CROSS-BORDER FLOW CALCULATOR

Corridor Comparative Economic Impact Assessment Report for TKC and MDC Corridors

March 2022

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EXECUTIVE SUMMARY

The purpose of the study was to compare the extent to which border delays and the related logistics costs differ between the Maputo and Trans Kalahari corridors. The comparison focused on delays at Lebombo, Kopfontein and Skilpadshek border posts which are the key border posts on the two corridors.

The average transit times at each of the border points for Lebombo, Kopfontein and Skilpadshek border posts were as illustrated below.

	Exports		Imports	
	South Africa	Foreign	Foreign	South Africa
Lebombo	16 hours 49 minutes	14 hours 31 minutes	5 hours 13 minutes	14 hours 19 minutes
Kopfontein	9 hours 24 minutes	6 hours 47 minutes	4 hours 37 minutes	7 hours 48 minutes
Skilpadshek	12 hours 24 minutes	7 hours 3 minutes	3 hours 51 minutes	6 hours 52 minutes

It was noted that, Lebombo incurs the longest average transit times at all four points. It was further noted that the South African side of the border post incurs longer delay times at Lebombo, Kopfontein and Skilpadshek.

The study established that the greatest additional costs incurred due to border delays are at the Lebombo border post. The other notable finding was that export costs are significantly greater than at the other two border posts, Kopfontein and Skilpadshek, as shown below.

	Exports	Imports
Lebombo	R861 770 332	R73 616 631
Kopfontein	R114 399 892	R22 063 745
Skilpadshek	R78 022 510	R18 257 887

The study results showed that the economic impact of border delays along both corridors have on trade logistics costs, were substantial. The border delays experiences at Lebombo are longer than at any of the previously studied border posts.

The recommendations made include implementation of One Stop Border Post (OSBP) at border posts along the two corridors to reduce the delays. Literature in this research emphasises the importance of an OSBP in Africa’s regional trade environment. An OSBP has been proven to lessen transit time between borders as part of the procedures can be merged, thus alleviating the issue of duplicated activities.

Secondly, the use of technology to facilitate cross-border trade through cross-border is essential to reduce administrative and operational procedures and therefore reducing delays. The third and last recommendation, is the introduction of Authorised Economic Operator (AEO) status to speed up customs clearance.

1. INTRODUCTION

The C-BRTA developed a CBFC Model for measuring transit time at border posts and in corridors in 2017-18. This was followed by pilot studies focusing on measurement of transit time at several border posts and the segment of the TKC corridor in South Africa, looking at multiple nodes of the corridor.

To appreciate the impact of delays along the various corridors in the ESA region, a comparison of the TKC and Maputo corridor was conducted to determine how each of the corridors is performing. These two corridors are very important to the region as they are strategic in linking SADC landlocked countries to international markets through the ports of Walvis Bay to the west and Maputo to the east. Thus, during the 2020-21 financial year, the Cross-Border Road Transport Agency (C-BRTA) collaborated with the University of Stellenbosch towards completing the Cross-Border Flow Calculator (CBFC) Economic Impact Assessment (EIA) Report for transit time and delays encountered by cross-border road transport on sections of the Trans-Kalahari Corridor (TKC).

This study focused on conducting a comparative economic impact assessment of the TKC and Maputo Corridor using the average transit time that a truck experiences on the two corridors, with a view to understand and quantifying the effect of transit time on trade logistics costs on the two corridors.

The report was compiled using qualitative and quantitative data collected by C-BRTA in 2019 on the segment of the TKC corridor in South Africa and 2018 on the Maputo development corridor section of the South African side and Kilometre 4 on the Mozambican side. The data was used in the calculation of trade logistics costs for the two corridors for purposes of comparison.

To understand the context of the study and approach taken in this report, it is important to look at the contribution of transport costs to total logistics costs. In 2014, transport costs accounted for 57% of total logistics costs, followed by inventory carrying costs (15.2%), warehousing (14.6%) and management & administrative costs (13.5%) (Havenga, Simpson, King, de Bod & Bruin, 2016). With freight transport costs accounting for the bulk of trade logistics costs, it is imperative to reduce these expenses where possible, to realise the benefits that follow (Jacoby & Minten, 2009). Due to trucks standing idle on certain points along the corridors and at border posts for extensive periods of time, this unnecessarily extends the cash-to-cash cycle between the sender and receiver of the goods. This results in frustrating the receiving party, consequently losing a business partner in the future. Thus, identifying key problems causing delays and how they impact trade logistics costs allows for more streamlined border post practices, encouraging higher levels of intra-African trade and lowering of generalised costs.

1.1 Project Background

The C-BRTA developed a CBFC Model for measuring transit time at border posts and in corridors in 2017-18. This was followed by pilot studies focusing on measurement of transit time at several border posts and the segment of the TKC corridor in South Africa, looking at multiple nodes of the corridor.

The purpose of the study was to:

- Quantify Transit Time and identify bottlenecks to seamless flow of cross-border traffic on two corridors; and
- Enable a comparative estimation of the economic impact of long Transit Times and delays on the TKC and Maputo corridor.

Responding to the above two objectives would enable identification of solutions for addressing corridor bottlenecks and reducing transit times which would result in efficient flow of both goods and passengers in the region.

Several reasons and objectives informed the development and piloting of the Cross-Border Flow Calculator. There is evidence from regional corridor studies conducted in Southern African Development Community (SADC) confirming that there are high logistics costs incurred in regional corridors that negatively affect the import and export business. This has unfortunately rendered SADC region unattractive for foreign direct investment and goods produced and traded uncompetitive. Furthermore, the high logistics costs continue to affect intra-regional trade as well as market integration and the overall competitiveness of the regional market. It is arguably and partly, for this reason that the rate of industrialisation within the region continues to lag in comparison to other developing regions such as the Asian counterparts.

Equally important is the fact that delays at border posts and resultant long transit times are a burden, not just to domestic and regional economies, but impede the seamless flow of passenger transport between countries. Other than affecting passenger comfort, safety, social wellbeing, and cause fatigue, it also has a negative impact especially on small-scale traders, who often use public transport for transportation of their consignments. The inefficiencies experienced along the corridors are a result of border post delays and contribute significantly to the high logistics costs within the region. These delays increase the cost of doing business and affect regional trade and market integration as well as the global competitiveness of the region.

The absence of a tool or mechanism in the country (South Africa) for calculating border-crossing transit time and for computing the economic impact of these delays has been a matter of concern. Prior to the development of the Cross-Border Flow Calculator/ Model (C-BFC) now at piloting phase, it was not possible to predict travel times for both freight and passenger along corridors and across commercial border posts servicing the country. Passenger and freight transport operators continue to complain about the inefficiencies and delays at the various commercial border posts, which contribute to high costs incurred while doing business.

To address the challenges raised above, the Cross-Border Road Transport Agency therefore developed a Cross Border Flow Calculator/ Model, during the 2017-18 financial year, to calculate border-crossing transit times and to establish the extent of transit delays and ultimately estimate the economic impact of the delays experienced by cross-border traffic. Dwell time for commercial cross-border vehicles is an important performance indicator of supply-chain as this affects asset utilisation and has a negative impact on vehicle operating costs (VOC).

To test the functionality of the C-BFC, the C-BRTA identified several points on the TKC for piloting of the calculator and commissioned several surveys aimed at collecting data to pilot the tool.

This report is an outcome of the pilot surveys conducted on the South African portion of the Trans Kalahari and Maputo Corridors. The surveys lasted for seven days where a combination of driver personal interviews, determination and recording of vehicle registration numbers and arrival/departure times were recorded at designated points as indicated. Data collected at these points was used to establish transiting time and delays by measuring minimum, mean, median and maximum transit times for commercial trucks, buses, and cross-border taxis

It is therefore envisaged that going forward, the C-BFC will assist in providing real-time data on transit time and travel times across corridors focusing on key nodes, and will have a range of tangible benefits, including improved decision making insofar as planning and targeted interventions aimed at improving cross-border road transport and trade flow is concerned. The locations of the studies from which data was collected for comparison of the two corridors area shown below.

1.2 Trans Kalahari Corridor

For the Trans Kalahari Corridor, two border posts between South Africa and Botswana, namely Skilpadshek/Lobatse and Kopfontein/Tlokweng were used in the study. The sections of the corridor where the data was collected are illustrated in the Figure below. Figure 1 shows the locations on the Trans Kalahari Corridor where data was collected.

Figure 1 Trans Kalahari Corridor Survey points

1.3 Maputo Corridor

Figures 2 through Figure 5 show the location of the various points where data was collected on the Maputo Corridor. The respective points shown comprise Kilometre Seven, Lebombo border post, Ressano Garcia and Kilometre Four, respectively. The Lebombo/Ressano Garcia border post is a commercial border post between South Africa and Mozambique to the east of South Africa and is the port of entry mostly used by cross-border road transport operators transporting commodities to and from South Africa and Mozambique and to some extent, for transit to SADC countries. Figures 1 to 4 below shows the points of interest which were measured.

Figure 2 Kilometre Seven

Figure 3 Lebombo Border Post

Figure 4 **Ressano Garcia**

Figure 5 **Kilometre Four**

1.4 Study objectives

The main aim of the study was to investigate and determine the Comparative EIA of Transit Time and delays established using the segregated and block transit times for cross border traffic flows on the Trans Kalahari Corridor and Maputo Corridor. The objectives of the study were to:

- Quantify Transit Time and identify bottlenecks to seamless flow of cross-border traffic; and

- enable estimation of the economic impact of long Transit Times and delays, along the two corridors and to compare the results.

The data was extracted from a Study conducted by C-BRTA on 'Assessment of the transit times for freight and public transport passenger vehicles (both taxis and buses)' which was undertaken on the Trans Kalahari Corridor over a period of seven days, from the 7th to the 14th of November 2019 and on the Maputo Corridor over a period of seven days from 12th to the 19th of November 2018.

The specific objectives for this study were as follows:

- To establish segregated and block transit time baselines for the time taken by trucks to pass through the two borders by gathering arrival and departure times of trucks at the points of entry and exit;
- To establish if time spend at border posts is a result of time required for formal clearance procedures or may be due to other reasons;
- To identify specific issues that impede the free movement of vehicles across borders; and
- To identify problems encountered by trucks using border posts.

During the surveys, traffic observation was conducted over 18 hours at all stations except at Bapong Traffic Control Centre TCC where the observations were 24 hours, over the seven days. The data obtained was analysed to calculate transit times for each of the two corridors. The transit times are vital inputs to the finalisation of the Cross-Border Flow Calculator Model and for the eventual automation of the transit calculation project. It is planned that the block transit will form a baseline in the implementation of future interventions on both the Trans Kalahari and Maputo Corridors.

1.5 Structure of report

The report comprises the following sections:

- Section 1: Introduction and Background: Highlights the project background, objectives of the study and explains the purpose of this report
- Section 2: Cross-Border Flow Calculator Model: Outlines the three levels of the Model
- Section 3: Methodology
- Section 4: Data collection and analysis
- Section 5: Results discussion
- Section 6: Comparative economic impact analysis

- Section 7: Conclusions
- Section 8: Recommendations for future similar studies.

2. CROSS-BORDER FLOW CALCULATOR MODEL

The Cross-Border Flow Calculator has three levels. The different levels provide different levels of analysis depending on depth of detail that may be required in the calculation of transit times at specific border posts. The three levels of the CBFC are:

- Block Transit Time
- Segregated Transit Time
- Detailed Analytical Transit Time.

2.1 Block Transit Time

The Model for calculation of Block Transit Time is presented below. This Model when applied provides block time taken to between start time of border processes on one side of the border and the time the vehicle is acquitted on the other side of the border. It does not do any analysis of how much time is spent on either side of the border or for each process.

Block Transit Time (Border Post) $= \sum(Exit\text{™}\ Border\ Post\ Side_b - Arrival\text{™}\ Border\ Post\ Side_a)$

Where:

- $Exit\text{™}\ Border\ Post\ Side_b$ is the time when the vehicle is acquitted and exits the border on the second side of the border
- $Arrival\text{™}\ Border\ Post\ Side_a$ is the time when the border crossing processes commence when the vehicle has arrived at the first side of the border.

This Model can be applied to establish overall transit time at a border or conduct comparative assessment of border post performance i.e., between border posts and to track performance of a border over time.

2.2 Segregated Transit Time

The model for calculating Segregated Transit Time is presented below. This model, when applied breaks down transit time into two portions: time spent on one side of the border and on the other side.

Segregated Transit Time is established calculating time taken between start time of border processes when the vehicle arrives and time the vehicle is acquitted and leaves one side of the border to cross to the other side. Then it adds the time taken between start time of border processes when the vehicle arrives on the other side and the time the vehicle is acquitted and leaves the second side of the border to continue its journey.

Segregated Transit Time (Border Post)

$$= \sum \left(Exit^{\text{™}}\ Border\ Post\ Side_a - Arrival^{\text{™}}\ Border\ Post\ Side_a \right)$$
$$+ \ \sum (Exit^{\text{™}}\ Border\ Post\ Side_b - Arrival^{\text{™}}\ Border\ Post\ Side_b)$$

- $Exit^{\text{™}}\ Border\ Post\ Side_a$ is the time when the vehicle is acquitted and exits the border on the first side of the border

- $Arrival^{\text{™}}\ Border\ Post\ Side_a$ is the time when the border crossing processes commence once the vehicle has arrived at the first side of the border

- $Exit^{\text{™}}\ Border\ Post\ Side_b$ is the time when the vehicle is acquitted and exits the border on the second side of the border

- $Arrival^{\text{™}}\ Border\ Post\ Side_b$ is the time when the border crossing processes commence once the vehicle has arrived at the second side of the border.

The Model provides a basic level of analysis that determines the time spent on each side of the border. Thus, it can be applied to provide information on the level of inefficiency associated with each side of the border. However, it does not determine the exact processes that cause inefficiencies.

2.3 Detailed Analytical Transit Time

The Model for calculation of Detailed Analytical Transit Time is presented below. The application of this Model breaks down transit time into two portions: time spent on one side of the border and on the other side of the border. Secondly, it breaks down the time spent on either side of the border into exact durations spent conducting each of the border crossing processes on both sides of the border.

Detailed Analytical Transit Time is established by summing up time taken executing each border crossing process on both sides of the border. This Model enables the establishment of durations associated with each process undertaken, calculating time taken between the start time of border processes when the vehicle arrives and the time the vehicle is acquitted and leaves one side of the border to cross to the other side. It then adds the time taken between start time of border processes when the vehicle arrives on the other side and the time the vehicle is acquitted and leaves the second side of the border to continue its journey.

Detailed Analytical Transit Time

$$
\begin{aligned}
&= \sum Border\ Post\ Side_a\ (P™1 + P™2 + P™3 + P™4 \ldots\ldots..+P™(n-1) + P™n) \\
&\qquad + \quad \sum Border\ Post\ Side_b\ (P™1 + P™2 + P™3 + P™4 \ldots\ldots..+P™(n-1) \\
&\qquad + P™n
\end{aligned}
$$

- $Border\ Post\ Side_a\ is$ first side of the border
- $Border\ Post\ Side_b$ is the second side of the border
- $P™1$ is time spent executing border crossing process one
- $P™2$ is time spent executing border crossing process two
- $P™3$ is time spent executing border crossing process three
- $P™4$ is time spent executing border crossing process four
- $P™n - 1\ is$ time spent executing second last border crossing process

- $P™n\ is$ time spent executing the last border crossing process.

The Model provides detailed level of analysis which enables determination of time spent on each process on either side of the border. Thus, it can be applied to provide information on the level of inefficiencies associated with each process and enable targeted interventions and improvements. It is the results of the model that were used to calculate the economic impact which are used to compare the two corridors.

2.4 Conclusion

The focus of the Model in both cases, TKC and Maputo was to the analysis of Block Transit Time and Segregated Transit Time only on the South Africa side and border posts of the adjourning neighbouring country. This report therefore provides analysis of transit times for KKC and Maputo Corridor focusing on the sections indicated.

3. RESEARCH METHODOLOGY

This section elucidates the design and methods used to answer the research questions. The research design clarifies the core principles for this research, followed by the methodology clarifying the instruments and methods that were used by researcher to collect, analyse and interpret the data received.

The collection points are further discussed in the preceding section, followed by the research constructs and variables identified.

3.1 Research Design

With the aim of the study to evaluate the economic impact of vehicles transit times at the Lebombo border post, an evaluative research case study was performed. This research discusses existing theories, methods, findings and results, whereby a deductive approach will be performed to assist this evaluative research. To quantify and evaluate the border delays at the Lebombo border post, a mixed-method approach was followed in this study. The research is developed around evaluating the quantitative impact border delays have of trade logistics costs. Qualitative data was explored to provide further context to the study.

Four secondary datasets were supplied to perform this research. Although the researcher was not involved in the planning of the intended use and the collection of the data, secondary data could give rise to new phenomenon and findings (Stewart & Kamins, 2011:2). As this research is time constrained, the use of valid and reliable secondary data was appropriate.

The CBRTA supplied two raw data sets, one focusing on transit times through the Lebombo border post which were captured over a one-week period from 12 to 19 November 2018. Secondly, the CBRTA conducted surveys from 12 to 15 November 2018. The CBRTA supplied the driver questionnaires. Additional datasets, including the FDM™ and LCM™ were supplied by Zane Simpson. These datasets permitted greater insight into the economic value the border delays have.

The mixed-method approach aids this case study research strategy to obtain a holistic understanding of the context from both observations on which calculations are performed as well as personal driver experiences which are collected through driver surveys. This study evaluates a cross-sectional study of the 2018 cross border delay at the Lebombo border post.

3.3 Research Methodology

To understand the impact of border delays on vehicle transit times and the reasons for the transit times and delays experienced in the corridor, a mixed methods approach was incorporated into the research. Quantitative and qualitative data were used and analysed, making use of numeric as well as non-numeric data. This was because a mixed methods approach allows for a deeper understanding of the data presented (Saunders *et al.,* 2016:169).

To calculate the logistics costs incurred because of long transit times and cross border delays, the Logistics Cost Model (LCM) and Freight Demand Model (FDM) were used. Once calculations were complete, Microsoft Excel and Tableau were used to visually portray the results using appropriate charts and graphs.

3.3.1 Quantitative research methods

For this research, most of the results stem from quantitative data, although qualitative data is used to support the conclusions reached from analysing the quantitative data. The quantitative data consisted of vehicle transit times through the northbound and southbound gates at Skilpadshek. This allowed the researcher to analyse the scope of the border delays. For this study, mathematical formulas and statistical analysis were used conjunctively when working on the data to extract the needed information to assist in answering the research questions.

3.3.2 Qualitative research methods

Interviews with truck drivers carried out by the CBRTA form the basis of the qualitative data. Contained in the interview data, are the truck drivers' first-hand experiences as to why they believe these delays occur. Qualitative aspects included in the research methods proved to be appropriate to this study, as it assisted in providing context for the transit time data provided by the CBRTA.

3.4 Secondary Data

The nature of this study involved the use of secondary data exclusively recorded and supplied by the CBRTA to credibly answer the research questions stated. Secondary data refers to data that had originally been collected for some other purpose, which can be further analysed to infer additional or different knowledge, interpretations, or conclusions (Saunders *et al.,* 2016:316). Two sets of secondary data were supplied, one focusing on transit times through Skilpadshek and the other centred around providing freight flow volumes and commodity groups from Zane Simpson.

Parts of the research results stem from survey-based secondary data which refers to present data initially collected for some other purpose by means of a survey strategy, usually questionnaires. Such data generally refers to government agencies, which was made available in data tables as a downloadable matrix on Microsoft Excel raw data for secondary analysis (Saunders *et al.,* 2016:322).

3.5 TKC Cross-Border Road Transport Agency's Data Recording Points and Process

The CBRTA recorded the transit times of the trucks at four points at the Skilpadshek border post, capturing the entry and exit times of the vehicles along with driver questionnaires. The format of the data provided by the CBRTA was in Microsoft Excel format as quantitative, unprocessed data. The data was recorded manually.

The process involved individuals to be positioned at various points across the border to measure the time that it took for a vehicle to pass through the gates by noting the arrival time and exit time, as well as number of days spent, if necessary. The date of entry and exit was recorded along with the vehicle registration. Maximum and minimum transit times were provided, as well as the average daily segregated transit times. The points below match those of the physical boundaries found at Skilpadshek as illustrated in Figures 2 and 3.

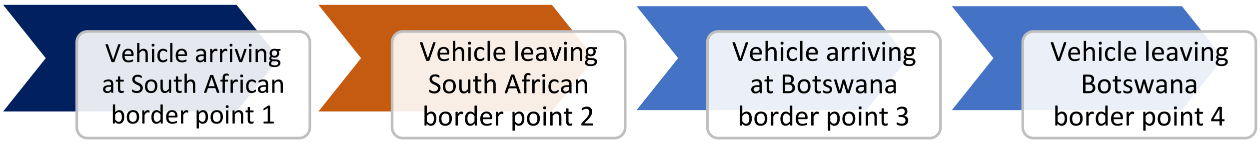


Figure 6: Recording points where the CBRTA captured the transit times of vehicles leaving South Africa entering Botswana (northbound)

This research conducted a mixed-method approach to provide greater insight and context to the topic. Four sets of secondary data were supplied. The CBRTA supplied the transit time dataset as well as the driver questionnaire. Zane Simpson provided the LCM™ and FDM™.

Quantitative data was used to measure the economic impact of the Lebombo border delays on trade logistics costs. The truck transit time dataset supplied by the CBRTA allowed the border delays to be calculated. The LCM™ and FDM™ were used to measure the associated logistics costs because of the Lebombo border delays. Qualitative data allowed for a deeper understanding of the quantitative findings. The proceeding sections will further describe the quantitative and qualitative research that were used.

3.3.1 Maputo Corridor Quantitative research

For this research, the key insights and results arise from the quantitative data findings. The transit data provided by the CBRTA provided core results to evaluate the border delays incurred at the Lebombo border post.

Quantitative data was used to calculate the transit delay time and the associated economic impact of the border delays on logistics costs at the Lebombo border post. The Lebombo border post transit data which the CBRTA provided consisted of various details for each vehicles crossing the Lebombo point at the different points of recording. The recordings were observed and manually entered on an Excel spreadsheet over a one-week period from 12 to 19 November 2018. For each individual vehicle that transited through the Lebombo border post the entry time, exit time, vehicle registration, vehicles code and date was recorded. The entry and exit times of the vehicles at the different points of the border post was a critical variable of interest, as this information was required to determine and analyse the border delays times. To extract the needed information from the data, mathematical formulas and statistical analysis was used.

Freight flow data was captured and supplied by Zane Simpson. This compiled data contained details of 2018's freight flow model, which was required for the calculation of the trade logistics costs. The FDM™ was used to identify the tonnage of a commodity imported and exported to determine the additional storage costs associated at the border.

The LCM™ supplied by Zane Simpson contained storage, fixed road cost and inventory carrying cost per commodity. This compiled data was required for the calculation of the trade logistics costs. Previous studies assessing the economic impact border delays have at various South African border posts used logistics costs that were previously calculated by Havenga, *et al*. (2013). It is assumed that the previously calculated logistics cost is outdated. For this research, the logistics costs were re-calculated to provide up-to-date accurate results and findings.

Data provided by Zane Simpson containing freight movements for 2018 using the FDM™ ensured accurate figures were used to assess the freight volumes passing through the Lebombo border. The importance of accurate freight flow volumes data was necessary to calculate accurate logistics costs incurred. Mathematical calculations were performed to answer the research questions pertaining to time, cost, and impact on national GDP. The LCM™ and FDM™ were used to determine the trade logistics costs involved because of the border delays at the Lebombo border post.

3.3.2 Qualitative Research Methods

The data on driver surveys that were performed over a one-week period from 12 until 15 November 2018 at the Lebombo border post provided qualitative data. The questionnaire contained questions pertaining to the Lebombo border post and the related delays experienced. The questionnaire included closed ended questions whereby the questions could be coded to categories. The open-ended questions and a comments section which allowed drivers to provide their views on the causes of border delays. Qualitative data was appropriate to confirm the findings and support the context of the quantitative findings.

3.4 Research Constructs and Variables

For this research, key constructs were used to highlight the key themes within the research questions. Constructs are not directly observable and were therefore further defined and measured using appropriate variables (Saunders *et al*., 2016:450). Trade logistics costs was identified as the key construct for this study and was expressed in Rands (ZAR).

The LCM™ was adopted to measure trade logistics costs associated for the movement of freight using road transportation within South Africa (Havenga, *et al.,* 270). The model categorises the movement of goods into 83 commodities (Havenga, *et al.,* 270). For this study, the logistics costs associated to carry out logistical functions for the various freight commodities traded to and from the Lebombo border by road transportation were calculated.

The costs to the border are segregated into five cost components:

- *Transport costs*.
- *Externality costs*.
- *Storage and port costs*.
- *Management and administration costs*.
- *Inventory carrying costs*.

For this research, the FDM™ had all costs to the border calculated. The calculations consider the cost per ton. This cost per tonne is unique for each commodity but is independent of origin and destination pairs.

A subconstruct was identified as the additional costs incurred due to border delays. Prolonged transit delay times decrease a driver's productivity. The lost productivity comes as a driver is not moving goods while there are border delays. The need for additional inventory becomes apparent as there is a higher level of uncertainty. Companies will therefore increase their safety stock levels which subsequently increases the inventory carrying costs and storage costs. The uncertainty border delays bring about has an impact on supplier-customer relationships. Uncertainty can result in lost relationship due to unpredictable customer service levels. Furthermore, border delays increase the fixed cost component of the vehicles. Trucks that are standing due to border delays incur additional fixed standing costs. As the vehicles is not running, the cost of the vehicles standing instead of running needs to be considered.

The additional costs incurred due to border delays can be segregated into the following three cost components:

1. Additional storage cost. The uncertainty associated to inventory availability due to the unknown time extent due to border delays causes inventory levels to increase. As stocking out is detrimental to any firm. Instead, companies decide to increase their inventory levels to compensate for the unreliability. The additional storage costs incurred can be expressed as follows:

$ASCex$ = ∑(dexc)(texc)(SCc)

c=1

and

$ASCim$ = ∑(dimc)(timc)(SCc)

c=1

Where;

ASCex	total additional storage cost incurred by exporting *ex* commodity *c* from South Africa
ASCim	total additional storage cost incurred from importing *im* commodity *c* from Mozambique
dexc	time delay *d* while exporting commodity *c* from South Africa
dim_c	time delay *d* while importing commodity *c* from Mozambique
tex_c	tonnage *t* of commodity *c* exported from South Africa
tim_c	tonnage *t* of commodity *c* imported from Mozambique
SCc	storage rate of commodity *c*

Inventory carrying cost in transit border. The opportunity cost associated with delayed inventories needs to be accounted for (Havenga, *et al.*, 2017:272). The opportunity cost is the cost of financing inventory until the payment is received is extended with delayed inventories; or the return that could be revived if the money was invested elsewhere.

This can be expressed as follows:

$$= \sum (\frac{c}{SD})(t_c^{ex})(d_c^{ex}) \qquad {}^{ex} \qquad IC$$

ICC

c c=1

and

$^{im} = \sum(\frac{\mathrm{c}}{\mathrm{SD}})(\mathrm{t}_{\mathrm{c}}^{\mathrm{im}})(\mathrm{d}_{\mathrm{c}}^{\mathrm{im}})$ IC

ICC

c c=1

Where;

ICCex	total additional inventory carrying cost incurred by exporting *ex* from South Africa
ICCim	total additional inventory carrying cost incurred from importing from Mozambique
ICc	inventory carrying cost of commodity *c* per ton
SDc	total days commodity *c* can be stored for

Road fixed delay cost. The delays freight trucks experience before reaching the border post increases transport costs. Other than the time delays experienced, the standing cost of the vehicle needs to be considered. The LCM™ was used to determine the fixed cost per vehicle configuration and amount of vehicles allocated per commodity (Havenga, *et al.,* 2017). Each commodity was allocated to the vehicles to its most likely vehicle configuration (Havenga, *et al.,* 2017:271). For example, citrus distribution to metropolitan areas will most likely use a V6R vehicle configuration. The fixed cost incurred per vehicle configuration were calculated to a per day basis, which could further determine daily and hourly costs.

The fixed cost calculation is comprised of average annual depreciation, average annual capital cost, average annual licence, average annual insurance, average annual wages and average annual overheads (Havenga, *et al.,* 2017). The annual fixed cost incurred by trucks during delays was calculated, and can be expressed as follows:

$RFDCex$ = $\sum(FCvdaily)(dvex)$

v=1

And

$RFDCim = \sum(FCvdaily)(dvim)$

v=1

Where;

RFDCex	road fixed delay costs incurred by exporting *ex* from South Africa
$RFDC^{im}$	road fixed delay costs incurred by importing *im* from Mozambique
$FC_v daily$	daily fixed cost for vehicle type *v*
$d_v ex$	time delay *d* for vehicle type *v* while exporting *ex* from South Africa
$d_v im$	time delay *d* for vehicle type *v* while importing *im* from Mozambique

4. DATA COLLECTION AND ANALYSIS

The case study-based research incorporated both quantitative and qualitative data to analyse and confirm the result yielded. Since the data provided was secondary data, it was collected for a reason other than this research. Thereby, the data provided was filtered and organised according to the attributes required for this study. The data was structured using data analysis skills on Excel.

The CBRTA recorded numerous aspects of data at several border posts between South Africa and Botswana in November 2019. Recordings in the data stretched over a period of one week. The structure of the data includes assembled spreadsheets of the transit times of the trucks arriving and departing at the recording points named northbound and southbound gates of Skilpadshek. Recordings for each individual vehicle's entrance and departure was captured with time being the variable of interest documented on each vehicle. Vehicle transit time proved to be a crucial variable of interest as it was analysed to determine delay times.

Along with vehicle transit times, questionnaires answered by the truck drivers stating their concerns as to why unreasonable delays were occurring at Skilpadshek were provided. Data of freight flows passing through the border were captured and supplied by Zane Simpson. This was processed to determine a current freight flow model needed for the trade logistics cost calculation.

4.1 Qualitative data

Data provided by the CBRTA aided in calculating more accurate trade logistics costs that encompass the current topic of border delays into the final calculation. Interviews conducted by an employee of the CBRTA with the truck drivers help to substantiate the reasoning behind why these delays were so apparent.

4.2 Validity and Reliability of Findings

Saunders *et al.* (2016) defines validity as *“the extent to which data collection methods accurately measure what they were intended to measure”*. The validity of this study was preserved by ensuring that trustworthy data from a credible government agency was used. For the accuracy of this study, the data was cross-checked. A process of filtering and grouping quantitative data for Skilpadshek border post was conducted with the use of Microsoft Excel.

The qualitative data was validated through the means of cross-checking the most relevant reasons for delays sourced from the interviews with reoccurring themes discussed in the literature review. The validity of the figures used in the calculation were thoroughly checked for accuracy by Zane Simpson as well as Crynos Mutendera who is employed by the CBRTA.

4.3 Quantitative data

Three sets of quantitative data were used to assess the border delay times and the associated logistics costs incurred. The CBRTA supplied the raw dataset that contained transit times of freight vehicles at the survey locations. Zane Simpson supplied two compiled datasets; the FDM™ and LCM™, which were used to determine the trade logistics costs associated to the border delays experienced.

4.4 Data Recording Points and Process

The transit dataset provided by the C-BRTA contained recordings of freight vehicles at four points on the Maputo Corridor and five points on the TKC. The data was manually entered by CBRTA individuals who were strategically placed at the four points across the border. The individuals were required to record entry and exit times accompanied with the vehicle registration. This allowed the data to be analysed to measure how long it takes freight vehicles to transit though the border. The dataset was received raw and unprocessed, whereby cleaning of the data was required.

The data was captured and recorded over a one-week November 2018 for Maputo Corridor and November 2019 for TKC. The data was captured and entered manually in the Excel spreadsheet. The CBRTA individuals recorded the truck details, arrival and exit times of vehicles passing through the border post at several points, shown in figure 7 for Maputo Corridor and Figure 8 for the TKC.

4.5 Trans Kalahari Corridor

The survey team recorded the truck details, arrival and exit times of vehicles passing through the border post at several points, shown in figure 7.

Figure 7: Lebombo border crossing process and data collection points of truck time recordings

4.5.1 Recorded Truck Transit Times

Using the segregated transit time data supplied by the CBRTA spanning across a period of one week, it was possible to calculate the average time a truck spent at each of the four border posts.

Tables 1 to 6 show the transit times recorded. The details of the Tables include minimum transit time, average transit time, median transit time and maximum transit time.

Table 1: Skilpadshek northbound - 1

Skilpadshek northbound - 1 (572 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	4
Average Transit Time (days: hours: min)	0	12	24
Median Transit Time (days: hours: min)	0	5	18
Maximum Transit Time (days: hours: min)	6	11	32

Table 2: Pioneer Gate northbound - 2

Pioneer Gate northbound - 2 (752vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	1
Average Transit Time (days: hours: min)	0	7	3
Median Transit Time (days: hours: min)	0	0	41
Maximum Transit Time (days: hours: min)	6	13	30

Table 3: Pioneer Gate southbound - 3

Pioneer Gate southbound - 3 (820 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	1
Average Transit Time (days: hours: min)	0	3	51
Median Transit Time (days: hours: min)	0	0	9
Maximum Transit Time (days: hours: min)	6	5	16

Table 4: Skilpadshek southbound - 4

Skilpadshek southbound - 4 (560 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	3
Average Transit Time (days: hours: min)	0	6	52
Median Transit Time (days: hours: min)	0	0	23
Maximum Transit Time (days: hours: min)	6	14	24

4.5.2 Dispersion of the Transit Time Data

By analysing the transit time tables above, certain summaries of the data were reached. When travelling northbound, it took on average 12hrs 24min to travel from the South African entry point to the South African exit point, while it took on average 7hrs 3min to travel from the Botswana entry point to the Botswana exit point.

By referring to Tables 10-11, it can be inferred that when travelling northbound, it took on average 12hrs 50minutes to travel from the South African point of entry to the Botswana point of exit, meaning that it took on average 12hrs 50minutes for South Africa to export goods through the Skilpadshek border to Botswana. When travelling southbound, it took on average 8hrs 23minutes to travel from the Botswana entry point to the South African exit point. Through this calculated time, one can infer that it took on average 8hrs 23minutes for South Africa to import goods through the Skilpadshek border from Botswana.

Table 5: Skilpadshek to Pioneer Gate Northbound Block Transit Time

Skilpadshek/Pioneer Gate Northbound (498 vehicles)	**Hours**	**Min**
Average Transit Time (hours: min)	12	50

Table 6: Pioneer Gate to Skilpadshek Southbound Block Transit Time

Pioneer Gate/Skilpadshek Southbound (665 vehicles)	**Hours**	**Min**
Average Transit Time (hours: min)	8	23

4.6 Maputo Corridor

The survey team recorded the truck details, arrival and exit times of vehicles passing through the border post at several points, shown in figure 7.

Figure 8: Border process of truck time recordings for valid entries

South African Eastbound can be defined as a truck exiting the South African border in the direction toward Mozambique (point 1A and 1B). Mozambique Eastbound can be defined as a truck entering the Mozambique border from South Africa (point 2A and 2B). Mozambique Westbound can be defined as a truck exiting the Mozambique border in the direction to South Africa (point 3A and 3B). South African Westbound can be defined as a truck entering the South African border from Mozambique (point 4A and 4B).

4.6.1 Metadata

In this research, four points of interest were used to calculate the transit time data at the Lebombo border post on both South Africa and Mozambique territory. The points of interest were namely;

- South Africa Eastbound

- Mozambique Eastbound
- Mozambique Westbound
- South Africa Westbound

Table 7 represents an outline of the different fields of data the CBRTA individuals recorded at each of the abovementioned points. Only the variables of interest are displayed in table 7. As a truck entered and exited one of these points, the CBRTA entry and exit vehicle registration, times, date, month, year, vehicle class and vehicle code, as displayed in Table below.

Table 7: Metadata of variables of interest recorded at entry and exit points

Variables of interest	Example of record	Definition of data field	Unit of measurement / data format	Quantitative or Qualitative value	Type of data
RSA Eastbound	Main field heading	From South Africa to Mozambique	Text	Qualitative	Nominal
MOZ Eastbound	Main field heading	From Mozambique border into Mozambique	Text	Qualitative	Nominal
MOZ Westbound	Main field heading	From Mozambique border to South Africa	Text	Qualitative	Nominal
RSA Westbound	Main field heading	From South African border into South Africa	Text	Qualitative	Nominal

Border post	Lebombo		Text	Qualitative	Nominal
Entry vehicle registration	AB226CM	The vehicle registration number	Text	Qualitative	Nominal
Time in	14:06:00	Vehicle entry time upon arrival	Time	Quantitative	Ratio
Entry date	13	Vehicle entry date upon arrival	Date	Quantitative	Ratio
Entry month	November	Vehicle entry month upon arrival	Date	Quantitative	Ratio
Entry year	2018	Vehicle entry year upon arrival	Date	Quantitative	Ratio
Exit vehicle registration	DZ42CXGP	The vehicle registration number	Text	Qualitative	Nominal
Exit time	14:39:00	Vehicle exit time upon arrival	Time	Quantitative	Ratio
Exit date	12	Vehicle exit date upon departure	Date	Quantitative	Ratio
Exit month	November	Vehicle exit month upon departure	Date	Quantitative	Ratio
Exit year	2018	Vehicle exit year upon departure	Date	Quantitative	Ratio

4.6.2 Transit Time Data

To calculate the transit delays time of trucks at the border, the data was cleaned. This included checking the border post, the way the data was collected, the information recorded within the data set, checking that there were no spelling errors, and checking the timeframe in which the data was recorded. As the transit time data was supplied by the CBRTA in Excel, this was the chosen software to analyse the transit time data.

For this study, vehicles were independently recorded at each border post point. Entry and exit times at each independent point had to be recorded to become a valid sample entry. From the sample supplied by the CBRTA, every truck had a possibility of being selected at each border post point.

The entries were matched by using a count-if function in Excel; where each single vehicle registration of the time in's was searched for a matching pair in the range of vehicle registration exiting at the same point. Once all the vehicles' registrations were matched according to time in, exit time, date, month and year, the data was consolidated. Exact duplications were omitted as it was assumed it is not possible to have the same vehicle registration going through the border at the exact same time. Further assumptions were made, that vehicle that passed through the border more than once were valid if the time between the entries seemed reasonable, otherwise the entries were omitted. This process allowed for a structured view to make sense of the data to be processed and arranged according to Table 8. Table 8 represents the typical entry of the matched entry and exit times at South Africa Eastbound. The transit delays time was calculated by subtracting the entry date and time from the exit date and time.

Table 8 : Matched entry and exit times of trucks at South Africa eastbound

Entry			**Exit**	
vehicle registration	**date and time**	**transit delay time dd:hh:mm**	**date and time**	**vehicle registration**
AAA511MC	2018/11/15 08:13:00	00:05:19	2018/11/15 13:32:00	AAA511MC
AAB111MP	2018/11/15 09:36:00	00:01:39	2018/11/15 11:15:00	AAB111MP

4.6.3 Freight Flow Data

The FDM™ was supplied by Zane Simpson. The data was complied, therefore it required no cleaning and transforming. Table 9 represents an outline of the different fields of data used from the FDM™. Only the variables of interest are displayed in table 9. All the variables displayed in table 7 were used to determine the cost to the border excluding the additional costs incurred due to the delays experienced. Import/export, year and FDM™ commodity code was used in the calculation to establish the additional cost incurred due to border delays.

Table 9: Metadata of variables of interest from the Freight Demand Model (FDM™)

Variables of interest	Example of record	Definition of data field	Unit of measurement / data format	Quantitative or Qualitative value	Type of data
Import/ Export	Import	From Mozambique to South Africa	Text	Qualitative	Nominal
Year	2018	Freight flows for the year	Date	Qualitative	Nominal
FDM™_com_co	FDM™30040	Commodity code	Text	Qualitative	Nominal
Road line and distribution tons	911	Annual volume of tons transported of commodity “x”	Number	Quantitative	Ratio

Vehicles needed (line haul)	0.01	Number of vehicles needed to transport “y” volume of commodity “x”	Number	Quantitative	Ratio
Total road line haul transportation cost	85 892,72	Annual line haul costs incurred to transport “y” volume of commodity “x”	Number	Quantitative	Ratio
Total distribution cost	123 817	Annual distributions costs incurred transport “y” volume of commodity “x”	Number	Quantitative	Ratio
Road line haul externality cost	36 415	Annual line haul externality cost incurred transport “y” volume of commodity “x”	Number	Quantitative	Ratio

Road distribution externality cost	32 400	Annual distribution externality cost incurred transport “y” volume of commodity “x”	Number	Quantitative	Ratio
Inventory carry cost	16 050	Annual inventory carrying cost incurred transport “y” volume of	Number	Quantitative	Ratio
		commodity “x” to the border			
Storage cost	16 050	Annual storage cost incurred transport “y” volume of commodity “x” to the border	Number	Quantitative	Ratio

Admin Management Profit cost	16 050	Annual administration and management cost incurred transport “y” volume of commodity “x” to the border	Number	Quantitative	Ratio

4.7 Logistics Cost Model (LCM™)

The LCM™ was used to determine the additional costs incurred due to border delays. The model required the updated transit time to accurately determine the associated costs. Table 10 represents an outline of the different fields of data used from the 2018 LCM™ supplied by Zane Simpson. Only the variables of interest are displayed in table 10. All the variables displayed in table 6 were used to determine the additional cost incurred due to the delays experienced at the Lebombo border post.

Table 10: Metadata of variables of interest from the Logistics Cost Model (LCM™)

Variables of interest	Example of record	Definition of data field	Unit of measurement / data format	Quantitative or Qualitative value	Type of data
Vehicle	V5FD	Type of vehicle used to transport commodity “x”	Text	Qualitative	Nominal

Fixed costs for year	455 963	Fixed cost incurred for vehicle type “v”	Number	Quantitative	Ratio
FDM™_com_co	FDM™10010	Commodity code	Text	Qualitative	Nominal
Inventory cost per ton	91,63	The inventory cost of commodity “x” per ton	Number	Quantitative	Ratio
Storage Cost per ton (excluding handling)	1227,43	The storage cost of commodity “x” per ton	Number	Quantitative	Ratio

To calculate the additional daily cost per ton, the commodity storage times were extracted from the commodity storage time file, which clarifies the amount of days each commodity can be stored for. Table 11 illustrates an outline of the different fields of data used from the commodity storage time file supplied by Zane Simpson. Only the variables of interest are displayed in table 11.

Table 11: Metadata of variables of interest from the commodity storage time

Variables of interest	Example of record	Definition of data field	Unit of measurement / data format	Quantitative or Qualitative value	Type of data

FDM™_com_co	FDM™10010	Commodity code	Text	Qualitative	Nominal
Days	252	Number of days commodity “x” can be in storage for	Number	Quantitative	Ratio

4.8 Assumptions in Calculations

For this research, it was assumed that the percentage split in freight volumes from the FDM™ is proportionate to the split in the number of vehicles recorded by the CBRTA. It was assumed that vehicles count during the week of observations from 12 to 19 November 2018 are representative of the annual vehicles counts.

4.9 Calculating the Trade Logistics Costs

The FDM™ consisted of all the costs incurred to the border. Thereby, only the additional costs incurred due to the border delays needed to be calculated.

To calculate the road fixed delay costs, variable from table 12 were used in the calculation. The fixed cost for the year was simplified to the fixed cost per day by dividing the fixed cost per year by 365. A sum-if function was used in Excel to sum the number of imports and exports for each vehicle type. Thereafter, the road fixed delay cost formulas from Section 4.3 were applied to calculate the road fixed delay cost for each vehicle for both imports and exports. Table 12 illustrates the road fixed delay cost for one vehicle type. This was done for all vehicle types.

Table 12: Road fixed delay cost for one vehicle type

Vehicle	Fixed cost for year	Fixed cost per day	Imports	Imports road fixed delay cost	Exports	Exports road fixed delay cost
V5FD	455 963	1 249	1 844,8	1 876 136,3	77,0	125 512,06

To calculate the additional inventory carrying cost, variables from table 12, 13 and 14 were used. The inventory carrying cost in transit border formula from Section 4.3 was applied to calculate the additional inventory carrying costs incurred for each commodity imported and/or exported.

Table 13 represents the additional inventory carrying cost for one commodity.

Table 13: Additional inventory carrying cost for one commodity

FDM™_com_co	Inventory cost per ton	Days in storage	Import tonnage	Export tonnage	Export additional ICC	Import additional ICC
FDM™10060	73,00	138	260,65	67,13	46,36	112.25

Similarly, the storage cost was calculated. Variable from the metadata table 10 and 11 were used. The additional storage cost formula from Section 5.3 was applied to calculate the additional storage cost incurred for each commodity imported and/or exported. Table 14 represents the additional storage cost for one commodity.

Table 14: Additional storage cost for one commodity

FDM™_com_co	Storage rate per ton (excluding handling)	Import tonnage	Export tonnage	Export additional storage cost	Import additional storage cost
FDM™10060	69,27	260,65	67,13	43,99	27,43

4.10 Qualitative Data

To confirm the quantitative findings, qualitative data in the form of driver interviews left comments expressing their concerns and reasons for the occurrence of the Lebombo border delays were provided by the CBRTA. This data aided in the confirmation of the calculated border delays.

The answered driver questionnaires were captured in an Excel file. The questionnaire consisted of five questions, and a comments section. Nine hundred and thirty-nine (939) respondents participated in this questionnaire over a four-day period from 12 to 15 November 2018. Initially the data was cleaned to remove any incomplete screening data from the respondents. This summed the total number of 938 valid respondents.

The five questions were:

- Where is your origin of departure and destination?
- What are the commodities transported?
- Are there any alternative routes?
- How often do you use this border?
- Average time at the border?

There was also a section provided for comments, in terms of the drivers' views (reasons relating to border delays)

Each of the questions were analysed individually to remove any irrelevant or incomplete answers. For question 4, 5 and the comments section the respondents answered were answered open ended. These were grouped according to relevant categories for ease of analysis.

5. RESEARCH RESULTS

This section presents the research results from the secondary data analysis. The November 2018 survey transit time data was used in conjunction with the freight flow model and LCM™ of the Stellenbosch University to calculate the economic impact of the Lebombo border post delays. The drivers' survey questionnaires further support the findings. It is from these results that the conclusions will be drawn.

5.1 Trans Kalahari Corridor results

5.1.1 C-BRTA metadata

For this study, data from four points of interest were used to capture transit time data on the South African and Botswana borders:

- Skilpadshek northbound (South Africa)
- Pioneer Gate northbound (Botswana)
- Pioneer Gate southbound (Botswana)
- Skilpadshek southbound (South Africa).

As a truck arrived at an entry or exit point, the CBRTA captured the following data, as portrayed in Table 15. Table 15 is a generic outline of the various data entries captured at the four border stop points.

Table 15: Metadata of variables of interest recorded at entry and exit stages

Variables of Interest	Example of a record	Definition of variable of interest	Unit of measurement	Data category	Type of data
Count	1	The number of times a truck	Count/Number	Quantitative	Ordinal

		was recorded passing the border			
Vehicle class	Class 4	The observed vehicle class	Text	Qualitative	Nominal
Arrival Day	Thursday	Entry day of arrival	Text	Qualitative	Nominal
Arrival Date	7	Entry date of arrival	Date/time	Qualitative	Ordinal
Arrival Month - Year	Nov - 19	Entry month and year of arrival	Date/Time	Quantitative	Ordinal
Exit Date	8	Vehicle exit date of departure	Date/Time	Quantitative	Ordinal
Days Spent	1	Amount of days the vehicle is delayed at border	Date/Time	Quantitative	Nominal
Vehicle Registration	B119APF	Vehicle registration number	Text	Qualitative	Nominal
Time In	16:05	Time of arrival	Date/Time	Quantitative	Ratio
Exit Time	18:47	Time of departure	Date/Time	Quantitative	Ratio
Segregated Transit Time (hh:mm)	26:42	Hours and minutes of the	Date/Time	Quantitative	Ratio

		vehicle waiting at border			
Skilpadshek Northbound	Spreadsheet heading	From South African border to Botswana	Text	Qualitative	Nominal
Pioneer Gate Northbound	Spreadsheet heading	From Botswana border into Botswana	Text	Qualitative	Nominal
Pioneer Gate Southbound	Spreadsheet heading	From Botswana to Botswana border	Text	Qualitative	Nominal
Skilpadshek Southbound	Spreadsheet heading	From Botswana border into South Africa	Text	Qualitative	Nominal

5.1.2 Botswana Road Freight metadata

To calculate updated logistics costs incorporating time delays at Skilpadshek, certain road freight data was used from 2018. Data, supplied by Zane Simpson, contained the following variables of interest and calculations. Figures for Botswana's importing and exporting activities were calculated, as shown in Table 16. Figures relating to Botswana are incorporated in the calculation of the updated logistics costs for Skilpadshek. These calculated figures made it possible to calculate new logistics costs at the Skilpadshek border that were influenced by the delay times at the border points, which are explored at a later stage of the "Research Results" section.

Table 16: Road freight data for Botswana

Region	**Botswana**	
International trade activity	Export to Botswana	Import from Botswana
Road Tons	3 294 813	969 651
Road Tkm	2 012 822 155	557 677 396
Value of Road Freight	R106 684 919 001	R12 225 665 555
Road Transport costs	R1 696 964 791	R514 945 102
Road Externality costs	R465 110 054	R128 864 522
Road ATD within SA borders (km)	611	575
Average ton value of Road freight	R32 380	R12 608

From Table 16 above, road tonnes, refers to the amount of freight moved on the road. Road tkm, are the ton kilometres of freight transported on the road. This was simply derived as taking the road tons and multiplying it by the distance travelled by the truck. Road ATD within SA borders refers to the Average Travelled Distance within SA borders. This figure was calculated as a weighted average of all road freight movements.

5.1.3 Truck recordings

Through analysing the data in the “segregated transit times” data file, the number of trucks recorded at each of the four stops were obtained for both northbound and southbound movements. The CBRTA made use of a random sampling method when recording truck entries at each point of interest, giving each truck an opportunity to be logged. Figure 8 visually portrays the number of observations recorded individually at the four points. The recording of the trucks was not synchronised as the number of trucks observed did not coincide with each other at the different points.

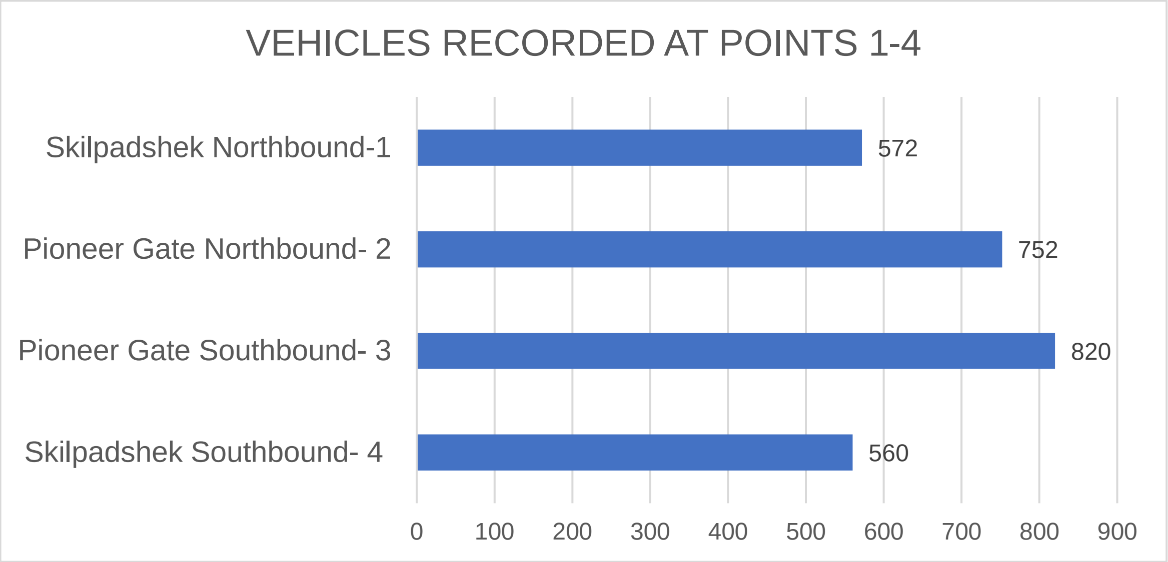


Figure 9: Truck observations recorded at points 1-4

The process of recording and matching truck entry times with their exit times was done by taking the registration and vehicle code of a truck arriving at the border point and subtracting the exit time from the arrival time. This resulted in the time showing the delay experienced at each border point. An example of a typical entry is shown in Table 17, which was recorded at the Skilpadshek northbound point.

Table 17: Matched data of entry and exit times of trucks

Count	Entry Reg & Class	Entry Date & Time	Exit Reg & Class	Exit Date & Time	Days spent	Time taken to travel through border (hh:mm)
1	B706BHF_4	07-11-19 15:44	B706BHF_4	08-11-19 19:42	1	27:58

1	CF158123_4	09-11-19 09:03	CF158123_4	09-11-19 14:59	0	5:56

5.1.4 Truck Transit Time Recording Process

The cycle chart below shows the detailed, step-by-step process of how the CBRTA went about recording transit times for trucks that passed through the Skilpadshek border post travelling into Botswana as well as a route of departure. The green icons indicate the South African side of the border, while the blue icons indicate the Botswana side of the border.

Figure 10: Border process of truck time recordings for valid entries

5.1.5 Recorded Truck Transit Times

Using the segregated transit time data supplied by the CBRTA spanning across a period of one week, it was possible to calculate the average time a truck spent at each of the four border posts. Tables 18-21 show the transit times recorded. The details of the Tables include minimum transit time, average transit time, median transit time and maximum transit time.

Table 18: Skilpadshek northbound - 1

Skilpadshek northbound - 1 (572 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	4
Average Transit Time (days: hours: min)	0	12	24
Median Transit Time (days: hours: min)	0	5	18
Maximum Transit Time (days: hours: min)	6	11	32

Table 19: Pioneer Gate northbound - 2

Pioneer Gate northbound - 2 (752vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	1
Average Transit Time (days: hours: min)	0	7	3
Median Transit Time (days: hours: min)	0	0	41
Maximum Transit Time (days: hours: min)	6	13	30

Table 20: Pioneer Gate southbound - 3

Pioneer Gate southbound - 3 (820 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	1
Average Transit Time (days: hours: min)	0	3	51
Median Transit Time (days: hours: min)	0	0	9
Maximum Transit Time (days: hours: min)	6	5	16

Table 21: Skilpadshek southbound – 4

Skilpadshek southbound - 4 (560 vehicles)	Days	Hours	Min
Minimum Transit Time (days: hours: min)	0	0	3
Average Transit Time (days: hours: min)	0	6	52
Median Transit Time (days: hours: min)	0	0	23
Maximum Transit Time (days: hours: min)	6	14	24

5.1.6 Dispersion of the Transit Time Data

By analysing the transit time tables above, certain summaries of the data were reached. When travelling northbound, it took on average 12hrs 24min to travel from the South African entry point to the South African exit point, while it took on average 7hrs 3min to travel from the Botswana entry point to the Botswana exit point.

By referring to Tables 22-23, it can be inferred that when travelling northbound, it took on average 12hrs 50minutes to travel from the South African point of entry to the Botswana point of exit, meaning that it took on average 12hrs 50minutes for South Africa to export goods through the Skilpadshek border to Botswana. When travelling southbound, it took on average 8hrs 23minutes to travel from the Botswana entry point to the South African exit point. Through this calculated time, one can infer that it took on average 8hrs 23minutes for South Africa to import goods through the Skilpadshek border from Botswana.

Table 22: Skilpadshek to Pioneer Gate Northbound Block Transit Time

Skilpadshek/Pioneer Gate Northbound (498 vehicles)	Hours	Min
Average Transit Time (hours: min)	12	50

Table 23: Pioneer Gate to Skilpadshek Southbound Block Transit Time

Pioneer Gate/Skilpadshek Southbound (665 vehicles)	**Hours**	**Min**
Average Transit Time (hours: min)	8	23

Figure 11 below portrays both the northbound and southbound block transit times through the studied border posts in a box and whisker graph. On the vertical axis, NB Hrs refers to the transit time of Skilpadshek to Pioneer Gate, in a northbound direction. SB_Hrs refers to the transit time of Pioneer Gate to Skilpadshek in a southbound direction. Due to the copious number of outliers experienced in the data for the southbound freight movement, a logarithmic scale was used to accommodate for these outliers to include both directions of freight movements onto the same figure.

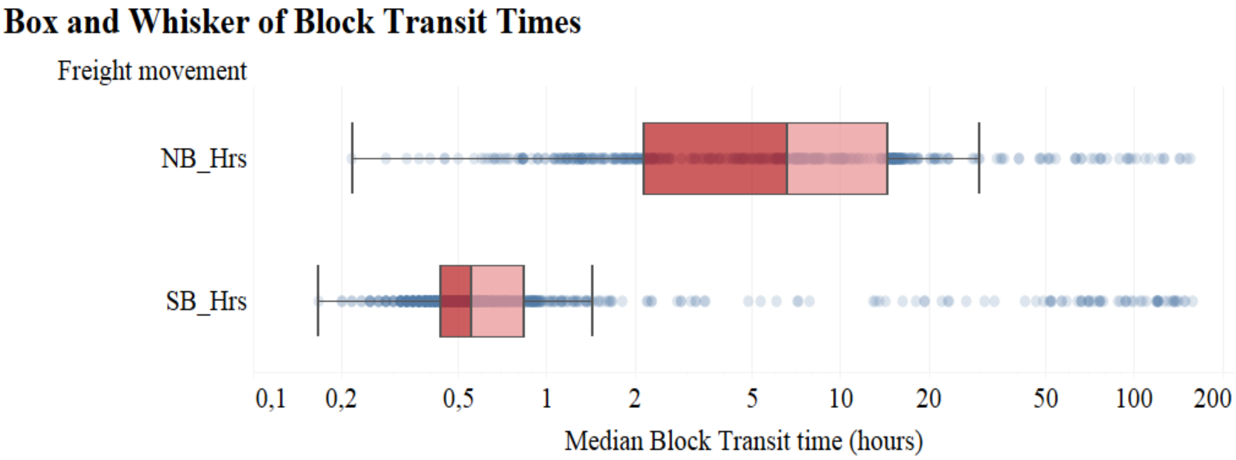
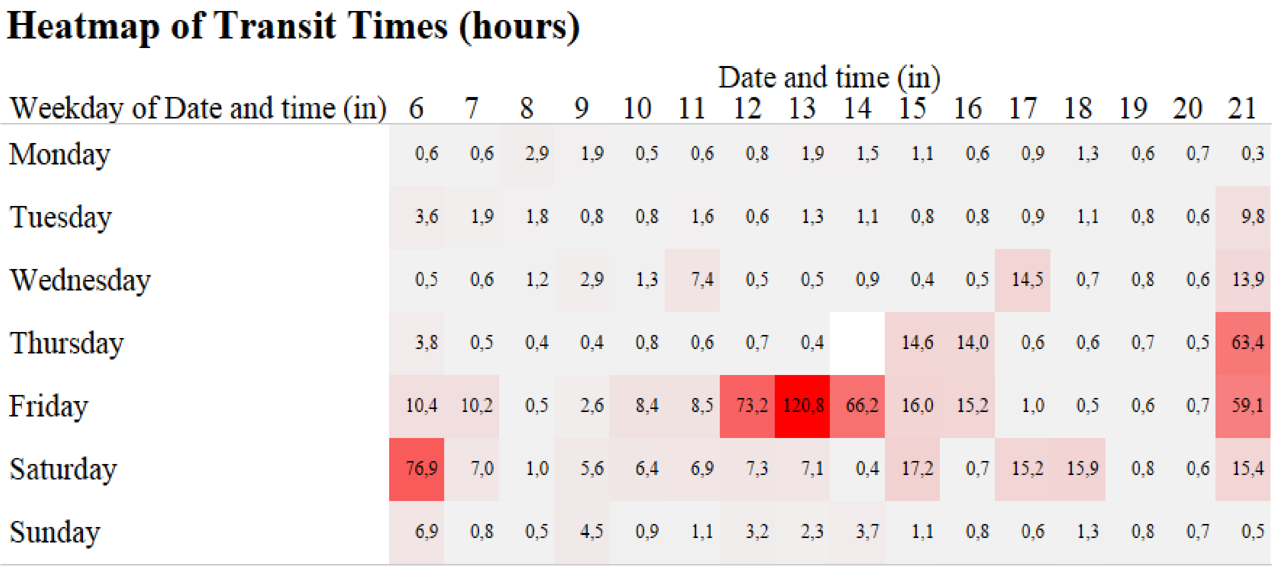


Figure 11: Box and whisker plot of northbound and southbound block transit times

Figure 12 below shows a heatmap of the combined block transit times for the northbound and southbound freight movements. The heatmap was able to bring forth an underlying pattern in the data. From the end of Thursday until the end of Saturday, the transit times are higher as compared to the other weekdays, as represented by the darker shades of red portraying times of the day that border clearance is slow. The times on the upper horizontal axis 6-21 refer to the time of day from 06h00 to 21h00. No trucks were recorded after 21h00 as this was when the recordings stopped for the day.



Heatmap of Transit Times (hours)

	Date and time (in)															
Weekday of Date and time (in)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Monday	0,6	0,6	2,9	1,9	0,5	0,6	0,8	1,9	1,5	1,1	0,6	0,9	1,3	0,6	0,7	0,3
Tuesday	3,6	1,9	1,8	0,8	0,8	1,6	0,6	1,3	1,1	0,8	0,8	0,9	1,1	0,8	0,6	9,8
Wednesday	0,5	0,6	1,2	2,9	1,3	7,4	0,5	0,5	0,9	0,4	0,5	14,5	0,7	0,8	0,6	13,9
Thursday	3,8	0,5	0,4	0,4	0,8	0,6	0,7	0,4		14,6	14,0	0,6	0,6	0,7	0,5	63,4
Friday	10,4	10,2	0,5	2,6	8,4	8,5	73,2	120,8	66,2	16,0	15,2	1,0	0,5	0,6	0,7	59,1
Saturday	76,9	7,0	1,0	5,6	6,4	6,9	7,3	7,1	0,4	17,2	0,7	15,2	15,9	0,8	0,6	15,4
Sunday	6,9	0,8	0,5	4,5	0,9	1,1	3,2	2,3	3,7	1,1	0,8	0,6	1,3	0,8	0,7	0,5

Figure 12: Heatmap of combined northbound and southbound median block transit times

5.1.7 Zeerust Truck Stop Transit Time Data

The Zeerust truck stop is a mandatory checkpoint that all trucks need to pass through on their journey. Transit times were recorded at the Zeerust truck stop for both northbound (NB) and southbound (SB) freight movements. The average transit time through the Zeerust truck stop in a northbound direction was an average of 8 hrs 55 minutes, which is the dark shade of green in Figure 8 on the tree map below. The minority of the tree map is made up of the southbound movement. This transit time was recorded at an average of 5 hours 25 minutes, represented by the lighter shade of green below. Table 24 summarises the average transit times for the Zeerust truck stop.

Table 24: Zeerust Truck Stop Average Transit Times

Average Transit Time (hours: min)	Hours	Min
Northbound (NB) (317 vehicles)	8	55
Southbound (SB) (197 vehicles)	5	25

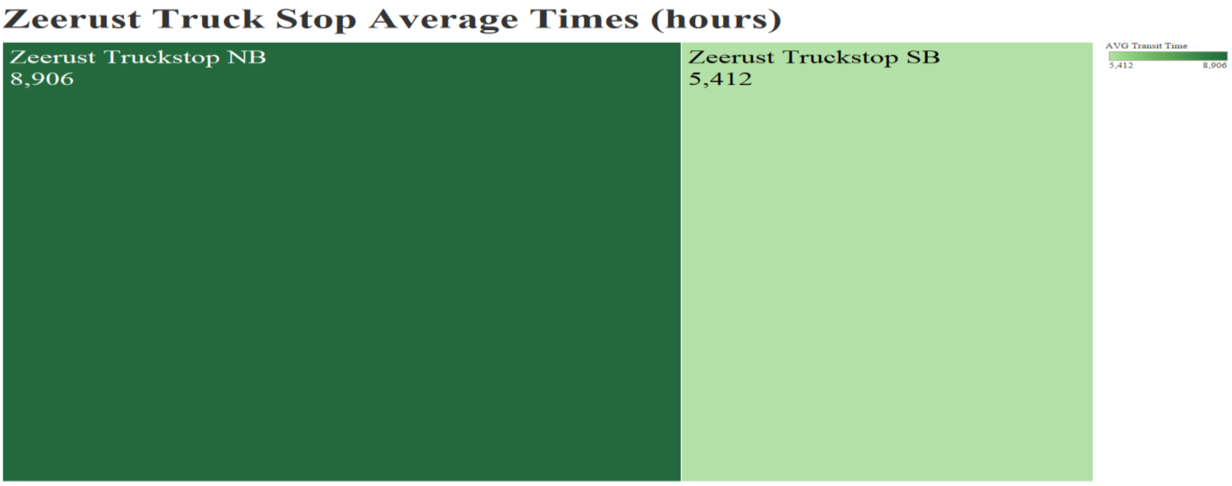


Figure 13: Tree map of the Zeerust truck stop average transit times (hours)

5.1.8 Combined Transit Time Data

To calculate accurate trade logistics costs, the full delay that a truck experiences when passing through the border needs to be accounted for. The average transit time for a truck to pass through Skilpadshek as well as the delay experienced at the Zeerust truck stop is shown in Table 25.

Table 25: Combined transit time

Average Transit Time (hours: min)	Hours	Minutes
Northbound	21	45
Southbound	13	48

5.1.9 Origin and destination of drivers

Seventy-three percent (73%) of trucks were found to depart from South Africa, whilst 8% departed from Botswana, 10% departed from Namibia and the rest departed from other Southern African countries. Botswana was the most popular destination for trucks, accounting for 57% of the total, with South Africa accounting for 16% and Namibia accounting for 20%. The rest were bound to other Southern African destinations.

5.1.10 Commodities transported

Figure 14 below, portrays a detailed figure of the commodity types flowing through the Skilpadshek border post.

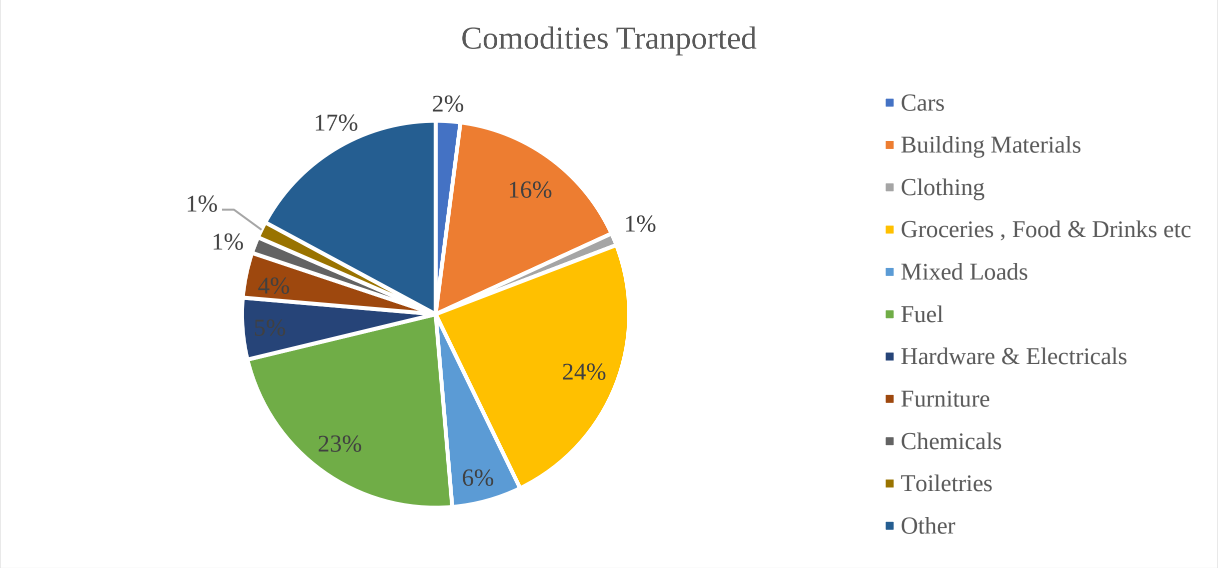


Figure 14: Commodity groups transported through Skilpadshek

5.1.11 Border usage frequency and average time

This section of the questionnaire was answered by 294 respondents. Blank answers were filtered out of the pivot table. The answers from the drivers were analysed and grouped into subsets for simpler visual interpretation. Respondents were found to use the border on a daily, weekly or monthly basis. Figure 14 indicates how often respondents passed through Skilpadshek border.

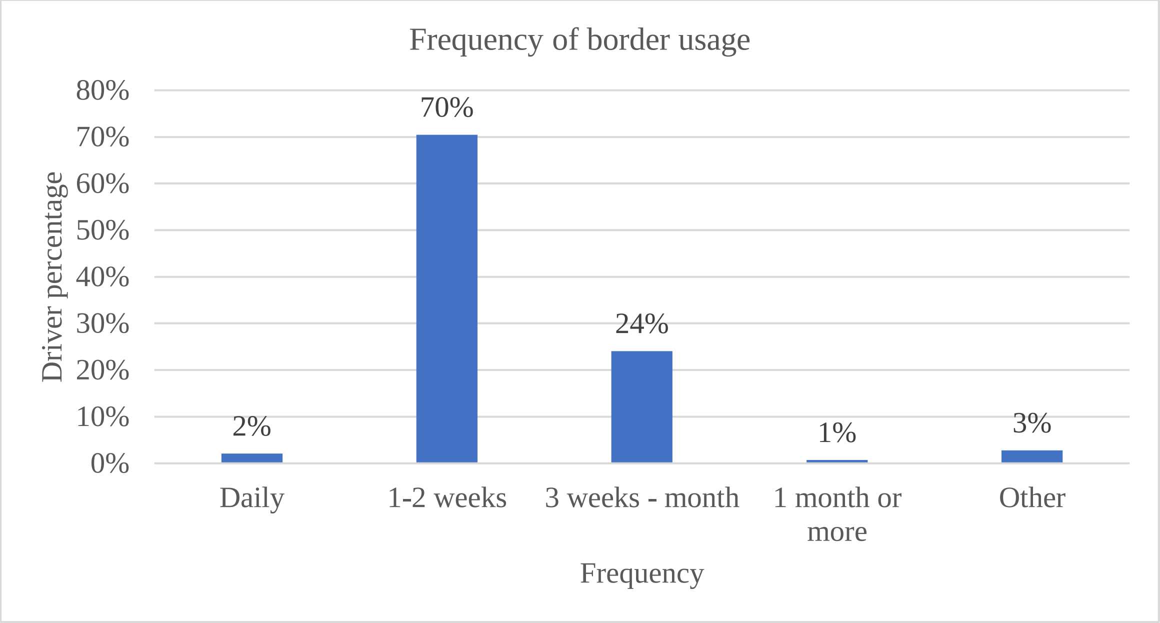


Figure 15: Frequency of border usage

Seventy percent (70%) of drivers pass through Skilpadshek every one to two weeks, 24% of drivers use the border every three weeks and 2% use the border daily. The next section of the survey asked the drivers what their average time spent at the border was. Figure 15 portrays the average time spent at Skilpadshek. A large percentage (37%) of the drivers spent between four to five hours at the border, followed by 30% of the drivers that spent 10-20 hours at the border post.

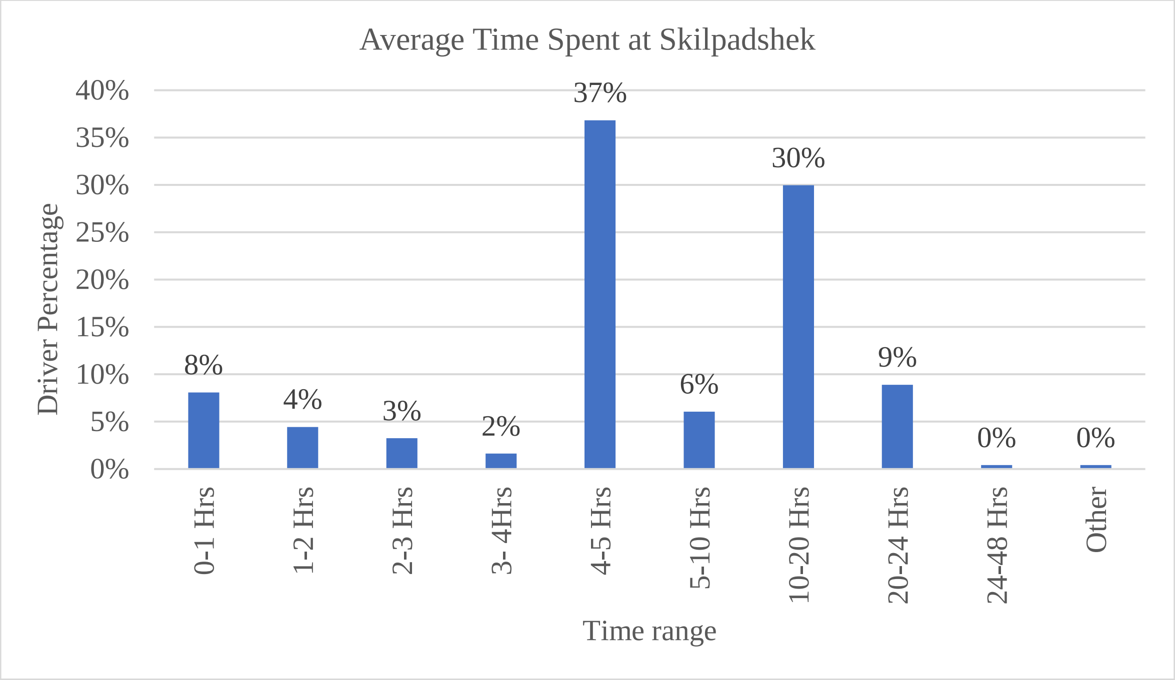


Figure 16: Average time spent at Skilpadshek border

5.1.12 Driver comments at Skilpadshek border post

A research question directed at the truck drivers in the survey was to gain first-hand insight, as to why the drivers were experiencing delays at the borders. The researcher went about cleaning the comments to remove any irrelevant and blank comments. After the cleaning process, a total of 139 comments were stated.

As can be seen in Figure 16, most complaints revolved around administrational challenges faced at Skilpadshek border. The next recurring problem was congestion issues causing traffic to extend at the border. Staff and network signal and facilities were closely grouped together adding to the frustration of the drivers. Infrastructure was brought up six times out of the 139 comments. These answers related to inefficient or lack of parking bays for the drivers to position their stationary vehicles. The fact that administrational challenges were a recurring issue at the Skilpadshek border was reiterated in literature written by Maredi (2014), emphasising the hindrance of administrational challenges.

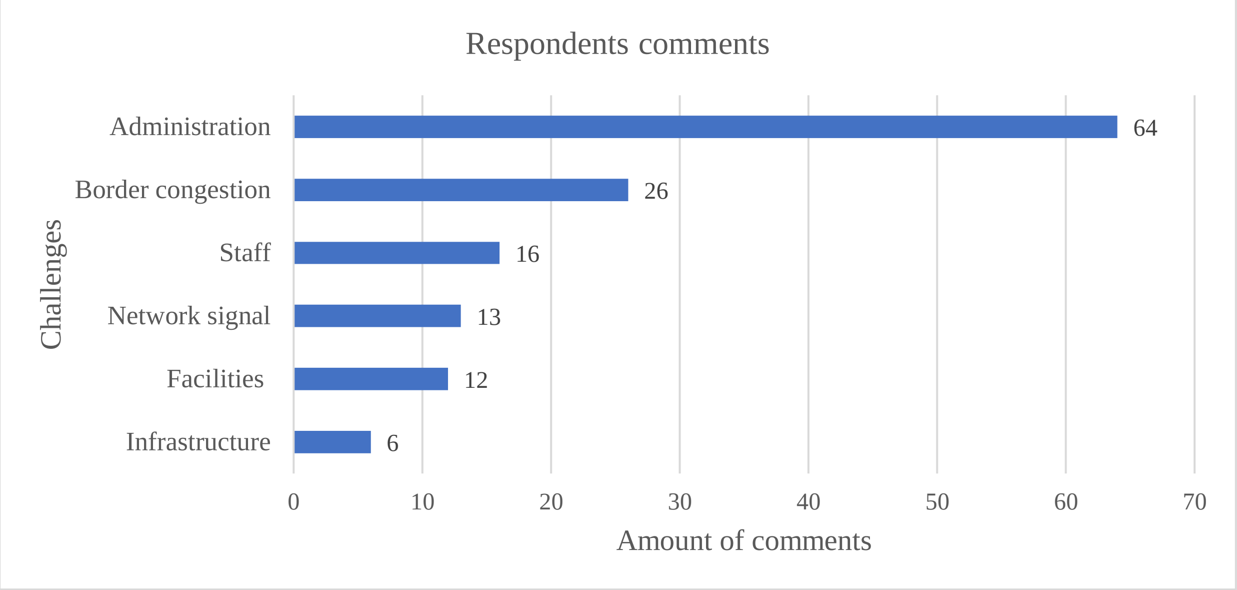


Figure 17: Respondents comments at Skilpadshek

5.1.13 Freight flows

The Botswana freight flow figures display vital information regarding the most recent volumes of imports and exports that move through the Botswana border. Updated road freight flow data was supplied by Zane Simpson for the purpose of calculating new trade logistics costs affected by time delays at Skilpadshek. Southbound freight movements are imports into South Africa from Botswana and northbound freight movements are exports from South Africa to Botswana. This allows the analysis of freight flows to be divided between northbound and southbound. Table 26 shows that exports to Botswana (77.3%) dominate imports from Botswana (22.7%). This large percentage of freight moving northbound from South Africa to Botswana is matched by a longer transit time delay than the southbound movement. From this pattern, one can infer that with more tons of freight being transported northbound. This would lead to more traffic being created and a longer delay in transit time at the border.

Table 26: Export and import volumes in tons moving through Botswana border in 2018

Sum of Road Tons	Total (2018 volumes)	Percentage of total
Export	3 294 813	77.3%
Import	969 651	22.7%
Grand Total	4 264 464	100%

5.1.13 Trade logistics costs

Calculating these news logistics costs affected by lengthy border delays, required updated transit time delays. This research updated the variables, freight volumes and time delays to determine a more accurate logistics cost of border delays at Skilpadshek.

Percentage weights were assigned to both Skilpadshek and Kopfontein to determine the breakdown of how many trucks passed through each border. Skilpadshek and Kopfontein are the two borders that are used, as these are the two most prominent freight clearance borders for Botswana. The percentages in Table 27 are proportional to the vehicle counts that passed through each border. It is also to be assumed that the Zeerust truck stop freight flow percentage is equal in percentage to the Skilpadshek border post.

Table 27: Freight flow percentage split between Skilpadshek and Kopfontein

	Skilpadshek	Kopfontein
Import (*southbound*)	51.21%	48.79%
Export (*northbound)*	43.38%	56.62%

5.1.14 Trade Logistics cost for Skilpadshek

The logistics costs as impacted by cross-border delays encountered at Skilpadshek border post in a northbound and southbound direction are displayed in Table 28.

Table 28: Logistics costs for Skilpadshek

	Import (*southbound)*	Export (*northbound)*	Total
Skilpadshek logistics costs	R18 257 887	R78 022 510	R96 280 397

With respect to the Zeerust truck stop, additional costs were calculated solely for the Zeerust truck stop, by looking at the delay times encountered at the truck stop. The following costs resulting from delays at the truck stop were calculated as stated in Table 29. From Table 29 one can infer that the Zeerust truck stop is adding R66 007 290 per annum for trucks passing through Skilpadshek border, due to delays. Skilpadshek border contributes 8.67% to total trade logistics costs. The southbound delay costs (imports) contribute 6.09% and northbound (exports) contribute 9.60% to the greater total of trade logistics costs.

Table 29: Zeerust truck stop delays costs

	Import (*southbound*)	**Export (*northbound*)**	**Total**
Zeerust truck stop costs	R11 796 845	R54 210 445	R66 007 290

When analysing the time delay that freight vehicles experience passing through the Skilpadshek border post, it is important to incorporate the delay time experienced when the trucks must pass through the Zeerust truck stop. New trade logistics costs have been calculated by adding the Zeerust truck stop delay time, onto the existing block transit time in both the required northbound and southbound directions. Trade logistics costs encountered at Skilpadshek affected by cross border delays as well as incorporating the Zeerust truck stop are presented in Table 30.

Table 30: Trade logistics costs for Skilpadshek (Including Zeerust truck stop)

	Import (*southbound*)	**Export (*northbound*)**	**Total**
Skilpadshek logistics costs	R30 054 732	R132 232 955	R162 287 687

Exports in a northbound movement account for a large portion of the total logistics costs, as the freight flow data was higher for exports as compared to imports. Another factor adding to the significantly large export value was that the total northbound delay was longer in comparison to the southbound delay. Due to unnecessary border delays at Skilpadshek border, a total of R162 287 687 is incurred per annum.

5.2 Maputo Corridor results

5.2.1 Recorded Count of Vehicles

Only observations that had matched entries were analysed for this study. This allowed the data to be analysed to determine the transit delay times. Figure 6 indicates the number of trucks were recorded at each of the Lebombo border post point in both directions; Eastbound and Westbound over a one-week period from 12 to 19 November 2018.

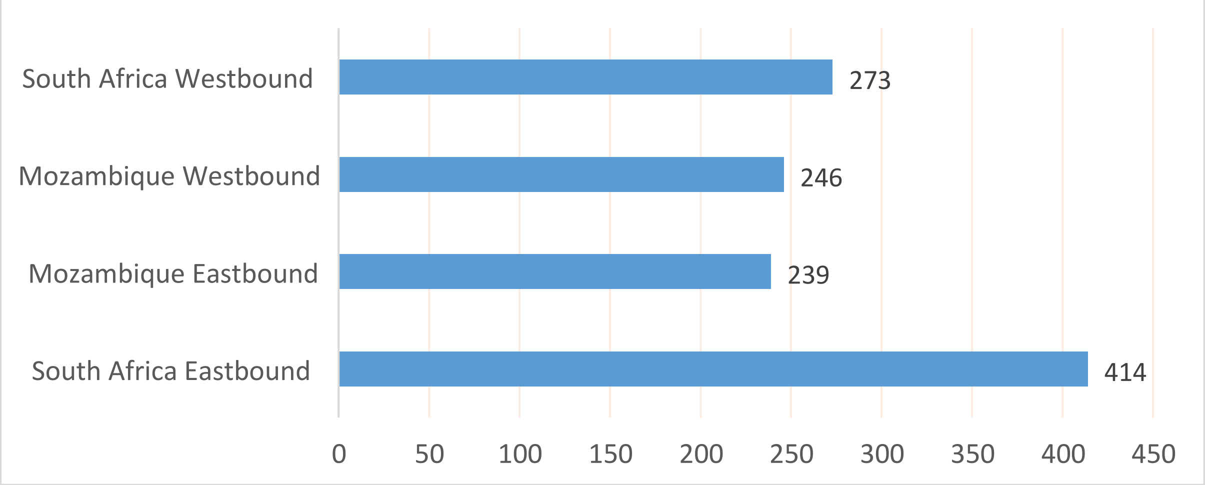


Figure 6: Number of freight vehicles recorded at the Lebombo border post in eastbound and westbound direction

From Figure 6, it is apparent that the recordings were not synchronized. The recordings were independent from one another as the number of freight vehicles recorded at each point differed. Hereby, a truck which was recorded at South Africa Eastbound could have been recorded at Mozambique Eastbound, or any of the other points, but had the chance of not being recorded.

5.1.2 Truck transit time results and dispersion of the data

Once the vehicle registrations had been matched at each entry and exit point, this allowed the data to be further analysed to determine the transit delay times. The transit delay time was calculated by subtracting the exit date and time from the entry date and time for each matched pair.

Tables 31-34 indicate the transit time recorded. The tables include details of the maximum transit time, minimum transit time, median transit time, average transit time and standard deviation of the transit time. Each table is followed by a box and whisker plot which visually indicates the dispersion of the data of each of the border points. Figure 7 displays the dispersion of the data to export goods from South Africa to Mozambique, South Africa Eastbound. Figure 8 displays the dispersion of the data for Mozambique Eastbound. Similarly, figure 9 displays the dispersion of the data for Mozambique Westbound and figure 10 for South Africa Westbound.

Table 31: South Africa eastbound transit time results

South Africa Eastbound (414 Vehicles)	Days	Hours	Minutes
Maximum Transit Time	14	13	38
Minimum Transit Time	0	0	1
Median Transit Time	0	1	49
Average Transit Time	0	16	49
Standard Deviation of the Transit Time	1	9	37

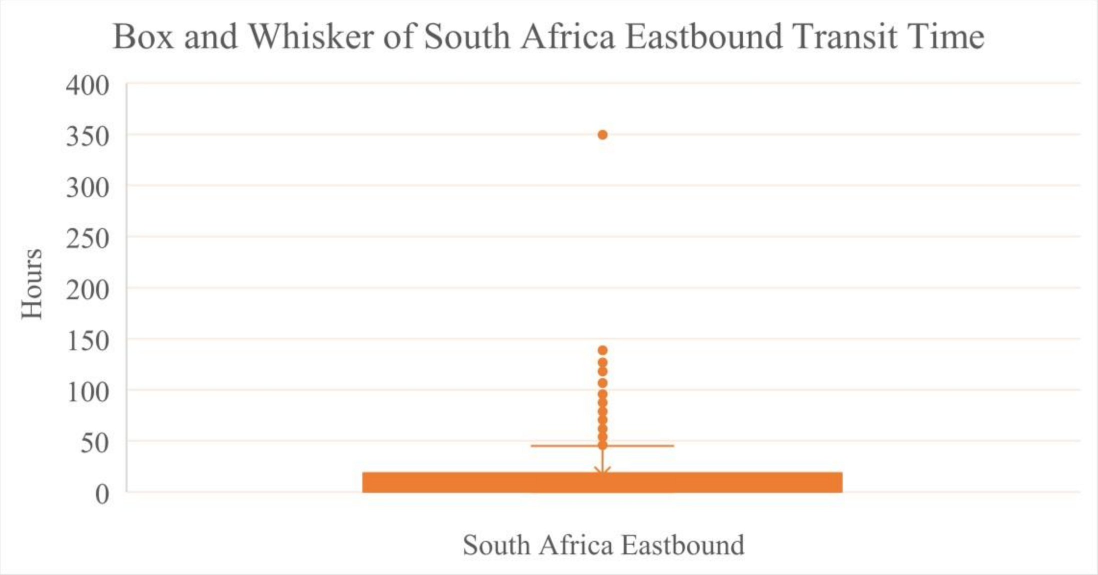


Figure 7: Box and whisker of South Africa eastbound transit time in hours

Table 32: Mozambique eastbound transit time results

Mozambique Eastbound (239 Vehicles)	Days	Hours	Minutes
Maximum Transit Time	6	2	41
Minimum Transit Time	0	0	2
Median Transit Time	0	0	37
Average Transit Time	0	14	31
Standard Deviation of the Transit Time	1	8	8

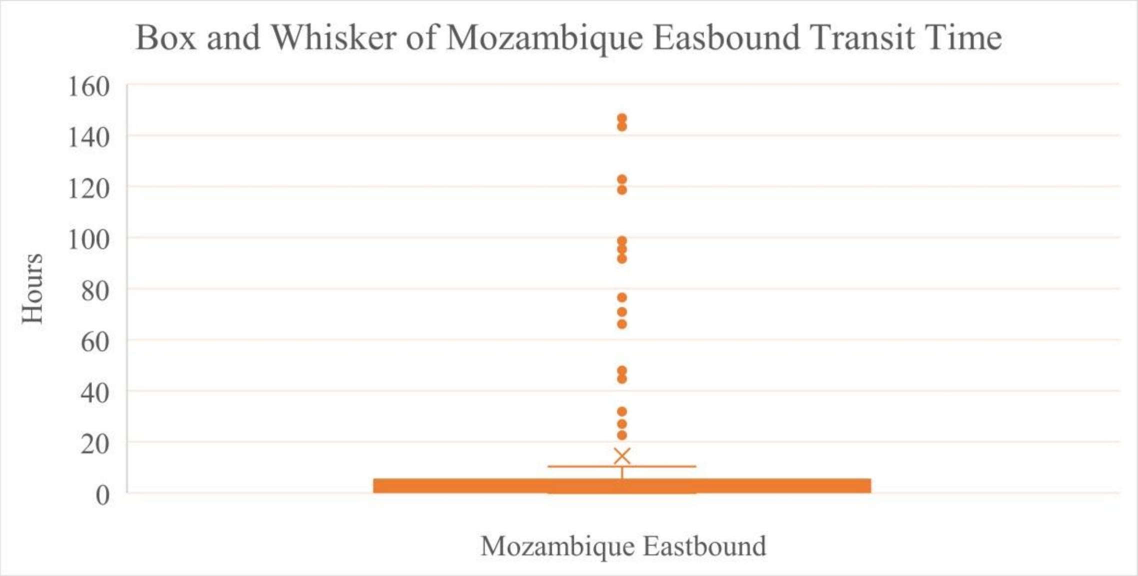


Figure 8: Box and whisker of Mozambique eastbound transit time in hours

Table 33: Mozambique westbound transit time results

Mozambique Westbound (246 Vehicles)	Days	Hours	Minutes
Maximum Transit Time	6	0	47
Minimum Transit Time	0	0	0
Median Transit Time	0	0	16
Average Transit Time	0	5	13
Standard Deviation of the Transit Time	0	18	44

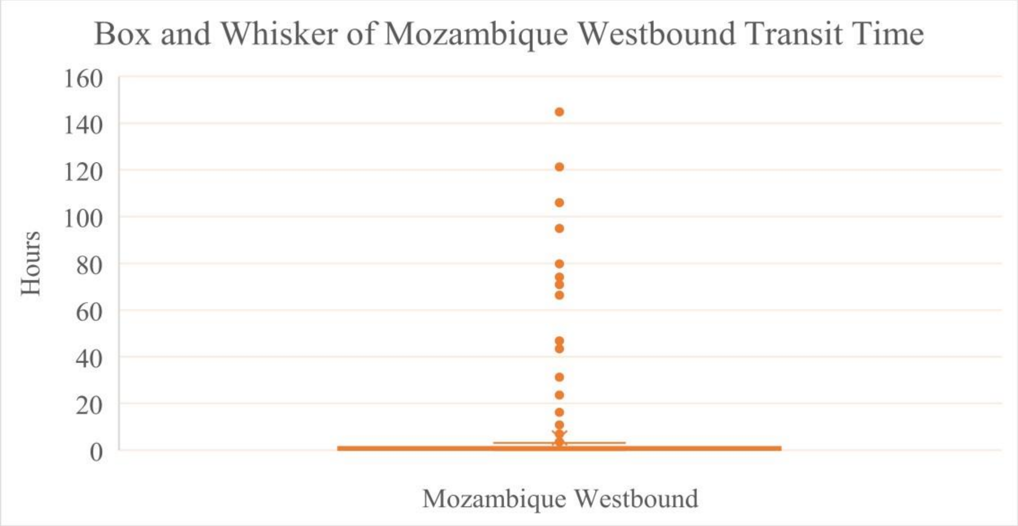


Figure 9: Box and whisker of Mozambique westbound transit time in hours

Table 34: South Africa westbound transit time results

South Africa Westbound (273 Vehicles)	Days	Hours	Minutes
Maximum Transit Time	5	23	45
Minimum Transit Time	0	0	1
Median Transit Time	0	0	31
Average Transit Time	0	14	19
Standard Deviation of the Transit Time	1	4	54

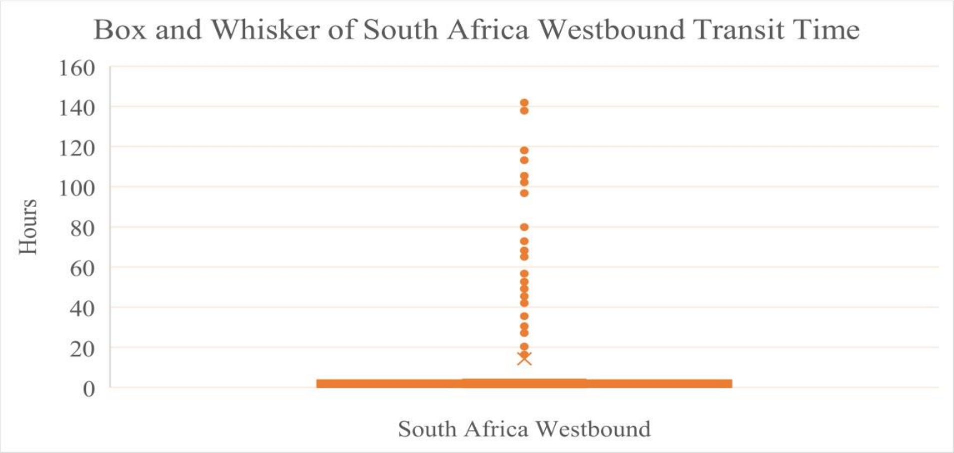


Figure 10: Box and whisker of South Africa westbound transit time in hours

From the above results, it can be noted that when travelling eastbound, it took on average 16 hours 49 minutes to travel from the South African entry point to the South African exit point. Thereafter, it took an additional average time of 14 hours 31 minutes to travel from Mozambique entry point to the Mozambique exit point. Discarding the time taken to travel through no-mans-land, it can be inferred that on average it takes 1 day 7 hours 20 minutes to exports goods from the South African entry point to the Mozambique exit point.

When travelling westbound it took on average 5 hours 13 minutes to travel from the Mozambique entry point to the Mozambique exit point. Thereafter, it took an additional average time of 14 hours 19 minutes to travel from South African entry point to the South African exit point. We can infer that on average it takes 19 hours 32 minutes to import goods from Mozambique entry point to South African export point. Again, this does not consider the time taken to travel no-mans-land.

In the above results, the standard deviation is large at all the border points, indicating that the observations are far from the average. The high variability indicates that the observations are less consistent. There tends to be a wide range between the minimum and maximum transit times in all the above results. Figure 7-10 display the dispersion of the transit time data, by looking at a box and whisker plot. From all the figures it appears that there tend to be extreme outliers which make the average of the data and unreliable statistic to draw conclusions from. The measures of central tendency indicate that the observations are widely spread out.

As the average is higher than the median in the results from Table 35-38, and the maximum point are considerably high, it is apparent that there are more cases of extreme delays. The outliers are increasing the average. For most trucks, the median should be considered as the average.

The median and interquartile range (IQR) are considered as these measures discard the effect of outliers. From the IQR, it is noted that 50 percent of the recordings lie between quartile 1 and quartile 3. With the median as the 50th percentile. To further investigate the average transit time most truck drivers experience, the IQR average was calculated and represented in table 35.

Table 35: Comparison of the average, median and IQR average at the four border points.

	South Africa Eastbound	Mozambique Eastbound	Mozambique Westbound	South Africa Westbound

Average	16 hours 49 minutes	14 hours 31 minutes	5 hours 13 minutes	14 hours 19 minutes
Median	1 hour 49 minutes	37 minutes	16 minutes	31 minutes
IQR average	3 hours 6 minutes	1 hour 5 minutes	22 minutes	50 minutes

The IQR average represents the average transit time for 50 percent of the transit recordings. While the average is largely affected by the outliers, the IQR average is a more representable average transit time that most trucks experience. However, it should not be discarded those outliers do exist. There are many observations that are considered as outliers. These trucks do experience extreme delays.

Further investigation was placed to identify which vehicle class experience the longest delays. Table 36 represents the average delays time experience at four border points for each vehicle class.

Table 36: Average transit time at each border point per vehicle class

	Class 1	Class 2	Class 3	Class 4
South Africa Eastbound	1 hour 7 minutes	18 hours 40 minutes	17 hours 23 minutes	1 day 3 hours 36 minutes
Mozambique Eastbound	52 minutes	16 hours 10 minutes	13 hours 25 minutes	20 hours 31 minutes
Mozambique Westbound	2 hours 53 minutes	10 hours 7 minutes	18 minutes	8 hours 8 minutes
South Africa Westbound	4 hours 29 minutes	2 hours 15 minutes	14 hours 10 minutes	1 day 7 hours 34 minutes

The results from table 36 indicate that Class 1 vehicles are processed considerably faster than any other class at all the border points. Class 4 appears to incur the longest transit times at all the respective border points. The results indicate that the transit times are longer for all vehicle classes on the South African side of the border. When exporting goods from South Africa to Mozambique, the transit time is longer at South African Eastbound than Mozambique

Eastbound for all vehicle classes. Similarly, when importing goods from Mozambique to South Africa, the transit time is longer at South African Westbound than Mozambique Westbound for vehicle Class 1, 3 and 4. It appears that vehicle Class 2 has a shorter transit time on South Africa Westbound than Mozambique Westbound. The results from table 36, could be reason as to why there are outliers present in the figures 7-10; further research could be done as to why there are such vast discrepancies to the delays times experienced.

5.2.3 Freight Flows

The FDM™ supplied by Zane Simpson contained 2018 freight flow figures of the volumes of imports and exports that moved through the Lebombo border post. Where export freight moved eastbound, moving from South Africa to Mozambique. Import freight moved westbound from Mozambique to South Africa. Figure 11 illustrates that exports account 6 857 011 road tons (90 percent) of trade flows and imports account for 784 046 road tons (10 percent) of trade flows at the Lebombo border post.

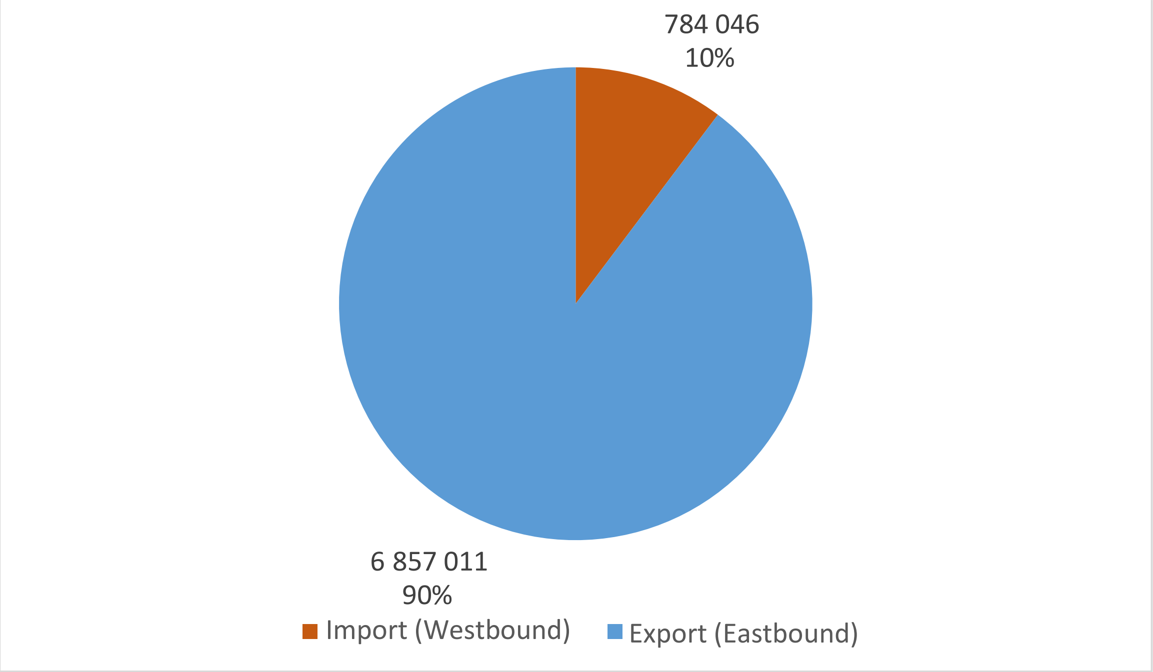


Figure 11: Lebombo border post freight flows in road tons

5.2.4 Trade Logistic Costs

The LCM™ was used with the FDM™ to determine the additional costs incurred due to border delays. The model required the updated transit time to accurately determine the associated costs.

The annual cost to the border (excluding the additional costs incurred due to border delays) are represented in table 37. These costs are incurred whether there are delays at the border. The total road transport externality costs were also calculated and are represented in table 38. The externality costs were not included in table 37, as this cost is not an element of the LCM™ according to Section 4.5.1.

Table 37: 2018 Cost to the Lebombo border (excluding the additional costs incurred due to border delays) in Rands (ZAR)

Costs	Export (Eastbound)	Import (Westbound)
Road transport costs	R 1 832 650 427	R 193 109 742
Storage and port costs	R 167 358 618	R 93 143 521
Management, admin and profit costs	R 171 312 034	R 41 308 760
Inventory carrying costs	R 178 545 649	R 43 053 014
	R 2 349 866 728	**R 370 615 037**

Table 38: 2018 Externality cost to the Lebombo border post in Rands (ZAR)

Costs	Export (Eastbound)	Import (Westbound)
Road transport externality costs	R 328 277 180	R 43 975 098

The logistics costs as impacted by the border delays experienced are shown in table 37, 88. Table 39 represents the trade logistics costs incurred in South Africa due to the border delays using the average transit time. Similarly, table 40 shows the trade logistics costs incurred in Mozambique due to the border delays using the average transit time.

From the results shown in table 39 and 40, the costs incurred due to border delays to exports goods is significantly larger than those costs to import goods. Figure 12 and 13 further illustrate that the costs incurred are in proportion to the freight flow road tones calculated from the FDM™ in figure 11.

Table 39: Additional Trade Logistics Costs in rands (ZAR) for South Africa at the Lebombo border post in 2018

Costs	South Africa Eastbound (Exports)	South Africa Westbound (Imports)
Additional trade logistics costs	R 462 548 348	R 53 945 659

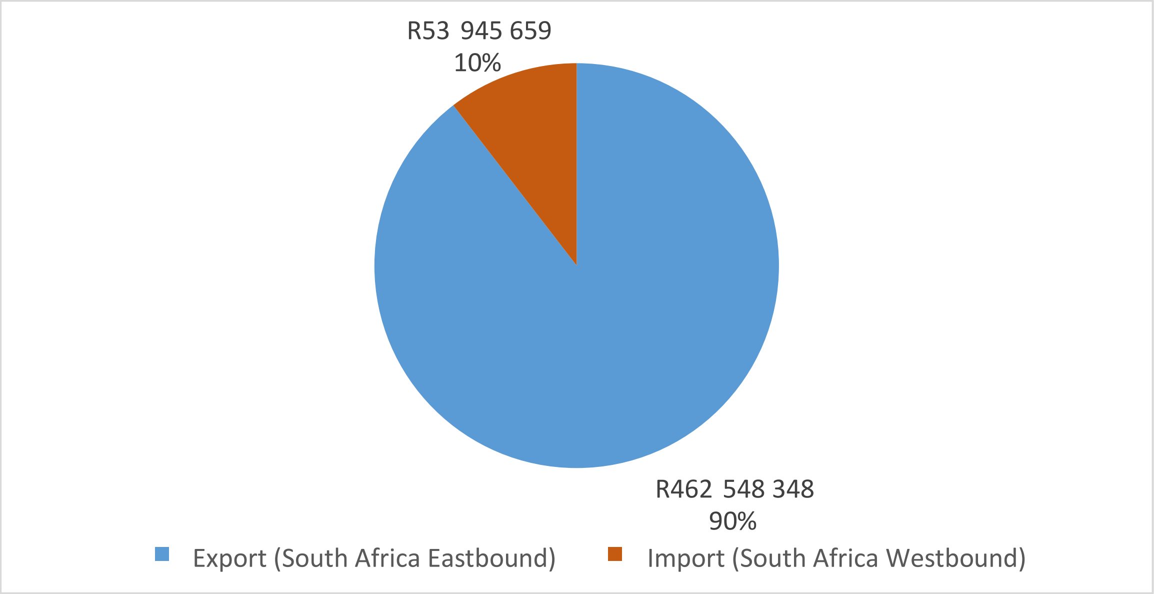


Figure 12: Additional trade logistics costs in rands (ZAR) incurred due to border delays in South Africa in 2018

Table 40: Additional trade logistics costs in rands (ZAR) for Mozambique at the Lebombo border post in 2018

Costs	Mozambique Eastbound (Exports)	Mozambique Westbound (Imports)
Additional trade logistics cost	R 399 221 984	R 19 670 973

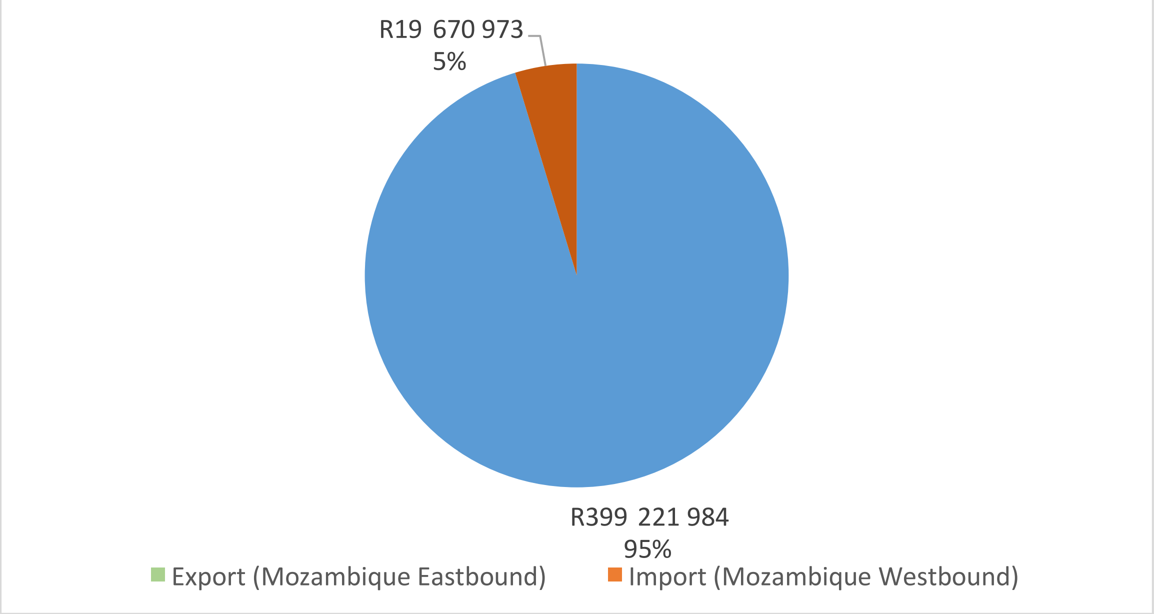


Figure 13: Additional trade logistics costs in rands (ZAR) incurred due to border delays in Mozambique in 2018

Although the same volumes of freight are processed at both sides of the border, it appears that Mozambique in incurring less additional costs, as there are shorter transit times in comparison to South Africa.

Table 41 shows the elements that make up the total trade logistics costs incurred due to the border delays at the Lebombo border post in both directions. Figure 14 and 15 further illustrate the composition of elements in each direction. In both cases, additional road fixed costs due to the border delays are the largest contributor to the additional costs incurred.

Table 41: Additional trade logistics costs incurred due to Lebombo border delays in rands (ZAR)

Additional Costs	Export (Eastbound)	Import (Westbound)
Storage Costs	28 391 042	17 702 801
Inventory Carrying Costs	135 461 768	12 258 166
Road Fixed Delay Costs	697 917 522	43 655 664
	861 770 332	**73 616 631**

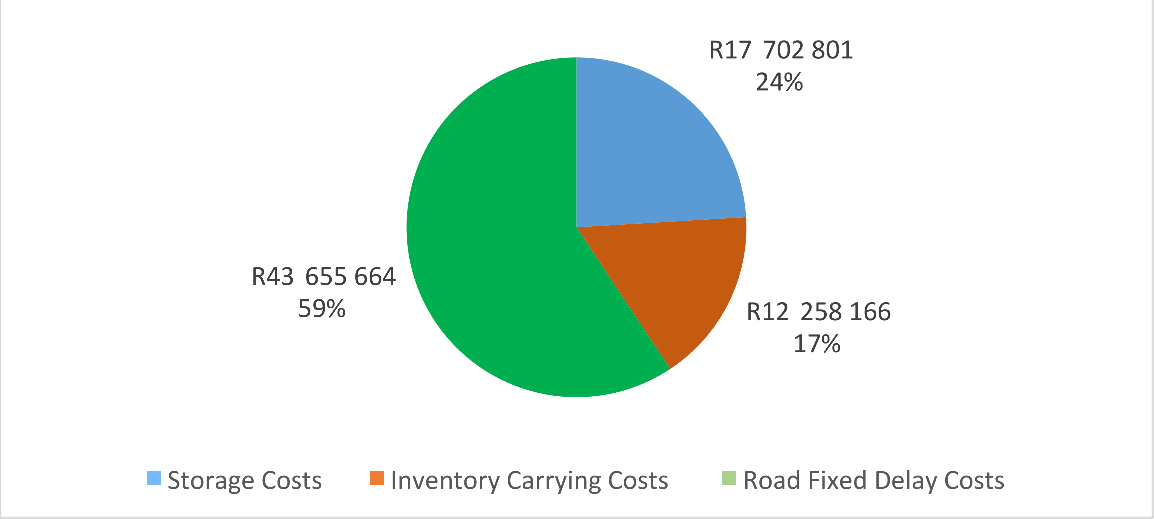


Figure 14: Import (westbound) trade logistics costs in rands (ZAR) due to Lebombo border delays in 2018

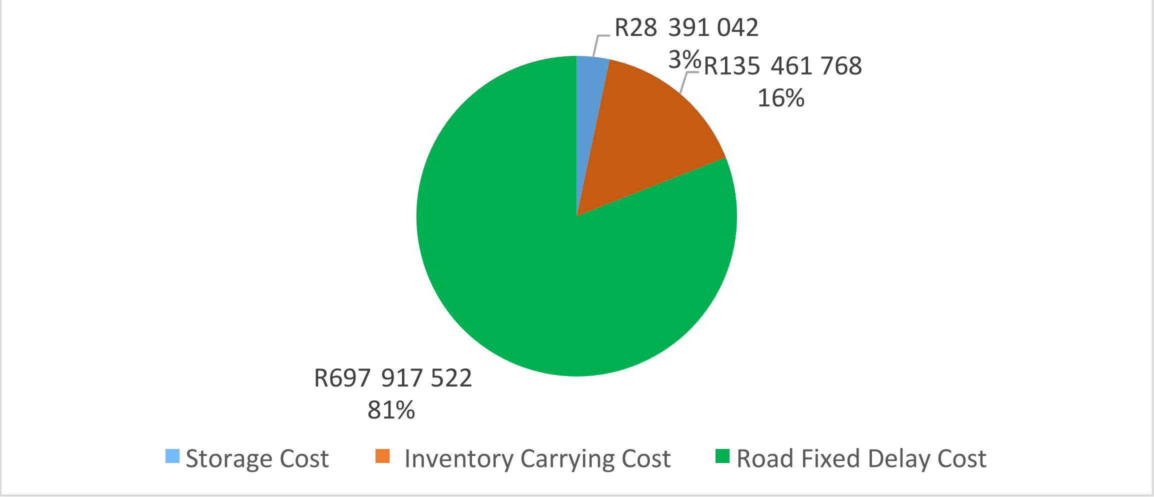


Figure 15: Export (eastbound) trade logistics costs in Rands (ZAR) due to Lebombo border delays in 2018

Table 42 shows the total trade logistics costs including the additional costs incurred due to Lebombo border delays. The additional costs are calculated using the average transit delay time at each of the border points. To simplify the distribution of costs incurred for export and imports. Figure 16 and 17 illustrate the distribution of the total export cost incurred, and total import costs incurred respectively. 27 percent of the total export's costs incurred are attributable to the additional export costs incurred. In figure 13 17 percent of the total import costs incurred are attributable to the additional import costs incurred. This is in line with the transit delay times experienced. The delay times for exports (eastbound) were longer than the transit items for imports (westbound).

Table 42: Total trade logistics costs including the additional costs incurred due to Lebombo border delays in 2018 in Rands (ZAR)

Costs to the Border	**Export (Eastbound)**	**Import (Westbound)**
Road transport costs	R 1 832 650 427	R 193 109 742
Storage and port costs	R 167 358 618	R 93 143 521
Management, admin and profit cost	R 171 312 034	R 41 308 760
Inventory carrying cost	R 178 545 649	R 43 053 014
	R 2 349 866 728	**R 370 615 037**
Additional Costs	**Export (Eastbound)**	**Import (Westbound)**
Storage Costs	R 28 391 042	R 17 702 801
Inventory Carrying Cost	R 135 461 768	R 12 258 166
Road Fixed Delay Cost	R 697 917 522	R 43 655 664
	R 861 770 332	**R 73 616 631**

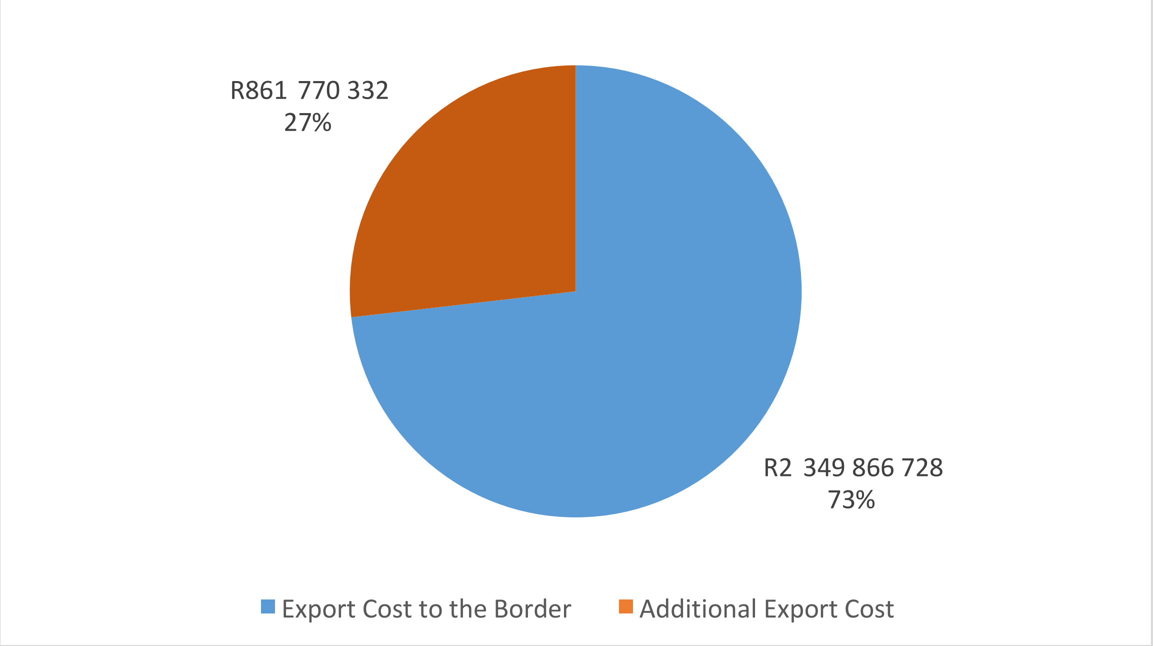


Figure 16: Distribution of the total export costs incurred in rands (ZAR)

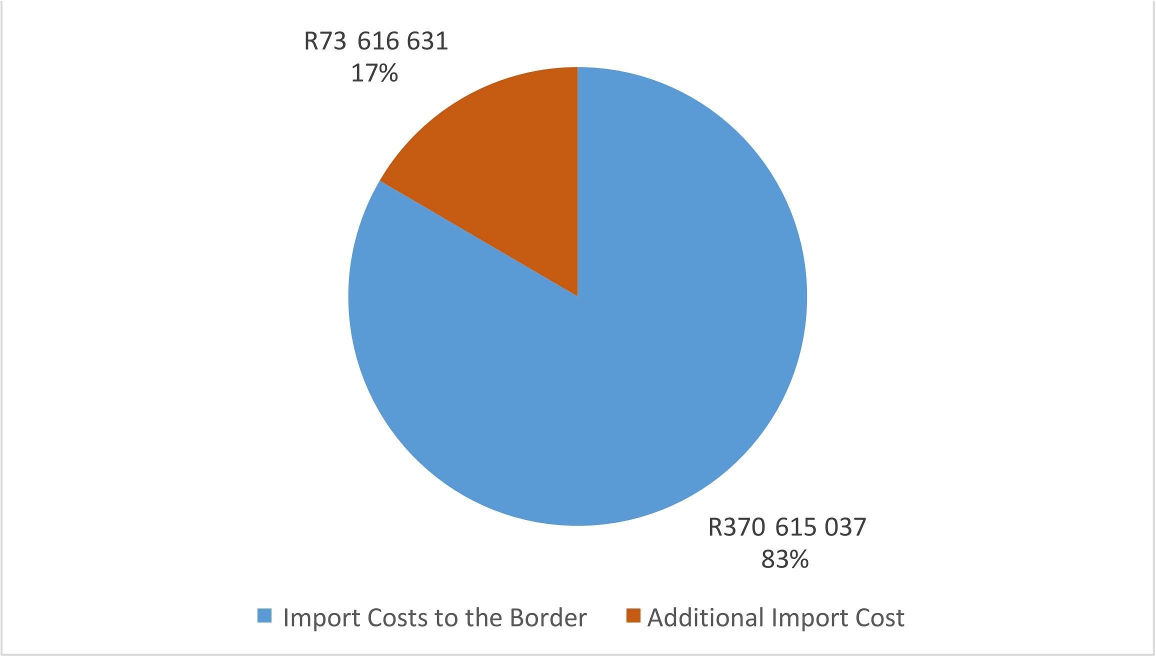


Figure 17: Distribution of the total import costs incurred in rands (ZAR)

Figure 18 indicates the distribution of the total trade costs incurred. 26 percent of the total trade costs incurred are attributable to the additional import and exports costs incurred. With additional exports costs contributing 24 percent and additional import costs contributing 2 percent. These costs confirm that more goods travel eastbound to be exported, congesting the border.

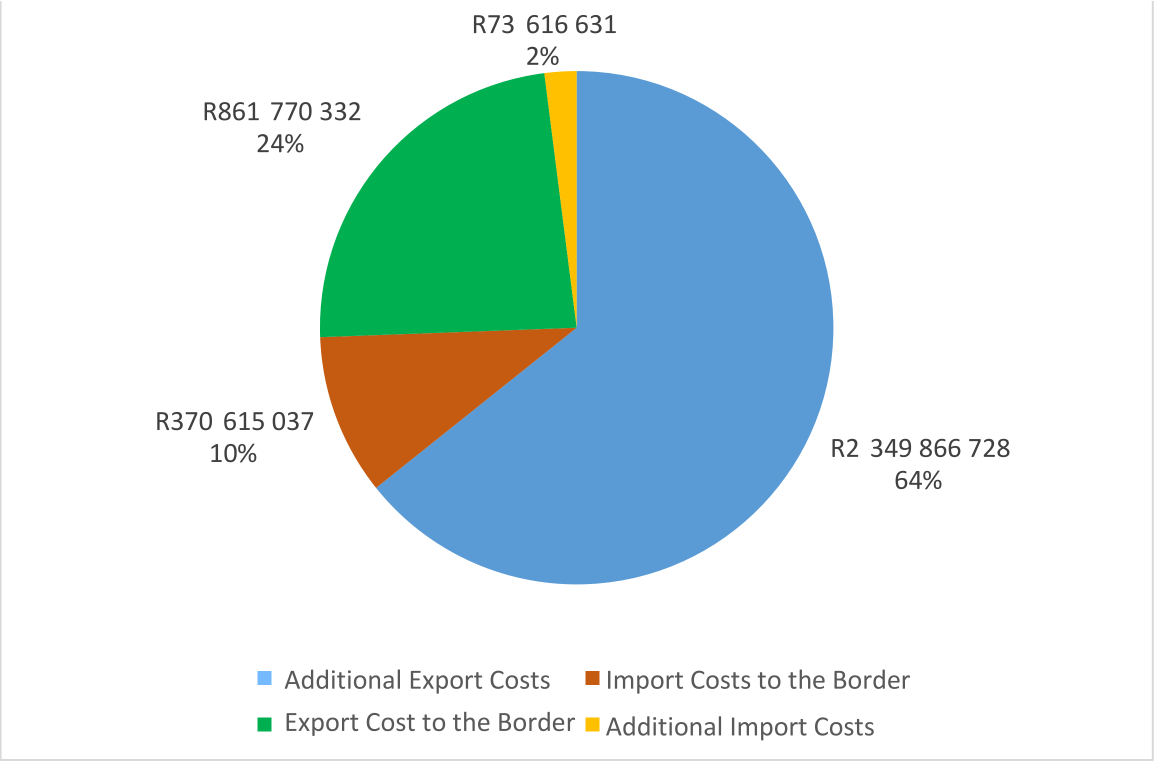


Figure 18: Distribution of the total trade logistics costs incurred in Rands (ZAR)

5.2.5 Driver Questionnaires

From the driver questionnaire the CBRTA provided, there were 938 respondents that participated after the data was cleaned to remove irrelevant or incomplete screening data. Five questions were asked, whereafter a comments section followed.

The five questions were:

- Q1. Where is your origin of departure and final destination?
- Q2. What are the commodities transported?
- Q3. Are there any alternative routes?
- Q4. How often do you use this border?
- Q5. Average time at the border?
- Comments (reasons relating to border delays)

Q1 part A provided insight where trucks depart from and part B listed the drivers final place of origin. Of the 938 respondents, 937 answered part A and 924 respondents answered part B. 95 percent of the respondent’s origin is from South Africa. 96 percent respondents’ destination is Mozambique

After matching the Mozambique – South Africa origin-destination pairs, the direction of drivers crossing the Lebombo border post was found. Figure 19, which represents the direction of respondents traveling between South Africa and Mozambique as the origin and destination points. It is apparent that there were more respondents exporting goods to Mozambique than respondents importing goods from Mozambique.

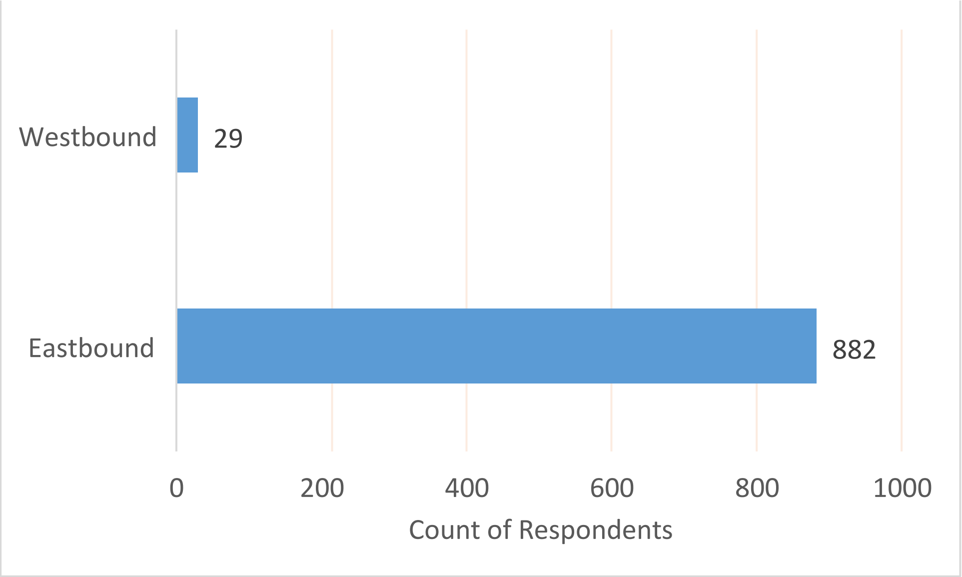


Figure 19: Direction of respondents at Lebombo border post

Respondents listed the commodities transported in Q2. From a total of 938 respondents, 633 respondents said they transport chrome; that is over 67 percent of the goods transported across the Lebombo border post.

For Q3, respondents indicated whether there are alternative routes that they use. From the respondents who answered this question, all 924 responded no, with no comments on the alternative route that are used.

There were 923 responses for Q4, of which after removing any irrelevant or incomplete answers, there were 915 valid responses. The answers provided were analysed and grouped according to figure 20. 39 percent of the drivers said they come every second week, or twice a month. 29 percent of the drivers responded that they come once a month or month; and 26 percent of the drivers said they use the Lebombo border daily, or every day. Figure 14 displays the driver’s frequency of using the Lebombo border as a percentage of all valid responses

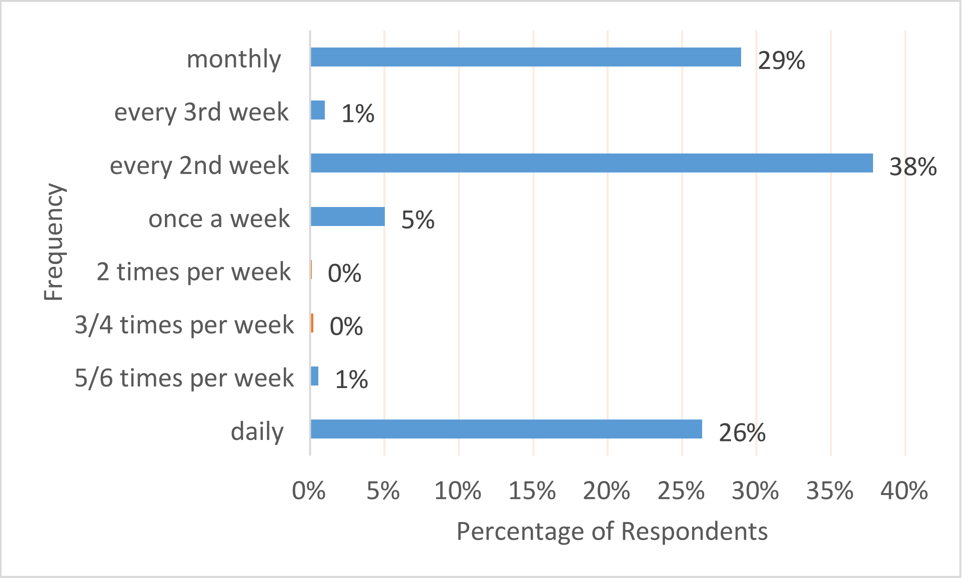


Figure 20: Usage frequency of Lebombo border post

For Q5, there were 922 responses of which there were 920 valid answers. The answers provided were analysed and grouped according to figure 21. Figure 21 represents drivers average time spent at the Lebombo border post as a percentage.

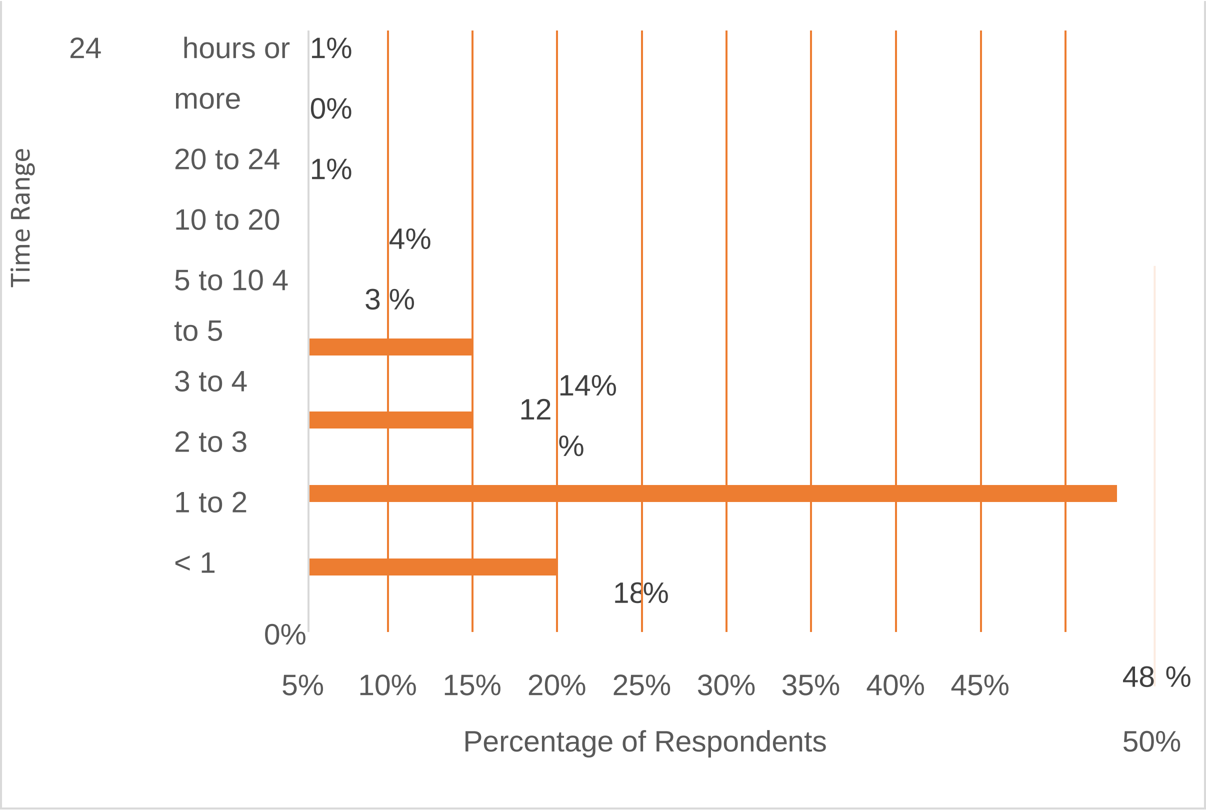


Figure 21: Average time spent at the Lebombo border post

From figure 21 it is apparent that 48 percent of the drivers spend an average of 1-2 hours at the border, followed by 18 percent spending less than 1 hour at the border and 14 percent spending 3-4 hours at the border. The findings in figure 21 correspond to the median and IQR average results in table 35.

A comment section was provided, allowing drivers to make a comment pertaining to the challenges that are faced at the Lebombo border post. There were 37 respondents who had left comments. After cleaning the comments to remove any irrelevant or incomplete answers, there were 29 comments. The 29 comments were analysed and grouped according the relevant themes depicted in Table 43.

Table 43: Classification of comments according to theme

Theme	Comment summary
Staff	• Increase staff • Staff must be quick
Administration	• Improve paperwork • Paper clearance
Operations	• Scanning Machine • Improve South Africa border
System	• Improve system • System too slow
Monitoring	• More police
Infrastructure	• Specific roads • Change the facility
Operating hours	• 24-hour operations

From the major themes identified, figure 22 illustrates the comments percentage of respondents according to theme. It appears that most respondents complained about the need for more staff. Thereafter, administrative challenges pertaining to paperwork processes and clearance thereof needs to be improved. System, operations, operating hours and infrastructure challenges had a close count, all contributing to the challenges experienced at the border. This is in line with the literature findings at South Africa’s border posts with Botswana and Zimbabwe.

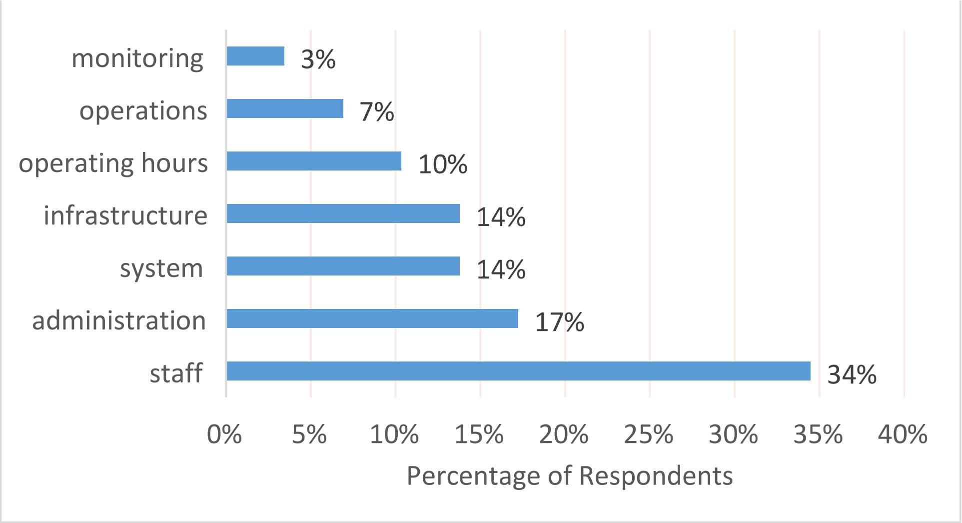


Figure 22: Respondents comment at Lebombo border post

6. COMPARATIVE ECONOMIC IMPACT ASSESSMENT

The purpose of the study was to compare the extent to which border delays and the related logistics costs differ between the Maputo and Trans Kalahari corridors. The comparison focused on delays at Lebombo, Kopfontein and Skilpadshek border posts which are the key border posts on the two corridors.

The average transit times at each of the border points for Lebombo, Kopfontein and Skilpadshek border posts are presented in Table 44. From the table it is evident, Lebombo incurs the longest average transit times at all four points. The associated trade logistics costs are represented in Table 45. Table 44 further illustrates that the South African side of the border post incurs longer delay times at Lebombo, Kopfontein and Skilpadshek.

Table 44: Average transit time to import and export goods through Lebombo, Kopfontein and Skilpadshek border posts

	Exports		Imports	
	South Africa	Foreign	Foreign	South Africa
Lebombo	16 hours 49 minutes	14 hours 31 minutes	5 hours 13 minutes	14 hours 19 minutes
Kopfontein	9 hours 24 minutes	6 hours 47 minutes	4 hours 37 minutes	7 hours 48 minutes
Skilpadshek	12 hours 24 minutes	7 hours 3 minutes	3 hours 51 minutes	6 hours 52 minutes

Table 45: Total additional costs in Rands (ZAR) incurred due to the border delays experienced at Lebombo, Kopfontein and Skilpadshek border posts

	Exports	Imports
Lebombo	R861 770 332	R73 616 631
Kopfontein	R114 399 892	R22 063 745

Skilpadshek	R78 022 510	R18 257 887

The study results show that the greatest additional costs incurred due to border delays are at the Lebombo border post. It is also evident that export costs are significantly greater than at the other two border posts, Kopfontein and Skilpadshek. It should be noted however, a revised approach was used to determine the cost incurred from the border delays.

7 OVERALL CONCLUSIONS

The economic impact the Lebombo border delays have on trade logistics costs were found to be substantial. The border delays experiences at Lebombo are longer than at any of the previously studied border posts. The additional costs incurred at Lebombo illustrate a great loss to the businesses and the economy on a national level. The inefficiencies prohibit increased trade at this border. Although extensive improvements in the border post may impose large capital funds in the short term, the long-term benefits will imply economic growth on a national level. Not only will there be substantially less additional costs incurred; improvements in the border post will attract increased levels of trade. Improvements in the border clearance system can result cost saving on a national level of 0.03 percent of the national GDP.

8. Recommendation

8.1 Trans Kalahari

The research conducted in this study has focused on numerous challenges and areas in need of more efficient practices. These recommendations are discussed within the context of the listed research questions.

For the CBRTA to evolve into a more efficient and effective agency, one must analyse the shortcomings of the operations and procedures that have been instilled for ages and implement an innovative solution that would eradicate these recurring challenges. A solution that has been successfully implemented in Africa is the One Stop Border Post (OSBP). Literature in this research emphasises the importance of an OSBP in Africa’s regional trade environment. An OSBP has been proven to lessen transit time between borders as part of the procedures can be merged, thus alleviating the issue of duplicated activities.

Skilpadshek could see substantial improvements in border clearance procedures, if international best practices were introduced to aid in alleviating problematic areas of Skilpadshek current border procedures. One international best practice as discussed in the literature is Authorised Economic Operator (AEO) status. This allows companies to work in close cooperation with customs authorities and distribute their goods without the inconvenience of detailed customs inspections.

Technology will play a pivotal role in restructuring past border procedures to accommodate for future growth in the volume of freight moving through borders. An example of an innovative practice is that of a Single Window System (SWS). Freight transporters will be able to submit all applicable documents required for clearance preceding their arrival at the border, avoiding queues. These documents can be forwarded to an agent via an electronic gateway. This procedure will reduce the number of documents going to different government officials, as all the documents are sent to one person beforehand, resulting in less time spent at the border. This kind of technology could replace the need for the Zeerust truck stop. This could help eliminate R66 007 290 that the Zeerust truck stop contributes to delay costs per annum.

By implementing an OSBP, it could be assumed that the transit time delay through Skilpadshek border post could be halved and using replacing the physical truck stop with an online procedure ensuring pre-clearance, it would eliminate the need for the Zeerust truck stop. Considering these assumptions, a 70% reduction in trade logistics costs through Skilpadshek could be realised, cutting down the total logistics costs from R162 287 687 to R48 140 198 per annum (Simpson, 2020). Constructing an OSBP might prove to be costly in the short run, but cost savings will be realised over the long term. If the recommendations previously stated are carried out, the 8.67% that Skilpadshek contributes to the total trade logistics costs can potentially be reduced by 6.10%. Skilpadshek southbound costs will potentially decrease to 4.24% from 6.09% and Skilpadshek northbound costs will potentially decrease to 6.77% from 9.60%.

Through these recommendations, externalities may be reduced. The 7.59% that Skilpadshek contributes to total trade logistics costs could potentially decrease by 5.34%. Skilpadshek southbound will potentially decrease by 3.74% from 5.37% and northbound will potentially reduce by 5.90% from 8.37%. This will result in a significant decrease in externality costs.

8.2 Maputo Corridor

The Lebombo border post is a crucial border post for South Africa and many SADC countries to gain access to the Maputo development corridor to engage in international trade. The CBRTA is an essential role player in enabling trade between South Africa and SADC members. Improvements in clearance procedures should be emphasised on the South African side of the border as South Africa experiences longer average transit times. It is therefore recommended the CBRTA reviews the Lebombo border post. A focus should be placed on staff and administrative processes pertaining to paperwork clearance procedures.

The clearance process should be reviewed and analysed. From the literature it is evident that several activities can be instilled to facilitate the movement of goods cross-border. The use of digitalised technology to aid cross-border trade is at the forefront to any best practice mentioned. To simplify the lengthy administrative procedures drivers and Customs needs to adhere to, it is recommended an eTIR system is established in the SADC region, but more specifically at the Lebombo border post. Through co-operation between South Africa and Mozambique, implementing an eTIR system can alleviate many of the administrative challenges faced. Simplifying paperwork requirements by using a single standardized Customs document that is internationally recognised will accelerate the speed of processing activities and eliminate several the procedures drivers currently must go through to get cleared. Further this will an enable a single window system to be implemented on each of side of the border.

The use of technology to facilitate cross-border trade through cross-border appears to be essential to reduce administrative and operational procedures. Technology can further aid border security and the processing of freight with the establishment of a Common Transit (CT) system. The CT system segregates border control procedures according a transport operator track record. For example, transporters entering the SADC CT system regions who have no track record or for companies registered out of this zone, complete a regular procedure set out; contrary, transport operators with a good track record followed simplified processes. In additional to improving border security, this recommendation aids in processing of freight whereby transporters who are registered and have a good track record are checked less frequently relieving border security bottlenecks.

Through further co-operation, a OSBP can be achieved which will further reduce the border delay times considerably as single window system is implemented and duplicated activities are eliminated. Although a OSBP is ideal, South Africa and Mozambique need to reach an agreement. Therefore, it is recommended that the two countries further work towards the OSBP by implementing the eTIR system which incorporates many of the one stop border principles.

8.3 Limitations

Due to the Covid-19 restrictions, it was not possible to collect recent primary data through conducting survey observations of the vehicles transit times and driver questionnaire. This limited the study to secondary data available, which required extensive cleaning and transformation to match vehicle pairs. The data was collected over a one-week period in November 2018, which is a small sample to represent the annual freight data.

8.4 Further Work

Some ideas for further research include; to evaluate the additional costs incurred due to the delays experienced at the Beitbridge, Grobler’s Bridge and Skilpadshek border post using the revised method of calculating the trade logistics costs. Furthermore, it is similar research could be conducted at all four border posts using data that has been collected over a longer period to be more representative of annual movements.