Empty Containers Repositioning in South African Seaports

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Abstract

Empty container repositioning arises as a result of the imbalance between inward and outward shipments in a port. A port with more inward than outward flow is usually referred to as a surplus (or supply) port, while that in which the outflow is more than the inflow is a deficit (or demand) port. This paper addresses empty containers repositioning (ECR) problems between South African seaports of Cape Town, Port Elizabeth, East London, Durban, and Richards Bay. The objective is to optimize the repositioning process by minimizing the total cost of the empty containers movements between supply ports and demand ports. The total container repositioning cost, which the proposed model seeks to minimize, includes transportation cost, inventory-holding cost, container leasing cost and the cost of purchase of new containers. An optimal allocation of containers to minimize the total cost was determined and the balance between lease and purchase quantity was determined.

Keywords
Container repositioning, South African Seaports, Linear programming

1. Introduction
Empty containers repositioning plays a very important role in both inland and sea transportation system. This is particularly due to the rapid growth in global trade, for which containerisation is becoming more and more popular. The repositioning system for empty containers in the inland transportation is different from that in sea transportation. The differences are in the management, capacities, routes, timetables, flexibility and constraints.

The availability of empty containers in seaports depends on the efficiency of its management. If the empty containers movements between seaports and depots are not managed carefully, it may lead to an increase in the risk of unmet customer demands due to unavailability of the right quantity of empty containers at the right period to meet customer's requirements at the right destination. And for this reason the repositioning system in the sea transportation is more complex than that in inland transportation.

Empty containers repositioning problem is a global problem which seems unavoidable because of the trade imbalance between exports and imports of empty containerised items in the different seaports. The main reason for the difficulty in the repositioning process is that it is not easy to know the suitable quantity of empty containers required in the different ports in the future.

2. Background
Empty container repositioning (ECR) has recently become one of the burning research issues in supply chain management. Choong et al (2002) discussed the effect of the length of the planning horizon on empty container management for multimodal transportation networks including truck, rail, and barge. A case study of potential container-on-barge operations within the Mississippi River was used to minimize the total cost of empty container flows between locations. Jula et al (2004) developed a mathematical model to optimize empty container reuse in the Los Angeles and Long Beach (LA/LB) port. The proposed model seeks to minimize the total cost of dynamic empty containers movements between ports and depots. Song et al (2007) focused on containers allocation on shipping routes to optimize the distribution volume at ports for each voyage. They proposed models to determine the containers allocation volume at ports and on vessels, and also as a measure for liner companies to make full use of containers and minimize the operational cost, considering the cargo supplies at the ports on the routes. Wang et al (2008) presented a liner programming model to reduce the cost of empty containers allocation and transportation among different ports. They presented a systematic description of the process of empty containers allocation and transportation and its characteristics, and explained the major factors and the subjective and objective reasons which result in empty container allocation. Feng and Chang (2008) addressed empty containers repositioning problems for intra-Asia liner shipping as a two-stage problem. Stage one identifies and estimates the empty container stock at

each port, and stage two models the empty container repositioning plan with shipping service network as a transportation problem. Belmecheri et al (2009) modified a mathematical model to optimize empty containers reuse between several sites, as well as to minimize the local costs of empty containers inland movements. Chandoul et al (2009) focused on the optimisation of the returnable container management problem. They proposed an integer linear program model to minimize the total cost resulting from empty containers transportation between sites, purchasing new containers and container storage cost. Lin and Han (2009) used stochastic programming to reposition empty containers under uncertain demand and supply. The proposed mathematical model was used to minimize the total costs of transportation, cost of renting, cost of storing of empty containers. Sun et al (2009) focused on empty container repositioning problem between seaports, and developed a mathematical model to minimize the total cost of empty containers repositioning between two ports in a cycle which includes railway freight, stock change and handling change. Dong and Song (2009) focused on Container fleet sizing and empty repositioning problem in multi-vessel, multi-port and multi-voyage shipping systems with dynamic, uncertain and imbalanced customer demands. Xiaolong (2010) analyzed the inland empty container reposition (ECR) problem under certain and uncertain conditions, and established a model based on the random parameters of inland reposition system. Huang (2011) presented a dynamic model based on time expanded to minimize the expected total cost of multi-class empty containers reposition. Gou et al (2011) proposed a model construct of two strategies for empty container allocation in maritime container shipping networks, allocation by minimum cost (AMC) and allocation by shortest distance (ASD), to minimize the total costs including operating costs and capital costs during containers transportation in the container shipping network. Song and Dong (2011) addressed empty container repositioning problem between ports by using two polices (The flexible destination port policy (FDP) and determined destination port policy (DDP)) to evaluate the effectiveness of empty containers management for three major shipping routes (Europe-Asia, Trans-Pacific, and Trans-Atlantic).

In this paper, the empty container repositioning problem in South Africa seaports is studied. The main objective of this research is to model empty container repositioning through mathematical programming to minimize the total costs including transportation cost, inventory-holding cost, leasing cost & purchasing new empty containers cost.

3. Problem Description

Empty containers repositioning (ECR) has become one of the important problems faced by seaports and shipping companies, as it is almost impossible to avoid the empty containers repositioning and distribution problems between several ports. When the empty containers are transported to the destination ports, they are exported, otherwise, if the empty containers are received from another ports, they are imported. Therefore if the number of imported empty containers is less than or greater than the number of exported empty containers, there will be an imbalance. Depending on the level of trade imbalance in terms of the numbers of import and export empty containers between seaports due to different economic needs in different regions, the empty containers should be repositioned from seaports which has surplus of empty containers to seaports which has shortage of empty containers. Sometimes the seaports must lease or purchase new empty containers and store the surplus empty containers in the depots to satisfy the customers' demands.

This paper focuses on the empty containers repositioning problems in South Africa seaports (Cape Town, Port Elizabeth, East London, Durban, and Richards Bay) as a case study, and also addresses the distribution problems between seaports and depots. The data shown in Table 1 shows the empty containers flow and the numbers of import (landed) and export (shipped) empty containers into and from South African seaports. These numbers show that empty containers flow and imbalance are progressively increasing in South Africa. The imbalance between the numbers of landed and shipped empty containers in 2003 was 2832 TEUs, and the ratio of shipped ECs to landed ECs was 0.989. As at 2011, the imbalance was 345980 TEUs, and the volume of shipped empty containers was double the volume of landed empty containers. Table 2 shows the number of landed & shipped empty containers from South Africa seaports for the period from JANUARY - DECEMBER 2009. This presents a typical scenario, on a more micro level, the level of imbalance in the number of containers shipped into and out of South Africa. It can be seen that not only is there imbalance at the annualized aggregate level, but that the imbalance is probably even more pronounced at the monthly level.

	RICHARDS BAY	DURBAN	EAST LONDON	PORT ELIZABETH	CAPE TOWN	TOTAL
			JANUARY - DECEMBER 2011			
LANDED	9 329	153 334	4	59 556	115 537	337 760
SHIPPED	208	482 232	25 624	60 905	114 771	683740
			JANUARY - DECEMBER 2009			
LANDED	2 660	246 039	32	31 943	146 908	427 582
SHIPPED	466	358 352	19 119	67 200	83 336	528473
			JANUARY - DECEMBER 2008			
LANDED	2 765	217 264	4 632	27 676	140 390	392 727
SHIPPED	784	447 981	25 609	102 332	90 785	667491
			JANUARY - DECEMBER 2007			
LANDED	854	173 233	923	31 761	137 321	344 092
SHIPPED	160	451 356	17 613	101 338	121 723	692190
			JANUARY - DECEMBER 2006			
LANDED	454	158 714	1 432	24 014	131 562	316 176
SHIPPED	231	393 173	8 853	94 353	129 019	625629
			JANUARY - DECEMBER 2005			
LANDED	467	147 257	1 123	20 049	126 642	295 538
SHIPPED	203	298 882	10 367	84 519	96 486	490457
			JANUARY - DECEMBER 2004			
LANDED	528	138 889	1 968	16 306	89 156	246 847
SHIPPED	90	220 550	8 318	54 796	61 023	344777
			JANUARY - DECEMBER 2003			
LANDED	551	170 046	1 969	20 011	70 833	263 410
SHIPPED	295	162 490	4 482	52 475	40 836	260578

Table 1: Number of landed and shipped empty containers annually in 6M units (TEU'S)

4. Model Presentation

In this section we present a model to minimize the total cost of empty containers repositioning between several South Africa seaports. The model calculates the total cost as the sum of transportation cost, inventory-holding cost, leasing cost and the cost of purchasing new empty containers.

Assumptions :

The following assumptions are made in the model:

1. The seaports can be both shippers and customers.
2. The customer's demands (South Africa seaports) of empty containers must be satisfied.
3. Only one type of empty containers is used (Twenty-foot Equivalent Unit (TEU) 20×8×8 foot) to transfer item between seaports and depots.
4. One type of transportation modes is considered (vessel).
5. There is no limitation to the number of leasing and purchasing of empty containers to satisfy the customer's demands.
6. To simplify the model, we calculate the total costs (the objective function) for empty containers repositioning as the sum of transportation cost, inventory-holding cost, leasing cost and the cost of

purchasing new empty containers. We neglect the penalty cost for unmet customer's demands (since all demands are to be met), and lifting-on/lifting-off costs.

LANDED EMPTY CONTAINERS			JANUARY - DECEMBER 2009			
	RICHARDS BAY	DURBAN	EAST LONDON	PORT ELIZABETH	CAPE TOWN	TOTAL
JANUARY	4	17 296	0	60	12 802	30 162
FEBRUARY	0	22 401	0	431	15 704	38536
MARCH	0	21 252	0	1 264	19 968	42 484
APRIL	20	17 916	0	1 677	15 833	35446
MAY	0	29 431	0	1 438	18 576	49 445
JUNE	0	27 316	0	5 685	14 320	47321
JULY	0	25 377	20	3 788	9 415	38 600
AUGUST	0	24 355	10	3 402	6 231	33998
SEPTEMBER	390	22 120	2	5 464	8 413	36 389
OCTOBER	365	18 235	0	3 558	7 728	29886
NOVEMBER	1 120	11 282	0	3 229	9 297	24 928
DECEMBER	761	9 058	0	1 947	8 621	20387
TOTAL	2 660	246 039	32	31 943	146 908	
SHIPPED EMPTY CONTAINERS			JANUARY - DECEMBER 2009			
	RICHARDS BAY	DURBAN	EAST LONDON	PORT ELIZABETH	CAPE TOWN	TOTAL
JANUARY	12	39 499	1 284	3 627	4 562	48 984
FEBRUARY	0	40 659	1 880	8 519	9 980	61038
MARCH	15	25 896	1 118	2 256	6 540	35 825
APRIL	0	23 289	1 542	5 642	6 480	36953
MAY	0	23 064	1 056	4 692	6 931	35 743
JUNE	100	23 818	944	6 519	3 362	34743
JULY	0	18 856	1 234	1 528	7 238	28 856
AUGUST	0	21 292	1 403	3 727	5 160	31582
SEPTEMBER	41	23 383	1 173	10 928	7 389	42 914
OCTOBER	0	34 715	3 045	4 370	6 899	49029
NOVEMBER	0	49 252	2 132	10 217	12 528	74 129
DECEMBER	298	34 629	2 308	5 175	6 267	48677
TOTAL	466	358 352	19 119	67 200	83 336	

Table 2: Number of landed and shipped empty containers within a year in 6M units TEUs

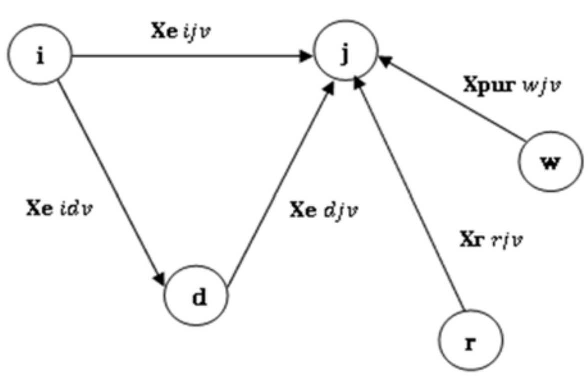

Figure 1: Container flow schema

Figure 1 is a diagrammatic representation of the schema of the slow. Containers can flow from a surplus point, i, to a deficit point, j, or be kept in a depot, d, from where it would later be moved to the deficit point, j. Also, empty container demand at j could be met by either leasing, r, or purchasing, w, from outside. The cost associated with each of these actions is indicated on the arc directed away from it.

The objective is to select the best positioning strategy, given all the possible connections between all the shipping points as shown in Figure 2.

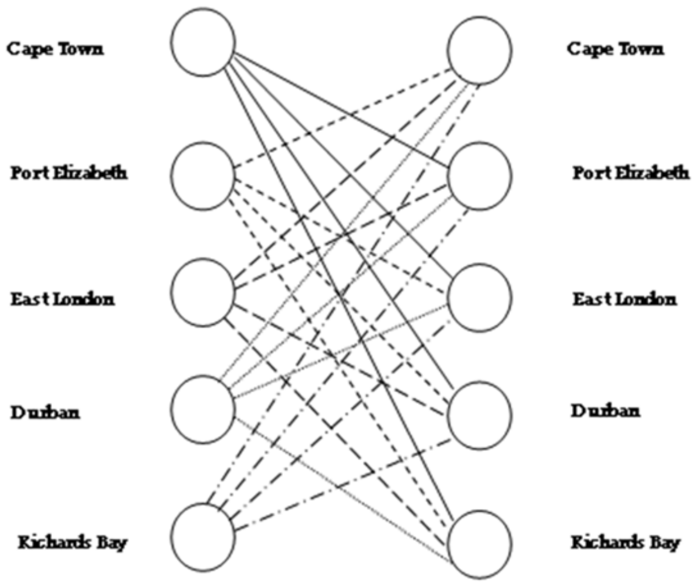

Figure 2: A depiction of possible links amongst South Africa ports.

<u>Notation :</u>

$\boldsymbol{i \in I}$, $\boldsymbol{j \in J}$, $\boldsymbol{d \in D}$, $\boldsymbol{t \in T}$, $\boldsymbol{v \in V}$, $\boldsymbol{r \in R}$, $\boldsymbol{w \in W}$
$\boldsymbol{I}$**:** Set of suppliers (or ports) who supply empty containers, $i = 1,2 \ldots . m$.
$\boldsymbol{J}$: Set of shippers (customers or ports) who need empty containers, $j = 1,2 \ldots \ldots n$.
$\boldsymbol{D}$: Set of depots (or containers yard), $d = 1,2, \ldots \ldots, b$.
$\boldsymbol{R}$: Set of leasing companies for empty containers, $r = 1,2 \ldots f$.
$\boldsymbol{W}$: Set of companies are selling new empty containers, $w = 1,2 \ldots \ldots y$.
$\boldsymbol{T}$: Time period.
$\boldsymbol{V}$: Transport mode (vessels, railway, trucks), $v = 1,2 \ldots \ldots c$.
Ch d : The inventory holding cost per TEU per day at depot d (Rand/TEU * day).
Ce ijv : The transportation cost per TEU (empty container) per day from port i to port j by transport mode v (Rand/TEU * day).
Cf ijv : The transportation cost per TEU (fully loaded container) per day from port i to port j by transport mode v (Rand/TEU * day).
Ce idv : The transportation cost per TEU (empty container) per day from port i to depot d by transport mode v (Rand/TEU * day).
Ce djv : The transportation cost per TEU (empty container) per day from depot d to port j by transport mode v (Rand/TEU * day).
Cr rj : The leasing cost per TEU per day at leasing company r (Rand/TEU * day).
Cpur wj : The purchasing cost per new TEU at company which selling new empty containers w (Rand/TEU).
Hd : The inventory level of empty containers at depot d (TEUs).
Xe ijv : Number of empty containers moved from port i to port j by transport mode v (TEUs).
Xf ijv : Number of fully loaded containers moved from port i to port j by transport mode v (TEUs).
Xe idv : Number of empty containers moved from port i to depot d by transport mode v (TEUs).
Xe djv : Number of empty containers moved from depot d to port j by transport mode v (TEUs).
Xr rjv : Number of leased empty containers at port j which moved from leasing company r to port j by transport mode v (TEUs).

Xpur wjv : Number of purchased empty containers at port j which moved from the company which selling new empty containers w to port j by transport mode v (TEUs).
A j: Number of empty containers requested by port j to satisfy the demand (TEUs).
B i : Number of empty containers available at port i (TEUs).
Th d : Inventory time of empty containers at depot d (day).
Te ijv : Transportation time of empty containers between port i and port j by transport mode v (day).
Tf ijv : Transportation time of fully loaded containers between port i and port j by transport mode v (day).
Te idv : Transportation time of empty containers between port i and depot d by transport mode v (day).
Te djv : Transportation time of empty containers between depot d and port j by transport mode v (day).
Tr rjv : Leasing time of empty containers moved between leasing company r and port j by transport mode v (day).

Objective function:

We propose a mathematical model as follows:

$$\begin{aligned}\min \mathrm{Z} = & \sum_{i=1}^{i=m}\sum_{j=1}^{j=n}\sum_{t=1}^{t=a}\sum_{v=1}^{v=c} \mathbf{Ce}\,ijv \;*\; \mathbf{Xe}\,ijv \;*\; \mathbf{Te}\,ijv \\ & + \sum_{i=1}^{i=m}\sum_{j=1}^{j=n}\sum_{t=1}^{t=a}\sum_{v=1}^{v=c} \mathbf{Cf}\,ijv \;*\; \mathbf{Xf}\,ijv \;*\; \mathbf{Tf}\,ijv \\ & + \sum_{i=1}^{i=m}\sum_{d=1}^{d=b}\sum_{t=1}^{t=a}\sum_{v=1}^{v=c} \mathbf{Ce}\,idv \;*\; \mathbf{Xe}\,idv \;*\; \mathbf{Te}\,idv \\ & + \sum_{d=1}^{d=b}\sum_{j=1}^{j=n}\sum_{t=1}^{t=a}\sum_{v=1}^{v=c} \mathbf{Ce}\,djv \;*\; \mathbf{Xe}\,djv \;*\; \mathbf{Te}\,djv \\ & + \sum_{d=1}^{d=b}\sum_{t=1}^{t=a} \mathbf{Ch}\,d \;*\; \mathbf{Hd} \;*\; \mathbf{Th}\,d \\ & + \sum_{r=1}^{r=f}\sum_{j=1}^{j=n}\sum_{t=1}^{t=a}\sum_{v=1}^{v=c} \mathbf{Cr}\,rj \;*\; \mathbf{Xr}\,rjv \;*\; \mathbf{Tr}\,rjv \\ & + \sum_{w=1}^{w=y}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Cpur}\,wj \;*\; \mathbf{Xpur}\,wjv\end{aligned}$$

The first four terms in the objective function represent the transport cost component. The fifth term is the inventory holding cost for the number of days considered. The sixth term is the cost of leasing containers in cases of shortages, while the last term is the cost of purchasing new containers to be used over the planning horizon. Constraint 1 indicates that all demands must be met, while constraint 2 is imposed to guarantee the balance of flow amongst all supply sources with the total containers made available.

Constraints:

$$\sum_{i=1}^{i=m}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Xe}\,ijv + \sum_{i=1}^{i=m}\sum_{d=1}^{d=b}\sum_{v=1}^{v=c} \mathbf{Xe}\,idv = \mathbf{B}i$$

$$\sum_{i=1}^{i=m}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Xe}\,ijv + \sum_{d=1}^{d=b}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Xe}\,djv + \sum_{r=1}^{r=f}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Xr}\,rjv + \sum_{w=1}^{w=y}\sum_{j=1}^{j=n}\sum_{v=1}^{v=c} \mathbf{Xpur}\,wjv = \mathbf{A}j$$

$$\mathbf{Xe}\,ijv, \mathbf{Xe}\,idv, \mathbf{Xe}\,djv, \mathbf{Xr}\,rjv, \mathbf{Xpur}\,wjv, \mathbf{Xf}\,ijv \geq \mathbf{0}$$

5. Calculations and Results

We use different scenarios to demonstrate the application of the model. First, we consider a scenario where there is a balance between the empty containers demanded and supplied among the ports. Next, we consider a scenario where the demand for empty containers is more than the supply for empty containers. Finally, we consider two cases where the supply is more than the demand under two different conditions. We consider the possible transportation network amongst the South Africa seaports as shown in Figure 2. Table 3 shows the transportation cost of empty containers between the Supply and demand ports in Rand/TEU. Table 4 shows the distance between South Africa seaports (Nautical mile), while Table 5 shows the total shipping time between South Africa seaports in days. All these constitute the remaining inputs parameter to our model.

Cost/TEU			**Ports *j***		
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**
Cape Town	0	1300	1600	2200	2500
Port Elizabeth	1300	0	500	1200	1500
East London	1600	500	0	800	1000
Durban	2200	1200	800	0	400
Richards Bay	2500	1500	1000	400	0

Table 3: Transportation cost of empty containers between South Africa seaports in Rand/TEU

DISTANCE BETWEEN PORTS (Nautical mile)			**Ports *j***		
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**
Cape Town	0	430	546	801	884
Port Elizabeth	430	0	134	390	473
East London	546	134	0	260	343
Durban	801	390	260	0	89
Richards Bay	884	473	343	89	0

Table 4: Distance between South Africa seaports in Nautical miles.

TOTAL TIME BETWEEN PORTS (Day)			**Ports *j***		
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**
Cape Town	0	1.292	1.625	2.375	2.625
Port Elizabeth	1.292	0	0.417	1.167	1.417
East London	1.625	0.417	0	0.792	1
Durban	2.375	1.167	0.792	0	0.25
Richards Bay	2.625	1.417	1	0.25	0

Table 5: Total time between South Africa seaports in days

The model was solved for the different scenarios using Microsoft Excel (2007) solver. The solutions obtained are presented in Tables 6 to 9, with a brief discussion of the solutions.

5.1 Scenario 1- When the total supply is equal to the total demand

Table 6 shows the result from MS Solver when the total supply of empty containers is 10700 TEU, and the total demand is 10700 TEU. The total cost of repositioning between South Africa seaports is 9540000 Rand.

No. Of TEUs			**Port *j***			
Port *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**	**Supply (TEUs)**
Cape Town	1100	0	0	3200	700	**5000**
Port Elizabeth	0	1600	900	0	0	**2500**
East London	0	0	900	0	300	**1200**
Durban	0	0	0	1000	0	**1000**
Richards Bay	0	0	0	0	1000	**1000**
Demand (TEUs)	**1100**	**1600**	**1800**	**4200**	**2000**	
Total	1100	1600	1800	4200	2000	
Cost	**0**	**0**	**450000**	**7040000**	**2050000**	
Total Cost (Rand)	**9540000**					

Table 6: Solution for a case of equal demand and supply

5.2 Scenario 2 - When the total supply is less than the total demand

Table 7 shows the result when the total supply of empty containers is 9700 TEU, and the total demand is 10700 TEU. The total cost of repositioning between South Africa seaports is 7040000 Rand. In this situation we must lease 1000 TEUs from the leasing company to satisfy the customers' demands. The leasing cost is 18 Rand per TEU per day and the minimum leasing period for ECs is 1 Month (which is a a condition in the leasing company).

Leasing cost = 18 × 30 × 1000 = 540000 Rand
The total cost = 7040000 + 540000 = 7580000 Rand
Richards Bay port must lease 1000 TEUs to meet the customer's requirements.

5.3 Scenario 3 - When the total supply exceed the total demand

Table 8 shows the result for the scenario where the total supply of empty containers is 10700 TEU, and the total demand is 9700 TEU. The total cost of repositioning between South African seaports is 7040000 Rand. In this situation we must store 1000 TEUs in the Cape Town port or send it to the nearest depot or container yard. If we suppose there is space in Cape Town port to store 1000 TEU, then we do not need to add additional inventory holding and/or transport costs to the total cost of repositioning. But if there is no space in Cape Town port to store 1000 TEUs, we must send them to the depot, and we need to add the inventory holding cost (Rand/TEU * day) to the total cost of repositioning.

We see from tables 7 & 8, the total cost of repositioning of ECs for two cases are the same (ZAR7040000), because there is no change in repositioning cost of ECs in the demand ports East London and Durban, ZAR300000 and ZAR6740000 respectively for each case. The changes occur only in the quantity of ECs in ports Richards Bay and Cape Town, which are a shortage and a surplus of empty containers respectively, and for this reason the two seaports must lease or purchase new empty containers or store the surplus of empty containers in the depots. We must also add the additional costs of leasing and inventory holding to the total cost of repositioning of ECs.
The table no. 9 shows another result when the total supply exceed the total demand in different case. We change the demand quantity of Durban only. The total supply of empty containers is 10700 TEU, and the total demand is 9700 TEU (the same value as the total supply and demand as in previous situations). The total cost of repositioning between South Africa seaports increased to ZAR7340000 because there is additional movement between ports (Cape Town-Richards Bay), and that means, there is additional repositioning cost of ECs (ZAR2500000) in the demand port (Richards Bay). Also, although the repositioning cost of ECs in Durban port decreased to ZAR4540000, the additional movement increased the total cost of repositioning by 34.06%, and by 55.07% compared to the repositioning cost of ECs in Durban port.

No. Of TEUs			Ports *j*			
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**	**Supply (TEUs)**
Cape Town	1100	0	0	2900	0	**4000**
Port Elizabeth	0	1600	600	300	0	**2500**
East London	0	0	1200	0	0	**1200**
Durban	0	0	0	1000	0	**1000**
Richards Bay	0	0	0	0	1000	**1000**
Dummy	0	0	0	0	1000	**1000**
Demand (TEUs)	**1100**	**1600**	**1800**	**4200**	**2000**	
Total	1100	1600	1800	4200	2000	
Cost	0	0	300000	6740000	0	
Total Cost (Rand)	**7040000**					

Table 7: Solution for a case where the total supply is less than the total demand

No. Of TEUs			Ports *j*				
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**	**Dummy**	**Supply (TEUs)**
Cape Town	1100	0	0	2900	0	1000	**5000**
Port Elizabeth	0	1600	600	300	0	0	**2500**
East London	0	0	1200	0	0	0	**1200**
Durban	0	0	0	1000	0	0	**1000**
Richards Bay	0	0	0	0	1000	0	**1000**
Demand (TEUs)	**1100**	**1600**	**1800**	**4200**	**1000**	**1000**	
Total	1100	1600	1800	4200	1000	1000	
Cost	0	0	300000	6740000	0	0	
Total Cost (Rand)	**7040000**						

Table 7: Solution for the first case where the total supply is more than the total demand

No. Of TEUs			Ports *j*				
Ports *i*	**Cape Town**	**Port Elizabeth**	**East London**	**Durban**	**Richards Bay**	**Dummy**	**Supply (TEUs)**
Cape Town	1100	0	0	1900	1000	1000	**5000**
Port Elizabeth	0	1600	600	300	0	0	**2500**
East London	0	0	1200	0	0	0	**1200**

Durban	0	0	0	1000	0	0	**1000**
Richards Bay	0	0	0	0	1000	0	**1000**
Demand (TEUs)	**1100**	**1600**	**1800**	**3200**	**2000**	**1000**	
Total	1100	1600	1800	3200	2000	1000	
Cost	**0**	**0**	**300000**	**4540000**	**2500000**	**0**	
Total Cost (ZAR)	**7340000**						

Table 7: Solution for the second case where the total supply is more than the total demand

5. Conclusion

This paper discusses the problem of Empty containers repositioning in South Africa seaports of Cape Town, Port Elizabeth, East London, Durban, and Richards Bay. We modelled the empty containers repositioning as a linear program, the objective being to minimize the total expected cost of the repositioning process. Four scenarios were considered for cases of supply and demand balance, where demand exceeds supply and where supply exceeds demand. These scenarios were solved using MS Excel solver. The solution provides valuable insight for making decisions about repositioning of containers under the different scenarios considered.

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