21-Sep-15	21-Oct-15	CMAU5009073	29-Oct-15	23-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	10-Nov-15
MLT282/15	22-Sep-15	21-Oct-15	CMAU5510085	29-Oct-15	28-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	10-Nov-15
MLT282/15	21-Sep-15	21-Oct-15	SEGU4818993	29-Oct-15	23-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	10-Nov-15
MLT282/15	22-Sep-15	21-Oct-15	TGCU0059498	29-Oct-15	24-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	10-Nov-15
MLT284/15	14-Sep-15	25-Oct-15	TCNU8791876	3-Nov-15	17-Sep-15	3-Nov-15	6-Oct-15	10-Nov-15	13-Nov-15
MLT284/15	15-Sep-15	23-Oct-15	MSCU8079796	3-Nov-15	18-Sep-15	3-Nov-15	6-Oct-15	10-Nov-15	13-Nov-15
MLT283/15	14-Sep-15	22-Oct-15	GVCU5287333	31-Oct-15	17-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	10-Nov-15
MLT283/15	15-Sep-15	22-Oct-15	TCLU9536482	31-Oct-15	17-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	22-Oct-15	ECMU9771726	31-Oct-15	16-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	23-Oct-15	CMAU4850136	31-Oct-15	17-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	23-Oct-15	CMAU4960154	31-Oct-15	17-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	23-Oct-15	BSIU9393760	31-Oct-15	16-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	22-Oct-15	CAIU8184858	31-Oct-15	29-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	22-Oct-15	SEGU4624961	31-Oct-15	18-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	14-Sep-15	23-Oct-15	CMAU5791059	31-Oct-15	16-Sep-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15
MLT283/15	7-Aug-15	22-Oct-15	TGHU6409014	31-Oct-15	10-Aug-15	1-Nov-15	6-Oct-15	9-Nov-15	7-Nov-15

Table 5: Sample data obtained from Freight Agent 3 – Road from Beira to Zimbabwe and Zambia

CONTAINERS Nº	ORIGIN	DESTINATION	DEMURRAGE	CUSTMSBROKER/IN & OUT	CORNELDER STAMP & PAY	STORAGE/PORT	LOADING DATE
MRKU 524 4683	CHINA	ZIMBABWE	0 DAY	19-01-2016/20-01-2016	21-Jan-16	06 DAYS UNTIL 21-01-16	22-01-2016
MSKU 149 6647	CHINA	ZIMBABWE	02 DAYS	19-01-2016/20-01-2016	21-Jan-16	11 DAYS UNTIL 26-01-16	26-01-2016
MSKU 930 2331	CHINA	ZIMBABWE	03 DAYS	19-01-2016/20-01-2016	21-Jan-16	12 DAYS UNTIL 27-01-16	27-01-2016
TRLU 757 5051	CHINA	ZIMBABWE	02 DAYS	19-01-2016/20-01-2016	21-Jan-16	11 DAYS UNTIL 26-01-16	26-01-2016
PCIU 461 6587	CHINA	MALAWI	0 DAY	05-FEV-2016/05-FEV-2016	15-02-2016	0 DAYS UNTIL 25-02-16	18-02-2016
PCIU 454 4722	CHINA	MALAWI	0 DAY	05-FEV-2016/05-FEV-2016	15-02-2016	0 DAYS UNTIL 25-02-16	18-02-2016
TEXU 483 4459	CHINA	MALAWI	0 DAY	05-FEV-2016/05-FEV-2016	15-02-2016	0 DAYS UNTIL 25-02-16	19-02-2016
PCIU 462 0524	CHINA	MALAWI	0 DAY	05-FEV-2016/05-FEV-2016	15-02-2016	0 DAYS UNTIL 25-02-16	19-02-2016

Table 6: Sample of data obtained from Freight Agent 4 - Road from Beira to Blantyre

Seq	TMFO	BOL No	Size	Weight	Container	Arrivd BEW/DAR/DBN	Date Clrd	Date Loaded	Date Arr BT
2	T697/11/10	KR3255636	20	21060	IPXU3212370	25-Nov-10	3-Dec-10	03-Jan-11	05-Jan-11
3	T681/10/10	MSCUD6131025	40	23000	MEDU8693199	3-Jan-11	5-Jan-11	10-Jan-11	14-Jan-11
4	T781/12/10	DBEE002742	40	25400	TOLU1708254	23-Dec-10	31-Dec-10	14-Jan-11	18-Jan-11
5	T812/12/10	NBCA024540	40	22500	CMAU5664178	23-Dec-10	31-Dec-10	14-Jan-11	18-Jan-11
6	T611/09/10	MSCUN3260287	20	8000	MEDU2447259	3-Jan-11	5-Jan-11	10-Jan-11	19-Jan-11
7	T663/10/10	MSCUT4155093	20	25000	TRLU3932443	3-Jan-11	5-Jan-11	10-Jan-11	19-Jan-11
8	T604/09/10	MSCUN3260279	20	7333	MSCU1927405	26-Dec-10	5-Jan-11	10-Jan-11	19-Jan-11
9	T660/10/10	MSCUN3225587	40	19760	MSCU9055171	26-Dec-10	8-Jan-11	11-Jan-11	19-Jan-11
10	T811/12/10	TH2258128	20	16214	ECMU1109272	25-Nov-10	31-Dec-11	13-Jan-11	19-Jan-11

4.4.2 Transporter Trip Records

The transporter that participated in the study made available a list of trip records as described in Table 3 above. All trips that included port visits were made to the port of Beira. As sample of these records is displayed in Table 7 below. It was possible to extract travel times from origin to destination with an accuracy of 1 day; as for the case of the freight agent data the averaging over many samples provided an accuracy of somewhat less than one day.

The trip record data was firstly separated into trips from Beira and trips to Beira at it is imported to determine if inbound and outbound traffic experience similar delays. Each of these sets were then sorted into specific destinations (for trips from Beira) and origins (for trips to Beira). The sets per origin or destination were then processed separately; in total there was about 250 destinations and a similar number of origins.

Table 7: Sample of trip records from transporter

VEHICLENUMBER	Origin	Destination	DESPATCHDATE	DELIVEREDDATE	IDUNIT
MBP52-78	BEIRA	LUSAKA	2013-01-08	2013-01-14	4636613
MBP52-78	LUSAKA	HARARE	2013-01-15	2013-01-15	4636613
MBP52-78	HARARE	BLANTYRE	2013-01-17	2013-01-21	4636613
MBP52-78	BLANTYRE	BEIRA	2013-01-21	2013-01-22	4636613
MBP52-78	BLANTYRE	BEIRA	2013-01-21	2013-01-22	4636613
MBP52-78	BEIRA	LUSAKA	2013-01-25	2013-02-01	4636613
MBP52-78	LUSAKA	BEIRA	2013-02-01	2013-02-01	4636613
MBP52-78	BEIRA	HARARE	2013-02-06	2013-02-10	4636613
MBP52-78	HARARE	BEIRA	2013-02-10	2013-02-12	4636613
MBP52-78	BEIRA	LUSAKA	2013-02-15	2013-02-22	4636613

4.4.3 GPS tracking data

GPS tracking data was available for a set of 1642 vehicles covering the same date range as the trip records; of the 105,000 trips only about 20,000 however appeared in the GPS tracking data set. This provides a statistically representative data set for most routes that cover the network feeding the port of Beira.

No information was available on the prescribed routes that drivers were supposed to follow between origins and destinations. The GPS data therefore had to be processed in several ways to extract accurate and reliable performance measures for the corridor network. This included extracting the following parameters:

- End-to-end time delay for a specific origin-destination combination (e.g. Beira to Lusaka), regardless of the route that was followed; this allowed the possibility that in between these two points the respective vehicle could also complete other assignments (e.g. starting off in Beira, travelling to Bulawayo, then to Harare and then on to Lusaka, in each case delivering different cargo). It was therefore possible that in some cases the time measurement could overstate the actual time that it takes if the vehicle tried to reach the destination by the shortest possible route. This problem was addressed partly by filtering out very long delays and partly by also measuring the time delays for cases where specific routes were followed, as described below.

- End-to-end time delay for a specific origin-destination combination (e.g. Beira to Lusaka) and where a specific route was followed, typically selecting the shortest possible route between the end points; this largely eliminated the above risk of measuring the time for a combination of routes rather than only the specific route under investigation. What was however observed is that in the majority of cases the vehicles did not follow the shortest routes but most of the time took detours at several points along the way; in the absence of more detailed information from the transporter it could not be established whether the truck deviated from the plan or whether the plan included these detours.
- Time delays for defined road segments that represented portions of the set of identified routes; these segments were defined in such a way that all routes could be compiled from a minimum number of unique segments. The time delays for segments were analysed both for the case where vehicles completed a specific defined route including that segment, as well as for general cases where the segment was completed, irrespective of the final destination of the vehicle. From these time delays and the length of the segments the average speeds could be calculated in each case.
- Time delays at waypoints, that include ports, weigh bridges, border posts and the points that connect different road segments. We defined a geofence (i.e. a geographic region described in terms of GPS coordinates) around each waypoint; the time period that the GPS coordinates stayed inside the geofence was used as estimate for the waypoint delay time. In the case of border posts there was uncertainty about the correct definition for these geofences as it was not known exactly where trucks may stop while the cargo was being cleared before crossing. In a case where a truck would stop just outside of the defined geofence, wait at this point for the completion of the clearing process and then drive through the border after being cleared, a very short measurement of typically less than 5 minutes would be obtained as the waiting time would not be included in the time that the GPS coordinates were inside the geofence. If, however the border post geofences were made very large it would include a significant period of travel time. We therefore used relative small geofences of approximately 1 km in diameter and then filtered the results from these measurements by using a minimum possible border post processing time, e.g. 30 minutes. This eliminated those cases where the geofence time delay included only the drive time and not the waiting time.

According to Leedy & Ormrod (2015) quantitative researchers identify one or a few variables that they intend to study and then collect data specifically related to those variables. Specific methods of measuring each variable are identified, developed and standardised, with attention to the validity and reliability of the measurement instruments. Data are collected from a population, or from one or more large samples that represent the population, in a form that is easily converted to numerical indices. In the case of the Beira Corridor, the research focussed on Transporters, Customs, and Clearing agents. The identified variables are the delay times for segments and waypoints as described above.

Qualitative researchers operate under the assumption that reality is not easily divided into discrete, measurable variables. According to Leady & Ormrod (2015) qualitative researchers are often described as research instruments because the bulk of their data collection is dependent on their personal involvement (interviews, observations) in the setting. Rather than sample many people with the intent of making generalisations, qualitative researchers tend to select a few participants who can best shed light on the phenomenon under investigation. Both verbal data (interview comments, documents, field notes) and nonverbal data (drawings, photographs, videotapes) may be collected. Of the two approaches, the qualitative method is appropriate to address a problem of an exploratory nature seeking to assess a phenomenon of corridor bottlenecks causing delays affecting the efficiency of the corridor. There are similar studies on corridor performance assessment that have used the same approach, research design and data collection methods, especially Regmi & Hanaoka (2012) in their case study where they assessed intermodal transport corridors from North-East and Central Asia.

Similarly, the Asian Development Bank (2014) describes how process-based corridor performance measurement and monitoring (CPMM) methodology captures data on the time and cost of moving freight within the Central Asia Regional Economic Cooperation (CAREC) region transport corridor. This was applied at border posts to improve operating efficiency and reduce bottlenecks along the CAREC corridors, thereby improving international and regional trade flows. Furthermore, Arnold (2005) used a similar approach a World Bank report on best practice on corridor management in measuring corridor performance. Hence, this study does not seek to test the causal relationship between variables; the focus is of a quantitative method exclusively. While this may be true, the data collected contained vast amounts of quantitative data, which compelled the use of mixed methods in line with a systems approach.

Therefore, the study employs elements of the quantitative approach to analyse data and in the development of a time-distance model as used in the Asian Development Bank report (2014). It is for this reason that the research eventually used a mixed method after the results generated a significant amount of quantitative data. While the initial inclination was towards a qualitative paradigm, the results compelled the research to adopt a pragmatism instead of pure intepretivism paradigm. The mixed approach is actually recommended as it capitalises on the strengths of both designs to the benefit of the quality of the research results (Creswell & Creswell, 2018).

For purposes of comparison similar data for Dar es Salaam and North-South corridors was also collected. It is this data that is used in the Total Economic Cost analysis for the three corridors. The data also provided insights on the transit times along the corridors and at various links and nodes. The behaviour of the trucks in terms travel speeds and stoppage at various points on the corridor prompted the desire to conduct a short survey to collect qualitative data that could be used to confirm and explain the types of behaviour extracted from the quantitative data. The survey was conducted on the section of the corridor between Beira and Mutare in May 2017 over a period of two days in order to understand the reason for long transit times and slow speeds.

Thus, the survey focussed on the section between Forbes border post in Zimbabwe and the port of Beira in Mozambique along the EN6 road. The surveys provided qualitative data from interviews with truck drivers, clearing agents, customs and dry port personnel over a period of seven days. Physical observation of the road condition and facilities along the EN6 further provided additional qualitative data on the status of the corridor.

The qualitative and quantitative data collected through the survey was necessary for comparison with the quantitative GPS data to determine the reasons for the long journey times and slow speeds on certain sections of the corridor and stoppages at nodes. Data on truck activity was also collected from 100 trucks using the corridor performance measurement (CPM) data collection form illustrated in Appendix 2. The Asian Development Bank (2014), Regmi & Hanaoka (2012) and Arnold (2006) have used a similar approach to collect corridor performance measurement data. The form records activities in terms of reason for stoppages and travel time between points and at nodes. This is then plotted to produce a time-distance model which can be improved to a cost-time-distance model to determine the impact of bottlenecks on the performance of a corridor.

Interviews were conducted with truck drivers, clearing agents as well as with officials at the GMS Dry Port to obtain qualitative data in the form of their views regarding various issues affecting the corridor. Observations of the facilities also provided qualitative data on the condition of infrastructure and capacity. A total of one hundred drivers were interviewed with data being recorded on a corridor performance measurement (CPM) data collection form noting reasons for stoppages and time spent at nodes and sections of the corridor. Observations of the condition of infrastructure such as the road, railway line and the border facility also provided a significant amount of qualitative data that helped with an understanding of the nature of bottlenecks.

4.5 Data analysis

In this section the data analysis of the data collected is explained for both interviews and GPS data. For instance, some traffic data was analysed using Microsoft Excel spreadsheet to identify the primary issues to be addressed using more detailed transactional and telemetry data. Telemetry

(GPS tracking) and transactional (ports) data was then used to perform a comparative analysis for the Beira Corridor, Dar es Salaam Corridor and the North-South Corridor. This analysis was performed using SQL queries and custom developed software in the .Net environment. A further analysis involved the calculation of the cost impact of the delays; this was performed in the Matlab environment. To convert the time delay data into the estimated cost from the perspective of corridor users, a Total Economic cost model was developed to calculate the total economic cost of the impact of bottlenecks. A systems perspective requires the consideration of all the generalised costs rather than a part, such as vehicle operating costs, transports tariffs or so in isolation. The Total Economic Cost Model is explained in the next section.

4.6 Total economic cost model

The equations appearing in this section indicate how the various cost parameters were used in the calculation of Total Economic Cost (Hoffman, 2019). The purpose of the TEC model is assist with the conversion of the time delay data into the estimated cost from the perspective of corridor users.

4.6.1 Direct costs

Table 8 and Table 9 below display the cost parameters that were used in the cost calculations; these figures were obtained through discussions with industry practitioners and reflect costs that are typical for the SADC region.

Table 8 Direct Transport Cost Parameters

Monthly interest rate on truck financing	1.0%
Number of monthly instalments	120
Average cost of truck	$180 000
Monthly instalment	$2 582
Average fuel consumption (km/l)	1.5
Cost of fuel per litre	$1.40
Cost of driver per month	$1000
Additional cross-border expenses per trip	$700
Other costs per trip	$180

Table 9 Costs Parameters used in Total Economic Cost Model

Annual Interest Rate on investment in stock	12%
Gross Margin	50%
Component cost as fraction of total manufactured product cost	70%
Inventory stockholding cost per annum as fraction of stock value	40%
Average number of imported components per product manufactured	5
Average shrinkage in stock per day of stockholding	1%
Average value of container load of retailer cargo	$ 100,000
Average value of container load of manufacturer cargo	$ 200,000
Average time duration for maritime transport	4 weeks

The following equations as also employed in Hoffman, et al., (2021) describe how direct costs were calculated:

$$RTD_i = 2 \times TD_i + 4 \tag{1}$$

where RTD_i = round trip delay in days for the i-th corridor and TD_i = trip delay from origin to destination. Four days are added to the travel time to provide for loading and offloading of cargo, refuelling and maintenance of vehicles.

$$DC_{trip,i} = \frac{DC_{monthly} \times RTD_i}{30} \tag{2}$$

where $DC_{\mathrm{trip,i}}$ = driver cost per trip for the i-th corridor and $DC_{monthly}$= monthly cost to employ a driver. The costs include subsistence allowances and salary.

$$FC_i = \frac{2 \times Dist_i \times FuelCost}{FuelEcon} \tag{3}$$

where FC_i= fuel cost for corridor i, $Dist_i$ = distance from origin to destination for corridor i, $\mathrm{FuelCost}$ is the cost of fuel per litre and $FuelEcon$ is the fuel economy in km/litre. Fuel cost is based on the price of fuel at the time which was taken as a proxy, but can be varied as it changes over time.

$$DTC_i = DC_{trip,i} + FC_i + CBE + OC \tag{4}$$

where DTC_i is the direct trip costs, CBE is cross-border expenses (e.g. road taxes) and OC are other costs (e.g. subsistence for driver).

$$NumTripspm_i = \frac{30}{RTD_i} \tag{5}$$

where $NumTripspm_i$ is the number of trips per month for the i-th corridor.

$$TCpm_i = NumTripspm_i \times DTC_i + Instpm \tag{6}$$

where $TCpm_i$ is the total cost per month per truck for the i-th corridor and $Instpm$ is the monthly instalment per truck.

$$TranspCost_i = \frac{TCpm_i \times RTD_i}{30} \quad (7)$$

where $TranspCost_i$ is the total cost per trip for the i-th corridor.

Transport cost for each corridor was then calculated as fraction of cost of cargo for both retail and manufacturing.

4.6.2 Costs resulting from variable time delays

By implementing a specific buffer stock level policy, the cargo owner will try to minimize the overall cost of his operation. As this policy remains constant after optimal buffer stock levels have been determined, it may still happen for each cargo delivery that an above average delay time will lead to a stock-out situation at the retailer or manufacturer, which will result in economic losses. To determine the actual TEC for either a retailer or manufacturer, it is therefore necessary to calculate the costs for the total spectrum of possible time delays, taking into consideration the likelihood of each possible time delay. For this purpose, the percentiles of time delays for each corridor were calculated using the measured data sets for each corridor, as well as the expected TEC for each percentile. By adding all these contributions, the total expected cost for all cargo deliveries could be calculated based on the actual spread of time delays as determined from measured cargo and truck time delays.

In addition to the above direct transport costs, the following indirect costs were identified from the perspective of retailers and manufacturers importing cargo as part of their operations, using the same approach as (Hoffman, 2019):

1. *Impact of varying time delays:* As time dependent costs increase with increase in the period that stock is in transit, total cost should be calculated by integrating over all possible time delays:

$$TotCost = \int_{t=0}^{\infty} Cost(t)p(t)dt \quad (8)$$

where $\mathrm{Cost}(t)$is the cost incurred for time delay t and $\mathrm{p}(t)$is the probability distribution for all possible time delays. Since the true probability distribution of time delays are not known, the best approach is to take the average over all percentiles for stock time delays:

$$TotCost = \frac{\sum_{i=1}^{100} Cost_i}{100} \quad (9)$$

where $\mathrm{Cost_i}$ is the cost incurred corresponding to the i-th percentile of time delays. This was applied to all time dependent costs calculated below. For simplicity the summation is not explicitly shown in each case.

2. *Interest paid on investments in stock-in-transit from origin to points of consumption, calculated as fraction of value of cargo:* As the importer must pay for goods once it is shipped on board at the port of origin, the importer must invest in stock-in-transit for the time duration as from cargo

being shipped until final delivery to a retail distribution centre or manufacturing plant. This cost can be expressed as fraction of the value of the goods:

$$CI = \sum_{i=1}^{100} IR \times VGIT_i \tag{10}$$

$$VGIT_i = \frac{VA\,C \times TD_i}{365} \tag{11}$$

therefore

$$\frac{CI}{VAC} = \frac{IR \times TD_i}{365} \tag{12}$$

where

$CI =$ Cost of interest p.a.

$IR =$ Interest Rate p.a.

$VGIT =$ Value of Goods In Transit

$VAC =$ Value of Annual Consumption

$\mathrm{TD_i} =$ Transit delay in days for the i − th percentile

3. *Shrinkage of stock in transit: As shrinkage losses increase with increase in the period that stock is in transit, the total shrinkage was calculated by summing over all percentiles for stock time delays:*

$$TotShrinkage = \frac{\sum_{i=1}^{100} Shrinkage_i}{100} \tag{13}$$

$$Shrinkage_i = Shrinkagepd \times (1 - Shrinkage_{i-1})(TDPercCorr_i - TDPercCorr_{i-1}) + Shrinkage_{i-1}$$

(14)

where $TotShrinkage$ is the total shrinkage for all stock, including all possible time delays, $Shrinkage_i$ is the shrinkage for the i-th percentile, $Shrinkagepd$ is the daily shrinkage fraction, and $TDPercCorr_i$ is the time delay in days for the i-th percentile. The equation above takes into account that after each day in transit there is less stock left that is still exposed to further shrinkage.

4. *Losses in sales or production, should an out-of-stock situation occur, as fraction of value of cargo:* These losses will occur if the actual delivery is delayed beyond the normally expected delivery time. If a buffer stock is maintained to prevent these losses, then an actual loss will only occur if the unexpected delay is longer than the period covered by the buffer stock (Hoffman, 2019).
   - *Retail:* For a retail operation it is assumed that losses in sales will occur when the buffer stock is depleted before the next delivery is made:

$$\frac{LRI}{VAC} = FSL \times GM \tag{15}$$

where

$$FSL = \frac{OTL}{ADT} \text{ if } OTL > 0, FSL = 0 \; otherwise \tag{16}$$

$$OTL = ADT - SDT - BSP \tag{17}$$

$$BSP = \frac{BSS}{UR} \tag{18}$$

where

$LRI = \ Loss\ in\ Retail\ Income$

$FSL = \ Fraction\ of\ sales\ lost$

$GM = \ Gross\ Margin$

$OTL = \ Operational\ Time\ Loss$

$ADT = \ Actual\ Delivery\ Time$

$SDT = \ Standard\ Delivery\ time$

$BSP = \ Buffer\ stock\ period$

$BSS = \ Buffer\ stock\ size$

$UR = \ Usage\ Rate$

- *Manufacturing:* For a manufacturing operation it is assumed that losses in production will occur when the buffer stock in any component used in production is depleted before the next delivery is made. The fraction of uninterrupted production runs is calculated, and these are those production runs for which no component experienced an out-of-stock situation. Annual consumption is taken as the total annual value of components imported for use in manufacturing. As the value of gross margin on the total manufactured product is lost if there is a production loss, the fraction that components represent of the total product value is also used.

$$\frac{LMI}{VAC} = \frac{FPL \times GM}{CFTC} \tag{19}$$

where

$$FPL \ = \ \frac{FIR \times OTL}{ADT} \text{ if } OTL > 0, FPL = 0\ otherwise \tag{20}$$

$$FIR \ = 1 - \ FUR \tag{21}$$

$$FUR = (1 - FCD)^n \tag{22}$$

$$FCD = \ \frac{OTL}{ADT} \tag{23}$$

n is the number of components used in the final product

$LMI = \ Loss\ in\ Manufacturing\ Income$

$FPL = \ Fraction\ of\ production\ lost$

$CFTC = \ Component\ value\ as\ fraction\ of\ total\ cost$

$FIR = \ Fraction\ Interrupted\ Runs$

$OTL = \ Operational\ Time\ Loss$

$FUR = \ Fraction\ Uninterrupted\ Runs$

$FCD = \ Fraction\ compoents\ delayed$

5. *Storage costs paid for buffer stocks, as fraction of value of cargo:*

$$\frac{SC}{VAC} = \frac{SR \times MIS}{VAC} \tag{24}$$

$$MIS = (BSP + SDT - MDT) \times UR \tag{25}$$

therefore

$$\frac{SC}{VAC} = \frac{(BSP+SDT-MDT)\times SR}{One\ Year} \tag{26}$$

where

$SC = Storage\ Cost\ p.a.$

$SR = 1\ Year\ Storage\ Rate$

$MIS = Max\ Inventory\ Size$

$MDT = Min\ delivery\ time$

Equations 1 to 26 above allows total cost resulting from transport and other logistics delays to be expressed as fraction of the total value of goods purchased:

$$TREI = CI + SC + LRI \tag{27}$$

$$TMEI = CI + SC + LMI \tag{28}$$

where

$TREI = Total\ Retail\ Economic\ Impact$

$TMEI = Total\ Manufacturing\ Economic\ Impact$

4.6.3 Sensitivity of TEC with respect to cost parameters

The above equations show that the Total Economic Cost from the perspective of the cargo owner depends on several cost parameters. To investigate this dependence, the TEC was calculated, while varying the values of these parameters over a range of values as indicated in Table 10 below. As components for products requiring large numbers of parts are often ordered in batches including many parts supplied by the same manufacturer, the study limited the maximum number of components to a reasonable amount.

Table 10 Range of values used to determine sensitivity of TEC w.r.t. cost parameters

Cost Parameter	**Minimum value**	**Maximum value**
Interest rate	1% p.a.	20% p.a.
Gross margin	10%	90%
Component cost as fraction of product value	5%	90%
Annual inventory cost as fraction of value of goods	10%	100%
Number of components per manufactured product	2	20

4.7 Analysis of type of products transported along corridors

It will be informative to estimate the potential for traffic growth on the Beira Corridor should the potential of intraregional trade be fully exploited. The International Trade Centre (ITC) Export Potential Map, a tool that turns economic analysis into practical trade information using the ITC export potential methodology, provides information about import and export opportunities between specific countries. For instance, the African Export-Import Bank (AFREXIMBANK) report used the ITC to analyse the trade-carrying infrastructure gap across one pilot African region to propose priority investments to fill these gaps (Nathan, 2020). This information, customised to the LLC understudy, was used to determine the type of products transported along corridors to and from the four landlocked countries of DRC, Malawi, Zambia and Zimbabwe. The specific requirements for corridor performance based on the needs of the respective import/export industries were determined using the data. For instance, some industries like fruits require faster processing to eliminate damage to goods. This was used as another aspect for comparing the Beira Corridor with the Dar es Salaam and the North-South Corridor.

This information is also invaluable in the estimation of the potential increase in traffic for the Beira Corridor resulting from the improvements of infrastructure and regulations in line with the research objectives of improving the performance of the corridor. The same approach was used in the AFREXIBANK 2040 traffic projections, where the ITC data was used as a baseline for projections. In this study this is used in conjunction with the reduction in logistics variation and TEC which should lead to more trips per month due to removal of delays.

The formula below indicates how the volume of commodities transported along the corridors were estimated.

$$Ev = \frac{\sum Cep}{Cp}$$

$$NumTrips = \frac{Ev}{28t}$$

Where:

Cep = Commodity export potential for each country

Cp = Commodity price (USD/ton) (the price value is in US$ in this case)

Ev = Estimate volume in tonnes

28t = truck equivalent tonnage

$NumTrips$ = number of truck trips required per annum to transport the cargo representing unexploited potential

This calculation is based on the assumption that the type of commodities exported or imported from the four landlocked countries under consideration (i.e. DRC, Malawi, Zambia and Zimbabwe) are a reflection of the commodities transported along the three corridors. Another assumption made was that cargo is transported on 30t trucks whereby the regulated weight in SADC is 28t which is why in the formula the total weight is divided by 28t to calculate the number of truck trips. To obtain the TEU traffic volumes the commodity volumes was divided by 24t which is the equivalent of 1 twenty-foot equivalent unit. The calculation was limited to commodities transported by road and with high untapped export/import potentials. The prices for commodities obtained from the Trading Economics website were used as proxy for purposes of calculation. Table 11 shows the four-countries' combined values from the ICT export potential analysis, and the commodity prices used in the calculation of the volumes. The Export Potential Map data for each of the four countries are presented and discussed in the next chapter.

Table 11 Combined export potential for the four LLCs

Commodities	**Actual exports ($)**	**Export potential ($)**	**Untapped potential**	**Price per ton**
Ferro Chrome	$200 600 000	$332 000 000	$53 000 000	$90
Cobalt	$2 186 400 000	$3 962 700 000	$1 793 900 000	$53 500
Unrefined copper	$4 449 100 000	$6 311 800 000	$2 288 200 000	$8 500
Copper cathodes	$5 100 000 000	$8 500 000 000	$3 800 000 000	$5 800
Raw sugar	$134 800 000	$259 500 000	$165 400 000	$42 990
Black tea	$105 300 000	$108 700 000	$34 500 000	$7 400
Wood in rough	$107 500 000	$171 900 000	$82 100 000	$686
Maize	$57 200 000	$80 700 000	$49 300 000	$165
Cotton	$93 500 000	$101 700 000	$40 600 000	$2 650
Soybean	$24 100 000	$59 900 000	$34 900 000	$45 484
Nuts	$61 000 000	$110 600 000	$63 800 000	$20 110
Oranges	$32 500 000	$34 400 000	$18 300 000	$2 932

4.8 Conclusion

This chapter has discussed the mixed methods approach, the qualitative and quantitative methodologies and case study research design used to answer the research questions for this study. The case study design has been identified as the appropriate qualitative methodology to explore the effect of a variety of bottlenecks on the performance of a transport corridor focusing on a single case: The Beira Corridor. In order to improve on the validity of the research outcomes and the heavy use of quantitative data, the quantitative method was also used making the way for a mixed method approach instead of one of the two, qualitative and quantitative. This was chosen in order to take advantage of the inherent strength found in each of the two, which could not be achieved if the research had relied on only one of the two approaches.

The case study research design has been explained in detail and the mixed method approach justified as the most appropriate to answer the research questions posed for this study. The case study strategy has been compared with other strategies, both qualitative and quantitative. The difference between qualitative and quantitative paradigms has equally been discussed in detail and the strength of combining the two discussed in detail to the effect of justifying a combination of both approaches in conducting a case study of the Beira Corridor bottlenecks assessment. The way data was collected, both qualitative and quantitative has been described and discussed. It has also been noted that there are studies that have used similar approaches especially by the Asian Development Bank (2014) and the World Bank (2005). The Total Economic Cost model used to compare the three corridors adopting a systems perspective was described and explained. Finally, The International Trade Centre (ITC) Export Potential Map methodology was used to identify the type of commodities with untapped export potential, in order to define the specific requirements for corridor performance, based on the needs of the respective import/export industries. The results of the analysis in terms of volumes of these commodities transported along the corridors are presented in the next chapter.

CHAPTER 5 COMPARISON OF BEIRA WITH COMPETING CORRIDORS

5.1 Introduction

The previous Chapter discussed the approach and methodology used to achieve the objectives of this study. The results of the analysis of data are important as the help with the resolution of the research questions presented in chapter 1. This Chapter follows up from the previous Chapter by discussing the results pertaining to conditions of the Beira Corridor and of the competing corridors. The findings will form the basis for comparing the Beira Corridor with other corridors as they bring out the bottlenecks that are affecting the performance of the corridor. The findings on the attributes of the Beira corridor and those of the other two corridors are discussed and compared with the other two corridors. An end-to-end analysis is performed to allow for comparison of the three corridors. The bottlenecks affecting Beira Corridor are identified and their impact on costs as well as how they can be resolved. A SWOT analysis is performed with the other corridors in order to identify possible improvements for the Beira Corridor.

The spatial relationship of eight corridors converging in the same hinterland are shown in Figure 27. The ones in direct competition with the Beira Corridor are Dar es Salaam and North-South Corridor. This Chapter focusses on these three corridors analysing them in terms of their attractiveness and to perform a SWOT analysis to determine possible areas of improvement, especially for Beira in order to address the paradox presented in the problem statement.

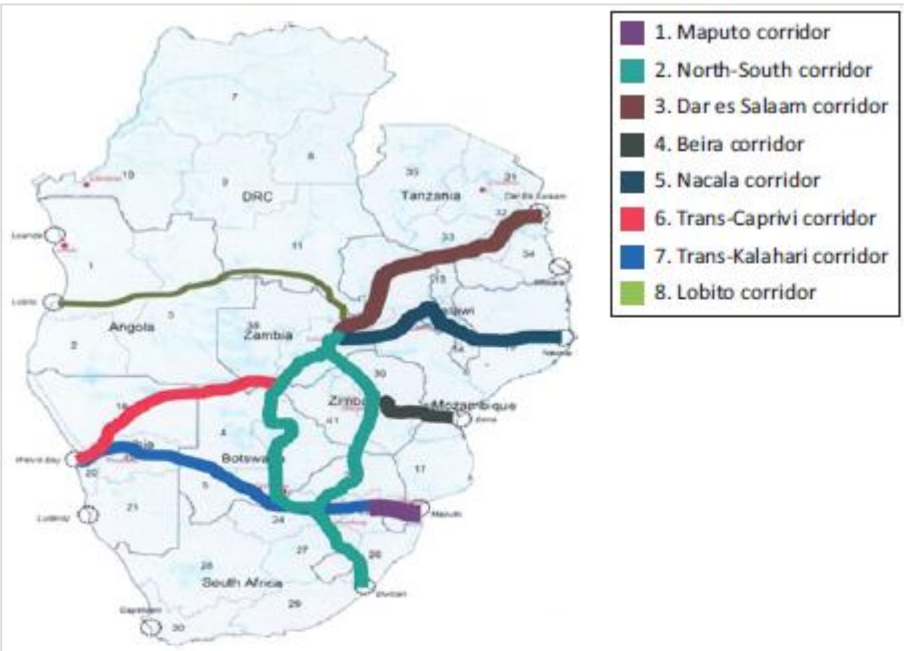

Figure 27 Major SADC Corridors

Source: Nabee et al (2018)

Fundamentally, the attractiveness or performance of a corridor is determined by several elements. These include the condition of physical infrastructure, border crossing process and the interaction of transport modes at nodes including borders. Furthermore, lack of rolling stock in the case of rail and availability or otherwise of freight rail, emerged as major bottlenecks that increase the total transportation time and cost along the corridors. This Chapter presents the findings of the assessment conducted on the Beira Corridor which sought to identify the bottlenecks existing on the corridor in terms of both physical and non-physical. The chapter then proceeds with a SWOT analysis the three ports which provides insights on the bottlenecks for the Beira Corridor that need to be addressed in order to improve on performance. The results on the sources of bottlenecks are discussed in the sections below starting with physical infrastructure related bottlenecks followed by non-physical related bottlenecks.

5.2 End-to-end analysis of the three corridors

In this section the study shows time measurements for the overall cargo movement process, broken down into the ports segment and the land based segment (road or rail) as applicable. These results are shown in terms of the corridor route network. In each case the results are displayed as obtained from different participants and then combine these results into a weighted average performance measure for the corridor as a whole. For comparative purposes, the end-to-end analysis of the three corridors is discussed in the next sub-sections in the respective order of Beira, North-South and Dar es Salaam.

5.2.1 Beira-Lusaka segment end-to-end analysis

In this section the analysis of the Beira-Lusaka segment of the Beira Corridor is presented. The data for the analysis was obtained from three different freight agents; all of these used road as land based mode of transport. For Agent 2 and Agent 3 cargo was inbound and was shipped to various destinations. In the case of Agent 4 cargo was outbound and originated from the Tete Province. The results for the port delays, road and end-to-end travel times are displayed in Table 12 below. As much more data was available for agent 2 compared to agents 3 and 4 the statistics for the combined set is dominated by the data from agent 2. It must however be noted that the road portion of the delays is not representative of all routes along the network of roads linking the port of Beira to the interior; the results displayed below are limited to the few destinations for which data was available from the freight agents. In section below the complete results for all major destinations that form part of the Beira road network is provided; in that case the port delays are however not included. The results in this section are therefore the only data for which the entire process including port and road is available.

While agents 3 and 4 experienced port delays of 4 to 7 days, this was much worse for agent 2 (14 to 16 days). For both agents 2 and 4 road delays were between 4 and 5 days; no road delay data was available from agent 3. The combined data overall delay for road plus port delays was around 20 days. The histogram of end-to-end corridor delays in 40 displays fairly smooth behaviour close to the shape of a Poisson distribution; based on the consistent behaviour over more than 4,000 observations we can therefore accept that the data is reliable.

Table 27 below shows results for the Beira corridor indicates that this corridor. From the histogram in Figure 28 it can however be seen that a significant percentage of consignments experienced delays of 40 to 60 days.

Table 12: End-to-end Performance Results for Beira Corridor

Agent 2	**Road**	**Port**	**Total**
Ave	4.9	16.2	21.2
Med	5.0	14.0	19.0
Std	3.8	11.9	12.6
Agent 3	**Road**	**Port**	**Total**
Ave		6.0	
Med		4.0	
Std		7.9	
Agent 4	**Road**	**Port**	**Total**
Ave	4.2	6.9	11.1
Med	4.0	5.0	10.0
Std	1.8	3.7	4.1
Combined	**Road**	**Port**	**Total**
Ave	4.9	15.9	21.2
Med	5.0	13.0	19.0
Std	3.8	11.9	12.6
Min	0.0	0.0	0.0
Max	129.0	100.0	129.0

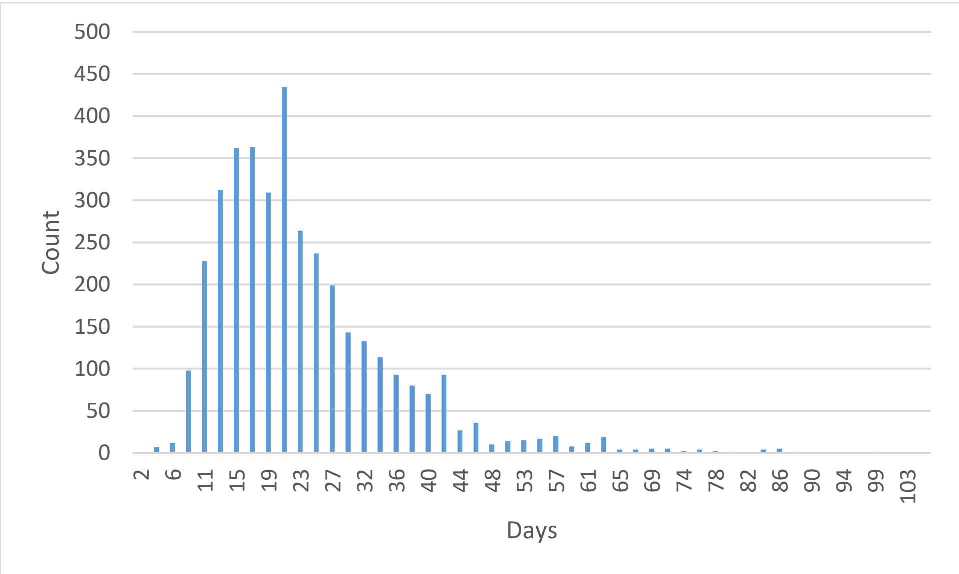

Figure 28: Histogram of end-to-end time delays for the Beira port plus road corridor

For a limited set of 154 containers it was possible to match the above ports and customs delay data from Agent 2 with road transport data based on GPS tracking results. Table 13 below displays the results where a more complete set of figures are provided for the entire process. The freight agent data was used to provide the date for loading and for arrival at destination, while the transporter GPS tracking data was used to provide the dispatch and delivery dates. It can be seen that there is good correspondence between the freight agent and the transport data: no negative value were found for the times between loaded (based on the freight agent information) and dispatched (based on transporter data), as well as between delivered (according to transporter) and arrived at final destination (according to freight agent) – negative values would have meant that either or both sources contained faulty data. The averages for these times are a fraction of a day which would be expected, given that they measure activities that are directly following upon each other.

For this sample the average total delay was 18 days, more than 12 days spent in the port and almost 6 spent on the road. This included three destinations: Blantyre, Lilongwe and Salima, all located inside Malawi. As could be expected there was little difference in delay along the road between these 3 destinations as they are located in relative close proximity compared to the distance from Beira.

While these combined results do not change the overall picture of performance on the Beira corridor, it provides a demonstration that it is possible to successfully combine data received from different participants to create accurate trails of the combined port and land based transport value chain based on which differences that do occur can be studied. It also confirmed the integrity of the data, as none of these cases displayed a large discrepancy between freight agent and transporter data.

Table 13: Delays for inbound cargo in the port of Beira moving by road to the interior

	Parameter	**Arrive to Clear Date**	**Clear to Load Date**	**Load to Dispatch Date**	**Dispatch to Deliver Date**	**Deliver to Arrive Dest Date**	**Days in Port**	**Days on Road**	**Arrive Port to Arrive Dest Date**
Blantyre	Number	57	57	57	57	57	57	57	57
	Ave	5.8	5.1	0.5	5.2	0.0	11.4	5.3	16.6
	Median	6	3	0	5	0	11	5	16
	StDev	4.7	6.2	0.7	1.3	0.1	6.0	1.3	6.1
	Max	14	25	2	8	1	34	8	40
	Min	-7	1	0	3	0	4	3	9
Lilongwe	Number	18	18	18	18	18	18	18	18
	Ave	5.9	3.9	0.3	5.2	0.1	10.2	5.3	15.4
	Median	6	4	0	5	0	11	6	17
	StDev	3.9	2.2	0.7	0.9	0.3	3.4	1.0	3.8
	Max	12	7	2	7	1	15	7	22
	Min	1	1	0	4	0	4	4	9
Salima	Number	79	79	79	79	79	79	79	79
	Ave	7.9	5.4	0.3	5.6	0.6	13.5	6.1	19.6
	Median	8	5	0	5	0	14	6	18
	StDev	4.6	3.6	0.5	1.6	1.0	5.6	1.6	6.1
	Max	21	22	2	10	4	27	11	33
	Min	1	1	0	0	0	5	3	9

Table 14: End-to-end Performance Results for Beira Corridor

Inbound	**Port**				**Road**	**Total**
Agent 2	**CUSTOMS IN - OUT**	**STAMP**	**LOAD**	**TOTAL PORT**	**DEPART - ARR**	**Total**
Average	11.1		6.1	16.7	5.0	**21.7**
Median	9.0		4.0	14.0	5.0	**19.0**
StDev	10.1		7.1	12.3	3.9	**12.5**
Agent 3	**CUSTOMS IN - OUT**	**STAMP**	**LOAD**	**TOTAL PORT**	**DEPART - ARR**	**Total**
Ave	1.9	2.8	2.0	6.0		
Median	1.0	1.0	1.0	4.0		
StDev	1.3	7.0	2.0	7.9		
Outbound					**Road**	**Total**
Agent 4	**CUSTOMS IN - OUT**	**STAMP**	**LOAD**	**TOTAL PORT**	**DEPART - ARR**	**Total**
Average				6.9	3.5	**10.4**
Median				5.0	3.0	**8.0**
StDev				3.7	1.9	**5.5**

As indicated above, data for Beira port was available from 3 different agents, 2 for inbound and 1 for outbound. The data was broken up into process steps, as displayed in Table 14 below. In addition, data was also obtained from GPS tracking data of trucks visiting the port of Beira to offload and load cargo. The delays experienced by different agents varied largely: while agents 3 and 4 experienced total port delays of 4 to 7 days, this was extended up to around 16 days for agent 2. Both the customs and loading processes took much longer for the latter agent compared to the other two.

The overall ports process consumed between 5 and 17 days – on this basis the port of Beira seemed efficient, in spite of the large traffic volumes handled. However, this is significantly inefficient compared with Durban for example where the longest delay is about 3 days as shown in Table 18. Figure 29 displays the histogram for Beira port inbound time delays, while Figure 30 displays outbound time delays (due to the small number of observations available the histogram in the latter figure is not very smooth). The information for inbound and outbound was obtained from different agents; in the latter case a smaller sample was available. For inbound cargo the histogram peaks around 10 days while for outbound the peak appears at about 5 days.

While no further information was available to investigate the reasons for the difference in time delays between inbound and outbound cargo, it must be taken into account that outbound cargo is typically raw materials (in this case tobacco) while inbound cargo is mostly consumer goods. The latter type of cargo is much more likely to be stopped for the purpose of pilfering and bribery as a viable black market exists for these kind of goods.

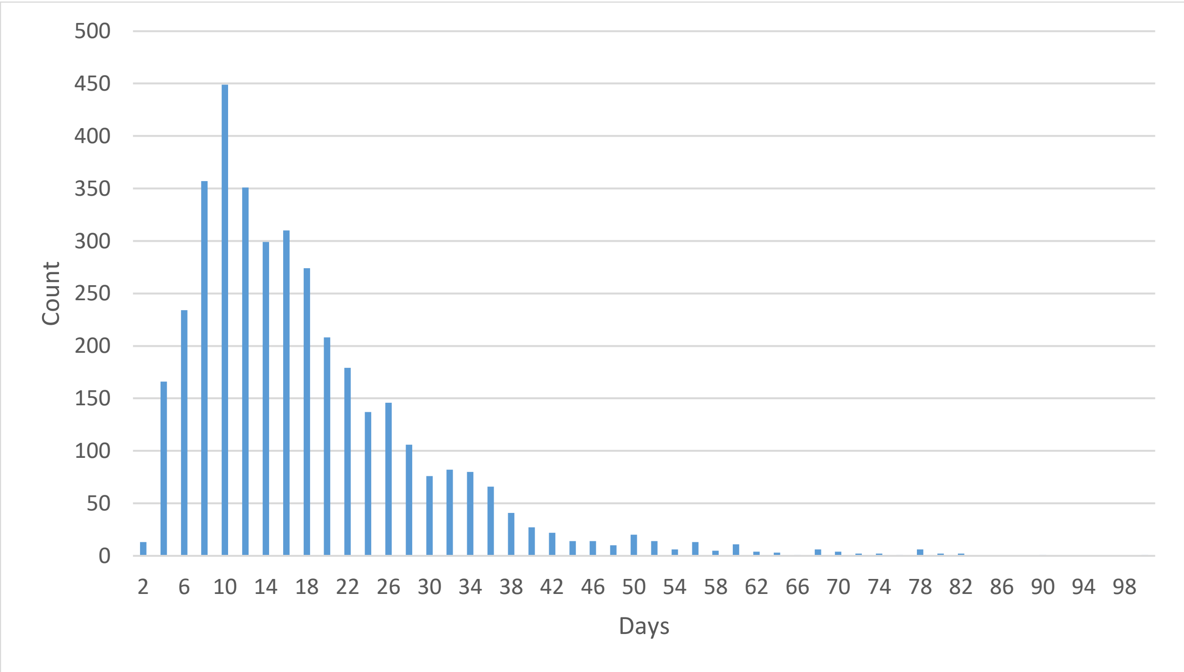

Figure 29 Histogram for Beira Port inbound time delays measured in days

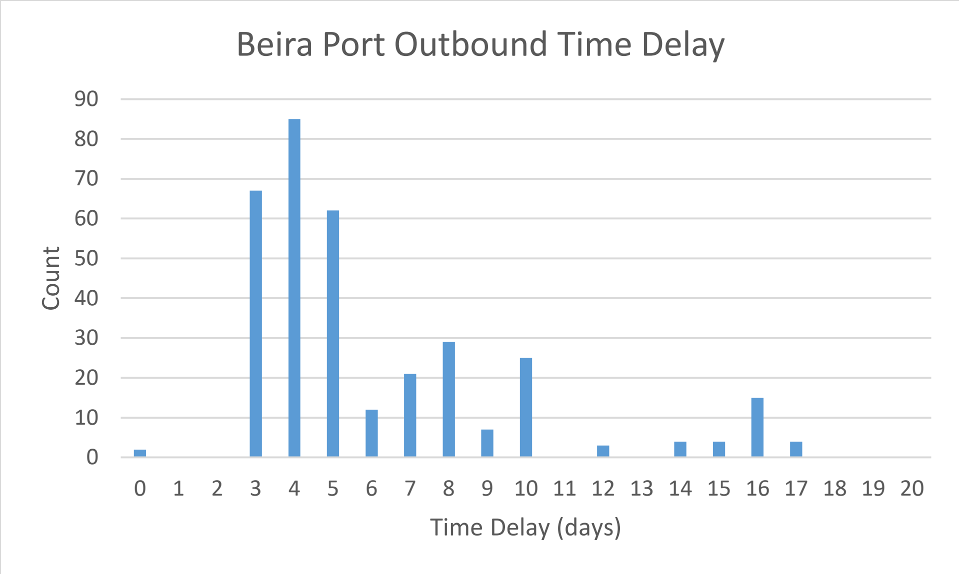

Figure 30 Histogram for Beira Port outbound time delays measured in days

The time spent by trucks when visiting the port was also measured based on GPS tracking data. Table 15 displays the statistics extracted from about 19,000 truck visits to the port, while Figure 31 displays the histogram for the same time delays. These results apply to both inbound and outbound traffic, as typically a truck will first offload as part of an outbound trip and then load as part of an inbound trip. For the same reason it is also not possible to separate the length of port visits for inbound and outbound trips.

It can be seen that the distribution is bimodal: most trucks either leave within 12 hours or spend around 20 to 34 hours inside the port. From Table 15 it can be seen that for these kind of distributions the average and median can give widely different results; this emphasizes the need to also study the probability distribution to obtain a better understanding of the nature of delays being experienced.

Table 15: Time delay in hours for trucks in the port of Beira based on GPS measurements

Average(Ave)	20.6
Median	9.7
Std	28.8
Coeff of Var	1.4
Skewness	0.00
Kurtosis	-1.20
Number	19098

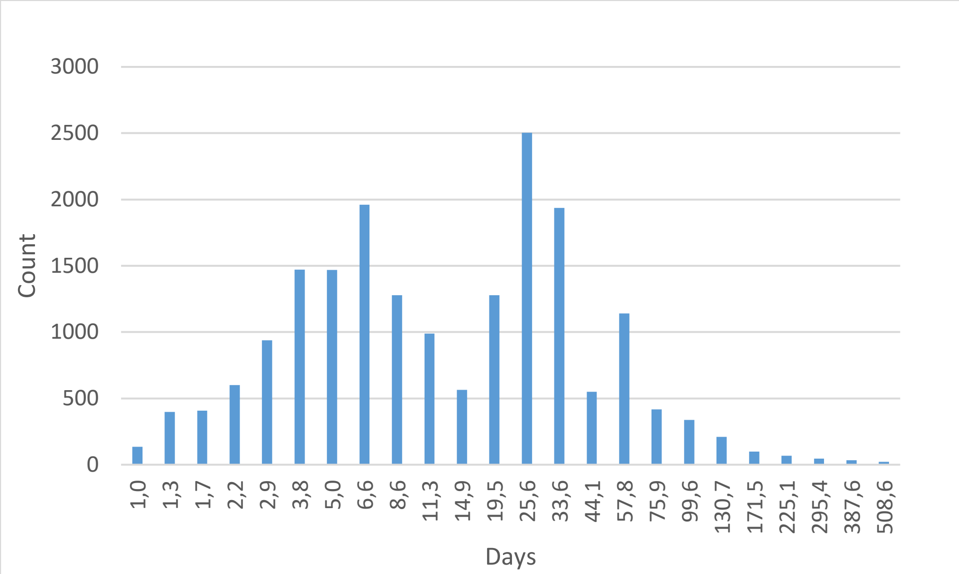

Figure 31: Histogram of time delay in hours for trucks in the port of Beira based on GPS measurements

Road infrastructure performance was measured using GPS end-to-end transit time analysis for the entire corridor. The data collected from trucks using GPS show the different travel times and speed between different sections of the corridor. The data obtained from the survey explains the reasons for the variations in transit times along the corridor and the possible reasons for stops by the trucks. These ranged from traffic checkpoints to customs process related stoppages and inspections, all of which pose bottlenecks which contribute long transit times to and from the port on the Beira Corridor. The travel time and speeds along various sections of the Beira-Lusaka route are shown in Table 16. The travel time of 6 days for 1019 km and average speeds of 7 km/h on some sections is a clear indication of the existence of bottlenecks.

Table 16: End-to-end analysis on the Beira-Lusaka segment of the corridor

Segment/Waypoint	Length (km)	Travel Time (days)	% of Time	Travel Speed (km/h)	Time per km (min/km)
Total Measured End-to-end	1019,6	6,021		7,1	8,5
Beira – Dondo	7,4	0,006	0,1%	52,7	1,1
Dondo		0,005	0,1%		7,0
Dondo – Inchope	107,6	0,108	1,7%	41,4	1,5
Inchope		0,105	1,6%		151,0
Inchope – Chimoio	62,2	0,058	0,9%	44,5	1,3
Chimoio		0,056	0,9%		80,0
Chimoio – EN6_102	16,5	0,013	0,2%	51,3	1,2
EN6_102		0,122	1,9%		175,0
Machipanda		0,081	1,3%		116,9
Forbes		0,079	1,2%		114,0
Mutare		0,198	3,1%		284,5

Mutare – Nyazura	71,8	0,074	1,2%	40,4	1,5
Nyazura		0,057	0,9%		82,0
Nyazura – Ruwa	169,3	0,336	5,3%	21,0	2,9
Ruwa		0,143	2,2%		206,0
Ruwa – Harare	17,3	0,131	2,1%	5,5	10,9
Harare		0,485	7,6%		34,9
Harare – Banket	94,8	0,617	9,7%	6,4	9,4
Banket		0,643	10,1%		926,0
Chirundu Zim		0,117	1,8%		168,6
Chirundu Zam		1,068	16,8%		1537,6
T2_M15		1,056	16,6%		1521,0
T2_M15 – Kafue	75,6	0,182	2,9%	17,3	3,5
Kafue		0,106	1,7%		152,5
Kafue – Lusaka	44,0	0,528	8,3%	3,5	17,3
Total	666,4	6,373	100,0%		13,8

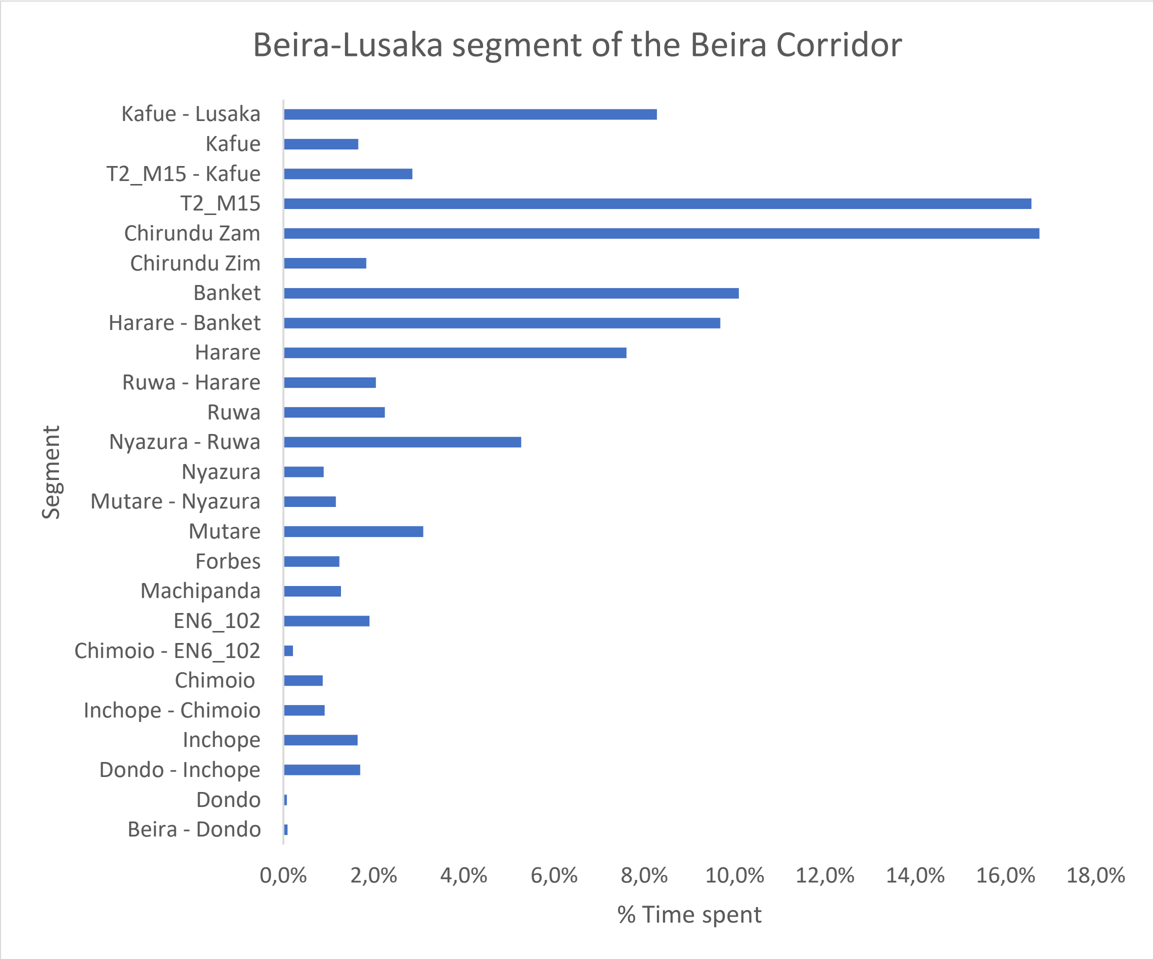

Figure 32 Travel speeds on the Beira-Lusaka segement of the Beira Corridor

The results in Figure 32 indicate that generally travel speeds on the Mozambican sections are reasonably higher than on the Zimbabwean section. This could be as a result of too many stoppages on the Zimbabwean side through roadblocks as reported by drivers during the interviews. The same low speeds are shown on the Zambian sections at Kafue and Kafue-Lusaka leg. However, the latter could be a result of traffic conditions since this section is within the urban area where traffic volumes are high creating a bottleneck on this section of the corridor.

5.2.2 Durban-Lusaka segment end-to-end analysis

The results in Table 17 and Figure 33 indicate that there is more than one border post with an average speed above 20 km/h. It can also be noted that the speeds on the Durban-Lusaka routes are higher than the average 7km/h for the Beira-Lusaka route, making the North-South Corridor more competitive than the Beira Corridor. There is also an indication that a significant amount of time is spent at Border Posts. At Beit Bridge the results show more time spent on the Zimbabwean side than on the South African side. At Chirundu Border Post more time is spent on the Zambian showing indicating the OSBP because traffic is processed on the Zambian side for north bound trucks. In terms of customs port delays, the results show a maximum of 86.3 and a minimum of 18.6 hours as shown in Table 18.

Table 17: End-to-end on the Durban-Lusaka segment of the North-South Corridor

Durban - Lusaka					
Segment/Waypoint	**Length (km)**	**Travel Time (days)**	**% of Time**	**Travel Speed (km/h)**	**Time per km (min/km)**
Durban		0,104	1,3%		
Durban - Pietermaritzburg	77,9	0,239	2,9%	13,6	4,4
Pietermaritzburg - MooiRivier	64,1	0,048	0,6%	55,5	1,1
MooiRivier - Harrismith	173	0,109	1,3%	66,4	0,9
Harrismith - Johannesburg	261	0,398	4,9%	27,3	2,2
Johannesburg		0,197	2,4%		
Johannesburg - Pretoria	65,5	0,196	2,4%	13,9	4,3
Pretoria - Polokwane	262	0,159	2,0%	68,7	0,9
Polokwane - BeitBridge	215	0,193	2,4%	46,4	1,3
BeitBridge_SA		0,107	1,3%		
BeitBridge_Zim		0,776	9,6%		
BeitBridge - Bulawayo	344	0,281	3,5%	51,0	1,2
Bulawayo		0,947	11,7%		
Bulawayo - Harare	439	0,613	7,6%	29,8	2,0
Harare		0,485	6,0%		
Harare - Banket	94,1	0,517	6,4%	7,6	7,9
Banket		0,100	1,2%		
Banket - Chirundu	263,0	0,643	7,9%	17,0	3,5
Chirundu Zim		0,117	1,4%		
Chirundu Zam		1,068	13,2%		
Chirundu - Kafue	92,9	0,182	2,2%	21,3	2,8
Kafue - Lusaka		0,106	1,3%		

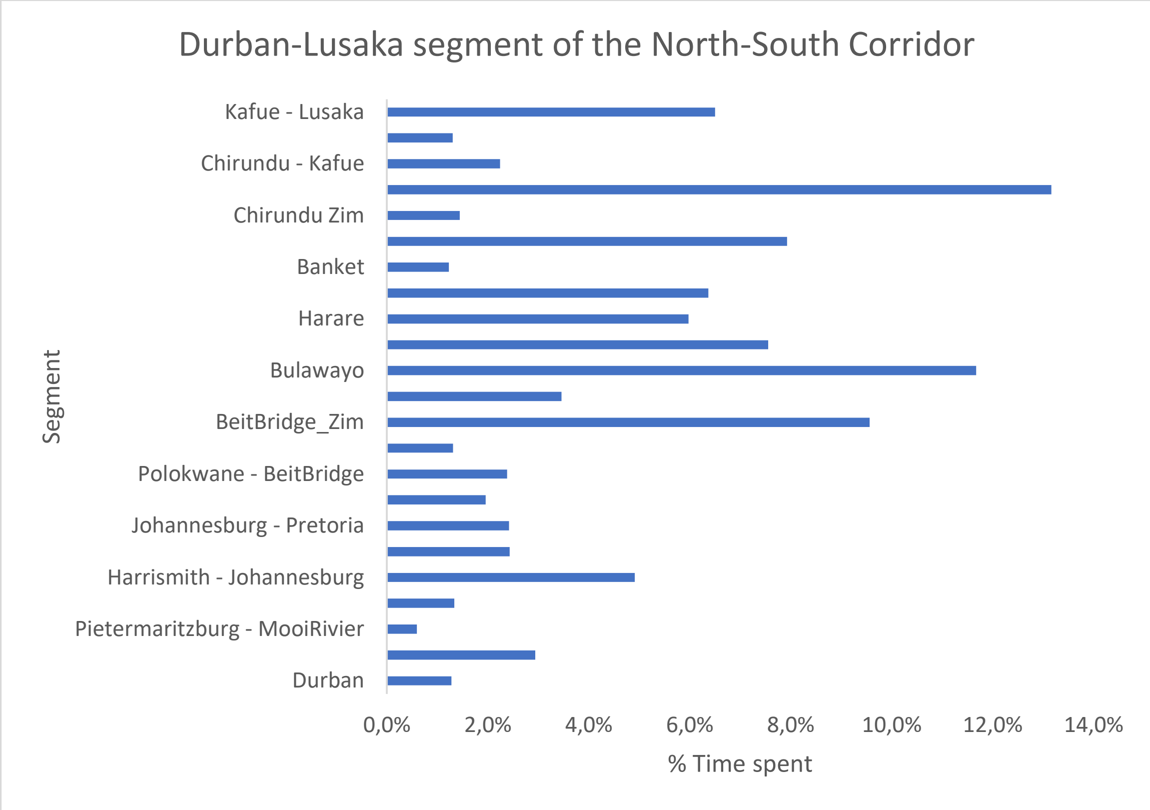

Figure 33 Percentage time spent along route Durban to Lusaka

Table 18: Customs Time Delays at Port of Durban (in hours)

Customs Office	Num Obs	Average Duration	Number Infractions	Fraction Infractions
All destinations	38453	18,6	278	0,72%
To Malawi	293	26,6	1	0,34%
To Zimbabwe	5820	57,9	15	0,26%
To Zambia	3485	86,3	14	0,40%

5.2.3 Dar es Salaam-Lusaka segment end-to-end analysis

The speeds on the Dar es Salaam Corridor are significantly higher than Beira-Lusaka and the average is above 20 km/hr as shown in Table 19 and Figure 34. The results show that most of the time is spent at Dar es Salaam Inland Container Deport (ICD) (2) accounting for 1,9 days 22.2% of the time followed by ICD (1), accounting for 1.4 days being 15.7% of the time. Very little time is spent at Nakonde-Tunduma border post, indicating the efficiency of the OSBP implemented. However, there is a significant amount of time spent at the port with a maximum of 19.2 days and a minimum of 14.3 days as shown in Table 20.

Table 19: End-to-end on the Dar es Salaam-Lusaka segment of the North-South Corridor

Dar es Salaam - Lusaka					
Segment/Waypoint	**Length (km)**	**Travel Time (days)**	**% of Time**	**Travel Speed (km/h)**	**Time per km (min/km)**
Dar Port		0,285	3,2%		
Dar Port Waiting Zone		0,062	0,7%		
Dar ICDs (1)	5	1,408	15,7%	0,1	405,5
Dar ICDs (2)	10	1,982	22,2%	0,2	285,5
Rest of Dar	10	0,093	1,0%	4,5	13,3
Rest of Dar - Misugusugu PS	45,5	0,058	0,7%	32,5	1,8
Misugusugu PS		0,117	1,3%		
Misugusugu PS - Vigwaza WB	19,3	0,054	0,6%	14,8	4,1
Vigwaza WB		0,031	0,3%		
Vigwaza WB - Mikese WB	89,6	0,126	1,4%	29,6	2,0
Mikese WB		0,014	0,2%		
Mikese WB - Morogoro	33,4	0,031	0,3%	45,3	1,3
Morogoro		0,113	1,3%		
Morogoro - Mikumi WB	117	0,134	1,5%	36,4	1,6
Mikumi WB		0,064	0,7%		
Mikumi WB - Iringa	189	0,415	4,6%	19,0	3,2
Iringa		0,068	0,8%		
Iringa - Wenda Weigh Bridge	24	0,021	0,2%	47,2	1,3
Wenda Weigh Bridge		0,008	0,1%		
Wenda Weigh Bridge - Makambako WB	141	0,273	3,1%	21,5	2,8
Makambako WB		0,183	2,0%		
Makambako WB - Uyole WB	164	0,408	4,6%	16,7	3,6
Uyole WB		0,029	0,3%		
Uyole WB - Mbeya	9,8	0,006801	0,1%	60,0	1,0
Mbeya		0,162241	1,8%		
Mbeya - Mpemba WB	93,2	0,156447	1,7%	24,8	2,4
Mpemba WB		0,061319	0,7%		
Mpemba WB - Nakonde/Tunduma Border	12,1	0,121173	1,4%	4,2	14,4
Nakonde/Tunduma Border		0,468888	5,2%		
Nakonde/Tunduma Border - Isoka Police Stop	115	0,297739	3,3%	16,1	3,7
Isoka Police Stop		0,030056	0,3%		
Isoka Police Stop - Chinsali Police Stop	91,3	0,106947	1,2%	35,6	1,7
Chinsali Police Stop		0,053576	0,6%		
Chinsali Police Stop - Mpika	178	0,240951	2,7%	30,8	1,9
Mpika		0,114629	1,3%		
Mpika WB - Pensulo Police Stop	209	0,384485	4,3%	22,6	2,6
Pensulo Police Stop		0,006763	0,1%		
Pensulo Police Stop - Serenje Police Stop	42	0,033705	0,4%	51,9	1,2
Serenje Police Stop		0,063745	0,7%		
Serenje Police Stop - Luanshimba Police Stop	80	0,084604	0,9%	39,4	1,5

Luanshimba Police Stop		0,005937	0,1%		
Luanshimba Police Stop - Kapiri Mposhi WB	128	0,121546	1,4%	43,9	1,4
Kapiri Mposhi WB		0,141842	1,6%		
Kapiri Mposhi WB - Kabwe Rail Station	60,7	0,112941	1,3%	22,4	2,7
Kabwe Rail Station		0,030405	0,3%		
Kabwe Rail Station - Chisamba Police Stop	85,8	0,140188	1,6%	25,5	2,4
Chisamba Police Stop		0,005948	0,1%		
Chisamba Police Stop - Lusaka	72,2	0,013832	0,2%	217,5	0,3
Total	**2024,9**	**8,9**	100,0%		**6,4**

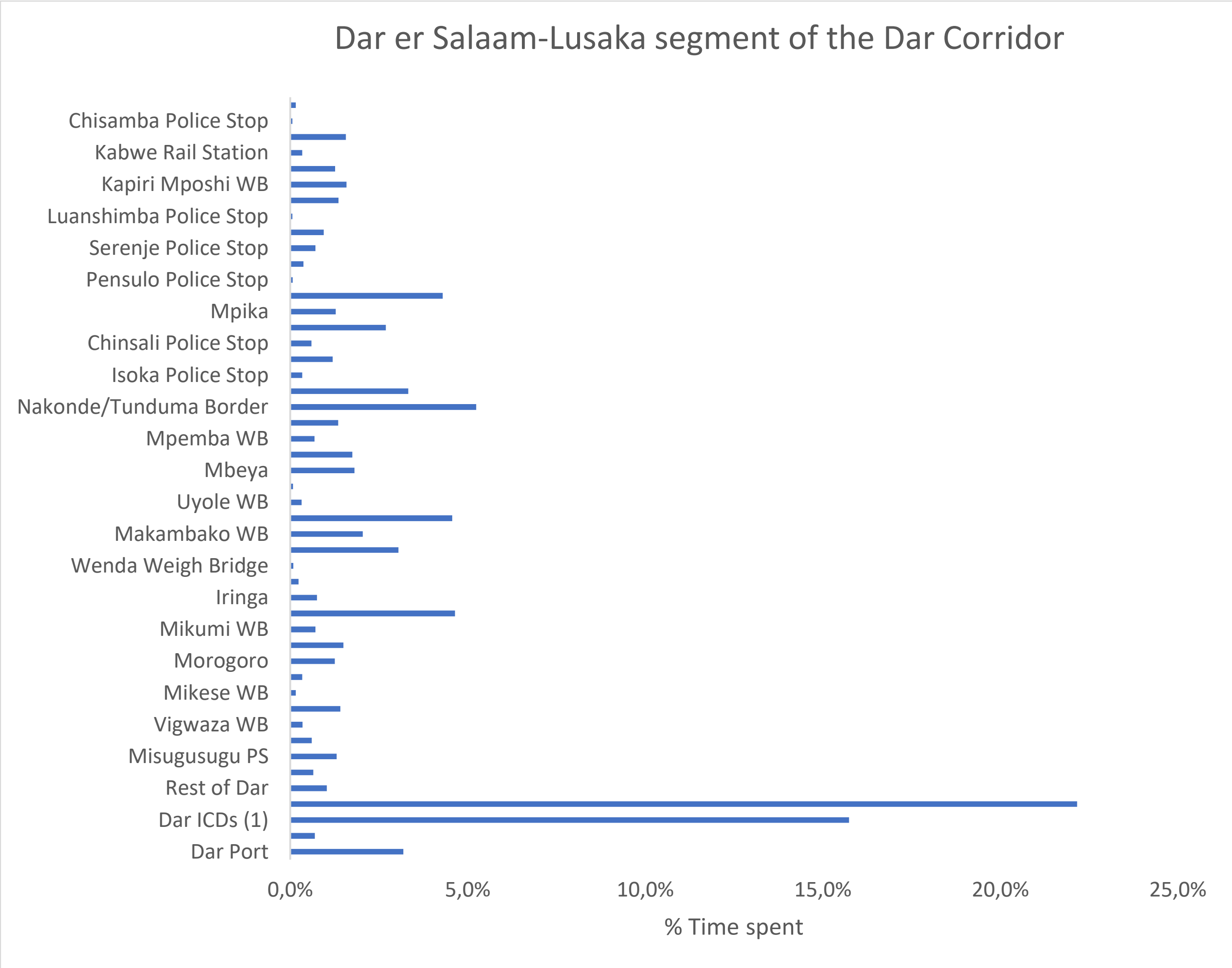

Figure 34 Percentage time spent along route Dar es Salaam-Lusaka

Table 20: Total Time in Dar Port (imported containers, average days)

Source	Terminal	Period	Process		Total (P)
			Arrival to Discharge (H)	Discharge to Truck-out (S)	
TRA/TICTS	TPA & TICTS	Apr ’14 – Mar ‘16	3,8	15	18,8
TRA/TICTS	TPA & TICTS	Apr ’14 – Mar ‘16	3,8	15,3	19,2
HPC Fig 165	TPA & TICTS	2016	3	11,3	14,3
HPC Table 90/91	TPA	Oct & Nov’16		7,5	
HPC Table 90/91	TICTS	Oct & Nov’16		10,6	
TICTS	TPA & TICTS	Sep ’17 – Jul ‘18	2,2	13,2	15,4

5.3 Beira Corridor bottlenecks

In this section bottlenecks related to physical infrastructure along the Beira Corridor are explained and discussed. Feedback obtained through the survey was used to identify those aspects justifying specific attention. The recorded low general speeds recorded, are a result of long down time incurred along the corridor as confirmed by the survey data. Figure 34 shows that much time is spent per kilometre between Inchope, Chimoio and Mutare, confirming the poor road condition on the Mozambican side and the delays at the dry port in Mutare on the Zimbabwean side as bottlenecks on the corridor. However, results indicate that at Inchope there are delays encountered, most likely because of the customs checks that are located there. In terms of the overall EN6 road, the condition of the road was a bottleneck that could have contributed to the slowness experienced due to the bad condition of the road during the time of data collection. On the Zimbabwean side, the bad condition of the road between Banket and Chirundu has a bearing on the time spent per segment. Furthermore, this section of the corridor is rugged terrain; hence vehicles travel at a slow pace.

5.3.1 Road infrastructure

The whole section of the EN6 road linking the port of Beira with Zimbabwe EN6 deteriorated due to the increase in traffic volumes following the port infrastructure upgrades. However, at the time of study several sections of the road were being rehabilitated including a section just after Inchope in Mozambique. Parallel to the old bridge (which would be renovated as part of the project) at the Pungwe River on the EN6 a new elevated bridge was being constructed as shown in Figure 35. This improvement is a very important development for the Beira Corridor as it eliminates the Pungwe flats as an obstacle during the rainy season and increase capacity to cater for the increased traffic. The completed bridge and the renovated new look of the old bridge is illustrated in Figure 36.

Figure 35 New Elevated bridge under construction over Pungwe River on the EN6

Source: Author (May 2017)

Figure 36 The renovated old bridge (left) parallel to the completed new bridge (right)

Source: Xinhua/Nie Zuguo (2019)

According to clubofmozambique.com (2020) tolls were due to be charged from 1 December on the EN6 road linking Beira, in Mozambique, to Zimbabwe. Toll charges on National Road Number Six (EN6), which connects the Mozambican port city of Beira with the border village of Machipanda on the Zimbabwe border, began in December 2019. The EN6 is one of the roads with the highest traffic levels in the country, but this level of traffic has also led to its poor state of repair. Charging tolls is intended to ensure the maintenance of the road and to reduce costs to the state in the road sector. The EN6, which is about 287 kilometres long, has been under reconstruction and enlargement work since April 2015, following a contract signed with Chinese company Anhui Foreign Economic Construction (Group) Co. Ltd. At a cost of US$410 million, financed by the China Export and Import Bank and the Mozambican government, the work was due to end on 31 March 2018 but was delayed due to lack of funds to relocate families and shops in the Inchope area. As part of this intervention, three toll booths have been built, two of which in Sofala province at Dondo and Nhamatanda with the third one in Manica at Vanduzi.

5.3.2 Rail infrastructure on the Beira-Machipanda line

Single-track-railway lines on the Mozambique–Zimbabwe route limit the capacity of the Beira corridor. With only a single-track railway, increase in freight volumes would result in congestion of the port and the road as rail fail to cope with increased volumes. The absence of electricity infrastructure, with no plans yet to electrify the Beira–Machipanda corridor, means that only diesel trains are operable on the corridor, another bottleneck that reduces the performance of the corridor. This is confirmed by the USAID, (2018) the cost per metric tonne on the road links range between $80 and $130. Currently there are speed restrictions on parts of the line as low as 10km/hour due to the poor condition of the track, which lowers service levels. The DFID (2016) report indicates that the only operational portion of the Machipanda line is the section between Beira port and Dondo.

The unavailability of rail service is clearly a major bottleneck that increases total transportation time and cost along the Beira Corridor, as the movement of bulk commodities from rail to road resulted in over usage of the road link and thus deterioration of road condition, which contributes to the slow average speeds as displayed in the graphs above.

5.4 Regulatory processes

This section explains and discusses elements of non-physical bottlenecks in terms of their impact on the performance of the Beira Corridor.

5.4.1 Governance and regulatory processes

The lack of cooperation and harmonisation of policies between countries is a bottleneck that affects the performance of the Beira Corridor. The misalignment of polices between Zimbabwe and Mozambique means that the turnaround times for cargo processing vary between the two, especially at the border post. Processing on the Mozambican side is faster than the Zimbabwean side due to the different operational structures. On the Mozambican side cargo does not stop at the border for processing, but rather farther inland, at the port. In between there are just spot checks to ensure compliance and these do not take more than five minutes. Shippers have the option of making declarations in advance or at the destination. This differs from the Zimbabwean processes, where every consignment has to be processed at Forbes Border post.

On a positive note, a change in the port governance model changed the fortunes of the Beira port, whereby it ceased to be just a feeder port to Maputo and Durban. The dredging of the port to increase drafts to more than 13m below chat datum attracted larger vessels, which used to only call at bigger ports such as Maputo and Durban. The government of Mozambique entered into a concession agreement with Dutch firm, Cornelder to run the port.

There have also been other governance improvements that improved the flow of traffic along the corridor where the single window platform was introduced to improve customs processes. The public private partnership in procuring projects has meant that the private sector provides funding for the improvement of the transport system on the Beira corridor. For instance, the construction of toll plazas on the EN6 will ensure the effective and reliable maintenance of the road through toll fees collected once the toll plazas are completed. The improvements taking place are made possible by the change of the governance structure. Before that the government of Mozambique was responsible for roads projects and the port, which led to very low levels of investment and low levels of productivity at the port leading to low levels of performance of the Beira Corridor. The GPS data results presented earlier confirm this as the speeds at some sections were extremely low resulting in long travel times to and from destinations and origins.

5.4.2 Logistics processes

The development of port physical infrastructure led to significant increases in traffic through the port of Beira, which required improved logistics processes to cope with the increased volumes. There was a significant information systems investment in the port which included the introduction of vehicle mounted computers. Furthermore, the introduction of a vessel planning system in 2018, improved productivity and the overall performance of the port leading to reduced port dwell time and turnaround time.

Equally, the introduction of an electronic Customs System allowed quick clearance also leading to improved performance of the logistics processes. The introduction of professional vessel and cargo agents also helped with ensuring fast and professional cargo handling and management. There was also improvement in trucking and rail operations. Finally, there was a marked increase in bonded warehouses and container facility terminals (CFTs) around Beira, which improved the logistics processes for the port leading to improved performance, as confirmed by the increase in cargo volumes handled by the port, discussed earlier Chapter 1. All this was a result of the capacity improvements at the port mentioned also in section 1.2. under the Beira corridor background.

5.4.3 Border crossing procedures at Forbes

Figures 36 through to 38 show the processes for clearing cargo for imports, transit and exports respectively, as described by agents interviewed in May 2017. There were four major clearing companies represented at the border post, all of whom were interviewed. The process flow for imports processing is illustrated in Figure 37 below.

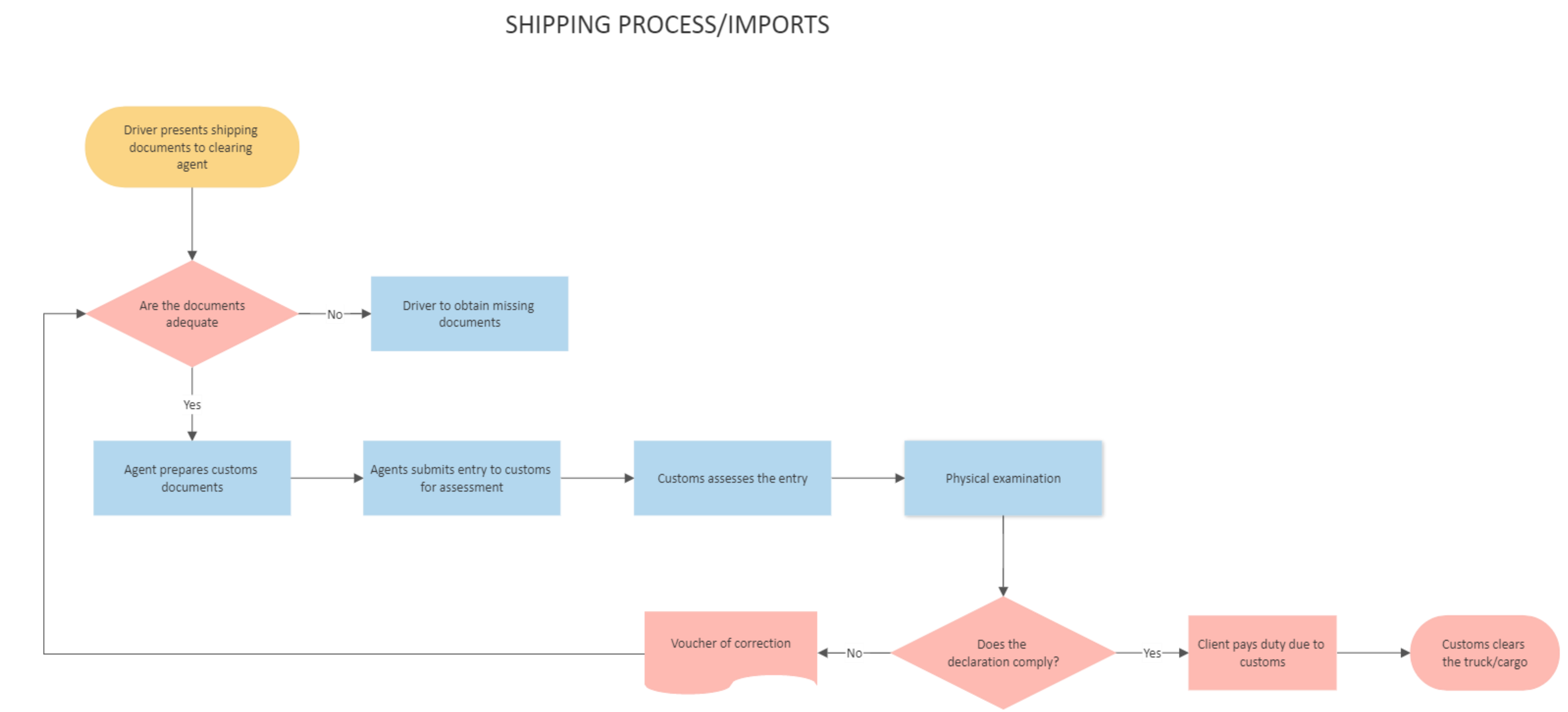

Figure 37 Imports clearing process

The process flow for clearing transit cargo is illustrated in Figure 38 Generally, transit consignments are supposed to be quicker than direct imports. However, with the inspection of transit cargo being conducted at the dry port this is no longer the case as transit trucks are taking a long time to clear due to the inspection. They sometimes spend three days or even more according to the drivers interviewed.

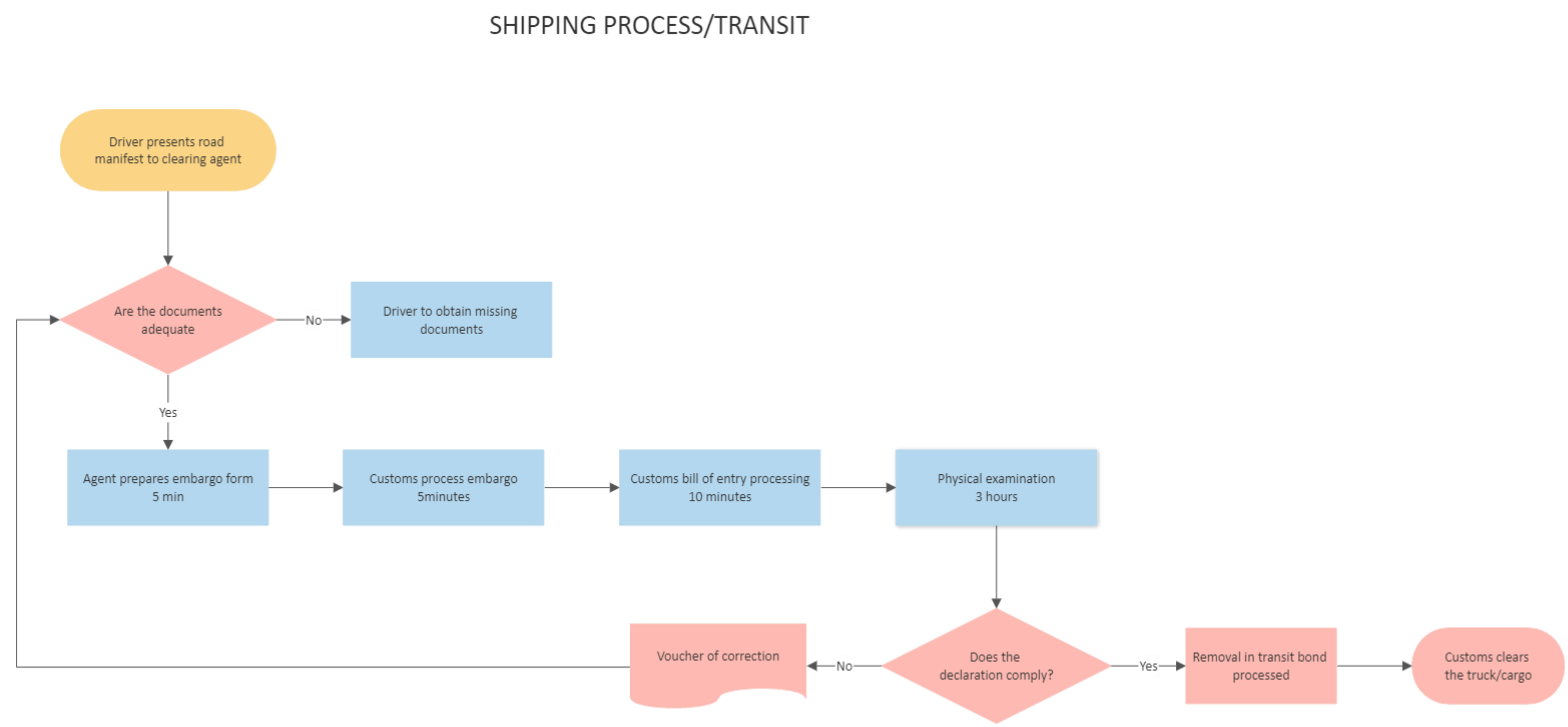

Figure 38 Transit cargo clearing process

Import cargo pays import and excise duty, hence it normally takes longer to process than other types of cargo. In some instances, even if customs have completed the assessment of the consignment, the truck and goods would not be released until the duty due is paid to customs. The export documentation process is illustrated in Figure 39 below.

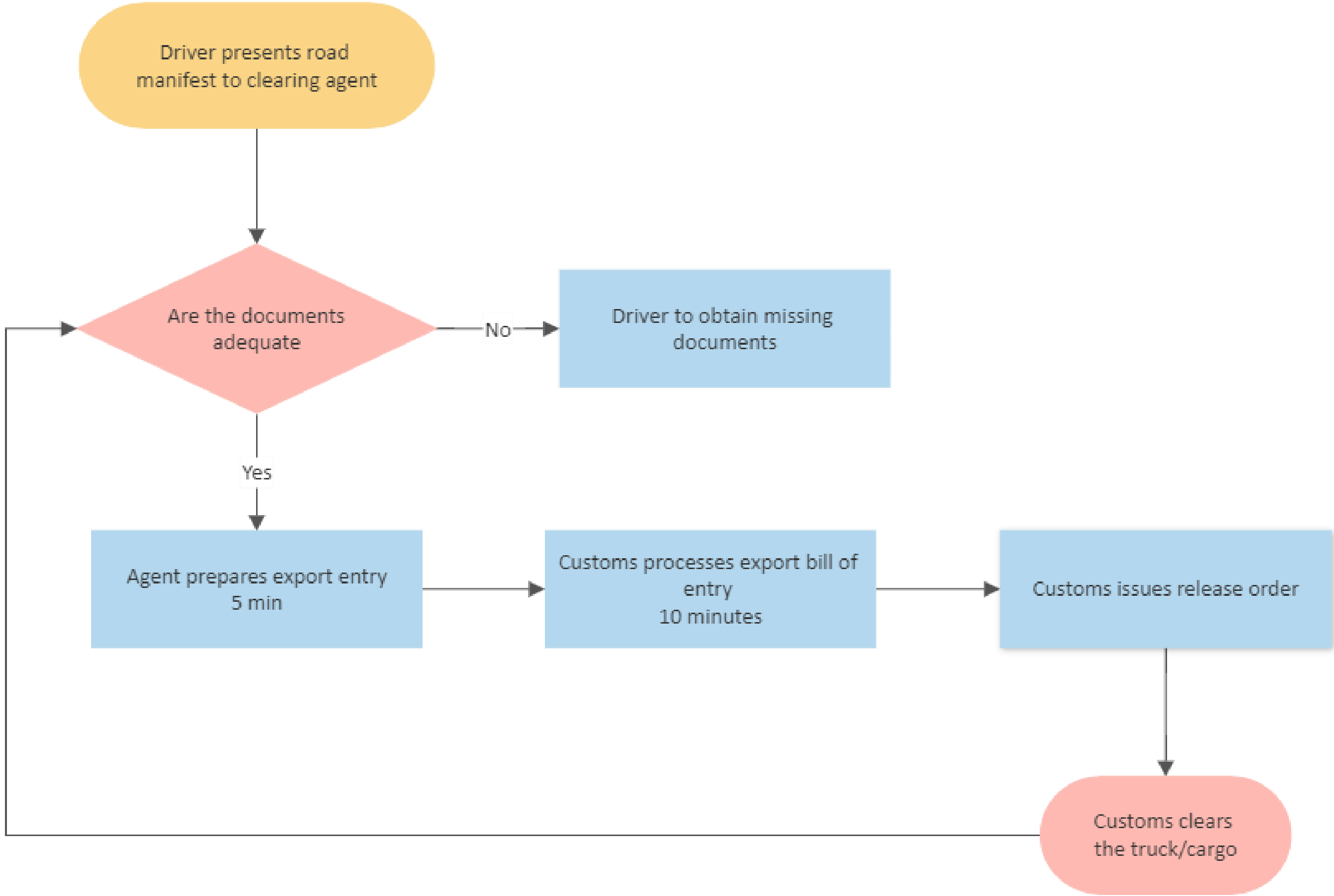

Figure 39 Export cargo clearing process

The causes and proposed remedies according to clearing agents are tabulated below in accordance with the nature of issue and cargo clearing category. During the interviews with clearing agents, some of the reasons for the delays experienced were discussed and these are Summarised in Table 21 below together with possible remedies proposed by clearing agents.

Table 21 Reasons for delays for imports processing and possible remedies

Reason for delay	Possible remedies
• Volume of traffic – determines the queue for submitting forms to ZIMRA for further processing • ZIMRA IT system- if system operates at constant rate with limited glitches ZIMRA process is completed quicker • Physical Examination- availability of ZIMRA staff, staff affected by volume of traffic- Mutare Dry Port is small • Drivers with inadequate supporting documents • Clearing fees debts. • Volume of traffic • Nature of Cargo	• Introduction of one stop border • one commodity per consignment or bulky categorising of each of the variety of goods • Expansion of Mutare Dry Port • Educate truck drivers and importer to safe keep supporting documents • Authorities carry out awareness to driver/ exporter on details/documents required for one to export goods • System updates at ZIMRA.

A few challenges were encountered by the researcher during the interviews as clearing agents' officials were sceptical due to the political activities at the time in Zimbabwe. Several clearing agents had relocated as per an order to clear the area they were operating from and the remaining ones were in the process of relocating. The reasons for relocation include sanitary facilities which were not yet constructed thus clearing agents had to downsize. This is a common phenomenon at border posts in the SADC region, where most border posts have no proper facilities for clearing agents.

ZIMRA confirmed the fact that the volume of traffic passing through the border had significantly increased but could not confirm capacity as a challenge. Before the interview, the senior official was locked in meetings with the dry port general manager and operations manager discussing the crisis that existed at the dry port. There was a serious congestion with the road to the border gridlocked. The interview was conducted with regional manager only, as the other officials were not authorised to grant the researcher an interview. Authority to obtain interviews with junior officials required permission from the head office in Harare. The process was said to take months; hence the conversation was limited to the port manager. However, the information obtained from the senior official was adequate to compare with what had been obtained from the clearing agents.

It was established that plans were under way to expand the border post and to have it designated as a stand-alone region with autonomy. Forbes border post had its entries processed either in Harare or Bulawayo depending on the system allocation because it had not been designated a processing region. This arrangement contributed to delays because Forbes had no control of the process. There was also mention of plans to extend operating hours to 24 hours. However, he cited that the clearing agents operating hours were affecting the efficiency of cargo processing as they closed earlier than customs. He agreed with clearing agents that while engagements between customs and clearing agents were taking place, they were not frequent enough to ensure constant updates and engagements to deal with issues. Overall, ZIMRA was positive about the improvement of relations between the two parties. The issue of a 24-hour document turnaround time was also confirmed. The official also said “clearing agents sometimes contribute to these delays when they make false declarations or when there are errors on the documents”. ZIMRA only verifies the declaration in terms of whether it is correct or not. If there is an error the entry is returned to the agent for correction and sometimes attracting a penalty, which may also contribute to delays in the release of trucks.

On the issues of the inspection of all trucks at the dry port, his answer was: “there has been a lot of smuggling through the border which prompted authorities to physically check all the trucks. There is also an exercise of installing electronic seals on tankers, again because of tampering with the cargo. We do not want to delay trucks as it is our business to facilitate speedy release, but we should be satisfied with the integrity of the cargo.” From this discussion it was clear that customs were aware of the need to improve the situation, but for it to do so, shippers and clearing engagements need to also play their part.

It was established that excessive security checks of cargoes, trucks, and wagons, differences in border crossing processes and turnaround times of the border control offices between Machipanda (Mozambique) and Forbes border post (Zimbabwe) added to further delay in transportation. This information was obtained from driver interviews and was corroborated by clearing agents’ officials. Table 22 summarises the responses given for stopping reasons by the drivers. For instance, 60% of the drivers gave customs check as the reason for stopping at Dondo. At Inchope the drivers cited customs checks and road works as the reason for the stop. On the Zimbabwe side at both Forbes border post and GMS all the drivers gave customs and security checks as the reason for stopping. As one official remarked “…customs officials on the Zimbabwean side of the border contribute to the delays by sometimes requiring drivers to go back to Mozambique to obtain just a stamp omitted just on one page.”

The inefficiency at the border crossing point between Machipanda (Mozambique) and Forbes (Zimbabwe), shown in Figure 40, was very visible as trucks queued for almost 5km on either side of the border post. The total time spent at the borders accounted for 25.8% on Beira–Forbes leg of corridor and 52.8% of the 252 hours between the port and the dry port, is spent at the GMS dry port. Zimbabwean customs detain trucks to conduct physical inspections on all shipments, an indication that more than 50% of the time is spent idle rather than travelling, an observation made in the USAID (2016) report as well. The delays experienced due to the physical inspection at the dry port are part of the regulatory processes bottlenecks.

Table 22: Reasons for and frequency of stoppages on sections of the corridor

Stop location	**Reason for stop**	**Frequency**
Dondo	Customs checkpoint	60%
Inchope	Customs control	100%
Inchope/Nhamatanda	Road works	80%
Forbes	Customs/Security check	100%
GMS	Customs inspections	100%
Other	Resting	60%

Figure 40 Forbes Border Post (Zimbabwe)

Source: Author (May 2017)

Figure 41 illustrates the average times spent at the three nodes, port, border posts and the dry port. All the fuel tankers were processed at Road Motor Services (RMS) where electronic seals were installed for all transit trucks carrying fuel. These trucks were released quickly due to the hazardous nature of the cargo as shown in Figure 41 below. This data was collected using a corridor performance measurement survey form. The worst bottleneck is the time spent at the dry port. When the GPS data was collected during the period 2014 – 2016, ZIMRA did not inspect all trucks at the dry port. This policy was however changed to enforce the inspection of all trucks by the time that the interviews were conducted in 2018. As a result, an average of 172.9 hours was reported according to the data collected from the survey of 100 trucks at the Mutare dry port. The bottleneck is a combination of physical infrastructure, regulatory processes as well as logistics activity capacity. The regulatory bottleneck is the long time spent by customs conducting physical examinations. The limited capacity of the dry port facility is a logistics activity issue, where there is only one facility leading to congestion and limited capacity to accommodate the huge volume of trucks subjected to physical examinations by customs. The lack of capacity is a physical infrastructure bottleneck, while the handling equipment deficiency is a physical and logistics related bottleneck.

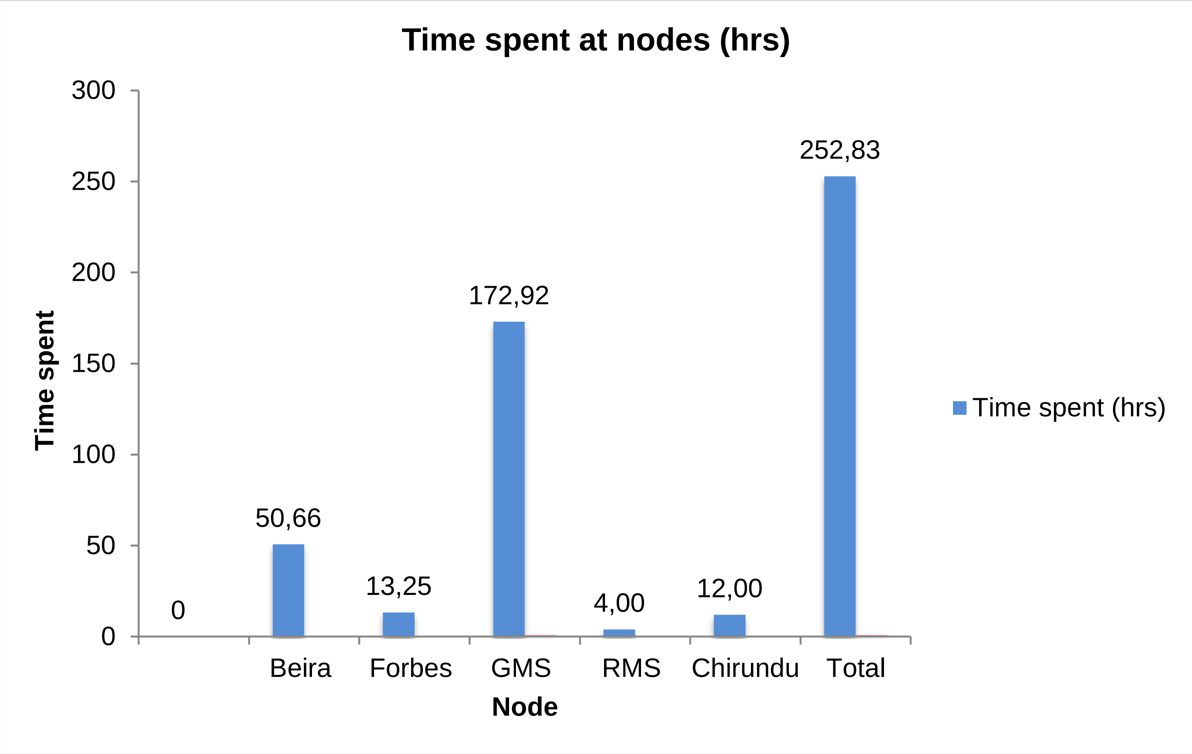

Figure 41 Time spent at notes along the corridor

Source: Survey data results

5.4.4 The contribution of the Mutare Dry Port processes to truck delays

The observations made during the interviews show the dry port as an extension of the Forbes Border Post providing ZIMRA with a physical examination facility. All vehicles issued with an embargo are referred to GMS for inspection. Table 23 and Figure 42 show the number of trucks that have been referred to the dry port from Forbes Border post for physical examinations. As indicated in the previous sector, the GMS Dry Port could play a very important role as a component of the Beira Corridor if it is integrated as an extension on the port to reduce bottlenecks in line with the theory of dry ports and inland terminals. The dry port handles a significant amount of cargo, both containerised and general cargo, passing through the port of Beira to and from the LLC of SADC. Figures 43 and 44 shows the different types of cargo handled at the dry port. Fertilizer is high volume and low value which should be transported by rail instead of by road. The consignment shown was transported by road from Beira to GMS dry port

Table 23: Number of trucks issued with an embargo for the period 2014-2021

Source: GMS Conerlder (2021) statistics records

Year	Number of Trucks
2014	28946
2015	37579
2016	36373
2017	42611
2018	41289
2019	47008
2020	59728
2021	49103

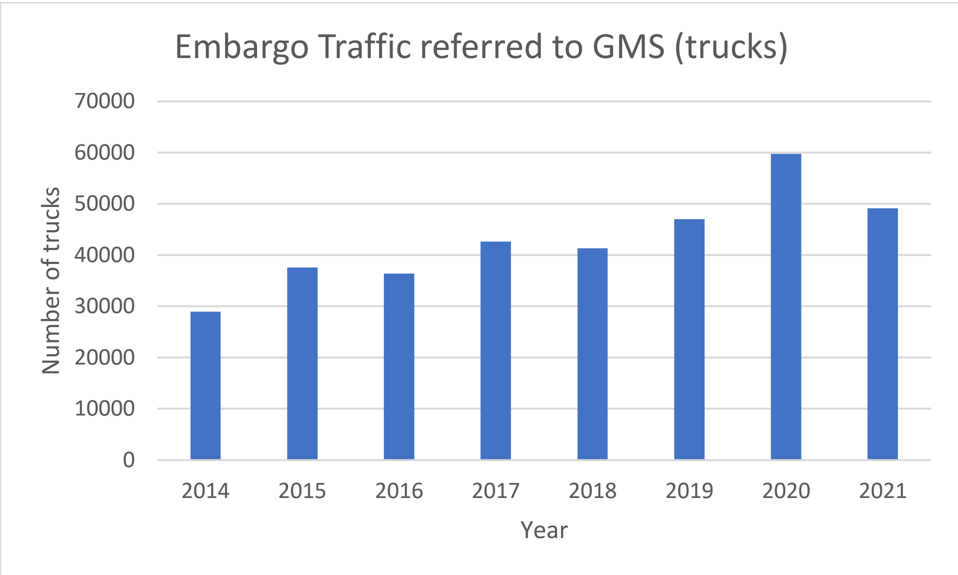

Figure 42 GMS embargo traffic for the period 2014-2021

Source: Source: Mutare Dry Port records

Figure 43 Break bulk ammonium nitrate fertilizer being stacked at the GMS dry port

Source: courtesy of GMS Management (2021)

Figure 44 A reach stacker offloading a container for inspection at GMS dry port

Source: courtesy of GMS Management (2021)

Tables 24 and Table 25 and Figures 44 and 45 shows the volumes of cargo handled at GMS for the period 2012 to 2021 for both general and containerised cargo, respectively. The volumes handled at the dry port continues to increase as shown in the two Tables, 21 and 22 and Figures, 45 and 46. The traffic volumes have been progressively increasing, however in 2015 there was a significant dip which could be explained by low economic activity in Zimbabwe and also the fact that transit consignments were not passing through the dry port for inspection.

Table 24: GMS dry port general cargo handled (MT) 2012-2021

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Jan - Oct 2021
Jan	6013	5659	3515	1	32	5681	4852	0	4783	4121
Feb	3604	3195	2644	121	120	3034	3416	0	2789	5097
Mar	6835	3826	1640	32	5	75	0	765	2855	1816
Apr	1781	1455	741	54	833	1	0	1451	9205	1472
May	853	713	939	86	901	0	6	5423	3392	247
Jun	1440	1767	655	147	262	12	10	5314	2826	545
Jul	1001	1665	1668	82	264	26	2184	3167	1324	715
Aug	1989	758	1257	180	34	2	322	2660	5685	946
Sep	3939	1569	1052	187	218	0	2077	1350	3763	3714
Oct	3481	3039	487	1444	247	83	1055	1650	8559	1259
Nov	3975	3630	1111	337	350	2586	2068	3422	5679	
Dec	4840	3687	791	156	1923	1926	449	5701	4337	
TOTAL	**39751**	**30963**	**16500**	**2827**	**5189**	**13426**	**16439**	**30903**	**55197**	**19932**

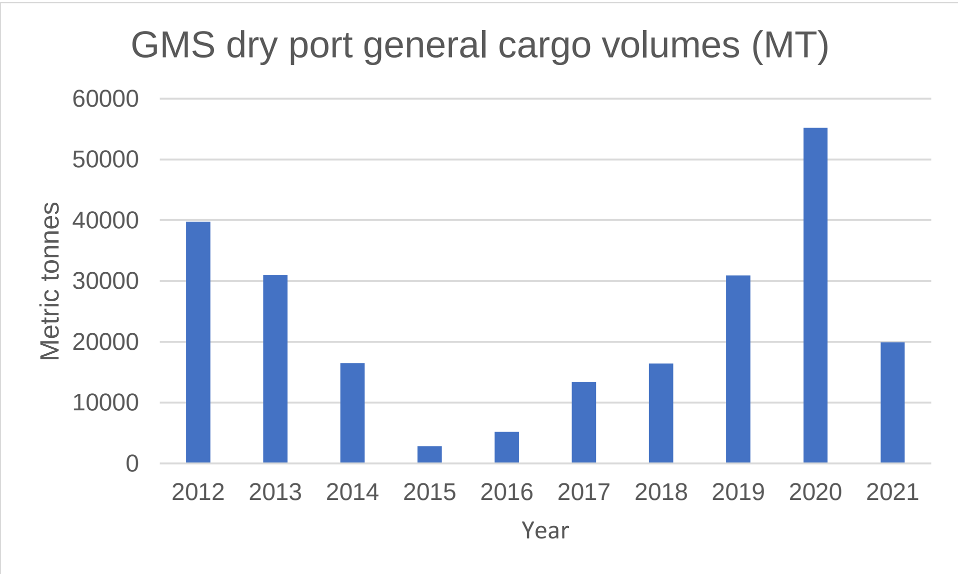

Figure 45 GMS dry port general cargo handled

Source: Mutare Dry Port records

Table 25: GMS dry port containerised cargo volumes (TEUs) – 2012-2021

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	2021
Jan	84	195	73	398	871	1560	1823	1770	1923	1817
Feb	67	108	90	469	861	1426	1799	1747	1675	1392
Mar	129	118	32	460	1044	1518	1497	1080	1497	2109
Apr	72	76	199	336	762	1299	1718	1127	1287	2142
May	62	102	258	320	1055	2103	1903	1299	1294	1438
Jun	42	236	88	600	1489	1977	1434	1141	1500	1337
Jul	148	310	17	628	939	1593	2077	1212	1168	1878
Aug	137	341	14	376	1264	2109	1891	1097	1091	1734
Sep	59	95	6	725	971	1401	1755	1207	1485	1792
Oct	124	46	33	850	1281	1921	1852	1407	1588	2005
Nov	359	26	16	898	1266	1588	2095	1456	1520	
Dec	144	65	2	956	1422	1461	2062	1517	1980	
TOTAL	**1427**	**1718**	**828**	**7016**	**13225**	**19956**	**21906**	**16060**	**18008**	17644

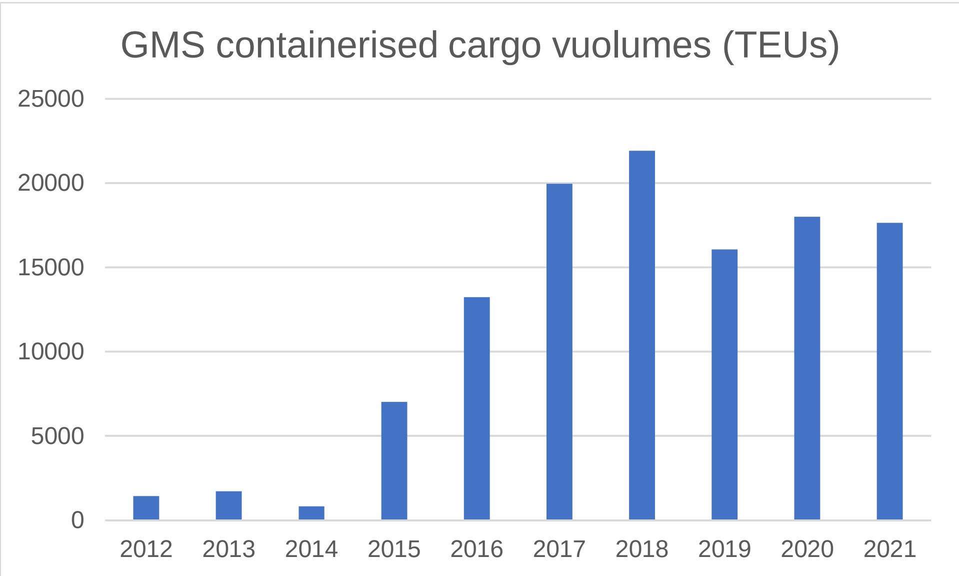

Figure 46 GMS containerised cargo handled

Source: Mutare Dry Port records

More insight into the nature of delays at the dry port is obtained by studying the histogram of delay times obtained from GPS data, as displayed in Figure 47. Both the linear and log version for the time axis are shown, to clearly show important behaviour both for short and long durations. Some trucks just drive past the dry port, either because they were not required to visit it or in the process of finding parking. A portion stays less than 10 hours, probably because their inspections are completed on the same day. Then there is a significant maximum for delay times between 10 and

30 hours, which seems to represent the typical time delay for inspection; a final batch must stay over for at least one night and are delayed by between 30 and 50 hours. The results show that the Mutare Dry Port is not currently serving the purpose for a dry port as described by the theory. Instead of lowering costs, it is adding to the delays experienced by users of the corridor.

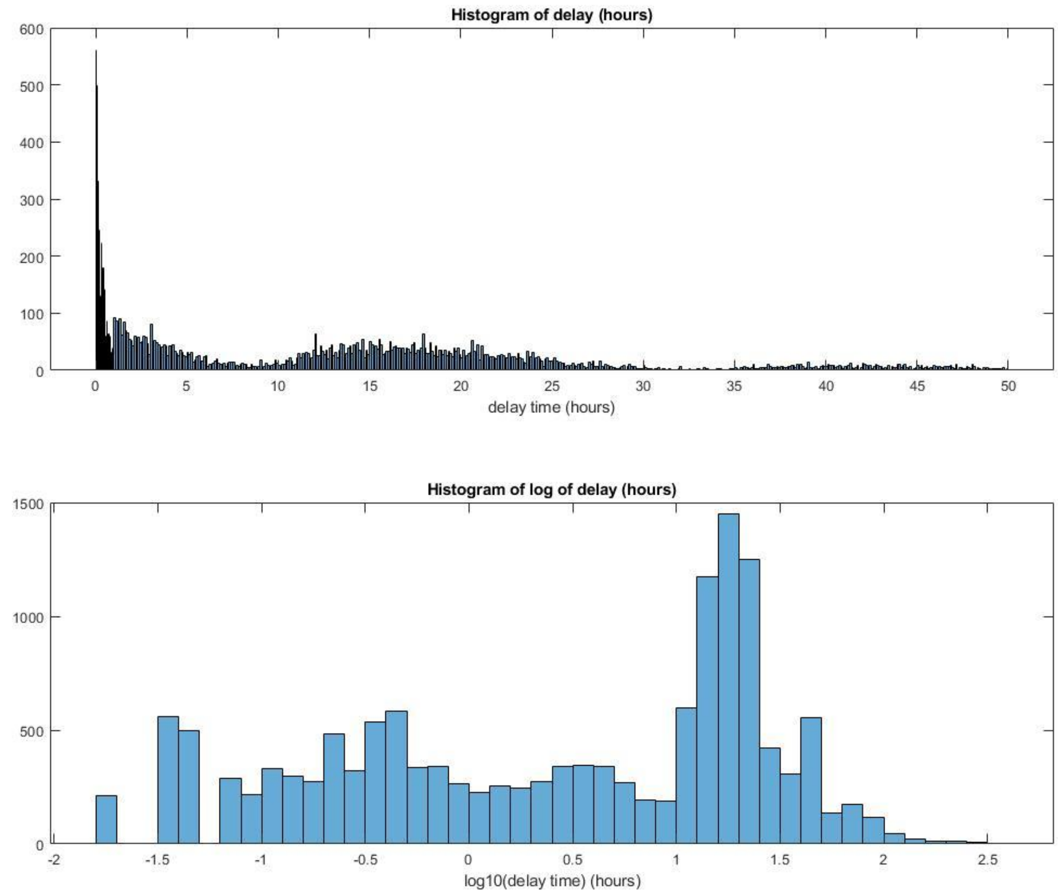

Figure 47 Histogram of time spent at GMS dry port

Data collected to assess the end-to-end route condition of the corridor revealed that there were bottlenecks with respect to route condition on the corridor. The condition of the road EN6, between Beira and its hinterland poses bottlenecks, which lead to very long transit times and very low speeds due to poor road conditions on the various sections of the corridor. An end-to-end assessment was conducted on time-distance analysis on trucks along the corridor. The results were modelled as shown in Figure 48, which shows the amount of time spent by trucks at and between nodes. The results show that trucks spent under 5 hours on average at the port, an indication that the port is less of a bottleneck from a handling point of view. However, travelling between the port and the border took on average 18 hours for just 279 km giving an average speed of 15.5 km/hr, a clear confirmation of the existence of bottlenecks on this section of the road.

The reason for the long transit times is the poor condition of the road on most sections of the 279-km stretch. This was compounded by stop-go points along the EN6 due to road rehabilitation works. The only sections that were completed include a 23-km section from Chimoio and some sections between Chimoio and Manica. It is envisaged that once the rehabilitation project is complete the transit time will be reduced significantly leading to improved performance by the road mode and the corridor. The completion of the bridge at Pungwe River will have a positive impact on the performance of road transport. Once the improvements have been completed it is estimated that there will be at least 60% reduction in travel time. This is because most of the delays on the EN6 road have been due to the bad condition of the road and the stop-go bottlenecks on bad sections of the road. The interview results from the corridor performance measurement form are plotted to model the corridor section Beira to Lusaka, incorporating the major nodes along that route as shown in Figure 48. It can be seen that the dry port contributes to significant delays on trucks, as much as 3 days. Contrary to theory, that dry ports contribute to lowering costs, the GMS dry port is currently adding to the costs incurred by users. This not only due to the delays, but also through the inspection fees, which amount to about $300 per truck.

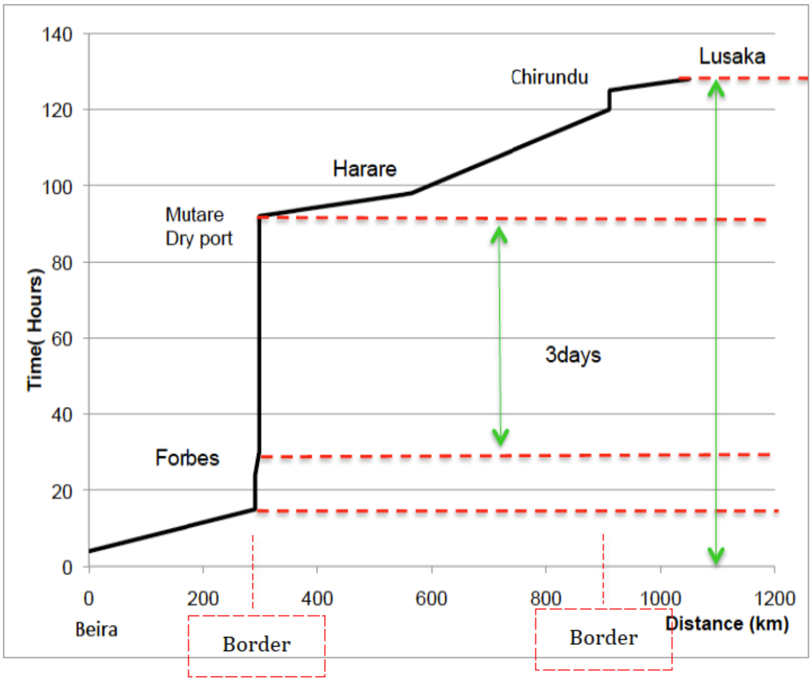

Figure 48 Time-distance graph depectiCting end-to-end analysis model

The results show a reasonable transit time from the port to Forbes/Machipanda border (flat gradient) indicating a moderate travel speed. The static perpendicular line at GMS indicates down time with the speed of 0km/h (a minimum of three days' delay). The section between Mutare and Harare has a flatter gradient signifying good road condition and faster speed compared with Harare-Chirundu section where the road is not in a good state hence steeper gradient and eventually the flatter section between Chirundu and Lusaka. However, in the GPS analysis the Chirundu-Lusaka section showed some significant delays on the contrary. This could be that at the time of the drivers' surveys the situation had improved, but it is in keeping with the earlier comment that the section of the road is in a good state.

These results support the argument of the importance of efficient hinterland connectivity for the performance of ports. Inadequate overland transport infrastructure, congested logistics networks, less sophisticated intermodal facilities and prohibitive transportation costs are the major constraints that undermined the effectiveness of the port as a key gateway to the region's international trade.
A proactive investment approach in transport infrastructure is necessary to open regional production locations and spur trade capacity. There is no doubt that many private port operators would be hesitant to invest in the region's ports, given the context within which they would have to operate and seek global competitiveness.

Compounding the port management and corridor deficiencies is the complexity of the region's politics and lack of a coordinated policy approach, although this no longer applies to Beira which was concessioned to Cornelder. Concessioning the running of the port has improved infrastructure development by the private sector, which has also established a dry port in Zimbabwe. However, the use of the GMS dry port as an extension of the port would require engagement of the two countries to establish a policy that allows such. The concession has been recently renewed for a further 25 years. Such regional policy coordination is essential, not only to keep cross-border trade and transportation channels open but also to ensure adequate and coordinated infrastructure funding along the entire corridor. It would also ensure effective cross-border transport regulation and the elimination of unnecessary bottlenecks at points such as frontier borders.

The other policy change that could assist regional transport is an integrated approach in policy implementation in order to harmonise regulatory processes across all countries involved in the corridor. The disjointedness of policies tends to affect the corridor negatively as each country does its own thing disregarding the consequences of high logistics costs due to delays at border posts and dry ports along the transport corridors. The misalignment of policies between Mozambique and Zimbabwe, for example, is affecting the overall performance of the section of the corridor between the two countries. For instance, trucks are exposed to physical checking and unloading of cargo adding to the delays. On the Mozambican side trucks are not processed at the border, they are processed inland which is why trucks do not spend time at the border post. There are also more checks on the Zimbabwe side than on the Mozambican side.

Effective regional policy coordination is also likely to achieve a more secure transport corridor as a result of member countries adopting joint and coordinated security operations. As noted, the security situation is a major issue affecting both upstream and downstream logistics and undermines trade logistics in the region. As exemplified by the piracy situation and corroborated by the experiences of inland transport service providers, there are constant security threats to transportation crews, their vessels and cargo. This was reported by truck drivers and clearing agents with respect to the Mozambican section where RENAMO had started raiding trucks on the corridor. This could not be verified with security officials but in the media, there were reports to confirm these claims.

Enhancing the port's logistical capacity and expanding inland transport infrastructure facilities, combined with the benefits of dedicated transport corridors, will create the potential for greater regional economic development. It is imperative, therefore, that all regional governments, industries and the community work out an effective, coordinated approach in planning, designing and developing an effective and internationally competitive integrated port hinterland interface.

5.5 Estimation of cost savings achievable by elimination of bottlenecks

The results from this study have identified the following three primary unresolved bottlenecks that negatively influence the performance of the Beira corridor:

1. Bad road conditions that result in slow average driving speeds and long travel times;
2. Ineffective application of law enforcement regulations, resulting in many stops along the route and long delays at ports and border posts.
3. Reduction of the dry port to an inspection facility instead of an intermodal facility where rail transport can contribute to lowering of costs on the corridor.

In order to determine the expected positive impact of the elimination of these two bottlenecks, a cost simulator was developed for road transport operations along the Beira corridor. The status quo was simulated by making assumptions about the cost to operate trucks between Beira and various destinations. In order to simplify the simulation, Lusaka was used as prototype destination, as it requires a traveling distance of more than 1000 kilometres and the crossing of two border posts to reach Lusaka from Beira (Machipanda/Forbes and Chirundu), thus clearly demonstrating the expected impact of resolving the identified bottlenecks.

In Table 23 to Table 25 below the following four scenarios are compared:

1. The status quo;
2. Improved road infrastructure that increases average trip speed while driving from 22 km/h (as calculated from actual GPS information) to 60 km/h (which has been measured on roads in good condition within the SADC region).

3. Improved regulations that reduce the number of customs and police stops en route from 16 to 2, as well as waiting time at border posts from average 22.5 hours (the average measured for the border posts under consideration) to 2 hours (which is a reasonable delay time for an efficiently operation border post).
4. A combination of both of the two above improvements.

Firstly, the number of round trips that can be completed per month for a truck operating between Beira and Lusaka was calculated, as shown in Table 26. Both bottlenecks have a very significant impact on the utilization level of road transport assets – when both bottlenecks are eliminated, the number of trips increase by more than a factor of three compared to the status quo.

Table 26: Number of round trips for Beira-Lusaka per month for different scenarios

	Status quo	Improved infrastructure	Improved regulations	Improved infr & regulations
Average distance per trip (km)	2150	2150	2150	2150
Average speed of travel (km/h)	22	60	22	60
Average number of hours driving per day	8	8	8	8
Average number of days driving per trip	12,2	4,5	12,2	4,5
Number of border crossings per trip	4	4	4	4
Average cross-border delay (hours)	22,575	2	2	2
Average cross-border delay (days)	0,94	0,08	0,08	0,08
Average total border delay per trip (days)	3,76	3,76	0,33	0,33
Average customs&police stop delay (hours)	0,5	0,5	0,5	0,5
Average customs&police stop delay (days)	0,02	0,02	0,02	0,02
Number of customs & police stops per trip	16,00	16,00	2,00	2,00
Average total customs & police stops delay per trip (days)	0,33	0,33	0,04	0,04
Average trip duration (days)	16,3	8,6	12,6	4,9
Number of trips per month	1,8	3,5	2,4	6,2

Secondly the estimated cost per round trip as well as the monthly profit per truck was calculated, as displayed in Table 27. As could be expected from the increased number of completed trips, there is a dramatic increase in profitability for both scenarios where a bottleneck is eliminated. Not only the income generated per month is improved, but also the net profit as percentage of turnover, resulting from improved asset utilisation levels.

Table 27: Monthly profit per truck operation from Beira to Lusaka for different scenarios

	Status quo	Improved infrastructure	Improved regulations	Improved infr & regulations
Monthly interest rate	1,0%	1,0%	1,0%	1,0%
No of monthly instalments	120	120	120	120
Average cost of truck	$180 000	$180 000	$180 000	$180 000
Monthly instalment	$2 582	$2 582	$2 582	$2 582
Average income per trip	$6 000	$6 000	$6 000	$6 000
Average fuel consumption (km/l)	1,5	1,5	1,5	1,5
Cost of fuel per litre	$1,40	$1,40	$1,40	$1,40
Average cost of fuel per trip	$2 007	$2 007	$2 007	$2 007
Cost of driver per month trip	$700	$700	$700	$700
Additional cross-border expenses per trip	$700	$700	$700	$700
Other costs per trip (tolls, etc.)	$180	$180	$180	$180
Total trip costs excluding financing of truck	$3 587	$3 587	$3 587	$3 587
Income per month	$11 035	$20 991	$14 296	$37 082
Costs per month	$9 179	$15 131	$11 128	$24 749
Profits per month	$1 856	$5 861	$3 168	$12 333

The cost per month is calculated using the cost parameters shown in Table 27 based on the number of trips made per month. Lastly in Table 28, the total number of trucks required to serve the port of Beira was calculated, based on the most recent information obtained for port tonnage and container volumes. As expected, the size of the required truck fleet can be significantly reduced if either or both bottlenecks can be eliminated, thus requiring a much smaller investment into trucks. If both bottlenecks are eliminated the total net profits will be approximately doubled, resulting in an increase in annual profits or about US$ 119 million – this will obviously translate into significant additional tax revenues for the fiscus of the countries linked to the corridor.

Table 28: Annual profit for truck fleet serving Beira port for different scenarios

	Status quo	Improved infrastructure	Improved regulations	Improved infr & regulations
Profit Comparison: Constant Cargo Tonnage				
Total Beira port annual tonnage	2500000	2500000	2500000	2500000
Fraction moved by road	0,90	0,90	0,90	0,90
Annual tonnage moved by truck	2250000	2250000	2250000	2250000
Average tons per truck	30	30	30	30
Number of twenty-foot container loads per annum	220000	220000	220000	220000
Estimated number of truck loads	110000	110000	110000	110000
Number of trips per truck per annum	20,14	38,31	26,09	67,67
Required size of truck fleet serving port	5 462	2 871	4 216	1 625
Investment in trucks	$983 160 000	$516 780 000	$758 880 000	$292 500 000
Annual lease purchase instalments	$117 979 200	$62 013 600	$91 065 600	$35 100 000
Total number of trips per month	10 046	10 044	10 045	10 043
Total profits per month	$10 137 708	$16 825 988	$13 355 038	$20 040 385
Increase in annual profits		$80 259 361	$38 607 954	$118 832 118

The above calculations only reflect the benefits accruing to the road transport operators serving the corridor. The multiplier effect for the entire region is expected to be much larger. Previous research has indicated that the regional economy can be expected to grow by approximately 1% for each day saved in moving cargo from port to destination or from origin to port (Djankov, 2006). In Table 25 it can be seen that the round-trip time can be reduced by more than 11 days – this provides an indication of the regional economic growth that can be expected should the Beira corridor be operated at close to optimal efficiency. In the next section, the attributes of the three corridors are discussed in terms the strengths and weaknesses of each of them. This analysis helps in the comparison of the three and to explain why the Beira corridor may not necessarily be the most preferred, despite being the shortest to Zambia in comparison to the North-South Corridor and the Dar es Salaam Corridor.

5.6 Strengths Weaknesses Opportunities & Threats (SWOT) analysis

5.6.1 Corridor 1: Beira

The Beira Corridor, as the nearest to the SADC landlocked countries is expected to attract most of the traffic for the region. However, due to a number of challenges discussed in this study, it has some weaknesses that range from lack of the right facilities, which if addressed, could see more traffic being handled on this corridor. Despite the challenges cited, the corridor still has some strengths, like the one of proximity to the cargo market. It also has several opportunities to attract additional traffic if improvements are carried out in terms of infrastructure and regulations. As shown earlier, adding missing facilities such as the handling of cars and the proper use of dry ports, would definitely make the corridor more attractive than it is under the status quo. The characteristics and features of the Beira Corridor are listed in a matrix in terms of strengths and weaknesses of the corridor compared with other two corridors. Beira port has the same catchment area as Durban port through the Beira corridor. However, it does not handle as much traffic due to historic reasons (civil war), limited capacity and the need for timely dredging at the port. Another problem that contributes to delays is poor access road to the port which causes congestion as trucks queue to collect cargo. There is need to create a staging area coordinated using ICT to relieve the congestion. All these factors have been constraints on the development of this corridor. The strengths, weaknesses, opportunities and threats for the port of Beira are listed in Table 29 below. The SWOT analysis helps to explain the issues identified earlier. It summarises the key issues affecting each corridor and also indicates the strengths of each, which seem to explain the current dynamics of traffic distribution.

Table 29: SWOT analysis of the port of Beira

Strengths, weaknesses, opportunities and threats analysis of Beira port.	
Analysis	**Description**
Strengths	- much closer proximity to SADC LLCs compared to Dar es Salaam and Durban
Opportunities	- Streamlining of processes at the port and border posts - Improvement of road infrastructure - EN6 Road improvements and new bridge on the Pungwe river - Implementation of single window platform and OSBP - Provide for Ro-Ro services - Provide for reefer services
Weaknesses	- Congestion and dwell times - Port security issues - Cannot accommodate post-Panamax and very large box carriers (VLBCs) - Poor road infrastructure - Inefficient rail system - Sedimentation requiring constant dredging - Limited draught on the access channel and berths limiting vessel sizes - Cascading effect cannot be sufficiently accommodated
Threats	- Port of Beira – alternative for uncleared cargo at Dar es Salaam port - Development of the port of Bagamoyo (Tanzania) - Port of Mombasa (Kenya) is on the same coastal line and closer to Dar es Salaam than Beira so any extra Dar traffic may go to Mombasa

5.6.2 Corridor 2: Dar es Salaam

The Dar es Salaam Corridor has been shown in this study to be the second most competitive of the three corridors. The corridor has seen several improvements, including the OSBP at Tunduma which has reduced turnaround times of trucks and reduced costs. It has both road and rail modes throughout and has seen port upgrades that have improved its capacity to handle larger vessels. It also has augmented its capacity through the implementation of inland container depots (dry ports) to cater for increased volumes. It also handles a wider range of cargo than Beira Port, such as vehicles and reefer services. It has been shown in this study that travel speeds are better than for the Beira Corridor, which could be the reason that it handles more transit traffic than Beira. The main attributes of the Dar es Salaam Corridor are illustrated in Table 25. This corridor competes directly with the Beira corridor through Dar es Salaam port. It is however mainly constrained by the limited capacity of the Dar es Salaam port (12.4 million tons). This port also serves the Central corridor, linking Rwanda, Burundi and Uganda all of which are part of the East African Community (EAC). Over 50% of imports and exports through the Dar es Salaam port is to and from the Tanzanian domestic market. The strengths, weaknesses, opportunities and threats for the port of Dar es Salaam are listed in Table 30.

Table 30: SWOT analysis of the port of Dar es Salaam

Strengths, weaknesses, opportunities and threats analysis of Beira port.	
Analysis	**Description**
Strengths	Established trading partners Ro-Ro terminal and reefer services makes Dar more competitive than Beira which does not handle cars and reefer
Opportunities	Development of dry ports Movement of bulk cargoes from the hinterland and landlocked neighbouring countries because of road and rail modes and Deepening of berths Dredging of the access channel
Weaknesses	- Congestion and dwell times compared to Durban Port security issues Limited draught on the access channel limits vessel sizes Cannot accommodate post-Panamax and VLBCs Poor road infrastructure Inefficient rail system Cascading effect cannot be sufficiently accommodated
Threats	- Port of Beira – alternative for uncleared cargo at Dar es Salaam port Development of the port of Bagamoyo (Tanzania) Port of Mombasa (Kenya)

5.6.3 Corridor 3: North-South

Of the three corridors, the North-South Corridor is the best performing and arguably the busiest of all SADC corridors. Anchored on the port of Durban, it is served by both road and rail. It is one corridor with a well-functioning dry port in the form of City Deep in Johannesburg, where it handles large volumes of cargo by rail from the port of Durban. It also has a rail service up to Lusaka and a multipurpose pipeline between Durban and Johannesburg. The North-South Corridor enjoys the majority share of transit cargo is demonstrated earlier and is the most competitive despite being the farthest from the market. The port of Durban is the busiest and caters for many shipping lines with the highest ship call frequency. The corridor has two main routes, one through Beitbridge-Chirundu, Linking DRC, Malawi and through Zimbabwe and the other one linking DRC and Zambia through Botswana via Martin's Drift-Kazungula.

Durban is the largest and most developed port in sub-Saharan Africa and has long functioned as the gateway port to Southern Africa through the North-South corridor. As such, it is not surprising to observe that it handles the largest volumes of total imports and exports of all corridors assessed. For traffic to/from LLC countries, it is the largest export port and the second largest import port. This even though Durban is father from the LLCs it serves compared to its competing ports such as Maputo, Beira, Dar es Salaam ports which serve the same LLCs. According to the 2020 PIDA study forecasts, the North-South corridor is expected to remain strong, remaining second in terms of volume for both LLC imports and exports behind the Northern corridor. Table 31 below lists the strengths weaknesses opportunities and threats for the port of Durban which serves the North-South corridor.

Table 31: SWOT analysis of Durban port

Strengths, weaknesses, opportunities and threats analysis of Beira port.	
Analysis	**Description**
Strengths	East–West trade route gives Durban a wider traffic market due to its locational advantage South–South–East trade route Biggest port – container capacity in Africa Favourable dwell time compared to other SADC ports Good port infrastructure Good port productivity
Opportunities	Durban dig-out port to expand port capacity Reduction of freight and logistics costs through improved productivity and efficiency will attract more users Support services for East Africa oil and gas reserves Growth of bulk commodities transiting along corridor Development of dry ports – Cato Ridge and City Deep Hub port to the SADC region
Weaknesses	Port congestion

	Costly port pricing Hinterland road congestion Poor utilisation of rail
Threats	Port of Bagamoyo (Tanzania) Port of Techobanine (Mozambique) Competition from other SADC corridors Economic slowdown of South Africa

5.7 Conclusion

This chapter has identified unresolved bottlenecks negatively influencing the performance of the Beira corridor, as a combination of bad roads, ineffective regulations and the inappropriate use of the dry port as an inspection facility rather than as an intermodal facility. Improving road conditions will improve speeds, leading to more trips per month thereby reducing costs. The second solution would be reduction of customs and police stops as well as reduction of waiting time reducing costs associated with delays at these stops and border posts.

It has been shown that the round-trip time can be reduced by more than 11 days, an indication of the regional economic growth that can be expected if the Beira corridor operated at close to optimal efficiency. The study findings in this chapter indicate that although the port of Beira satisfies the requirements for a corridor according to the corridor theory, it faces severe competition from Dar and NSC as a result of the upgrade of other SADC ports and their hinterland access, which cause the majority of cargo movements to shift away from Beira port due to the cited bottlenecks. This uncompetitive situation can only be addressed by reducing variability of time delays through the port as well as along road links and through border posts as explained. The SWOT analysis performed shows that Beira Corridor is the least competitive of the three corridors followed by Dar es Salaam, with the North-South Corridor being the most competitive.

The results of the end-to-end analysis which looked at speeds and time spent on various sections of the corridors confirm the superiority of the NSC followed by Dar with Beira being the least competitive. It has also been shown that the dry ports on the Dar corridor contribute to delays but not as much as GMS. The Dar ICD serve as an extension of the port unlike the GMS.

CHAPTER 6 RESULTS AND DISCUSSION

6.1 INTRODUCTION

In this Chapter the findings of this study on the Beira Corridor case study are presented and discussed. The estimated cost of the bottlenecks impacts to the users of the Beira Corridor and the results from the comparative assessment of the three corridor are discussed in detail. Firstly, the distribution of cargo by corridor in terms of truck traffic volumes crossing the various border posts is discussed. Secondly, the direct transport cost based on the outcome of the cost model calculations are discussed together with the average fraction that the direct transport cost represents of the value of the commodity and or cargo. Thirdly, the total economic model findings are discussed based on total cost model (TCM) calculations for the three corridors in terms of percentiles for time delays for the three corridors. Lastly, the analysis of commodity types and their untapped potential are also discussed in terms of their contribution to additional traffic transported along the three corridors and their implication as another aspect for comparing the Beira Corridor with the other two. The chapter concludes with a summary of the main points and conclusions drawn from the findings. The next section deals with the distribution of cargo across the three corridors competing for the same market.

6.2 Division of cargo between competing corridors

Table 322 below shows the average daily truck volumes that cross various border posts that link the 3 ports under consideration to Lusaka. As not all trucks crossing a border are destined for the same destination, in each case the fraction of transit trucks (i.e. trucks destined to leave the country into which the border leads with the same cargo) is used to determine the fraction of trucks to Lusaka.

In the case of the Dar es Salaam corridor, it is assumed that trucks crossing the Tunduma/Nakonde border post and that are not transit trucks are destined for Lusaka (or destinations beyond Lusaka like the copper belt). The number of trucks moving to Lusaka and related destinations on the other corridors are obtained by dividing the number of trucks crossing Chirundu border post between the border posts of Forbes/Machipanda (from Beira) and Beitbridge (from Durban). For Forbes/Machipanda and Beitbridge, that link the Beira and North-South corridors respectively to Zimbabwe, the fraction of traffic destined for Lusaka and destinations beyond Lusaka was determined by using the fraction of transit trucks.

Based on this approximate analysis, it can be seen that the Durban-Lusaka corridor has the largest share of traffic, in spite of being the largest distance from Lusaka. It is clear that there must be specific reasons why a majority of commercial traders give preference to Durban port that is more than twice the distance from Lusaka compared to Beira. The rest of our analysis will try to explain this observation in terms of Total Economic Cost to traders.

Table 32: Average daily truck volumes crossing various border posts that connect the 3 corridors to Lusaka

Border post/corridor	Number crossing border	Number on Beira-Lusaka corridor	Number on Durban-Lusaka corridor	Number on Dar es Salaam-Lusaka corridor
Tunduma	400		-	350
Forbes/Machipanda	423	208	-	-
Beitbridge	1000		492	-
Chirundu	700	208	492	-
Number on corridor to Lusaka	-	208	492	350
Fraction on corridor to Lusaka	-	19.8%	46.8%	33.3%

6.2 Direct transport costs

Table 33 displays the direct transport cost based on the cost model for each corridor, as well as the average fraction that direct transport cost represents of the value of the cargo itself. The Table displays the distance from each port to Lusaka, the transport charge for each corridor based on the direct transport cost model, as well as the actual transport charges obtained from various freight agents using these corridors. Beira is approximately only 50% of the distance from Lusaka compared to the other ports and should therefore be in a very strong competitive situation if all other aspects of corridor performance are identical. This is confirmed by the fact that, based on the model, direct transport cost for Beira should represent a lower fraction of average cargo value compared to the other ports.

Table 33: Road Transport Costs Parameters for Different Corridors

Cost Item	Beira	Dar es Salaam	Durban
Distance (km)	1055	1947	2149
Round trip duration (days)	14.8	17.6	19.2
Number of trips per month	2.0	1.7	1.6
Cost of driver per trip ($)	494.75	585.96	640.68
Cost of fuel per trip ($)	1,645.78	3,339.78	3,342.89
Costs per truck per month ($)	8,687.15	10,783.50	10,173.26
Transport Cost per trip ($)	4,297.97	6,318.68	6,517.80
Transport Cost Fraction for Retail	4.6%	6.7%	7.0%
Transport Cost Fraction for Manufacturing	2.3%	3.4%	3.5%
Costs charged by freight agents ($)	4000	4800	6750

It is observed that freight agents operating from Durban charge their customers at relatively higher levels for the same service, when compared to either charges produced by the cost model or actual charges from Beira or Dar es Salaam. This suggests that the Durban-Lusaka corridor is more competitive in terms of the other factors incorporated into the Total Economic Cost model. The results from the application of this model to actual time delay data will indicate if this can indeed explain the higher rates charged by operators on the Durban-Lusaka corridor.

6.3 Total Economic Cost model

The percentiles for time delays for the three corridors were calculated and for each corridor these percentiles were calculated separately, for ports, road segments and border posts, as well as for the total corridor. This allowed the study to quantify the contribution of each of these elements towards the total costs as experienced by cargo owners. These percentiles are displayed in Figure 49 below. It can be observed that for Beira and Dar es Salaam the port operations are the biggest contributor to delays, while for Durban, which is the furthest from Lusaka, road transportation represents the biggest delay. It is furthermore clear that there is a very wide spread of time delays experienced by different cargo consignments, from a few days up to more than 60 days. This confirms the importance of calculating the impact of variability in time delays on total economic costs to the cargo owner.

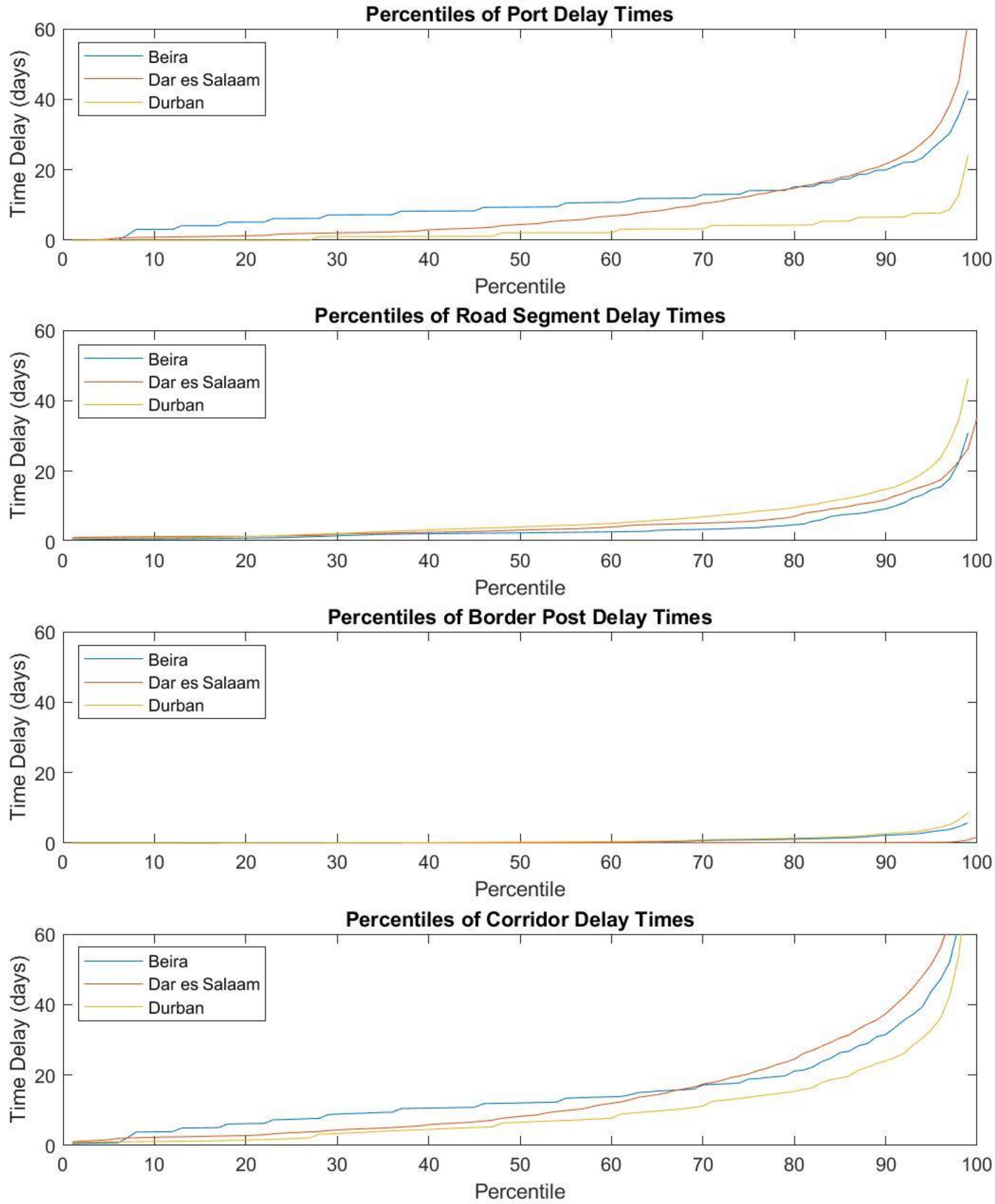

Figure 49 Percentiles of time delays for the 3 corridors and for each contributing corridor element

In Figure 50 below it can be seen how different contributions towards logistics cost vary as function of buffer stock period for both Retail and Manufacturing operations. As buffer stock period increases the cost of interest and storage costs increase, but cost of lost sales or production is reduced. Figure 51 displays how total logistics cost vary as function of buffer stock; the curves display an optimal value for buffer stock period where the total cost reaches a minimum value. The rest of the Total Economic Cost valuations were performed by using this optimal buffer stock value for each corridor and for Retail or Manufacturing operations.

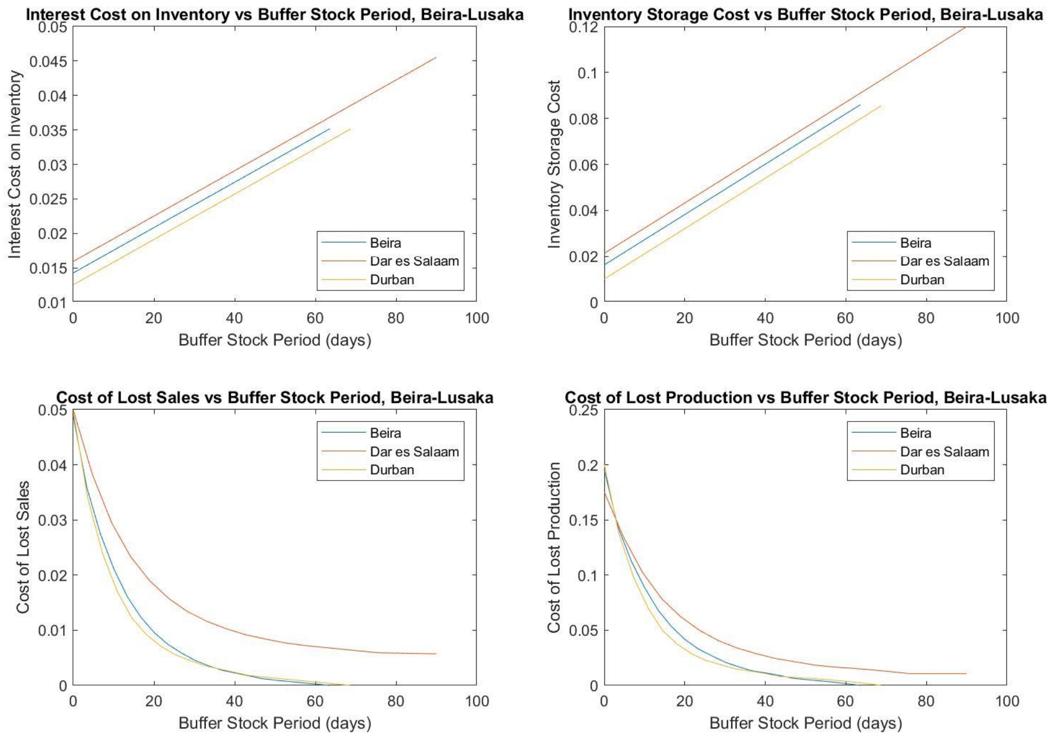

Figure 50 Contributors to cost resulting from time delay variability for three corridors to Lusaka: Beira, Dar es Salaam and Durban. Graphs on the left are for Retail and on the right for Manufacturing

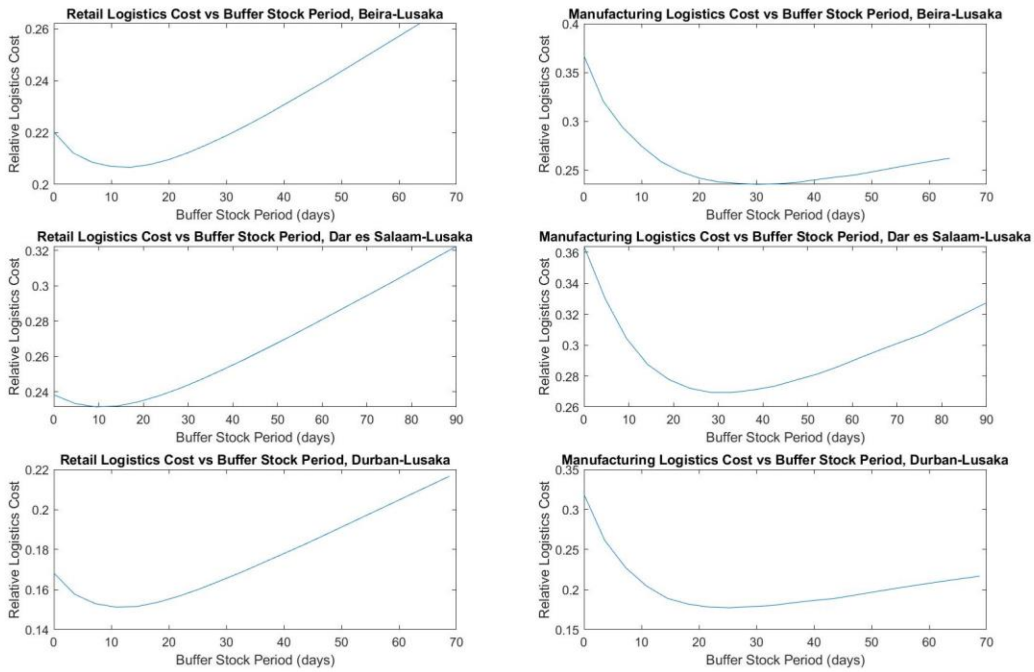

Figure 51 Total logistics costs as fraction of cost of cargo for different buffer stock periods for three corridors to Lusaka: Beira, Dar es Salaam and Durban

Table 34 below displays the different elements contributing towards Total Economic Cost from the perspective of Retailers and Manufacturers for all three corridors; a summary of these results is also displayed in Figure. Given the access to the percentiles for the individual corridor elements comprising the total corridor, it was possible repeat these calculations by taking into consideration only the time delay and variability caused by a specific corridor element. In such cases it was assumed that only one corridor element showed variable time delays, while all the other corridor elements produced their respective average time delays. This allowed the study to quantify the contribution of each separate corridor element to TEC. The steps followed in calculating the contributions to total logistics costs for the three corridors, are explained as follows:

1. To determine the TEC from the perspective of cargo owners that must select a specific corridor, a model was constructed that incorporates direct charges as from the respective port to the final destination, as well as interest costs on investment in cargo in transit, shrinkage costs, stock holding costs and of the costs suffered by the cargo owner due to disruptions in operations should cargo not arrive by the time that buffer stocks have been depleted. The calculation of the latter cost required quantifying the variability in delivery times as caused by variations in port, customs and road transport delays.
2. To quantify the time variability of moving cargo from maritime transport to final destination and vice versa, cargo turnaround time was extracted from actual ports data and from GPS tracking data collected from fleets of trucks using the respective corridors to transport cargo from each port to Lusaka. The time delays were divided into waypoints where specific processing actions occurred, like ports and border posts, as well as road links between these waypoints. Trip level data was used to calculate the statistics of delay times per individual waypoint and road link, as well as for the total corridor. This allowed for the calculation of not only the contribution of the corridor as a whole, but also of each corridor element, more specifically ports, border posts and road links. These results enabled the study to identify which of the factors forming part of corridor performance had the biggest impact on costs as experienced by cargo owners.
3. The costs to the cargo owner resulting from variability in delivery times will obviously be impacted by the buffer stock policy implemented by the cargo owner. To obtain realistic cost figures, it was assumed that the cargo owner is rational in terms of minimising total costs, and that buffer stock levels are optimised to minimize total costs. Higher buffer stock levels result in higher interest charges and higher stock holding costs but would reduce losses due to disrupted operations, and vice versa for lower buffer stock levels. Therefore, the total costs were calculated for a wide spectrum of buffer stock periods (the period that buffer stock would last before it is depleted should there be no new stock deliveries) and used the buffer stock periods that coincide with the lowest total costs. Higher variability in transport and logistics

delays result in policies that use higher buffer stock levels, and therefore also higher total costs, compared to a scenario where the variability in time delays is smaller. Since the optimal buffer stock level is in each case determined based on actual historical corridor time delays, it can be accepted that the calculated costs reflect the true impact of corridor operations on costs and the resulting decisions of rational corridor users that try to minimize their costs.

It is this three-step approach that produced the results shown in Table 34 below. The calculation shows that while Beira corridor has the lowest direct transport cost, the cost of total variability of corridor time delays is much higher for Beira compared to Durban. As a result, the Total Economic Cost of transport and logistics between port and destination is higher for Beira than for Durban. This at least partly explains why Durban enjoys the highest share of this market despite being the longest distance from Lusaka.

When the contributions towards costs resulting from variability of delay times are broken down, it is observed that it is mainly the high variability in port delay times that causes both Beira and Dar es Salaam to suffer from higher Total Economic Costs compared to Durban. While border posts and road links also play a role, it is not of the same magnitude as port delays. This result is similar for both Retailers and Manufacturers. The fact that Dar es Salaam port enjoys a higher fraction of trade than Beira corridor, despite having a higher Total Economic Cost, can possibly be attributed to the fact that it has more regular visits from vessels compared to Beira port.

Table 34: Road Transport Costs as Fraction of Value of Cargo for Different Corridors

Retail	**Beira**	**Dar es Salaam**	**Durban**
Transport Cost	4.6%	6.7%	7.0%
Port Variability	14.9%	16.6%	5.3%
Border Post Variability	2.5%	1.4%	2.8%
Road Segments Variability	7.4%	8.8%	10.5%
Total Variability Impact	20.7%	23.1%	15.1%
Total Cost	25.2%	29.9%	22.1%
Manufacturing	**Beira**	**Dar es Salaam**	**Durban**
Transport Cost	2.3%	3.4%	3.5%
Port Variability	16.6%	19.3%	6.4%
Border Post Variability	2.8%	1.5%	3.2%

Road Segments Variability	8.8%	10.3%	12.6%
Total Variability	23.5%	26.9%	17.7%
Total Cost	25.8%	30.3%	21.2%

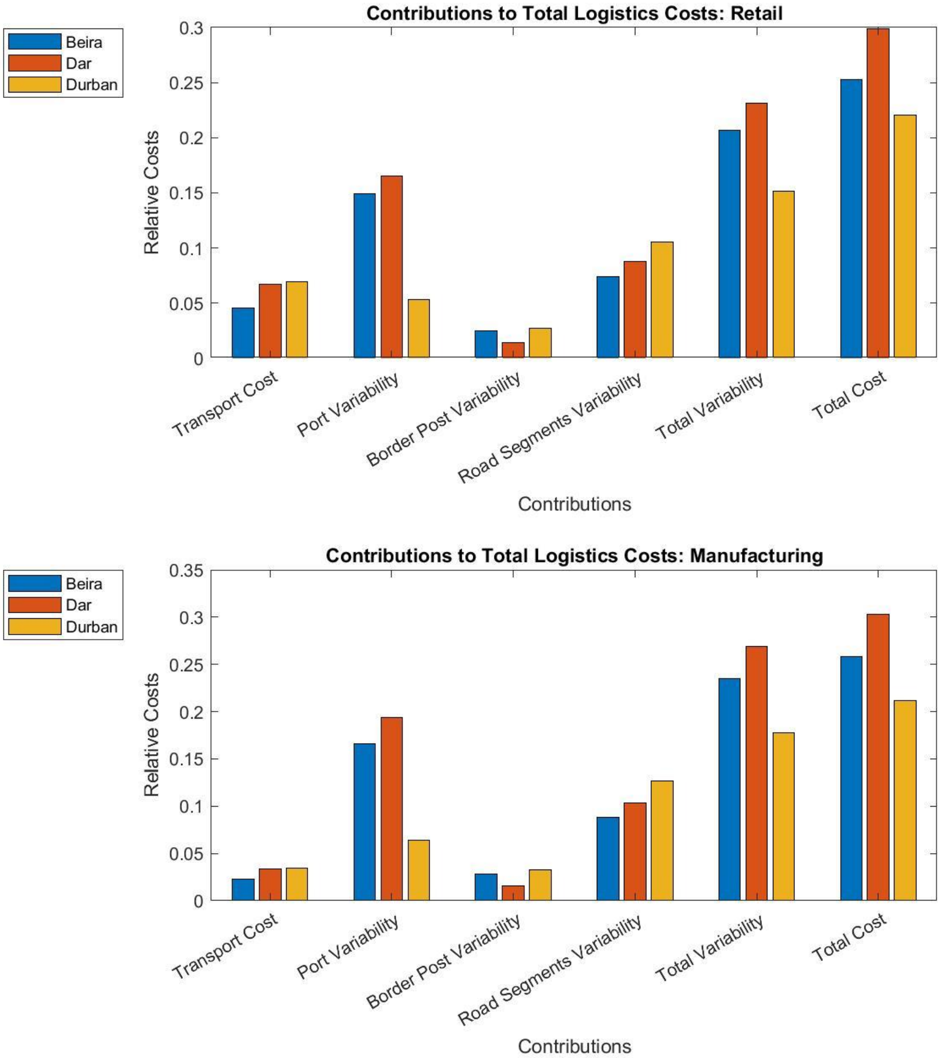

Figure 52 Contributions of delay time variability to Total Logistics Costs for three corridors to Lusaka: Beira, Dar es Salaam and Durban

In actual reality the cost parameters displayed in Table 33 will not be the same for all retail and manufacturing operations. To test the sensitivity of our results for these parameter values, the cost calculations for a spread of values for each of these parameters were repeated. Some of these results are displayed in Figure 53 (varying inventory costs) and Figure 54 (varying component cost as fraction of total cost). While these parameters have a significant impact on total logistics cost, the behaviour for each corridor is similar across the range of values, and the ranking of relative cost remains the same for all three corridors over the entire range of values. Similar results were obtained for all the other cost parameters but are not displayed here due to lack of space. It can therefore be stated with a sufficient level of certainty that the comparative results for the corridors will not be different if a different set of cost parameter values were used.

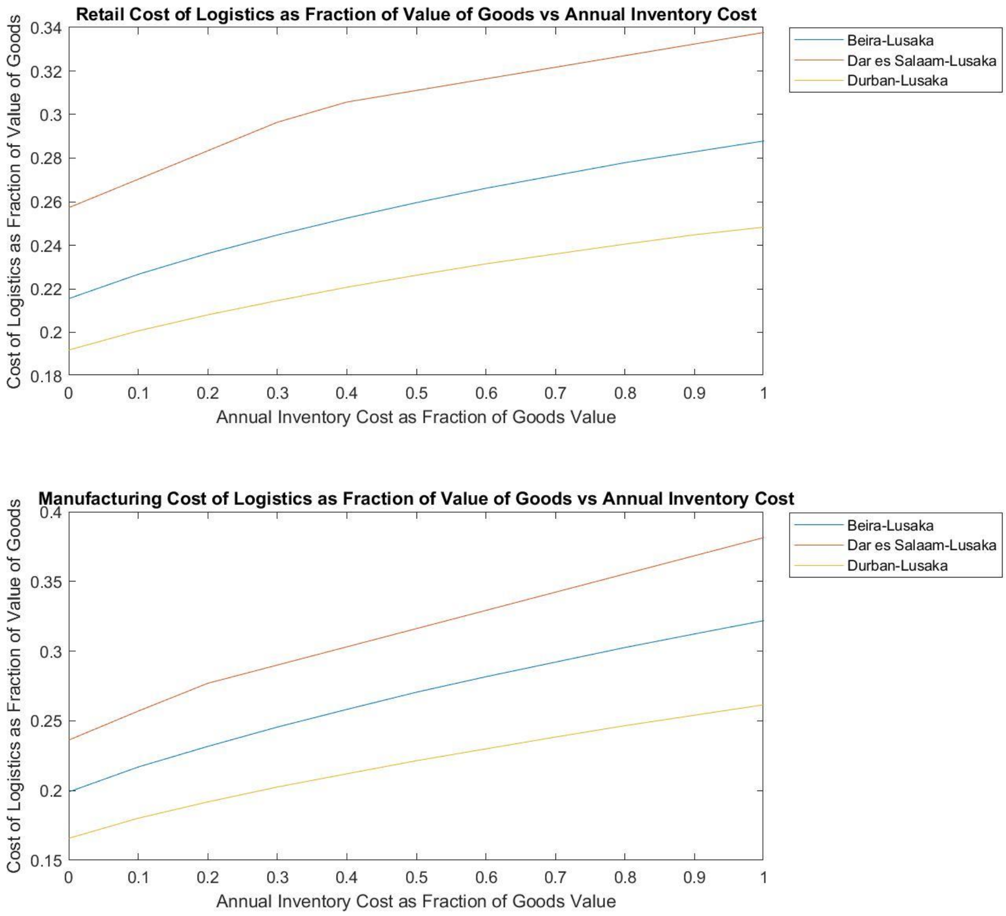

Figure 53 Logistics cost as fraction of value of goods for different values of annual inventory costs

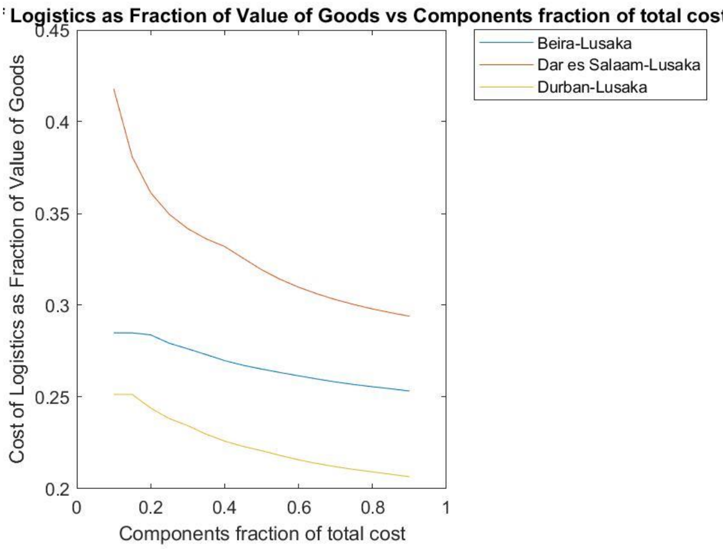

Figure 54 Logistics cost as fraction of cost of cargo for different values of component cost as fraction of total cost

6.4 Product type untapped export/import potential analysis

The product export potentials for the four countries were analysed to determine the main products transported along the three corridors (International Trade Centre, 2021). This allowed the study to quantify the total volumes generated by the four countries in terms of volume of traffic for both imports and exports potential. The untapped potentials for all major commodities for the four countries were consolidated in order to calculate the total volumes per each product type converted to number of trucks and TEUs.The products with significant untapped potential are shown in Tables 32 to 39 for Zambia, Zimbabwe, DRC and Malawi, respectively.

It can be observed that there are products that feature in more than one country in terms of untapped export potential. For exports these include, unrefined copper, copper cathodes, cobalt, raw sugar, black tea, cotton and wood and nuts. These were added together to determine the total volumes from all the four countries and used in the calculation to estimate the number of trucks or TEUs. The same applied to imports with products that appeared in more than one country such as motor vehicles, heavy duty trucks, insecticides and diesel trucks <=5t. The results from the Export Potential Maps for the four countries' major products are shown in Tables 32 to Table 39.

6.4.1 Zambia exports/imports potential

Table 35 below shows that the products with greatest export potential from Zambia comprise un-refined copper, copper cathodes and cobalt. Apart from these three products, it is shown that products such as wood, maize, raw sugar and cotton also have a significant potential for exports.

Table 35: Annual exports untapped potential for Zambia

Product	Actual exports (US$)	Export potential	Untapped potential
Unrefined copper	$4, 200, 000, 000	$5, 800, 000, 000	$2, 000, 000, 000
Copper cathodes	$1, 700, 000, 000	$2, 600, 000, 000	$1, 100, 000, 000
Cobalt products	$85, 700 000	$162, 700 000	$93, 900, 000
Wood in the rough	$65, 700, 000	$107, 600, 000	$45, 500, 000
Maize	$57, 200, 000	$80, 700 000	$49, 300 000
Raw cane sugar	$27, 900, 000	$71, 500, 000	$52, 400, 000
Cotton not carded	$52, 200, 000	$71, 000, 000	$37, 500, 000

Data Source: International Trade Centre, (2021).

Unrefined copper shows the largest absolute difference between potential and actual exports in value terms, leaving room to realise additional exports worth $2.0 billion. This is a product that was also among the products that was recorded as being shipped through the Beira Corridor from the product origin and destination observations in the interviews conducted in May 2017.

Table 36below presents major commodities imported from the World to Zambia.

Table 36: Annual imports untapped potential for Zambia

Product	Actual imports	Import potential	Untapped potential
Medicaments for retail	$127, 500, 000	$199, 200, 000	$108, 600, 000
Fish nes/whole, frozen	$89, 200, 000	$165, 000, 000	$78, 800, 000
Telephone & related	$128, 800, 000	$158, 400, 000	$73, 500, 000
Parts of machinery	$93, 100, 000	$116, 700, 000	$58, 400, 000
Motor vehicles	$87, 600, 000	$106, 200, 000	$53, 800, 000
Chemical fertilisers	$76, 100, 000	$104, 800, 000	$50, 800, 000
Heavy duty trucks	$69, 700, 000	$87, 700, 000	$60, 900, 000
Insecticides & similar	$60, 800, 000	$87, 600, 000	$45, 200, 000
Diesel trucks <=5t	$70, 500, 000	$87, 000, 000	$29, 400, 000

Data Source: International Trade Centre, (2021).

The products with greatest export potential from World to Zambia are medicaments consisting of mixed or unmixed products, for retail sale, Fish nes, whole, frozen, and Telephone sets & other voice/image transmission apparatus. According to the results, medicaments consisting of mixed or unmixed products, for retail sale shows the largest absolute difference between potential and actual exports in value terms, leaving room for additional exports worth $108.6 million. Other products with substantial potential include telephone products, fish nes, vehicles and fertilizers. The commodity with the least potential from the nine, is diesel trucks <5t.

6.4.2 Zimbabwe export/import potential

In Table 37, major export products from Zimbabwe to the rest of the World are listed.

Table 37: Annual exports untapped potential for Zimbabwe

Product	Actual exports (US$)	Export potential	Untapped potential
Ferro-chromium	$200, 600, 000	$332, 000, 000	$53, 000, 000
Raw cane sugar	$50, 700, 000	$79, 500, 000	$46, 400, 000
Oranges fresh/dried	$32, 500 000	$34, 400 000	$18, 300, 000
Cotton not carded	$41, 300, 000	$30, 700, 000	$3, 100, 000
Nuts	$12, 400, 000	$20, 100 000	$11, 000 000
Black tea	$23, 800, 000	$19, 600, 000	$6, 700, 000

Data Source: International Trade Centre, (2021).

The results indicate that products with greatest export potential from Zimbabwe to World include Ferro-chromium, raw cane sugar, and Oranges. Ferro-chromium shows the largest absolute difference between potential and actual exports in value terms, with room to realise additional exports amounting to $53.3 million.

In terms of import potential for Zimbabwe, the major products are listed in Table 35 below.

Table 38: Annual imports untapped potential for Zimbabwe

Product	**Actual imports**	**Import potential**	**Untapped potential**
Medicaments	$115, 100, 000	$175, 500, 000	$96, 400, 000
Motor vehicles	$83, 500, 000	$105, 600, 000	$42, 800, 000
Maize	$75, 700, 000	$100, 500, 000	$56, 000, 000
Insecticides & similar	$70, 100, 000	$98, 600, 000	$36, 700, 000
Telephone & other	$73, 100, 000	$90, 600, 000	$32, 700, 000
Diesel trucks <=5t	$69, 400, 000	$82, 200, 000	$40, 400, 000
Heavy duty trucks	$37, 800, 000	$48, 500, 000	$24, 600, 000

Data Source: International Trade Centre, (2021).

The results in Table 38 above show that products with greatest export potential from World to Zimbabwe are medicaments consisting of mixed or unmixed products, for retail sale, and Motor vehicles for the transport of people. Medicaments consisting of mixed or unmixed products, for retail sale shows the largest absolute difference between potential and actual exports in value terms, leaving room to realise additional exports worth $96.4 million.

6.4.3 DRC export/import potential

Table 39 below on the other hand show the results for export potential for DRC major products.

Table 39: Annual exports untapped potential for DRC

Product	Actual exports (US$)	Export potential	Untapped potential
Copper cathodes	$3, 400, 000, 000	$5, 900, 000, 000	$2, 700, 000, 000
Cobalt mattes	$2, 100, 700, 000	$3, 800, 000, 000	$1, 700, 000, 000
Unrefined copper	$249, 100 000	$511, 800 000	$288, 200, 000
Wood in the rough	$41, 800, 000	$64, 300 000	$36, 600 000
Peroxo/carbonates	$39, 900, 000	$73, 500, 000	$33, 600, 000
Coffee not roasted	$18, 400, 000	$20, 600, 000	$12, 800, 000

Data Source: International Trade Centre, (2021).

Results in Table 36 show that the products with greatest export potential from Congo, Democratic Republic include copper cathodes, cobalt mattes & intermediate products; cobalt and unrefined copper. Copper cathodes show the largest absolute difference between potential and actual exports in value terms, leaving room for additional exports amounting to $2.7 billion.

In terms of imports to DRC the results are shown in Table 40 below.

Table 40: Annual imports untapped potential for DRC

Product	Actual imports	Import potential	Untapped potential
Medicaments	$263, 700, 000	$499, 900, 000	$315, 600, 000
Motor cycles	$76, 800, 000	$130, 000, 000	$60, 600, 000
Structures & parts	$72, 100, 000	$124, 100, 000	$69, 900, 000
Motor vehicles	$69, 400, 000	$123, 300, 000	$83, 600, 000
Fish nes, whole,frozen	$87, 700, 000	$112, 700, 000	$40, 900, 000
Parts of machinery	$64, 400, 000	$103, 100, 000	$47, 400, 000
Telephone sets	$57, 900, 000	$100, 900, 000	$58, 200, 000

Data Source: International Trade Centre, (2021).

Table 40 shows products with greatest export potential from World to Congo, Democratic Republic as Medicaments consisting of mixed or unmixed products, for retail sale, and motorcycles, piston engine >50cm3 but <=250cm3. Clearly, medicaments consisting of mixed or unmixed products, for retail sale show the largest absolute difference between potential and actual exports in value terms, leaving room for additional exports worth $315.6 million.

6.4.4 Malawi export/import potential

Lastly, Malawi results on export and import potential are presented in Table 41 below.

Table 41: Annual exports untapped potential for Malawi

Product	Actual exports (US$)	Export potential	Untapped potential
Raw cane sugar	$56, 200, 000	$108, 500, 000	$66, 600, 000
Black tea, packs >3kg	$81, 500, 000	$89, 100, 000	$27, 800, 000
Oilcake of soya-bean	$24, 100 000	$59, 900 000	$34, 900, 000
Groundnuts	$23, 000, 000	$46, 400 000	$28, 400 000
Nuts nes	$25, 600, 000	$44, 100, 000	$24, 400, 000
Legumes nes dried	$15, 700, 000	$26, 800, 000	$12, 300, 000
Sacks of polyethylene	$3, 800, 000	$20, 300, 000	$16, 500, 000

Data Source: International Trade Centre, (2021).

Table41 shows products with greatest export potential from Malawi to comprise raw cane sugar, black tea and oilcake of soya-bean oil. Of these products, raw cane sugar shows the largest absolute difference between potential and actual exports in value terms, leaving room to for additional exports worth $66.6 million to be realised.

The results for import products potential for Malawi are listed in Table 42 below.

Table 42: Annual imports untapped potential for Malawi

Product	Actual imports	Import potential	Untapped potential
Medicaments	$96, 500, 000	$181, 800, 000	$91, 500, 000
Human & animal blood	$29, 600, 000	$55, 900, 000	$32, 800, 000
Telephone & other app	$54, 600, 000	$55, 600, 000	$30, 800, 000
Motor vehicles	$25, 000, 000	$41, 800, 000	$22, 800, 000
Wheat & meslin	$25, 300, 000	$40, 400, 000	$19, 700, 000
Parts of machinery	$64, 400, 000	$103, 100, 000	$47, 400, 000
Diagnostic/lab reagents	$21, 300, 000	$40, 400, 000	$27, 100, 000
Insecticides	$19, 000, 000	$34, 800, 000	$16, 600, 000
Diesel trucks <=5t	$16, 800, 000	$29, 500, 000	$15, 100, 000

Data Source: International Trade Centre, (2021).

Table 42 shows that products with greatest export potential imports to Malawi comprise medicaments consisting of mixed or unmixed products, for retail sale, and Telephone sets & other voice/image transmission apparatus. Clearly medicaments consisting of mixed or unmixed products, for retail sale shows the largest absolute difference between potential and actual exports in value terms, with room for additional exports worth $91.5 million. According to the results, Malawi has the least export and or import potential of the four landlocked countries under study, which suggests that most of the traffic is likely to come from, DRC, Zambia and Zimbabwe

It can be seen that the main product types transported along corridors, are mainly mining and agricultural commodities for exports, while for imports it is mainly medicines, grain, machinery and vehicles. Each of these products have specific requirements that may affect the performance of the corridor based on the needs of the respective import/export industries. For instance, fresh commodities like fruits, dairy products and vegetables require faster processing to eliminate damage to goods. In terms of port facilities, these require reefer services and also frequent ship calls to avoid damage and quality loss. Equally vehicles are carried in specialised vessels, RO-ROs that require dedicated customised berths. This analysis is also considered in terms of comparison between Beira and other corridors. Beira currently does not accommodate RO-RO vessels and did not have reefer facilities at the time of this study. In the next section commodity volumes are estimated using the ICT product export/import potential results discussed above.

6.5 Estimation of commodity volumes transported along the corridors

In this section, the commodity estimates for untapped potentials for both exports and imports are presented and discussed respectively. Table 43 shows the combined untapped export potentials for common products for each country as shown above, added together in order to estimate the number of trucks or twenty-foot equivalent units (TEUs). The results of the calculation are presented and discussed in this section.

Table 43: Combined-commodities' annual export potential for the four LLCs

Commodity	Actual exports	Export potential	Untapped potential
Ferro Chrome	$200 600 000	$ 332 000 000	$ 53 000 000
Cobalt	$ 2 186 400 000	$ 3 962 700 000	$ 1 793 900 000
Unrefined copper	$ 4 449 100 000	$ 6 311 800 000	$ 2 288 200 000
Copper cathodes	$ 5 100 000 000	$ 8 500 000 000	$ 3 800 000 000
Raw sugar	$ 134 800 000	$ 259 500 000	$ 126 600 000
Black tea	$ 105 300 000	$ 108 700 000	$ 1 706 700 000
Wood in rough	$ 107 500 000	$ 171 900 000	$ 82 100 000
Maize	$ 57 200 000	$ 80 700 000	$ 49 300 000
Cotton	$ 93 500 000	$ 101 700 000	$ 40 600 000
Soya-bean	$ 24 100 000	$ 59 900 000	$ 34 900 000
Nuts	$ 61 000 000	$ 110 600 000	$ 63 800 000
Oranges	$ 32 500 000	$ 34 400 000	$ 18 300 000

Data Source: International Trade Centre, (2021).

The figures in the fourth column of the Table represent the total value of the untapped potential for DRC, Malawi, Zambia and Zimbabwe for the shown products. The untapped potential value for cobalt, unrefined copper and copper cathodes is the sum of the untapped potentials for both DRC and Zambia. The same applies to black tea for Malawi and Zimbabwe as well as raw sugar for Malawi, Zambia and Zimbabwe. The values per tonne according to (Anon., 2021) of each commodity of the total untapped potential for the four landlocked countries are shown in Figure 44 below These figures have been used to calculate the volumes estimates for each product in order to determine possible number of trucks and or TEUs transported along the corridors. Figure 55 and Table 45 below presents exports volume estimates in terms of number of truck loads and TEUs. Table 46 shows the daily estimates obtained by dividing the annual truckloads estimates by 365 days. The current ratios of 20%, 47% and 33% for Beira, North-South and Dar es Salaam respectively were used to distribute volumes by corridor. These translate to 52, 123 and 86 truckloads respectively.

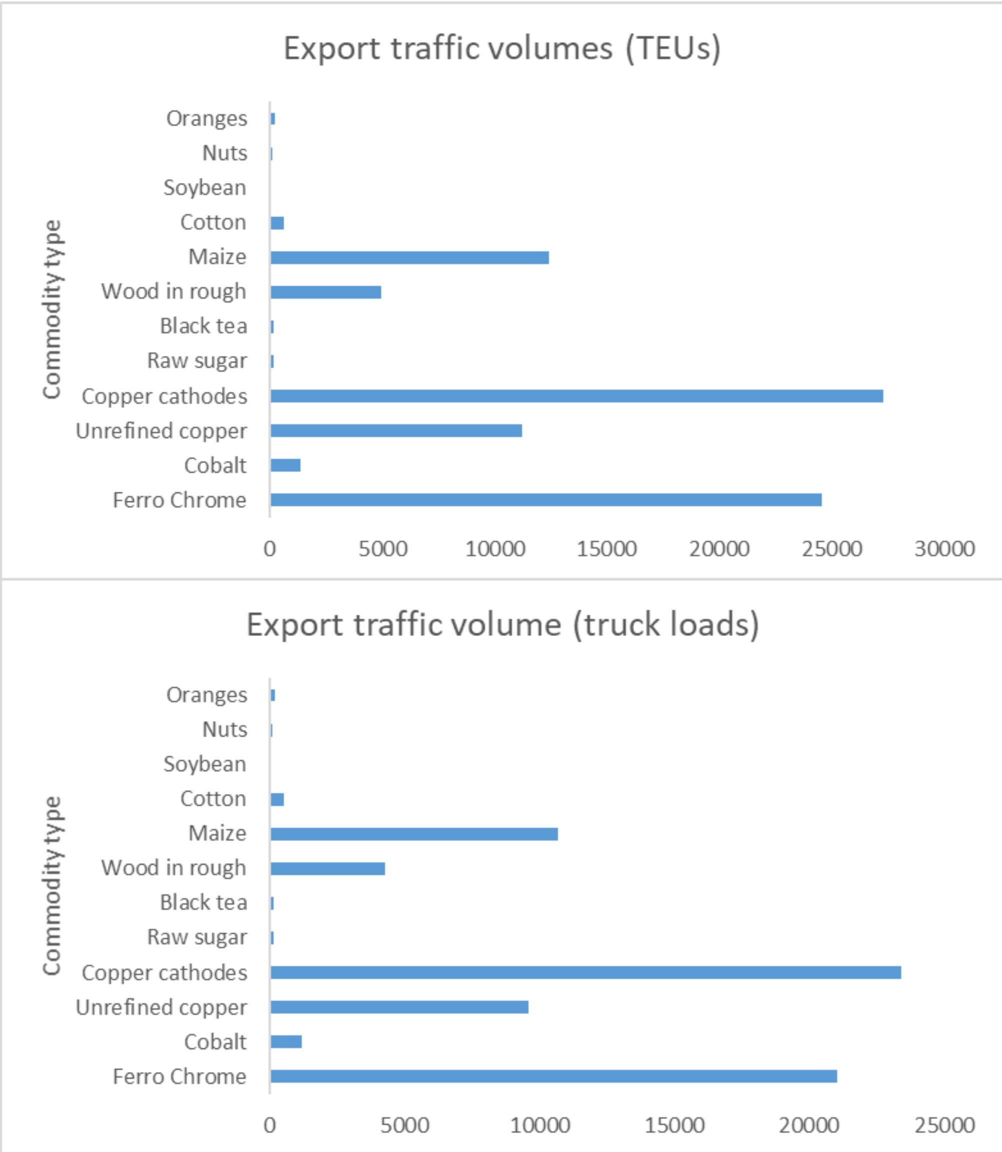

Figure 55 Estimate annual traffic volumes for untapped potential exports from the four LLCs

Table 44: Value per ton for each commodity for untapped potential exports from the four LLCs

Commodity (Combined)	Untapped potential ($)	Price per ton
Ferro Chrome	$53 000 000	$90
Cobalt	$1 793 900 000	$53 500
Unrefined copper	$2 288 200 000	$8 500
Copper cathodes	$3 800 000 000	$5 800
Raw sugar	$126 600 000	$385
Black tea	$1 706 700 000	$7 400
Wood in rough	$82 100 000	$686
Maize	$49 300 000	$165
Cotton	$40 600 000	$2 650
Soybean	$34 900 000	$407
Nuts	$63 800 000	$1 564
Oranges	$18 300 000	$2 932

Data Source: International Trade Centre, (2021).

Table 45: Estimate annual traffic volumes for untapped potential exports from the four LLCs

Commodities	Volume (ton)	Truck loads	TEUs
Ferro Chrome	588889	21032	24537
Cobalt	33531	1198	1397
Unrefined copper	269200	9614	11217
Copper cathodes	655172	23399	27299
Raw sugar	328831	11744	13701
Black tea	230635	8237	9610
Wood in rough	119610	4272	4984
Maize	298788	10671	12449
Cotton	15321	547	638
Soybean	85749	3062	3573
Nuts	40802	1457	1700
Oranges	6241	223	260
Total	2672769	95456	111365

Data Source: International Trade Centre, (2021).

Table 46 Annual and daily traffic truckload estimates for untapped export potential

Commodities	Volume (ton)	Truck loads	Beira (20%)	North-South (47%)	Dar es Salaam (33%)
Ferro Chrome	588889	21032	4206	9885	6941
Cobalt	33531	1198	240	563	395
Unrefined copper	269200	9614	1923	4519	3173
Copper cathodes	655172	23399	4680	10998	7722
Raw sugar	328831	11744	2349	5520	3876
Black tea	230635	8237	1647	3871	2718
Wood in rough	119610	4272	854	2008	1410
Maize	298788	10671	2134	5015	3521
Cotton	15321	547	109	257	181

Soybean	85749	3062	612	1439	1010
Nuts	40802	1457	291	685	481
Oranges	6241	223	45	105	74
Total	2672769	95456	19091	44864	31500
Daily estimates	7323	262	52	123	86

Data Source: International Trade Centre, (2021).

Table 41 and Figure 55 shows copper cathodes to be the product with the largest number of trucks and or TEUs followed by Ferro chrome, maize, unrefined copper, and black tea respectively. Soybean is shown as the product with the least volume in terms of trucks and TEUs. Whereas in terms of the product with the highest percentage untapped potential, it is raw sugar with 64% followed by maize with 61% potential as shown in Figure 56.

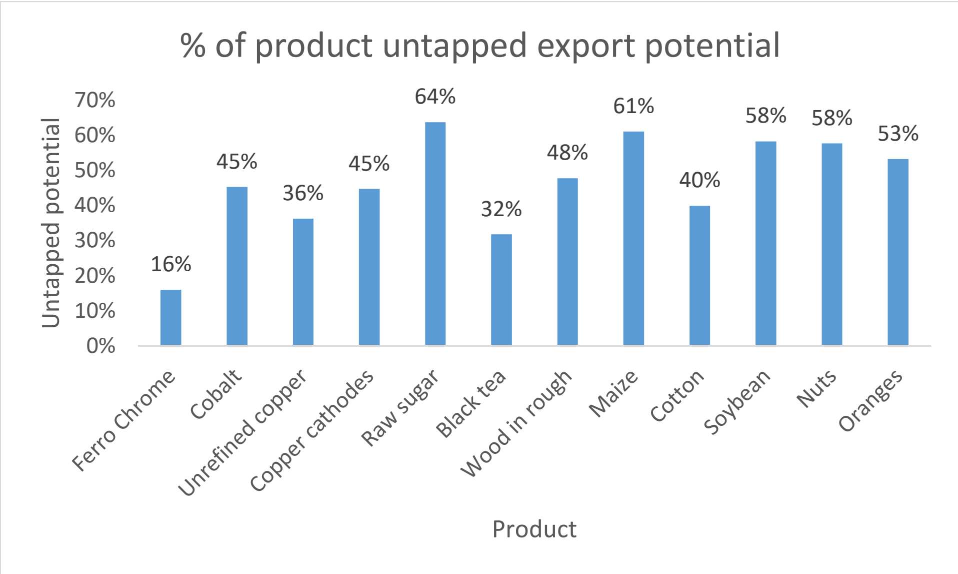

Figure 56 Percentage of untapped annual export potential for the four LLCs

Table 47 shows the combined untapped import potentials for common products for each country as shown above, added together in order to estimate the number of truckloads or twenty-foot equivalent units (TEUs). Table 48 shows the commodities price per tonne which was used to convert the dollar values to tonnes in order to estimate truckloads.

Table 47 Combined-commodities’ annual import potential for the four LLCs

Commodity	Actual Imports	Import potential ($)	Untapped potential
Fish nes/whole, frozen	$176 900 000	$277 700 000	$119 700 000
Motor vehicles	$240 500 000	$335 100 000	$180 200 000
Chemical fertilisers	$76 100 000	$104 800 000	$50 800 000
Heavy duty trucks	$107 500 000	$136 200 000	$85 500 000
Insecticides & similar	$130 900 000	$186 200 000	$81 900 000
Diesel trucks <=5t	$156 700 000	$198 700 000	$84 900 000
Maize	$75 700 000	$100 500 000	$56 000 000
Motor cycles	$76 800 000	$130 000 000	$60 600 000
Wheat & meslin	$25 300 000	$40 400 000	$19 700 000

Data Source: International Trade Centre, (2021).

Table 48 Value per ton for each commodity of untapped annual import potential for the four LLCs

Commodity	Actual exports (combined)	Export potential ($)	Untapped potential	Price per ton
Fish nes/whole, frozen	$176 900 000,00	$277 700 000,00	$119 700 000,00	$2 574,00
Motor vehicles	$240 500 000,00	$335 100 000,00	$180 200 000,00	$45 000,00
Chemical fertilisers	$76 100 000,00	$104 800 000,00	$50 800 000,00	$388,00
Heavy duty trucks	$107 500 000,00	$136 200 000,00	$85 500 000,00	$165 000,00
Insecticides & similar	$130 900 000,00	$186 200 000,00	$81 900 000,00	$270,00
Diesel trucks <=5t	$156 700 000,00	$198 700 000,00	$84 900 000,00	$35 000,00
Maize	$75 700 000,00	$100 500 000,00	$56 000 000,00	$570,00
Motor cycles	$76 800 000,00	$130 000 000,00	$60 600 000,00	$4 000,00
Wheat & meslin	$25 300 000,00	$40 400 000,00	$19 700 000,00	$29 156,36

Data Source: International Trade Centre, (2021).

Table 49 and Figure 57 shows insecticides to be the product with the largest number of truckloads and or TEUs followed by fertilisers, maize, fish, motor vehicles, diesel trucks, motorcycles and heavy duty trucks respectively. Wheat is shown as the product with the least volume in terms of trucks and TEUs. These numbers are also presented in a bar graph for visual illustration of the commodities to show variability across commodities. However, Figure 58 shows that in terms of the product with the highest percentage import potential it is heavy duty trucks, with 63% followed by maize and motor vehicles with 56% and 54% respectively. The daily import truckloads estimates are shown in Table 46 obtained by applying the current distribution ratios across the three corridors to obtain annual share of each corridor and then divide by 360 days to get daily number pf truckloads.

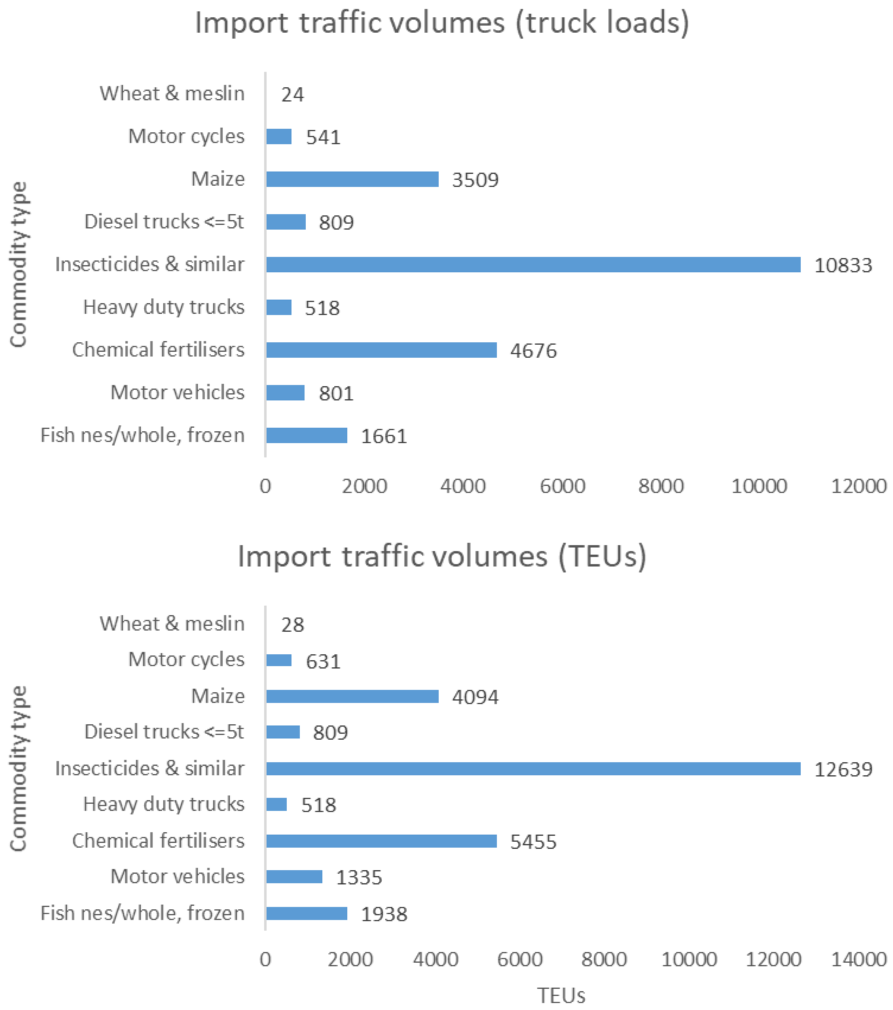

Figure 57 Estimate annual traffic volumes for untapped potential imports from the four LLCs

Table 49 Annual traffic volume estimates for untapped import potential

Commodity	Volume (ton)	Truck loads	TEUs
Fish nes/whole, frozen	46503	1661	1938
Motor vehicles	4004	801	1335
Chemical fertilisers	130928	4676	5455
Heavy duty trucks	518	518	518
Insecticides & similar	303333	10833	12639
Diesel trucks <=5t	2426	809	809
Maize	98246	3509	4094
Motor cycles	15150	541	631
Wheat & meslin	676	24	28
Total	601784	23372	27447

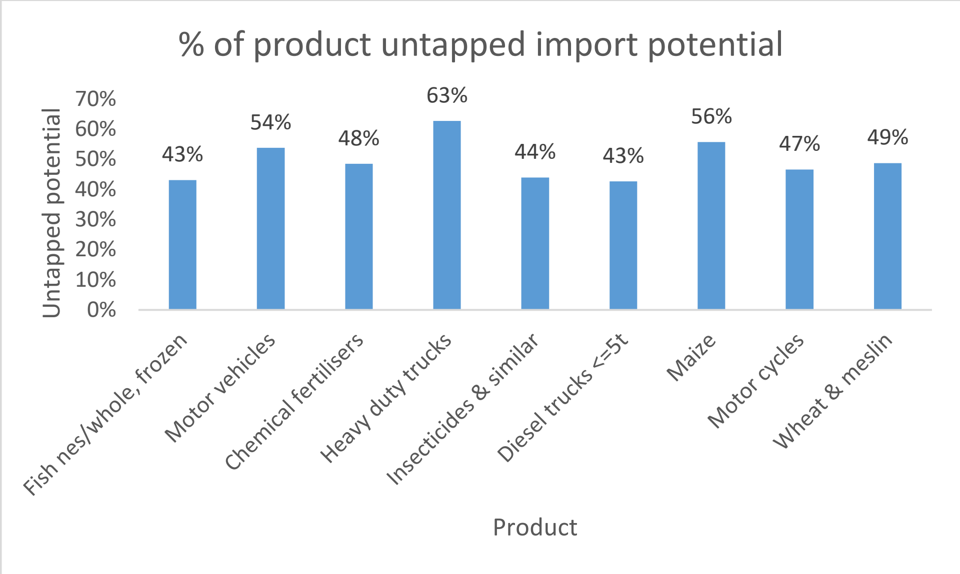

Figure 58 Percentage of untapped import potential for the four LLCs

According to the calculations in Table 45 and Table 49 the total annual truckloads from export and import untapped potential, they amount to 95 456 and 233 72 truckloads respectively. Using the current traffic distribution among the three corridors, the total number of truckloads is converted to additional annual truck volumes passing through the corridors, where the ratios would be 20% for Beira, 33% for Dar es Salaam and 47% for North-South Corridor. This translates to 19 091 trucks and 4 674 trucks for exports and imports respectively for the Beira Corridor. For the North-South Corridor this translates to 44 864 and 10 985 trucks for export and import respectively. Whereas, for the Dar es Salaam it translates to 31 500 trucks export and 7 713 trucks imports. However, if the improvements proposed for Beira are implemented, and the number of trips per month double to 4, then Beira could see its share doubling to 40% as is discussed in section 6.6 under traffic increase estimates. 6. The results in Table 50 show that the estimates for untapped import potential for the are highest higher for North-South Corridor than for Beira and Dar es Salaam, further confirming the the attractiveness of the corridor.

Table 50 Annual and daily truckload estimates for untapped import potential for the three corridors

Commodity	**Volume (ton)**	**Truck loads**	**Beira (20%)**	**North-South (47%)**	**Dar es Salaam (33%)**
Fish nes/whole, frozen	46503	1661	332,2	781	548
Motor vehicles	4004	801	160,2	376	264
Chemical fertilisers	130928	4676	935,2	2198	1543
Heavy duty trucks	518	518	103,6	243	171
Insecticides & similar	303333	10833	2166,6	5092	3575
Diesel trucks <=5t	2426	809	161,8	380	267
Maize	98246	3509	701,8	1649	1158
Motor cycles	15150	541	108,2	254	179

Wheat & meslin	676	24	4,8	11	8
Annual estimates	601784	23372	4674	10985	7713
Daily estimates	1793	64	13	30	21

Table 50 above shows the additional imports daily-estimates for each corridor as: 13 for Beira, 30 for North-South and 21 for Dar es Salaam. After adding these estimates, the daily tucks by corridor would be in the order 65 for Beira, 153 for Dar es Salaam and 107 for North-South Corridor.

6.6 Estimation of increase in traffic for the Beira Corridor

There are basically two sources of potential traffic growth assumed in this study. The first source being the share of existing traffic that can be gained by the Beira Corridor if delay time variations can be reduced to be comparable that of the North-South Corridor (Durban). This is based on the assumption that Beira Corridor TEC compared with that of Durban would be proportional to the current ratio of fixed transport costs. This would increase the fraction of traffic that the Beira Corridor would carry, of the combined freight of the three corridors. Under the status quo, it is carrying 20% of the combined freight passing through the three corridors.

The second source of growth potential is assumed to come from the untapped potential of exports based on the ITC untapped potential data and the fraction that Beira may carry of this potential additional number of trips. The total estimate is obtained by adding these two together. The increased volume is compared with the current volume carried by Beira corridor and used to estimate the percentage by which corridor capacity will have to be increased to cater for the estimated growth.

In the previous Chapter, under the status quo there are 208 trucks daily on the Beira-Lusaka corridor, which is about 20% of the total number of trucks traveling daily to Lusaka region. With improved infrastructure and regulations, it is estimated that this could at least double the share of traffic currently being handled, along the corridor to 416 trucks or about 40% of the total. The additional capacity for untapped export potential would add an additional 31% approximately in the long run if the current ratio distribution across the corridors is taken into consideration and also considering the average GDP growth rates for the LLC. This was arrived at by expressing the additional daily as a percentage of the current distribution of daily trucks by corridor. The additional exports and imports are added together and expressed as a fraction of the current numbers on each corridor. The additional combined daily estimate imports and exports potential applied are shown in Tables 46 and 50 above. The new daily trucks distribution by corridor after adding the 31% is shown in Table 51 below. The additional annual values were expressed as a fraction of the current distribution to determine the growth, which came out to be 31% as shown in Table 51. This was distributed as 6% for Beira, 15% for North-South and 10% for Dar es Salaam. Regarding the daily estimates by corridor with the additional daily potential the is shown in Table 52. For each of the corridors, the additional combined daily potential for exports and imports were added to get the new daily number of truckloads. For Beira the new figure was obtained by adding 208 plus 52 (daily export truckloads) plus 13 (daily import truckloads) to get 273 truckloads. The same was done with the other two corridors to get 645 and 457 for North-South and Da es corridor respectively.

Table 51 Percentage growth of daily truckloads due to additional capacity

	Additional capacity	Beira (20%)	North-South (47%)	Dar Corridor (33%)
Exports	262	52	123	86
Imports	64	13	30	21
Total	326	65	153	107
% growth calculation	326/1050*100	65/1050*100	1533/1050*100	107/1050*100
Growth	31%	6%	15%	10%

Table 52 Daily truckload with additional estimates for untapped potential included

Border post/corridor	**Number crossing border**	**Number on Beira-Lusaka corridor**	**Number on Durban-Lusaka corridor**	**Number on Dar es Salaam-Lusaka corridor**
Tunduma	440			385
Forbes/Machipanda	448	220	-	
Beitbridge	1150		566	
Chirundu	805	220	566	
Number on corridor to Lusaka	-	220	566	385
Fraction on corridor to Lusaka	-	19%	48%	33%

The projected GDP growth rates for DRC, Malawi, Zambia and Zimbabwe for 2021 is 3.3%, 3.3%, 1% and 7.8% respectively (Anon., 2021). This conservative growth for Beira Corridor takes into consideration the low frequency of ship calling times which will only improve in the long run. It is assumed that the freight traffic distribution across the corridors is determined not only by the capacity of the port, but also by the shipping lines service availability at a particular port. The estimated distribution of fraction of trucks on the corridor to Lusaka, should Beira Corridor implement the recommended improvements, would be of the order 39.8% Beira-Lusaka, 36.8% Durban Lusaka and 23.3% Dar es Salaam-Lusaka. The results of this change in the share of total traffic, including the 31% growth are shown in Table 53 below. This indicates a gain of 10% by Beira Corridor from each of the two competing corridors. These results indicate that in order for Beira Corridor to handle this growth, it needs to more than double its processing capacity. The current infrastructure capacity cannot handle this growth. Ideally this should be addressed by reviving the railway line, improving road conditions, implementing dry port intermodal facilities at GMS and by shortening the turnaround times of trucks through improved processing capacity at the port and border post to increase productivity of equipment and facilities.

Table 53 Daily truckload estimates with the additional untapped potential included

Border post/corridor	Number crossing border	Number on Beira-Lusaka corridor	Number on Durban-Lusaka corridor	Number on Dar es Salaam-Lusaka corridor
Tunduma	396			269
Forbes/Machipanda	542	468	-	
Beitbridge	1035		433	
Chirundu	725	468	433	
Number on corridor to Lusaka	-	468	433	269
Fraction on corridor to Lusaka	-	40%	37%	23%

6.7 Conclusions

This research identified limitations and opportunities for the three major corridors serving landlocked SADC countries regarding the impact of bottlenecks on the performance of these corridors. The main objective of the study was to assess each corridor in terms of infrastructure, regulations, quality of available logistics services and cost from port to destination and to evaluate the impact of these bottlenecks on its ability to compete effectively in serving the region. This was addressed by developing an integrated model for Total Economic Cost experienced by Retailer and Manufacturers, including both direct and indirect costs resulting from time delays and variability in time delays as experienced by cargo moving through the port and road transport processes. Lusaka was used as proxy for SADC LLCs that depend on the Beira, Dar es Salaam and Durban ports for imports and exports.

The results show that, although Beira port is the closest to Lusaka and the copper belt, it enjoys the smallest share of cargo traffic of the three competing corridors. This can be largely explained by the fact that the Total Economic Cost for Beira corridor is higher than that of the North-South corridor from Durban. The primary contributor to this higher cost is the variability of delay times experienced through the port of Beira, compared to Durban port. Road link and border post delays also contribute towards the high Total Economic Cost, although to a lesser degree. In terms of products, it was established that Beira corridor had limitations on products such as motor vehicles and perishable products such as fruits because for the non-existence of facilities. The fact that Dar es Salaam port, with a higher Total Economic Cost still enjoys a higher share of trade than Beira corridor, could be because it has more regular visits from vessels compared to Beira port.

Commodity type export/import potential was also considered to determine the type of commodities transported along the corridors and the limitations of each corridor in respect of particular products. In terms of products, it was established that Beira corridor had limitations on products such as motor vehicles and perishable products such as fruits because for the non-existence of facilities. The untapped import and export potential was converted into the potential increase in daily truck volumes. These figures were compared against current figures and an assessment was made whether existing infrastructure will be able to support such growth in traffic volumes.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The aim of this study as presented was to assess corridor bottlenecks affecting the performance of the Beira Corridor and to compare its performance with Dar es Salaam and North-South (Durban) corridors which all compete for the same landlocked SADC countries export and import cargo. The motivation for the research is the paradox that, while Beira port is much closer to the landlocked countries served by these corridors compared to Durban and Dar es Salaam, it attracts much less cargo compared to the other two corridors. Hence the study sought to compare the attractiveness of the Beira Corridor and that of Dar es Salaam and North-South Corridor. The attractiveness of each corridor was assessed based on a holistic perspective looking at Total Economic Cost (TEC) from the perspective of the combined set of stakeholders, including transporters, retailers, and manufacturers. The TEC model includes not only direct costs but takes a holistic (systems) perspective, encompassing the impact of logistics delays and variability in delays and further quantifies the relative contributions of ports, border posts and road travel.

The primary objective of this research is to compare Beira Corridor with other competing SADC corridors using the Total Economic Cost model that includes bottlenecks related to infrastructure, regulations, quality of logistics services, cost from port to destination and product type. A secondary objective is to generate policy recommendations to address the weaknesses that are identified for Beira corridor compared to other corridors. It sought to do so by addressing following research main research question and sub-questions presented in Chapter 1:

Main Question:

1. *What role can a systems perspective play in solving the bottlenecks that currently affect the performance of the Beira corridor?*

Sub-questions:

2. *What are the bottlenecks affecting the performance of the Beira corridor?*
3. *What is the economic impact of bottlenecks to corridor users?*
4. *How does the Beira corridor compare with competing corridors?*
5. *By how much can traffic on the Beira Corridor be increased through improvements on the corridor?*

The focus of this study was to assess the bottlenecks on the Beira corridor which may compromise the be ability of the corridor compete effectively with such corridors as Dar es Salaam and North-South corridors which compete for the same traffic. The assessment focussed on physical and non-physical bottlenecks. The competing corridors were also assessed in terms of bottlenecks and their comparative advantage viz a viz the Beira Corridor. The analysis outlines the key bottlenecks, including physical infrastructure regulatory issues, and logistics activities including the role of inland terminal in improving port performance and the modal choice role in ensuring corridor competitiveness. ICT is considered in terms of its role in improving corridor performance, particularly its role in integrating the supply chain and fostering cargo visibility and enhancement of delivery predictability as a way of supporting just-in-time delivery, thereby eliminating unnecessary costs caused by delays. and the prices of road transport relative to the associated costs. In particular, the emphasis has been on understanding the explanatory factors for the bottlenecks and their cost implication emanating from delays and long transit time the increase the cost of logistics on the Beira corridor rendering it uncompetitive to the detriment of being uncompetitive in comparison to its competitors. The ultimate goal was to propose an ideal design for the Beira Corridor that would make it cost efficient, more attractive to shippers and competitive versus its competitors. Through a SWOT analysis, each port was assessed to determine its competitiveness as the corridor of choice.

The review of the literature on the corridor concept emphasises the fact that, other than physical infrastructure investment, investment in improving the efficiency of border procedures, implementing and monitoring measures to address bottlenecks, and enhancing the efficacy of administrative systems for road transport are equally important, hence supporting the integrated approach and systems thinking as the epitome of ensuring corridor efficiency and competitiveness. The next section presents the possible role of a systems approach in dealing with bottlenecks in line with the main research question and objectives of the study.

7.2 Research Question1: What role can a systems perspective play in solving the bottlenecks that currently affect the performance of the Beira corridor?

Given the complexity of the transport corridor formation it can only be better analysed in terms its various components of links and nodes. Thus, applying a systems theoretical approach provides for a holistic perspective that helps with a better understanding of the interdependence of nodes and links that constitute the corridor and the bottlenecks generated by each one of the corridor components. Viewing the corridor as a system allows one to appreciate the interactions of all the components of the corridor and how they are interdependent in the overall performance of the corridor. This is very important because it helps with ensuring that investment decisions on improving the performance of the corridor are correctly allocated. Furthermore, since the various sub-systems are also sources of cost drivers, determining the costs incurred by users can only be accurate through treating these as a whole through the systems approach. The application of the Total Economic Cost model used in this study and the comparative analysis of the performance of three corridors as one whole serving the same hinterland is an appreciation of systems thinking.

Systemology derives from the realisation of the existence of interdisciplines, a phenomenon that exists in transport corridors as complex formations. The analysis of corridor performance and management can obviously benefit from the science of systems in resolving complex problems associated with corridor performance analysis. Systemology enables the ability to perceive wholeness of things, recognising the connections between the various components in terms of their interaction, perceiving the internal composition of sub-components, interconnected and interacting to constitute the corridor. Proponents of Engineering Systems Thinking conceive it as a high order thinking skill that allows the successful performance of systems engineering tasks.

In terms of corridor performance assessment systems thinking can play an important part in the analysis of the corridor formation and the interaction of components constituting a corridor:

- The sea ports and their components (terminals, berths/quays and their components)
- The links connecting the hinterland (road network, railways, inland water ways
- Inland terminals (dry ports, rail terminals, container terminals)
- Border posts and traffic control stations
- Regulatory regimes and legislation
- Institutional formations and their interactions
- ICT systems that link the various components

The systems approach is unique in that it requires the treatment and analysis of a phenomenon as a whole. Hence, in terms of corridor analysis an end-to-end analysis is required, with every component of the corridor being considered in terms of its interaction with the rest of the components and its impact on the other components. This way, it ensures that in addressing problems affecting the corridor, all aspects of the corridor must be considered in order to avoid transference of the problem to the other part of the system (the corridor) by treating components in isolation. It is for this reason that in this study, a total economic costing approach was adopted to portray a holistic view. Equally, the treatment of bottlenecks followed the same approach whereby all bottlenecks were taken into consideration in the development of the Total Economic Cost model used in the study.

Extension of port operations to inland terminals as integral components of the system, especially dry ports, addresses congestion challenge faced by the port of Beira. The GMS dry port is a classic example for the Beira Corridor which is linked to the port by rail. The repair and revitalisation of the railway infrastructure will ensure that the dry port serves as an intermodal facility that would reduce transport cost. The majority of trucks would collect cargo from the dry port instead of from the port, thereby reducing the number of trucks getting into the port, reducing the problem of congestion. This system perspective helps with identification of additional locations for setting up dry ports to support the expansion of the port to cater for the growth in both imports and exports from the four LLCs. In the next section the various bottlenecks identified in line with the study objective to identify bottlenecks affecting the performance of the Beira Corridor are presented.

7.3 Research Question 2: What bottlenecks are affecting the performance of the Beira Corridor?

The results of this study confirm the existence of both physical infrastructure and non-physical bottlenecks on the Beira Corridor. In terms of physical infrastructure bottlenecks, the corridor suffers a dysfunctional infrastructure on the Beira-Machipanda railway line. The line is not carrying sufficient cargo due to lack of maintenance and investment. The EN6 road which is the main road from the border post to the port has deteriorated on most sections affecting speeds and transit time by trucks transporting cargo on the corridor. The dry port in Mutare does not have adequate space capacity to serve as an extension of the port to ease congestion experienced at the port currently. The limited space at the dry port causes congestion and overcrowding, contributing to incidents and damage of equipment. The dry port has been reduced to a road only facility serving as an extension of the Forbes Border Post used to conduct customs physical examinations which add to logistics costs not only due to the delays, but the $fees charged for the inspections. This fee is paid by transporters which increases their operational costs, hence it is a major bottleneck. The extension on customs operations to the GMS dry port is seen as a bottleneck related to regulatory processes whereby cargo is offloaded for physical examination. Furthermore, the Dry port is not serving as an intermodal facility where rail is supposed to lower costs as suggested by theory. To explain this paradox, it has been noticed that this is because of the collapse of the rail infrastructure on the Machipanda line the links the port. The lack of adequate handling equipment at the dry port is also affecting the performance and productivity of the dry port, which explains the long delays experienced by trucks.

Finally, the research findings established that there are transportation operations related bottlenecks and processes-related bottlenecks at Forbes border post. These include the limited manpower on the part of customs, leading to long waiting hours by trucks carrying cargo for both direct imports and transit. This process takes a long time to the extent that some vehicles spend more than seven days before they can proceed. The issuance of embargos to transit trucks is unnecessarily adding to transport costs to the users of the corridor leading to some shifting to competing corridors such as the North-South Corridor and Dar es Salaam Corridor as alternatives. The next section answers the objective relating to the economic impact of the bottlenecks to the users of the Beira Corridor.

7.4 Research Question3: What is the economic impact of bottlenecks to corridor users

Corridor bottlenecks have an economic impact not only to the region, but to companies including retailers, wholesalers and transport operating entities. The transportation cost includes vehicle operation cost, cost of fuel, driver, loading and unloading, handling of containers at ports and borders, and trans-shipment, while in the case of railway it also includes locomotive operation cost, track access fee, and cost of return of empty containers. The average cost of one leg was high due to the use of road transport for the other leg. The cost of the third leg was also high due to the high cost resulting from of insufficient cargo volume in both legs.

While Beira corridor has the lowest direct transport cost, the cost of total variability of corridor time delays is much higher for Beira compared to Durban. As a result, the Total Economic Cost of transport and logistics between port and destination is higher for Beira than for Durban. This at least partly explains why Durban enjoys the highest share of this market in spite of being the longest distance from Lusaka.

When the contributions towards costs resulting from variability of delay times are broken down, it can be seen that it is mainly the high variability in port delay times that causes both Beira and Dar es Salaam to suffer from higher Total Economic Costs compared to Durban. While border posts and road links also play a role, it is not of the same magnitude as port delays. This result is similar for both Retailers and Manufacturers. The fact that Dar es Salaam port enjoys a higher fraction of trade than Beira corridor, in spite of having a higher Total Economic Cost, can possibly attributed to the fact that it has more regular visits from vessels compared to Beira port. The next section responds to the objective of comparing the Beira Corridor with the Dar es Salaam and North-South corridors.

7.5 Research Question 4: How does the Beira Corridor compare with competing corridors?

The results show that, while Beira port is the closest to Lusaka and the copper belt, it has the smallest share of cargo traffic of the three competing corridors. This can be largely explained by the fact that the Total Economic Cost for Beira corridor is higher than that of the North-South corridor from Durban. The primary contributor to this higher cost is the variability of delay times experienced through the port of Beira, compared to Durban port. Road link and border post delays also contribute towards the high Total Economic Cost, although to a lesser degree.

Furthermore, the results indicate that although the port of Beira satisfies the requirements for a corridor according to the corridor theory, it faces severe competition from Dar and NSC as a result of the upgrade of other SADC ports and their hinterland access, which cause the majority of cargo movements to shift away from Beira port. This uncompetitive situation can only be addressed by reducing variability of time delays through the port as well as along road links and through border posts. Achieving this objective will require a combination of infrastructure upgrades and regulatory improvements.

The results of this study confirm the existence of both physical infrastructure and non-physical bottlenecks on the Beira Corridor. In terms of physical infrastructure bottlenecks, the corridor suffers a dysfunctional infrastructure on the Beira-Machipanda railway line. The line is not carrying enough cargo due to lack of maintenance and investment. The EN6 road which is the main road from the border post to the port has deteriorated on most sections affecting speeds and transit time by trucks transporting cargo on the corridor. The dry port in Mutare does not have adequate space capacity for customs physical examinations as it is overwhelmed with trucks, posing a major bottleneck.

The findings also indicate that the port has physical infrastructure constraints that affect the capacity of the port to accommodate certain traffic of a specialised nature. For instance, the port does not provide for RORO vessels that transport motor vehicles, yet there is a huge volume of motor vehicle imports to the four landlocked countries served by the Beira Corridor. Apart from vehicles, there are no reefer services, which means that the port cannot handle reefer containers which are used to transport fruits, vegetables and fish and any commodities that require controlled temperature. All such commodities are transported through either the North-South Corridor via the port of Durban or through the Dar es Salaam Corridor via the port of Dar es Salaam. Hence again due to this bottleneck, the Beira corridor is less competitive in comparison to the other two corridors.

The research findings established that there are transportation operations related bottlenecks and processes-related bottlenecks at Forbes border post. The bottlenecks include the limited manpower on the part of customs, leading to long waiting hours by trucks carrying cargo for both direct imports and transit. The extension on customs operations to the GMS dry port is another bottleneck related to regulatory processes whereby cargo is offloaded for physical examination. This process takes a long time to the extent that some vehicles spend more than seven days.

Apart from the long processing periods endured by transport operators, there is another bottleneck associated with the $300 fee paid for the physical examination. This fee is paid by transporters which increases the operations costs. There is also another bottleneck identified and also confirmed by drivers, that of limited space at the dry port, which leads to congestion and overcrowding causing incidents and damage of equipment. The lack of adequate handling equipment at the dry port is again a bottleneck that affects the performance and productivity of the dry port.

The cost-benefit study provided evidence that users of the Beira corridor and the regional economy will significantly benefit from the elimination of the identified bottlenecks. As a prominent example, the size of the truck fleet required to service the port of Beira can be reduced by approximately a factor of 3, should the quality of the roads be improved to allow average driving speeds of about 60 km/h, as typically observed on other corridors with roads of acceptable quality, and should the average border delay be reduced to 2 hours, which is also a reasonable objective. In the next section the possible increase in traffic volume resulting from addressing the bottlenecks is presented and explained as part of the objectives to resolve the poor performance of the corridor compared to others.

7.6 Research Question 5: By how much can traffic on the Beira Corridor be increased through improvements on the corridor

In the study it has been estimated that there will be a significant growth in the fraction of trucks passing through the Beira Corridor if infrastructure and regulation is improved which would remove the time variability bottlenecks. As the Total Economic Cost decrease, on the Beira Corridor to the same levels as Durban, the number of trips for Beira will increase to 4 trips per month from the current 1.8. Our estimate is that this may increase the share of all hinterland traffic for Beira Corridor to 40% compared to the current 20%. The additional 20% will come from gaining 10% market share from the other two corridors. To accommodate this growth, the processing capacity needs to double.

The estimated traffic volume increase is not only due to improvement on time variability, but from the untapped export/import potential as expressed in the ITC Trade Map data. It is assumed that improvements at the port will only have more impact in the long run provided that the frequency of ship calls will improve. The current congestion experienced at the port would be addressed by the upgrade of the GMS dry port which will serve as an integral part of the port and being an extension of the port of Beira. This will be possible if rail is vitalised, where cargo would be shipped by rail to Mutare and transhipped at the dry port to trucks. The next section presents the concluding remarks of the study following the resolution of the study objectives in the preceding sections.

7.7 Concluding remarks

In this study, it has been found that while the Beira corridor has the lowest direct cost to the hinterland if only average travel time is considered, the North-South corridor proves to be the most competitive corridor when the variability in time delays is also considered. Port's efficiency proved to be the biggest differentiator between these corridors, followed by border posts and road links. This explains why the North-South corridors enjoys the largest share of cargo transported between the coast and the landlocked hinterland.

Furthermore, the study has identified limitations and opportunities for the three major corridors serving landlocked SADC countries regarding the impact of bottlenecks on the performance of these corridors. The main objective of the study was to assess each corridor in terms of infrastructure, regulations, quality of available logistics services and cost from port to destination and to evaluate the impact of these bottlenecks on its ability to compete effectively in serving the region. The study addressed this by developing an integrated model for Total Economic Cost experienced by Retailer and Manufacturers, including both direct and indirect costs resulting from time delays and variability in time delays as experienced by cargo moving through the port and road transport processes. In the study Lusaka served as a proxy for SADC LLCs that depend on the Beira, Dar es Salaam and Durban ports for imports and exports.

The study results show that, although Beira port is the closest to Lusaka and the copper belt, it enjoys the smallest share of cargo traffic of the three competing corridors. This can be largely explained by the fact that the Total Economic Cost for Beira corridor is higher than that of the North-South corridor from Durban. The primary contributor to this higher cost is the variability of delay times experienced through the port of Beira, compared to Durban port. Road link and border post delays also contribute towards the high Total Economic Cost, although to a lesser degree.

In-depth scrutiny of the reasons for long port delays indicated that this results from several factors (Hoffman, et al., 2021):

1. Customs authorities tend to subject 100% of import cargo to intrusive inspections as well as X-ray scanning; this results in delays of up to two weeks before cargo is allowed to leave the port.
2. Ports either does not have electronic systems to issue invoices to and receive payments from importers, or they only allow local freight agents to access the electronic system, thus causing long delays for transit cargo handled by freight agents operating from LLCs.
3. Congestion in ports resulting from limited infrastructure capacity and suboptimal maintenance practices cause long delays for trucks visiting the ports.

Long and highly variable delays related to road travel time can be attributed to the following causes:

1. The bad state of the road network, specifically along the Beira corridor, results in average truck travel speeds of as low as 10 km/h on some sections.
2. The large number of police stops along the corridors, specifically in Zimbabwe, Mozambique and Tanzania, results in unnecessary delays for trucks.
3. Weighbridges along the same route are not linked to each other; as a result, a truck that is legally loaded is often weighed several times during the same trip, resulting in unnecessary queueing times (Hoffman & De Coning, 2014).
4. Embargo on all traffic processed at Forbes Border Post.

Border post delays can mostly be attributed to the high level of physical customs inspections that cause some trucks to spend more than 2 weeks at a border. The reason for the high rate of customs inspections can be linked to the lack of intelligent use of available data to implement accurate cyber inspections to all cargo. Intelligent risk profiling may reduce physical inspections to a much smaller fraction of cargo without incurring higher compliance risks (Laporte, 2011) (Davaa & Namsrai, 2015).

The recommendations to address the bottlenecks affecting the Beira are presented in the next section together with possible future research opportunities. It is hoped that the performance of the Beira Corridor will improve significantly with the implementation of the proposed interventions.

7.8 Recommendations

Based on the findings of this research, the following recommendations are proposed to improve the competitiveness of the corridors serving SADC LLCs, and in the process the global competitiveness of the entire region:

1. <u>Regulatory</u>

    - Regulations for road transport should be harmonised for all countries along a corridor, to prevent avoidable delays at borders where trucks that were legally loaded on one side of the border becomes illegal once it crosses the border.
    - Transport policy, as implemented by the governments of the countries through which the corridors run, must support a higher level of competition regarding the provision of logistics services, as this has proven to increase the quality of service on corridors serving developed economies
    - A single institution should be established to manage each transport corridor from end-to-end. Such an institution should have sufficient authority to enforce regulations and procedures that have been optimised from the perspective of the corridor and thus the entire economic region, rather from the perspective of a single authority operating in one of the corridor countries. This will most likely prove to be the biggest challenge, as existing authorities are unlikely to give away their current powers of decision-making.

2. <u>Information & Communication Technologies</u>

    - Customs authorities should increasingly rely on intelligent customs risk engines that are trained on historical data reflecting the behaviour of traders and the outcome of physical inspections. This will allow them to drastically reduce the rate of physical inspections without increasing the risk of reduced levels of compliance.
    - Embargos on transit cargo should be eliminated by improved risk profiling through the use of SMART tools.

- Ports and customs authorities should use modern ICT solutions to streamline both the physical processing of cargo as well as the enforcement of compliance, as this has proven to be critical elements to achieve the levels of efficiency observed for corridors operated on other continents
- Ports should improve the quality of their ICT systems to improve the efficiency of terminal operations and to streamline the exchange of information with port stakeholders. Such systems should be online accessible to all port stakeholders, including cargo owners and freight agents operating from LLCs.

3. Physical infrastructure

- The quality of the road networks should be improved to allow trucks to travel at reasonable speeds along the main road networks. To achieve this goal, the efficiency of overload control should be improved through scrutiny of weighbridge officials to eliminate corrupt practices. The network of weighbridges along the entire corridor should be linked to avoid the unnecessary repeated weighing of vehicles that are legally loaded.
- The port of Beira should develop berths that cater for RORO vessels in order to cater for vehicles imports to DRC, Malawi, Zambia and Zimbabwe as the unavailability of these facilities means this cargo goes to any of the other two corridors with the appropriate services
- The establishment of reefer facilities to cater for fresh commodities such as fruits and vegetables is required. Reefer services are also required for the importation of fish products which are imported as demonstrated in the cargo type analysis.
- The Mutare dry port should be upgraded so that it serves as an extension of the Beira port to ease congestion.

The Beira-Machipanda railway line should be revitalised so that users have alternative modal choice where cost can be reduced when the dry port returns to its original role of an intermodal facility.

In terms of future work, there is scope for refining the Total Economic Cost model from the perspective of specific import and export industries. Such a refined model could be used to determine which of the competing corridors is optimal for each industry sector. It would also allow corridor performance to be optimised from the perspective of the primary industries served by that corridor.

Also, the Total Economic Cost model could further be used to evaluate the economic feasibility of planned infrastructure improvements to the corridors. While historical studies have estimated the cost to infrastructure improvements, these costs have not been compared with the benefits to the regional economy measured in terms of the expected impact on local traders.

Lastly, the systems thinking perspective can be used to identify where investment should be directed to improve corridor performance. Equally, the systems approach can also be applied to analyse the overall performance of the corridor to establish parts of the corridor not performing optimally or to compare different corridors based on benchmarking in terms of impediments or bottlenecks identification.

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APPENDICES

APPENDIX 1 APPENDIX 1 CONSENT FORM

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

CONSENT FORM

I have read the information presented in the information letter about a study being conducted by CRYNOS MUTENDERA for his PhD RESEARCH at the University of North-West: Faculty of Engineering. The supervisor is Professor Alwyn Hoffman. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the PhD to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time by advising the student researcher.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

YES ☐ NO ☐

I agree to have my interview tape recorded.

YES ☐ NO ☐

I agree to the use of anonymous quotations in the course project paper.

YES ☐ NO ☐

Participant Name: ______________________________ (Please print)

Participant Signature: ______________________________

Witness Name: __________________________________ (Please print)

Witness Signature: _______________________________

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APPENDIX 2 CORRIDOR PERFORMANCE ME

ASUREMENT DATA COLLECTION SHEET

Please fill out the form properly and return to the researcher upon completion of the trip. Shaded areas are to be filled by the CPM Coordinator.																
Route					Commodity				Commodity classification							
Perishable			Cargo Weight					Container				TIR?				
STOP No	STOP No 1				STOP No 2				STOP No 3				STOP No 4			
City																
SADC Corridor																
Mode of transport																
Distance from previous stop (km)																
Duration of travel (hrs)																
Vehicle operating cost																
BCP																
Reason for Stop	1 2 3 4 5				1 2 3 4 5				1 2 3 4 5				1 2 3 4 5			
ROAD	hr	min			hr	min			hr	min			hr	min		
Port/loading/offloading																
Border Security/Control																
Customs (Single Window)																
Customs Control																
Health/Quarantine																
Phytosanitary																
Veterinary Inspection																
Visa/Immigration																
Traffic Inspection																

hr = hour, km = kilometre, min = minute, OC = official cost (US$), TC = total cost (US$), TIR = Transports Internationaux Routiers /International Road Transport (carnets used by drivers). (TIP) Note: Reasons for stopping include: 1 – place of departure, 2 – an intermediate stop, 3 – exiting from the border crossing, 4 – entering the border crossing, and 5 – reaching final destination

APPENDIX 3 DRIVERS QUESIONNAIRE

NORTH-WEST UNIVERSITY
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A CASE STUDY OF THE BEIRA CORRIDOR BOTTLENECKS

INTERVIEW FORM

List of questions used to engage truck drivers at Green Motor Services (GMS) dry port (Zimbabwe)

1. What type of goods do you transport to and from the port?
2. How often do you use the Beira Corridor?
3. How often do you pass through Forbes border post?
4. How many stops or checkpoints did you encounter?
5. What were the reasons for stopping?
6. Do you have alternative routes to and or from the port?
7. What do you think would be the reasonable travel time from origin to destination?
8. Do you sometimes achieve such travel time?
9. What are the reasons for your not being able to achieve these travel times?
10. Which other corridors do you use if any?
11. What are the main challenges do you face in using this corridor?
12. What steps do you follow to proceed on the Zimbabwe and Mozambique side?
13. What are the major challenges you face regarding clearance of goods at the dry port?
14. What suggestions or recommendations could you make for ease of transportation of goods along the Beira Corridor?

APPENDIX 2 APPENDIX 4 DRY PORT MANAGEMENT QUESTIONNAIRE

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

A CASE STUDY OF THE BEIRA CORRIDOR BOTTLENECKS

INTERVIEW FORM

List of questions used to engage management of Green Motor Services (GMS) dry port (Zimbabwe)

1. What is the Mutare dry port's role in the facilitation of goods conveyance?
2. What is the role of the dry port in the transportation of goods along the Beira Corridor?
3. What documents are used for the control of goods at the dry port?
4. How long does it take to process a truck at the dry port?
5. How many trucks do you deal with per day?
6. What is the link between the dry port, clearing agents and customs and drivers?
7. What modes of transport do you deal with at the dry port?
8. Which of these modes is best suited for the transportation of goods along the Beira Corridor in your view?
9. Is Mutare dry port operating at a capacity that enhances efficiency for drivers to meet delivery schedules?
10. What challenges do you face in conducting your daily activities?
11. What are the possible solutions to these challenges in your view?
12. What would you recommend should be done by each stakeholder?

APPENDIX 3 APPENDIX 5 CLEARING AGENTS QUESTIONNAIRE

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

A CASE STUDY OF THE BEIRA CORRIDOR BOTTLENECKS

INTERVIEW FORM

List of questions used to engage with Clearing Agents at Forbes Border Post

1. For how long has your office been operational at this border post?
2. Where else do you have offices along the Beira Corridor?
3. What time do you open and close office daily?
4. On average how many trucks do you process per day
5. How long does it take to process a truck?
6. How essential is the service in facilitating the passage of goods?
7. Is it possible for a truck to pass without the involvement of a clearing agent?
8. Do you deal with trucks only?
9. Who are your main stakeholders and what is the role of each of them in facilitating or your work?
10. Do you think the Beira corridor makes it easy for the passage of goods to and from the port?
11. What would you say are the main challenges that the corridor currently faces?
12. What do you suggest could be done to improve the flow of cargo traffic at this border post and along the entire corridor?
13. What range of services do you provide on the Beira Corridor?

APPENDIX 6 CUSTOMS QUESTIONNAIRE

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

A CASE STUDY OF THE BEIRA CORRIDOR BOTTLENECKS

INTERVIEW FORM

List of questions used to engage customs management at Forbes border post (Zimbabwe)

1. In your view what are the major bottlenecks at this port of entry?
2. Do you think the port of entry is operating at its optimum capacity or it is constrained in terms of capacity?
3. What is the role of customs in the facilitation of the clearance of goods?
4. In your view what role should the clearing agent play in order to ease the passage of goods through the port of entry?
5. How is the working relationship between customs and clearing agents currently?
6. Do customs and clearing agents meet regularly to address challenges faced at the port of entry?
7. How often do customs/government officials meet with clearing agents to discuss issues relating to goods clearance?
8. How many trucks is port of entry handling daily?
9. What has been the traffic trend in terms of increase or decrease?
10. What are the major challenges faced at the port of entry currently?
11. What could be done in order to improve the performance of the port of entry in facilitating passage of goods?
12. What recommendations can be made to ease the challenges?