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Comparing Transport Corridors Based on Total Economic Cost

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Comparing Transport Corridors Based on Total Economic Cost

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Abstract

This paper compares the performance of three competing corridors serving landlocked SADC countries (Beira, Dar es Salaam and Durban) based on Total Economic Cost from the perspective of transporters, retailers, and manufacturers. The motivation for the research is the paradox that, while Beira is closest to the hinterland served by these corridors, it attracts the least cargo. Historical research compares corridors in terms of both direct costs and time delays, but without translating time delays and variability in time delays into the economic costs experienced by corridor users. Unpredictable time delays reduce the competitiveness of cargo owners forming part of global Just-in-Time value chains. Our novel TEC model includes direct costs and the cost impact of delays and variability in delays, and quantifies the relative contributions of ports, border posts and road travel. Port's efficiency proved to be the biggest differentiator between these corridors, followed by border posts and road links. We found that while Beira corridor has the lowest cost if only average travel time is considered, the Durban corridor proves to be the most competitive when variability in time delays is also considered, explaining why Durban enjoys the largest share of cargo transported to the landlocked hinterland.

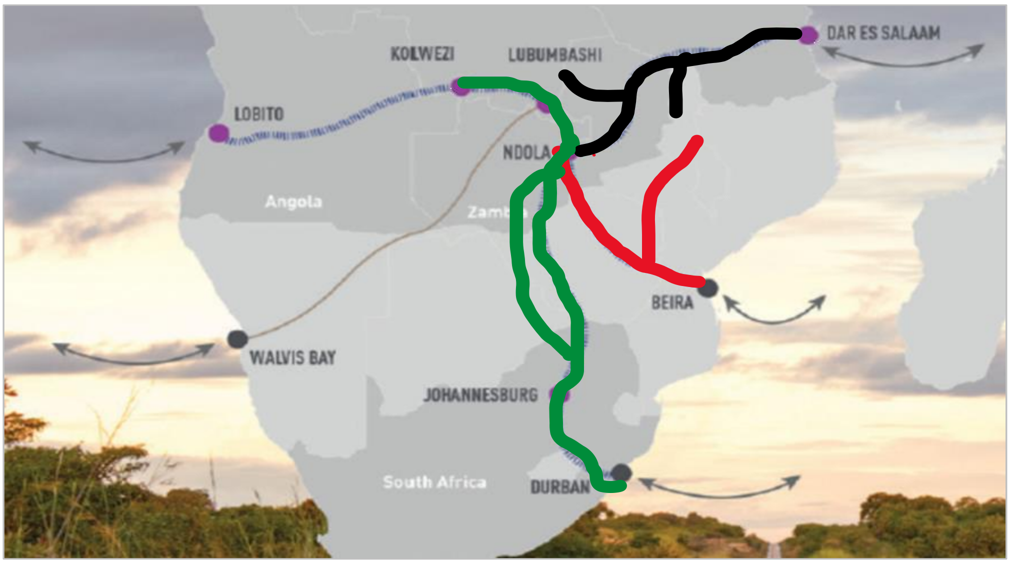
Keywords: *transport corridor, performance, total economic cost, landlocked countries*

Introduction

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

Various studies have reviewed the development of multinational transport corridors and assessed their performance (Goldmann & Wessel, 2020) (Hanaoka, et al., 2019). Barriers to cross-border movement exist because of lengthy customs procedures, while inefficiencies in the transport system have an adverse impact on the economic development of LLDCs (Hoffman, et al., 2013). From an economic cost perspective, it would be expected that the proximity of competing ports to the hinterland should determine the share of cargo moving on each corridor between the hinterland and the seaboard. This is however not true for this case study: while Beira Port is by far the closest to the primary economic hubs of the landlocked SADC countries, it also enjoys the smallest share of imports and exports. We investigate this paradox by developing a novel Total Economic Cost (TEC) model to explain the rational choices made by cargo owners and logistics service providers when selecting the most appropriate route to move cargo between the coast and the hinterland.

Figure 1. *The Three Main Corridors Serving SADC Landlocked Countries*



Hanaoka et al (2019) evaluated corridor performance from the perspective of infrastructure owners (ports, roads, and railways), considering the cost of infrastructure and direct transport costs, but without converting time delay and variability of time delay into their respective economic impacts on corridor users. We found that this approach could not explain the above paradox, as both the cost required to provide and operate infrastructure as well as the direct transportation cost is the lowest for Beira Corridor. Our study conducts the evaluation from the perspective of retailers and manufacturers importing goods as part of business operations. The three corridors are evaluated in terms of the cost impact of both total transportation time and variability in time delays. These corridors are depicted in Figure 1. We therefore proceeded to quantify the hidden costs from the perspective of cargo owners, mostly resulting from variability in time delays, to explain the reasons for the observed share of cargo that each corridor enjoys.

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

The rest of the paper is structured as follows: In the next section we review literature on intermodal transport corridor performance assessment. This is followed by the method for corridor assessment used for this paper and an outline of data collection. Then next section describes the theory behind the TEC model that forms the core of the method to compare different corridors from the perspective of corridor users. The quantified results are reported in afterwards, while conclusions and policy recommendations for the improvement of respective corridors are addressed lastly.

Literature Review

Transport corridors can provide an answer to LLDCs' poor accessibility to resources and markets via maritime transport. According to Rodrigue, et al. (2016) a transport corridor is a linear orientation of one or more transport routes and flows connecting important locations that act as origins, destinations, or points of transhipment. Yang et al. (2018) define a corridor as an international intermodal transport route that can expedite the movements of goods and people across international borders by connecting key freight transport points in different countries. International cooperation is essential to provide transit access and efficient transportation systems for landlocked countries (Regmi & Hanaoka, 2012).

The level of development of the logistics industry in a country as reflected by the Logistics Performance Index (LPI) has much bearing on the overall efficiency of transport processes. According to the 2018 LPI scores, among the four SADC LLCs along the case study corridors, Malawi (2.59) and Zamabia (2.53) have higher LPI compared to their two counterparts, DRC (2.43) and Zimbabwe (2.12). Among the countries operating the respective ports, South Africa has the highest LPI of 3.38, with Tanzania at 2.91 and Mozambique at 2.24. This provides an indication of the condition of infrastructure, procedural impediments and intermodal transport operation and management along the respective corridors.

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

Lehtinen and Bask (2012) found that while theoretical studies indicated a particular corridor as being favoured by importers, this was not the case in practice. According to Regmi and Hanaoka (2012) the time-cost-distance approach is extensively used by the Economic and Social Commission for Asia and the Pacific and Asian Development Bank for the assessment of transport operations. They also noted contributions of emerging ICT technology for efficient intermodal transport operations and freight transport. A decision support tool, including a cost model, was developed to assist logistics service providers to select optimum multimodal routes, in the process optimizing transportation routing within GMS countries (Kengpol, et al., 2012).

Several other studies, especially Athukorala & Narayanan (2018), Yang et al. (2018), Hanaoka, et al. (2019) and Goldmann & Wessel (2020), combined the evaluation of international transport processes with trade and transport facilitation measures. Jiang (2019) used a simple time-cost-distance approach to evaluate intermodal transport corridors in North-East and Central Asia and identified time and cost related barriers. Yang, et al (2018) built a performance evaluation model to understand the relative performance of the Traditional Sea-Land Line (TSLL) alongside the two emerging container routes forming part of the Belt and Road (B&R) initiative between China and Europe. Rodrigue (2020) recommends the use of ICT, Radio Frequency Identification (RFID) and satellite positioning systems to reduce cargo processing and border clearance time as well as transportation cost.

Methodology

The economic impact of logistics time delay performance on corridor users was the topic of previous research (Hoffman, et al., 2013). Hoffman (Hoffman, 2019) demonstrated that, in addition to service fees charged by transport operators, the time delay and variability in time delay of transport operations result in various additional costs to the overall operations of the cargo owner. To objectively compare the Beira, Dar es Salaam and North-South corridors we use a definition of TEC that includes direct transport and logistics cost, interest paid on cargo, stock shrinkage, cost of stockholding of cargo and losses due to out-of-stock situations in case cargo is delivered late. This approach incorporates the impact of indirect cost factors like infrastructure and regulations, as it quantifies the consequences of time delays and variability in time delays both on transport service providers as well as cargo owners, regardless of the underlying causes of such time delays.

Our methodology consists of the following steps:

1. We obtained figures of the average number of trucks crossing borders per annum for each of the corridors, using border posts that connect LLCs to the respective ports. This allowed us to determine the current market share of each corridor to service the needs of SADC LLCs. To simplify the comparison, we used Lusaka, Zambia as proxy for all SADC LLCs, to determine the preference of commercial cargo owners that have to select a corridor based on economic considerations, as Lusaka is the biggest economic hub that is located approximately the same distance from Durban to the south and Dar es Salaam to the north.
2. We obtained actual figures of direct transport and logistics charges for a standard 40-foot container to be transported from either of the 3 competing ports to Lusaka. This provided an indication of the comparative costs that cargo owners are prepared to pay to have their goods transported along each of the competing corridors. Transport operators using corridors that are in a less competitive situation would have to charge less compared to transport operators using corridors that are more competitive in terms of non-tariff related factors. Should cargo owners be prepared to pay a higher direct charge for one corridor compared to the other, it would indicate that there are other considerations, not reflected by direct costs, that influence their decisions.
3. We then constructed a model of direct transport costs based on distance and time, to determine what the charges for a 40 ft container from each port to Lusaka should be if the competitive playing field is equal for transporters operating along all corridors. We calculated direct transport costs by considering the cost to operate a truck as an economic asset over its economic life, the cost to employ the driver and fuel costs, using the same approach as (Hoffman, et al., 2013). We assumed values for the different cost parameters as displayed in

4.
5. Table **1** below to calculate the monthly cost to own and operate a truck. Using the total round trip time delay for each corridor we converted this into an ownership cost per trip. We added to this the fuel cost, using the distances covered per corridor and fuel economy figures as obtained from industry data (Hoffman & Van der Westhuizen, 2019). Typical monthly driver salary was converted to driver cost per trip by using average trip turnaround time.
6. To determine the TEC from the perspective of cargo owners that must select a specific corridor, we constructed a model that incorporates direct charges from port to destination, interest costs on investment in cargo in transit, shrinkage costs, stock holding costs and losses suffered by cargo owners should cargo not arrive by the time that buffer stocks have been depleted. The calculation of the latter cost required us to quantify the variability in delivery times as caused by variations in port, customs and road transport delays.
7. To allow us to quantify the time variability of moving cargo from port to destination and vice versa, we extracted cargo turnaround time from actual ports data and GPS tracking data collected from fleets of trucks using the respective corridors to transport cargo from each port to Lusaka. The time delays were divided into ports, border posts and road links between these waypoints. As we had access to trip level data, we could calculate the statistics of delay times per individual waypoint and road link, as well as for the total corridor. This allowed us to calculate not only the contribution of the corridor as a whole, but also of each corridor element, more specifically ports, border posts and road links. These results enabled us to identify which of the factors forming part of corridor performance have the biggest impact on costs as experienced by cargo owners.
8. The costs to the cargo owner resulting from variability in delivery times is impacted by the buffer stock policy implemented by the cargo owner. To obtain realistic cost figures, we assumed that the cargo owner is rational in terms of minimising total costs, and that buffer stock levels are optimised to minimize total costs. Higher buffer stock levels will result in higher interest charges and higher stock holding costs but will reduce losses due to disrupted operations, and vice versa for lower buffer stock levels. We therefore calculated total costs for a wide spectrum of buffer stock periods (the period that buffer stock will last before it is depleted should there be no new stock deliveries) and used the buffer stock periods that coincide with the lowest total costs. Higher variability in transport and logistics delays will result in policies that use higher buffer stock levels, and therefore also higher total costs, compared to a case where the variability in time delays is smaller. As the optimal buffer stock level is in each case determined based on actual historical corridor time delays, we can accept that the calculated costs reflect the true

impact of corridor operations on costs and the resulting decisions of rational corridor users that try to minimize their costs.

Total Economic Cost Model

The equations appearing in this section indicate how the various cost parameters were used in the calculation of TEC.

Direct Costs

Table **1** and Table 2 display the cost parameters that were used in the cost calculations; these figures were obtained through discussions with industry practitioners and reflect costs that are typical for the SADC region.

Table 1. *Direct Transport Cost Parameters*

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

Table 2. *Cargo Owner Costs Parameters*

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

The following equations describe how direct costs were calculated:

$$RTD_i = 2 \times TD_i + 4 \qquad (1)$$

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

$$DC_{trip,i} = \frac{DC_{monthly} \times RTD_i}{30} \qquad (2)$$

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

$$FC_i = \frac{2 \times Dist_i \times FuelCost}{FuelEcon} \qquad (3)$$

where FC_i= fuel cost for corridor i, $Dist_i$ = distance from origin to destination for corridor i, FuelCost is the cost of fuel per litre and $FuelEcon$ is the fuel economy in km/litre.

$$DTC_i = DC_{trip,i} + FC_i + CBE + OC \qquad (4)$$

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

$$NumTripspm_i = \frac{30}{RTD_i} \qquad (5)$$

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

$$TCpm_i = NumTripspm_i \times DTC_i + Instpm \qquad (6)$$

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

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

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

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

Costs Resulting from Variable Time Delays

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

The following indirect costs were identified from the perspective of retailers and manufacturers importing cargo as part of their operations, using the same approach as (Hoffman, 2019):

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

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

where $\mathrm{Cost(t)}$is the cost incurred for time delay t and $\mathrm{p(t)}$is the probability distribution for all possible time delays. As however we do not know the true probability distribution of time delays, the best we can do is to take the average over all percentiles for stock time delays:

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

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

2. *Interest paid on investments in stock-in-transit from origin to points of consumption, calculated as fraction of value of cargo*: As the importer must pay for goods once it is shipped on board at the port of origin, the importer must invest in stock-in-transit for the time duration as from cargo being shipped until final delivery to a retail distribution centre or manufacturing plant. This cost can be expressed as fraction of the value of the goods:

$$CI = \sum_{i=1}^{100} IR \times VGIT_i \quad (10)$$

$$VGIT_i = \frac{VAC \times TD_i}{365}$$

(11) therefore

$$\frac{CI}{VAC} = \frac{IR \times TD_i}{365} \quad (12)$$

where
$CI =$ Cost of interest p. a.
$IR =$ Interest Rate *p.a.*
$VGIT =$ Value of Goods In Transit
$VAC =$ Value of Annual Consumption
$\mathrm{TD_i} =$ Transit delay in days for the $\mathrm{i-th}$ percentile

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

$$TotShrinkage = \frac{\sum_{i=1}^{100} Shrinkage_i}{100} \quad (13)$$

$$Shrinkage_i = Shrinkagepd \times (1 - Shrinkage_{i-1})(TDPercCorr_i - TDPercCorr_{i-1}) + Shrinkage_{i-1} \quad (14)$$

   where $TotShrinkage$ is the total shrinkage for all stock, including all possible time delays, $Shrinkage_i$ is the shrinkage for the i-th percentile, $Shrinkagepd$ is the daily shrinkage fraction, and $TDPercCorr_i$is the time delay in days for the i-th percentile. The equation above takes into account that after each day in transit there is less stock left that is still exposed to further shrinkage.
4. *Losses in sales or production, should an out-of-stock situation occur, as fraction of value of cargo*: These losses will occur if the actual delivery is delayed beyond the normally expected delivery time. If a buffer stock is maintained to prevent these losses, then an actual loss will only occur if the unexpected delay is longer than the period covered by the buffer stock (Hoffman, 2019).
   - *Retail:* For a retail operation it is assumed that losses in sales will occur when the buffer stock is depleted before the next delivery is made:

$$\frac{L\,R\,I}{VAC} = FSL \times GM \quad (15)$$

     where

$$FSL = \frac{OTL}{ADT} \text{ if } OTL > 0, FSL = 0 \text{ } otherwise \quad (16)$$

$$OTL = ADT - SDT - BSP \quad (17)$$

$$BSP = \frac{BSS}{UR} \quad (18)$$

     where
     $LRI = Loss\ in\ Retail\ Income$
     $FSL = Fraction\ of\ sales\ lost$
     $GM = Gross\ Margin$
     $OTL = Operational\ Time\ Loss$
     $ADT = Actual\ Delivery\ Time$
     $SDT = Standard\ Delivery\ time$
     $BSP = Buffer\ stock\ period$
     $BSS = Buffer\ stock\ size$
     $UR = Usage\ Rate$

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

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

where

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

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

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

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

n is the number of components used in the final product
$LMI = Loss\ in\ Manufacturing\ Income$
$FPL = Fraction\ of\ production\ lost$
$CFTC = Component\ value\ as\ fraction\ of\ total\ cost$
$FIR = Fraction\ Interrupted\ Runs$
$OTL = Operational\ Time\ Loss$
$FUR = Fraction\ Uninterrupted\ Runs$
$FCD = Fraction\ components\ delayed$

5. *Storage costs paid for buffer stocks, as fraction of value of cargo*:
6.

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

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

therefore

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

where
$SC = Storage\ Cost\ p.a.$
$SR = 1\ Year\ Storage\ Rate\ per\ unit$

$\text{SRFrac} = 1\, Year\ Storage\ cost\ as\ fraction\ of\ unit\ value$
$MIS = Max\ Inventory\ Size\ in\ units$
$MDT = Min\ delivery\ time$
Equations 1 to 26 above allow total cost resulting from transport and other logistics delays to be expressed as fraction of the total value of goods purchased:

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

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

where
$TREI = Total\ Retail\ Economic\ Impact$
$TMEI = Total\ Manufacturing\ Economic\ Impact$

We stated before that TEC will be calculated for the optimal value of the buffer stock period *BSP* where TEC reaches its minimum value. As the effect of *BSP* on TEC must be obtained by integrating over all possible values of actual time delays, and as we do not have an analytical expression for the probability distribution of actual time delays, it is not possible to find an analytical expression for the optimal value of *BSP*. Instead, we determine this value through numerical means, by firstly averaging TEC over the measured percentile values for total time delays, and by then repeating this calculation over a sufficient range of possible *BSP* values, allowing us to find the optimal value for *BSP*.

Sensitivity of TEC with Respect to Cost Parameters

The above equations show that the TEC from the perspective of the cargo owner depends on several cost parameters. To investigate this dependence, we calculated the TEC while varying the values of these parameters over a range of values as indicated in

Table **3**. As components for products requiring large number of parts are often ordered in batches including many parts supplied by the same manufacturer, we limited the maximum number of components to a reasonable amount.

Table 3. *Range of Values Used to Determine Sensitivity of TEC w.r.t. Cost Parameters*

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

product		

Results

Division of Cargo between Competing Corridors

In

Table **4** we show the average daily truck volumes that cross various border posts that link the 3 ports under consideration to Lusaka. As not all trucks crossing a border are destined for the same destination, we separately counted total and transit trucks. Transit trucks are destined to leave the country of entry with the same cargo.

In the case of the Dar es Salaam corridor, we assume that trucks crossing the Tunduma/Nakonde border post (from Tanzania to Zambia) and that are not transit trucks (to the DRC), are destined for Lusaka. In the case of the other corridors, trucks destined for Lusaka move through Zimbabwe, using the border posts of Forbes/Machipanda (from Beira) and Beitbridge (from Durban). We obtain the number of trucks moving through each of these borders to Lusaka by counting the number of transit trucks. Using these numbers, we divided the number of trucks crossing Chirundu border post from Zimbabwe to Zambia between the Beira and Durban corridors.

The results of this approximate analysis are displayed in

Table **4**. We found that the Durban-Lusaka route has the largest share of Lusaka traffic, despite being the largest distance from Lusaka. There must be specific reasons why most commercial traders give preference to Durban port that is more than twice the distance from Lusaka compared to Beira. The rest of our analysis will try to explain this observation in terms of TEC to traders.

Table 4. *Average Daily Truck Volumes Crossing Border Posts Connecting the 3 Corridors to Lusaka*

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

Direct Transport Costs

Table 5 displays the distance from each port to Lusaka, the direct transport cost based on the cost model for each corridor, the average fraction that direct transport cost represents of the value of the cargo itself, as well as the actual transport charges obtained from various freight agents using these corridors. Beira is approximately only 50% of the distance from Lusaka compared to the other ports and should therefore be in a very strong competitive situation if all other aspects of corridor performance are identical. This is confirmed by the fact that the direct transport cost for Beira represents a lower fraction of average cargo value compared to the other ports.

Table 5. *Direct Road Transport Costs Parameters for Different Corridors*

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

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

TEC Model

We calculated the percentiles for time delays for the three corridors, and for each corridor we separately calculated these percentiles for ports, road segments and border posts. This allowed us to quantify the contribution of each of these elements towards the total costs as experienced by cargo owners. When quantifying these contributions, we assumed that only that corridor element showed variable time delays, while all the other corridor elements produced their respective average time delays.

The percentiles are displayed in

Figure **2**. It can be observed that for Beira and Dar es Salaam the port operations are the biggest contributor to delays, while for Durban, which is the furthest from Lusaka, road transportation represents the biggest delay. It is furthermore clear that there is a very wide spread of time delays experienced by different cargo consignments, from a few days up to more than 60 days.

This confirms the importance of calculating the impact of variability in time delays on TECs to the cargo owner.

Figure 3 displays how different contributions towards logistics cost vary as function of buffer stock period for both Retail and Manufacturing operations. As buffer stock period increases the cost of interest and storage costs increase but cost of lost sales and lost production is reduced. Figure 4 displays how total logistics cost vary as function of buffer stock; the curves display an optimal value for buffer stock period where the total cost reaches a minimum value. The rest of the TEC valuations were performed by using this optimal buffer stock value for each corridor and for Retail or Manufacturing operations respectively.

Figure 2. *Percentiles of Time Delays for the 3 Corridors and for Each Contributing Corridor Element*

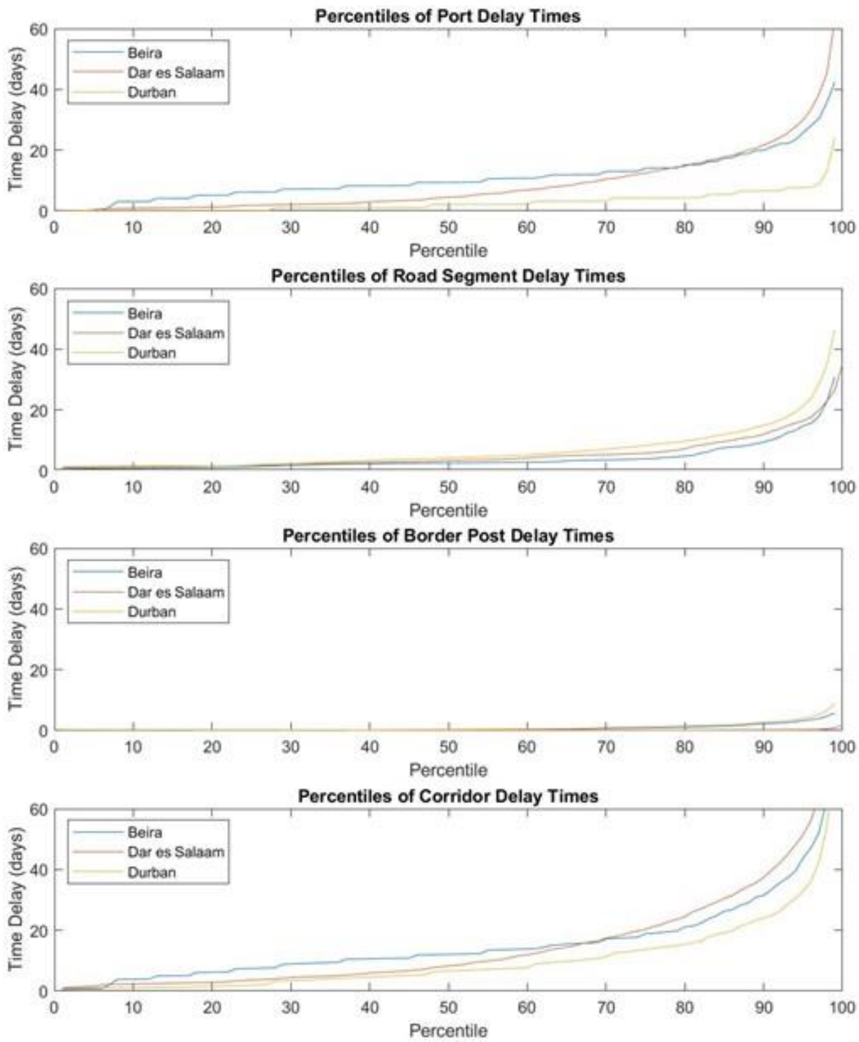


Figure 3. *Contributors to Cost Resulting from Time Delay Variability for Three Corridors to Lusaka: Beira, Dar es Salaam and Durban (Graphs on the left are for Retail and on the right for Manufacturing)*

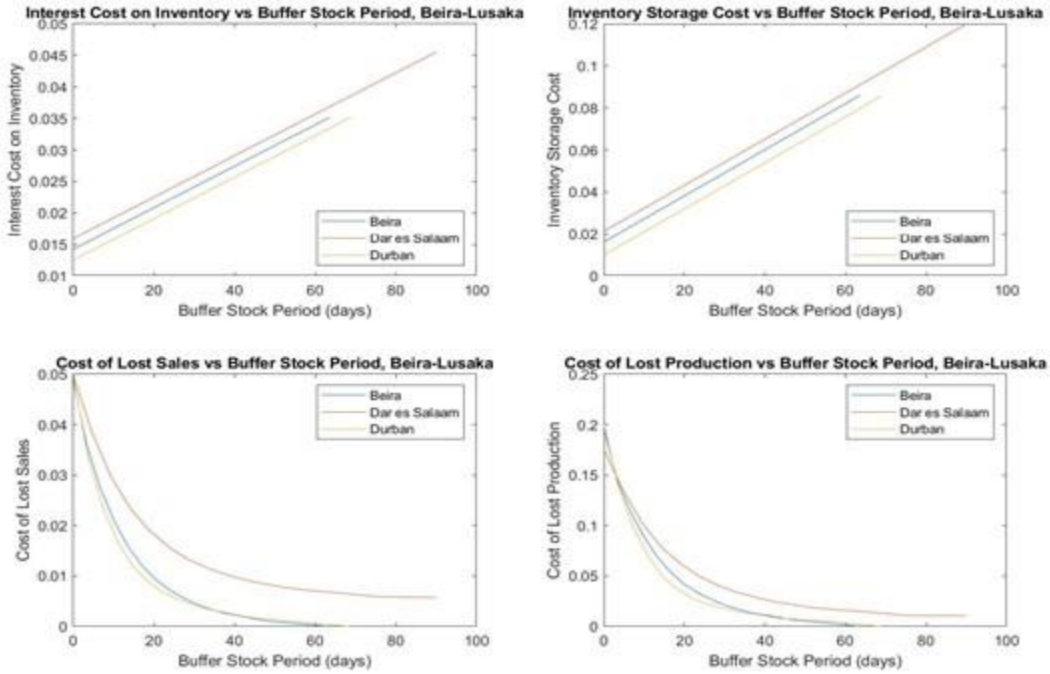


Figure 4. *Total Logistics Costs as Fraction of Cost of Cargo for Different Buffer Stock Periods for Three Corridors to Lusaka: Beira, Dar es Salaam and Durban*

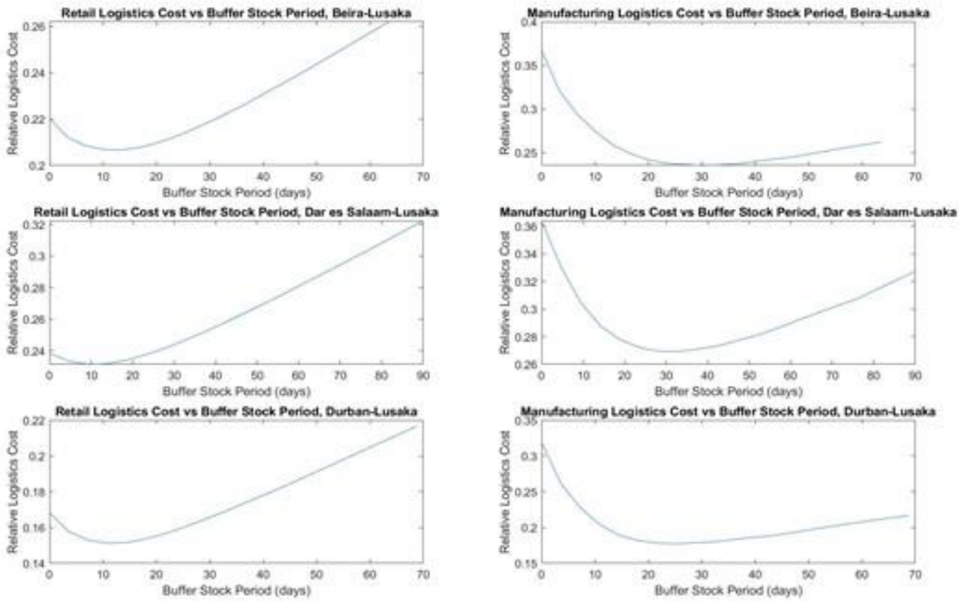


Table **6** displays the different elements contributing towards TEC from the perspective of Retailers and Manufacturers for all three corridors; a summary of these results is also displayed in Figure 5. While Beira corridor has the lowest direct transport cost, the cost of total variability of corridor time delays is much higher for Beira compared to Durban. As a result, the TEC of transport and logistics between port and destination is higher for Beira than for Durban. This at least partly explains why Durban enjoys the highest share of this market despite being the longest distance from Lusaka.

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

Table 6. *Road Transport Costs as Fraction of Value of Cargo for Different Corridors*

Retail	**Beira**	**Dar es Salaam**	**Durban**
Direct Transport Cost	4.6%	6.7%	7.0%
Port Variability	14.9%	16.6%	5.3%
Border Post Variability	2.5%	1.4%	2.8%
Road Segments Variability	7.4%	8.8%	10.5%
Total Variability Impact	20.7%	23.1%	15.1%
Total Cost	25.2%	29.9%	22.1%
Manufacturing	**Beira**	**Dar es Salaam**	**Durban**
Direct Transport Cost	2.3%	3.4%	3.5%
Port Variability	16.6%	19.3%	6.4%
Border Post Variability	2.8%	1.5%	3.2%
Road Segments Variability	8.8%	10.3%	12.6%
Total Variability	23.5%	26.9%	17.7%
Total Cost	25.8%	30.3%	21.2%

In practice the cost parameters displayed in Table 2 will not be the same for all retail and manufacturing operations. To test the sensitivity of our results for these parameter values, we repeated the cost calculations for a spread of values for each of these parameters. Some of these results are displayed in Figure 6 (varying component cost as fraction of total cost) and Figure 7 (varying inventory costs). While these parameters have a significant impact on total logistics cost, the behaviour for each corridor is similar across the range of values, and the ranking of relative cost remains the same for all three corridors over the entire range of values. Similar results were obtained for all the other cost parameters but are not displayed here due to lack of space. We can therefore state with certainty that the comparative results for the corridors will not be different if a different set of cost parameter values were used.

Figure 5. *Contributions of Delay Time Variability to Total Logistics Costs for Three Corridors to Lusaka: Beira, Dar es Salaam and Durban*

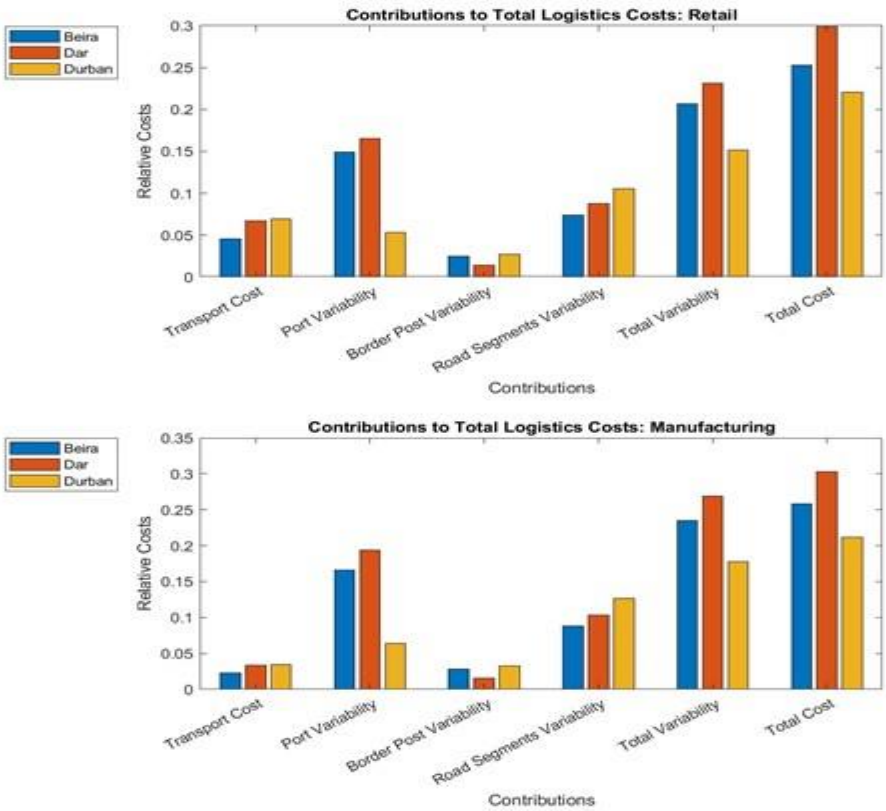


Figure 6. *Logistics Cost as Fraction of Cost of Cargo for Different Values of Component Cost as Fraction of Total Cost*

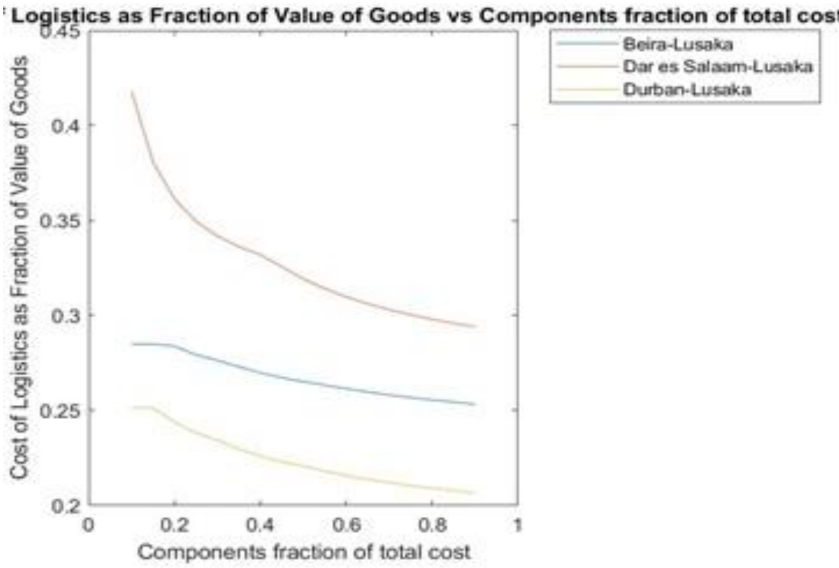
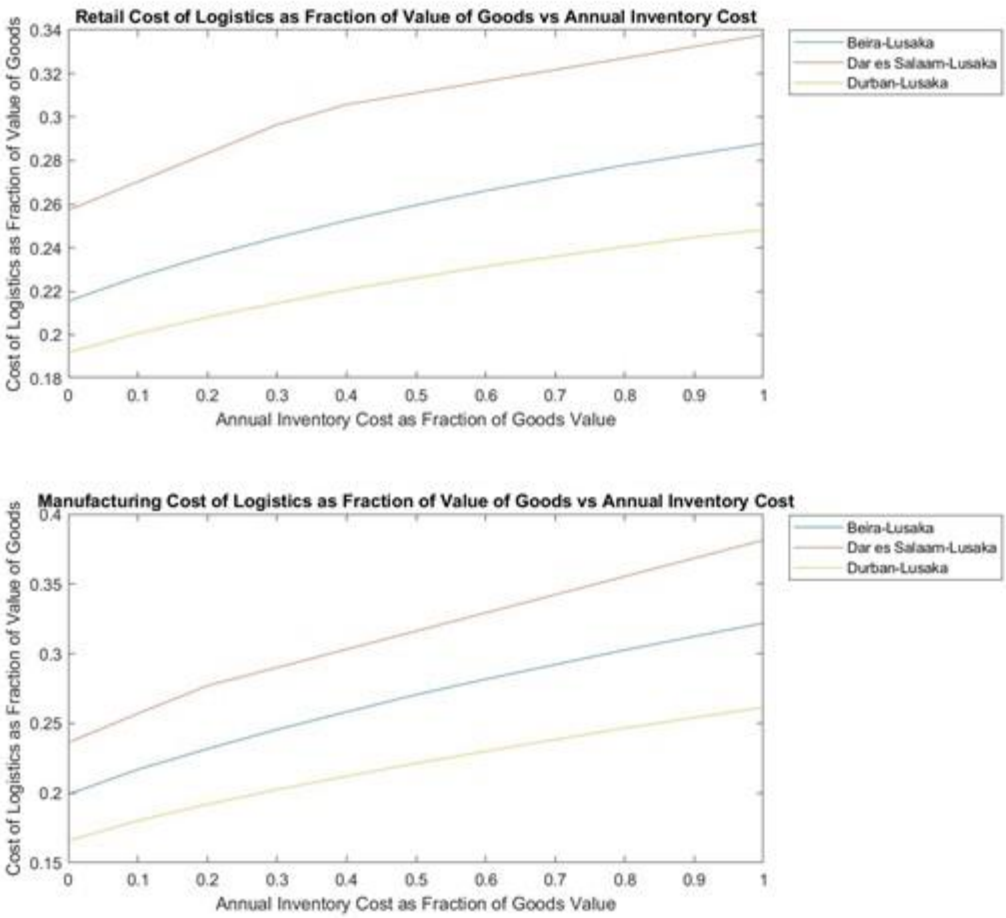


Figure 7. *Logistics Cost as Fraction of Value of Goods for Different Values of Annual Inventory Costs*



Conclusions and Recommendations

The objective of this work was to assess the ability of three corridors to compete effectively in serving LLCs. We addressed this by developing an integrated model for TEC as experienced by Retailers and Manufacturers, including both direct costs and indirect costs resulting from time delays and variability in time delays experienced by cargo moving through the corridors. We used Lusaka as proxy for SADC LLCs that depend on the Beira, Dar es Salaam and Durban ports for imports and exports.

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

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

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

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

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

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

Based on the above findings we make the following policy recommendations to improve the competitiveness of the corridors serving SADC LLCs, and in the process the global competitiveness of the entire region:

- Ports should improve the quality of their ICT systems to improve the efficiency of terminal operations and to streamline the exchange of information with port stakeholders. Such systems should be online accessible to freight agents operating from LLCs.
- Regulations for road transport should be harmonized for all countries along a corridor, to prevent avoidable delays at borders where trucks

that were legally loaded on one side of the border become illegal once it crosses the border.
- Customs authorities should rely on intelligent customs risk engines to drastically reduce the rate of physical inspections without increasing the risk of reduced levels of compliance.
- The quality of the road networks should be improved to allow trucks to travel at reasonable speeds along the main road networks.
- The network of weighbridges along the entire corridor should be linked to avoid the unnecessary repeated weighing of vehicles that are legally loaded.
- A single institution should be established to manage each transport corridor from end-to-end. Such an institution should have sufficient authority to enforce regulations and procedures that have been optimised from the perspective of the corridor and thus the entire economic region.

Future research should include the impact of vessel schedules on TEC to refine the model from the perspective of specific import and export industries. Such a refined model can be used to determine which of the competing corridors is optimal for each industry sector. It will also allow corridor performance to be optimized from the perspective of the primary industries served by that corridor.

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