USING EXCEL SOLVER IN THE OPTIMIZATION OF PREPOSITIONED DISASTER RELIEF SUPPLY CHAIN IN A HUMANITARIAN OPERATION

J.M. Baraka[1*], S. Yadavalli[2] and M. Dewa[3]
[13]Department of Industrial Engineering
Durban University of Technology, South Africa
20618160@dut4life.ac.za[1], mendond@dut.ac.za[3]

[2]Department of Industrial and Systems Engineering
University of Pretoria, South Africa
Sarma.Yadavalli@up.ac.za[2]

ABSTRACT

In this research, a transportation problem is resolved using Excel solver. This study intends to optimize transportation time and cost solution in order to assist humanitarian operations to prepositioned Distribution Centre (DC) in Southern African Development Community (SADC) countries. The objective of this research is to develop a holistic approach to regional humanitarian supply chain including all countries and their available transportation modes. Following a number of assumptions and constraints, the results reveal that incorporating all SADC countries and their available transportation modes into the transportation problem optimize the region response capacity by minimizing transportation cost during a disaster relief operation.

Key words

Disaster relief supply chain; Transportation problem; SADC; Humanitarian operation; EXCEL Solver

*Corresponding author

1 INTRODUCTION

Disaster relief supply chain is the movement of personnel and humanitarian supplies to affected zones in order to alleviate the suffering of the vulnerable [1]. As documented by several researches, the impacts of natural and man-made disasters in the Southern African Development Community (SADC) region have been in the rise, with the prediction of more events in the future. According to the Centre of Research on the Epidemiology of Disasters [2], during the period 1900–2013, there was 642 drought events reported across the world resulting in a huge toll to humanity, killing about 12 million people and affecting over 2 billion [3]; [4]. The total economic damages are estimated at US$135 billion. In 1996, it was estimated over 100 disastrous droughts, floods and related epidemics and pest infections affected about 70 million people in the SADC region over the period of thirty years [5] [6]. Climate variability also impacted economic performance in Sub-Saharan African countries as they are dependent on primary production [7]. Based on the ever-increasing number of disasters in the past half century, Oseni and Masarirambi [8] believe the current situation is likely to worsen due to slow progress in drought risk management, while the populations in the region are increasing as well as the demand for water and the degradation of land and environment. With this eminent growing threat, many researches are acknowledging the need of increased scientific efforts in disasters mitigation in order to curb the disturbing trends.

Logisticians in humanitarian organization have to deal with various types of difficult and complex tasks producing delay in responses and ultimately loss of lives and resources [9]. Hamedi et al. [10] believe that with road transportation, the impact of delivery is constantly at stake and usually directly related to human lives and health. The research therefore intends to use excel solver to optimize the transportation humanitarian decision during relief operations throughout SADC countries.

2 LITERATURE REVIEW

Humanitarian logistics play a major role before and during disaster activities. Looking at the global increase in natural and man-made disasters, the use of logistic and supply chain management can help communities' pre or post-disaster recovery in different ways [11]. It is crucial to prepare and be pro-active to any disaster eventuality.

2.1 Transportation problems

Less literature have explicitly targeted the regional transportation problems and ways to optimize their efficiency (quick action) and effectiveness (low-cost) during a humanitarian operation. Mathematical optimization problem either maximize or minimize the objective function given the set of alternatives. Alternatives (feasible or constraint region) need to be considered in order to minimize the transportation and time in SADC region.

Among the alternatives with major impact to the model's objective function is the quality of infrastructure, the delay in border gates as well as prices associated with fuel, lubricants, tyres and bribes. According to Nikolic [12], the problem of minimization of the total transportation cost is commonly treated in literature as a basic single objective linear transportation model. With transportation cost (TC) reduction targetting important componeent of the total cost production, Rekha et al. [13] developed an algorithm with the purpose of determining the Initial Basic Feasible (IBFS) Solution of Transportation Problem (TP) to minimize the cost.

The transportation time is also relevant in a variety of real transportation problems. Vukadinović [14] highlights two types of problems regarding the transportation time: (i) minimization of the total transportation time (linear function, as aggregate the products of transportation time and quantity), called minimization of 1st transportation time, and (ii) minimization of the transportation time of the longest active transporting route (nonlinear function), called minimization of 2nd transportation time or problem of Barasov [15]. Hamedi et al. [10] paper minimizes the total number of units on transportation operation with longest time for minimization of the transportation time of the longest active transporting route.

2.2 Transportation Modes in SADC

In order to compute an optimal routing plan for first aid material, food, equipment, and rescue personnel from supply points to a large number of destination nodes geographically scattered over SADC region [16], information was collected from local and international organization operating in the region's databases. Table 1 shows the SADC countries, the geographical locations, potential disaster areas, distribution Centre, type of infrastructures, and type of disasters and exposes population.

Table 1: Exposed population in key cities in SADC

	COUNTRIES	GEOGRAPHICAL LOCATIONS	POTENTIAL LOCATIONS	DISTRIBUTION CENTRE	TYPE OF INFRASTRUCTURES	TYPE OF DISASTERS	EXPOSED POPULATION
1	ANGOLA	Sea Access	Luanda	Luanda	Marine, Railway, Airport, Road	Floods, Drought, Epidemic	6 945 386
2	BOTSWANA	Landlocked	Central	Serowe	Airport, Road, Railway	Drought, winds, Floods, Desert, Contaminated soil, Cyclone,	585 595
3	DRC	Sea Access	Katanga	Lubumbashi	Marine, Airport, Road, Railway	Volcanoes, Political conflicts, Epidemics, Artisanal and small-scale mining	5 608 683
4	LESOTHO	Landlocked	Berea	Berea Hill	Railway, Airport, Road	Seismic disaster, chronic food insecurity, HIV/AIDS, Poverty, wind, localized floods, early frost natural and pest infestations, Drought, Snowfall, landslide, lightning, fire and road accidents	300 000
5	MADAGASCAR	Island Access	Analamanga	Antananarivo	Marine, Railway, Airport, Road	floods, cyclone,	3 439 600
6	MALAWI	Landlocked	Lilongwe	Lilongwe	Railway, Road, Airport	Land degradation, Poverty, Drought, Floods, HIV/AIDS	1 346 360
7	MOZAMBIQUE	Sea Access	Zambezia	Quelimane	Marine, Railway, Airport, Road	Cyclones, Erosion, Deforestation	3 850 000
8	MAURITIUS	Island	Plaines Wilhems	Vacoas	Marine, Road, Railway, Airport	floods, cyclone, droughts, Earthquakes	368 621
9	NAMIBIA	Sea Access	Khomas	Windhoeck	Marine, Road, Railway, Airport	Floods, droughts, storms, wildfires	415 800
10	SECHELLES	Island	Mahe Island	Victoria	Marine, Road, Railway, Airport	Floods, Earth quakes, Tsunami, Cyclones	77 000
11	SOUTH AFRICA	Sea Access	Kwazulu Natal	Durban	Marine, Railway, Airport, Road	Wild fire, floods, hail storm, Tremors, Seism	10 456 900
12	SWAZILAND	Landlocked	Lubombo	Siteki	Road, Railway, Airport	food insecurity, HIV/AIDS, Chronic Poverty, droughts, floods, windstorm, hailstorm, environmental degradation	207 731
13	TANZANIA	Sea Access	Dar es Salaam	Dar es Salaam	Marine, Road, Airport, Railway	Floods, Tremors, Volcanoes, Air pollution, Artisanal and small-scale mining	4 364 541
14	ZAMBIA	Landlocked	Lusaka	Lusaka	Railway, Airport, Road	Lead Poisoning, Floods, Earthquakes	2 888 600
15	ZIMBABWE	Landlocked	Manicaland	Mutare	Road, Railway, Airport	Drought, Tremors, Earthquakes, erosion, water and air pollution, wildlife	1 753 000

2.2.1 Average transportation time and cost

Further cost to be associated within the Southern Africa is the delay cost. This cost relates to border gate, weighbridges, ports and lengthy customs processes. Simulation led to the suggestion that reduction on border delays could reduce transport costs. These delays cost over US$ 200 a day and represent a loss of US$ 120 million per year, given traffic volumes. The journey from Lusaka to Durban takes over eight days to complete, with almost four days spent at border crossings. While trucks can operate at 50–60 kmph, the effective speed along the route averages a little over 12 kmph. The costs of delays for an eight-axle interlink truck has been estimated to be around US$ 300 per day; given traffic volumes, this represents a loss of more than US$ 50 million annually [17][18][19]. The SADC corridor comprises thirty border crossings and for the benefit of the research, two active ones have been studied, Beit Bridge (a Border between South Africa and Zimbabwe) and Chirundu (a border between Zambia and Zimbabwe). Curtis [18] posited that Beit Bridge handles as many as 500 trucks a day; delays for northbound traffic are 34 hours and for southbound traffic 11 hours. Estimation for Chirundu border indicates that it takes northbound traffic approximately 39 hours to cross the border and southbound traffic 14 hours. The total cost of trucks standing at these two border posts is over US$ 60 million per year. The cost at other borders—such as Groblersbrug/Martins Drift and Kazungula—are factored, the costs increase with an additional US$ 100 million per annum ([18]; [17]). Additional costs include the following: “A Mozambican Company entering Zimbabwe must pay a road user fee of US$ 25 per 100 kilometers, an entry visa that costs approximately US$ 30 for a month, and a guarantee of US$ 120 per year” [20].

2.2.2 Transportation Infrastructures

2.2.2.1 Road

SADC region main trading artery is the North-South corridor, running north from the port of Durban in South Africa toward the Southern Democratic Republic of Congo and Tanzania. This corridor allows landlocked countries such as Botswana, Zimbabwe, Malawi and Zambia to have sea access. Durban port is also the main supplier for Swaziland and Lesotho, both landlocked countries also. Other corridor exists in the region, for instance Lubumbashi (DRC) has an alternative access to Dar es Salaam (Tanzania) instead of the 3000 km to Durban. Table 2 indicates the road conditions along major transit corridors in the region. Enhancing the capacity, the conditions and the safety of these alternative routes add into the decision-making factors and minimize the transportation cost.

Table 2: Road conditions along major transit corridors in the SADC [19]

	Condition (%)				Type (%)			Percentage in traffic bands (AADT)			
Corridors	Good	Fair	Poor	Unknown	Paved	Unpaved	Unknown	<300	300–1,000	>1,000	Unknown
Gaborone to Durban*	***97.1***	***0.5***	***0***	***2***	***99.5***	***0***	***0.5***	***0***	***0***	***96.5***	***3.5***
i) Botswana	90.5	0	0	10	100	0	0	0	0	100	0
ii) South Africa	97.4	0.5	0	2	99.5	0	0.5	0	0	96.3	3.7
Harare to Durban*	***72.9***	***25.3***	***0.5***	***1***	***100***	***0***	***0***	0.8	***3.3***	***94.7***	***1.2***
i) Zimbabwe	0	100	0	0	100	0	0	3.3	13.9	82.8	0
ii) South Africa	95.8	2	0.7	2	100	0	0	0	0	98.4	1.6
Lusaka to Durban*	***62***	***34.6***	***2.4***	***1***	***100***	***0***	***0***	***1.3***	***5.5***	***92.1***	***1***
i) Zambia	26.1	31.3	42.5	0	100	0	0	0	59	41	0
ii) Zimbabwe	0	100	0	0	100	0	0	4.2	8.7	87.1	0
iii) South Africa	95.8	2	0.7	2	100	0	0	0	0	98.4	1.6
Lubumbashi to Durban	***59***	***35.3***	***4.9***	***1***	***100***	***0***	***0***	***1.1***	***6.4***	***89***	***3.4***
i) Congo DR	0	100	0	0	100	0	0	0	0	0	100

ii) Zambia	46.2	28.4	25.4	0	100	0	0	0	23	77	0
iii) Zimbabwe	0	100	0	0	100	0	0	4.2	8.7	87.1	0
iv) South Africa	95.8	2	0.7	2	100	0	0	0	0	98.4	1.6
Lilongwe to Nacala	***27.2***	***60.2***	***12.5***	***0***	***61***	***39***	***0***	**0**	***0***	***34.7***	***65.3***
i) Malawi	78.4	18.5	3	0	100	0	0	0	0	100	0
ii) Mozambique	0	82.4	17.6	0	40.2	59.8	0	0	0	0	100
Harare to Beira*	***0***	***72.4***	***0***	***28***	***100***	***0***	***0***	**4.2**	***0***	***44.3***	***51.5***
i) Zimbabwe	0	100	0	0	100	0	0	8.7	0	91.3	0
ii) Mozambique	0	46.4	0	54	100	0	0	0	0	0	100
Gaborone to Walvis Bay	***59.2***	***17.3***	***0.1***	***23***	***100***	***0***	***0***	**11.5**	***44.3***	***44.2***	***0***
i) Botswana	50.7	5.1	0	44	100	0	0	8.2	65.4	26.4	0
ii) Namibia	68.8	31	0.2	0	100	0	0	15.3	20.6	64.1	0
Lusaka to Dar Es Salaam*	***68.9***	***19.1***	***9.8***	***2***	***100***	***0***	***0***	**34.2**	***23.6***	***42.2***	***0***
i) Zambia	70.1	19.3	10.6	0	100	0	0	63.7	26.1	10.2	0
ii) Tanzania	67.5	19	8.9	5	100	0	0	0	20.7	79.3	0

2.2.2.2 Railways

The Rail Transportation in Southern Africa is by far the most developed in the Africa. SADC has seven well-developed interconnected national railways going from Durban (South Africa) to Kasai (DRC). Unlike in other parts of Africa, Foster and Ranganathan [17] believe that the rail network in the SADC is integrated with the use of a uniform gauge. With 55,000 km of track, Sub-Saharan carries much more freights than any region in the continent, handling in overall 74 percent of Sub-Saharan Africa's freight traffic (including coal and minerals) and more than 80 percent of the total net tonne-kilometers. Table 3 shows rails corridors across Southern African railways and list various SARA (Southern African Rails Association).

Table 3: SARA rail Corridors

No	Rail Corridor	Sea Port	End Point	Rail Companies
1	Central	Dar es Salaam	Kigoma, Mwanza, Moshi	TRL
2	Tazara	Dar es Salaam	Lubumbashi	Tazara (RSZ/SNCC)
3	Nacala	Nacala	Beira	CCFB/CEAR (needs checking)
4	Beira	Beira	Lubumbashi	CCFB/NRZ/(RSZ/SNCC)
5	Plumtree	Durban	Lubumbashi	TFR/BR/NRZ/(RSZ/SNCC)
6	Beitbridge	Durban	Lubumbashi	TFR/BBR/NRZ/(RSZ/SNCC)
7	Limpopo	Maputo	Lubumbashi	CFM/NRZ/(RSZ/SNCC)
8	Ressano Garcia	Maputo	Johannesburg	CFM/TFR
9	Goba	Maputo	Manzini	CFM/SR
10	Richards Bay	Richards Bay	Phalaborwa	TFR/SR
11	Namibian	Walvis Bay	Johannesburg	TransNamib/TFR

2.2.2.3 Airways

Among the 60 Intercontinental routes in Africa, Johannesburg's OR Tambo is by far the busiest air transport hub in the region (Figure 1). Nairobi, Lusaka is also emerging as headquarters in the regions. According to Foster and Ranganathan [17], SADC region has the largest and most advanced domestic air transport market on the African continent, with South Africa considered to be the most important Intercontinental Gateway. The intraregional seats are also larger than other parts of Africa. SADC Countries such as Angola, the DR Congo, Mauritius, Madagascar, Mozambique, South Africa, and Tanzania have higher domestic connectivity; while Malawi, Zambia, Botswana and Seychelles have a much lower level of air connectivity.

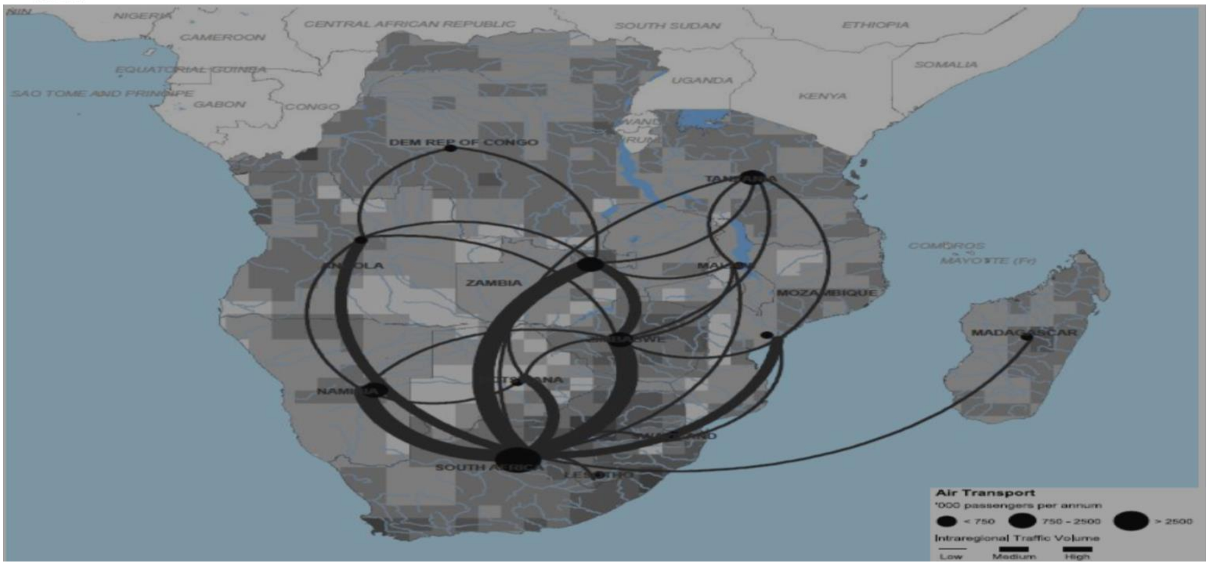

Figure 1: The SADC's regional airports and air traffic flows. ***Source [19]*.**

2.2.2.4 Seaports

For Ocean Shipping Consultants Limited (2010), Southern African ports have seen a considerable increase between 1995 [1,356.0 (TEUs) for the Container traffic and 2.7 (000s Tonnes)] for Cargo traffic and 2005 [3,091.8 (TEUs) for the Container traffic and 14.5 (000s Tonnes] for Cargo traffic. SADC is comprised of approximately 60 ports from which Durban and Dar Es Salam are by far the most important in terms of their utilization and capacity. Both mentioned ports have containers capacity exceeding 100%. According to the global average, SADC ports are 75 % more expensive and subject to unlimited number of delays. Across the SADC region, port terminals offer free storage for up to seven days, and thereafter they apply a daily storage charge. Table 4 shows all the major SADC regional Ports.

Table 4: Strategic SADC regional Ports [19]

No	Port	Country	Corridors
1	Durban	South Africa	North-South, Maseru Durban
2	Maputo	Mozambique	Maputo, Limpopo
3	Beira	Mozambique	Beira
4	Dar es Salaam	Tanzania	Dar es Salaam, Central
5	Walvis Bay	Namibia	Trans-Cunene, Trans-Kalahari, Trans-Caprivi
6	Benguela	Angola	Lobito
7	Luanda	Angola	Malange
8	Mtwara	Tanzania	Mtwara
9	Luderitz	Namibia	Trans-Orange
10	Cape Town	South Africa	Trans-Orange
	Matadi	Dr Congo	Kongo Central-Kinshasa

2.3 Transportation model

Rekha et al. [13] believe that a transportation model has an increasingly great impact on the management of transport. According to these authors, it is one of the subclass of linear programming problem with the aim of transporting various quantities of a single homogeneous commodity, that are initially stored at prepositioned Distribution Centres (DC) to different destination in such that the transportation cost, transportation distance or time is minimum. The pre-positioning problem falls into the area of humanitarian logistics, which has been formally defined by an advisory committee at the Fritz Institute as "the process of planning, implementing and controlling the efficient, cost-effective flow of and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary's requirements" [22].

The two main elements in the development of transportation model involve a number of shipping sources (prepositioned Distribution Centres (DC)) and number of destinations [23]. It deals with the minimum cost plan to transport a commodity from a number of sources to destinations using initial feasible solution max min penalty approach [13]. The well-known methods are: Vogel's Approximation Method (VAM) [24], Balakrishnan's version of VAM [15], and H.H. Shore version of VAM [25]. In this paper we present a method which gives same minimization cost as Vogel approximation method.

3 RESEARCH METHODOLOGY

This quantitative analysis intended to enquire about the relief organizations challenges in the region, their level of their preparedness, the region quality of infrastructure, the quality of the transportation system available, the transportation modes utilized, the decision affecting the selection of those transportation modes, etc.

3.1 Linear Optimization problem

According to Vignaux and Michalewicz [26], transportation problems require the determination of a minimum cost transportation plan for a single commodity from a number of sources to a number of destinations. Prasad et al. [27] expressed the transportation problem in mathematical language. The mathematical language of the transportation problem is as follows:

$$Min\, z_q = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}^{q} X_{ij}, q = 1,2 \qquad \textit{(1)}$$

Subject to:

$$\sum_{j=1}^{n} X_{ij} = a_i \,, i = 1,2,3,4,5,6,7, \dots, m \qquad \textit{(2)}$$

$$\sum_{i=1}^{m} X_{ij} = b_j,\ j = 1,2,3,4,5,6,7, \dots, n \qquad \textit{(3)}$$

$$X_{ij} \geq 0, \qquad \forall i, j \qquad \textit{(4)}$$

With C_{ij}(t) as the unit cost of transportation from supply point m $i(i = 1,2, \dots, m)$ to demand point $j(j = 1,2, \dots, n)$ when the duration allowed for the transportation is t units and the destination q units. Now, setting X_{ij} to be the variable denoting the amount transported from supply point i to demand point j, let a_i be the availability at source points i and b_j the demand at demand point j.

3.2 Optimization problem using Excel Solver

Although various relief chain distribution problems has been encountered and studied [28], many countries in the regions (SADC) still have minimal available structures and resources for supply chain management activities and techniques that have relief solutions for the affected people caused by the disaster [9]. In order to obtain optimal humanitarian decision during disaster relief operations, the research made use of "Excel Solver" taking into account all relevant available information stated in this study. Excel Solver allows us to find solutions of optimization problems of all kinds (single or multiple variables, with or without constraints).

4 PROBLEM SOLUTIONS

In the development of Excel Solver, information was loaded using the following instructions:

- To each variable we have to attribute a position on the worksheet.
- Define the objective function.
- Define all constraints: The constraints are defined a bit differently than the objective function. A constraint is a relation linking two expressions.

4.1 Variable Definition

The first step in developing Excel Solver modeling process is to identify and label the decision variables. These are the variables that represent the quantifiable decisions that must be made in order to determine the daily production schedule or in this research case, humanitarian supply decision. That is, we need to specify those quantities whose values completely determine a production schedule and its associated profit.
Table 1 listed SADC countries with each one vulnerable city including the number of population exposed. Table 5 below determines each country supply quantities, represented respectively by the following symbols: $S1$, $S2$, $S3$, $S4$, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14 and S15.

Table 5: Supply Quantity of reliefs for SADC countries

SC	$S1$	$S2$	S3	$S4$	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
SQ	200	90	300	30	190	50	110	250	150	30	80	50	160	120	140

N.B: SC: Supplier code; SQ: Supply quantity (piece/day; 1 Batch of Maize = a Tonne

The demand for each country is represented respectively by the following symbols: D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14 and D15. Each variable relate to those following countries: Angola (S1, D1), Botswana (S2, D2), Democratic Republic of Congo (S3, D3), Lesotho (S4, D4), Madagascar (S5,D5), Malawi (S6, D6), Mauritius (S7, D7), Mozambique (S8, D8), Namibia(S9, D9), Seychelles (S10, D10), South Africa (S11, D11), Swaziland (S12, S12), Tanzania (S13, D13), Zambia (S14, D14), and Zimbabwe (S15, D15). The quantities demanded in each country are assumed in Table 6.

Table 6: Demand Quantity of reliefs for SADC countries

SC	$D1$	$D2$	$D3$	$D4$	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
DQ	220	50	350	30	190	50	90	230	150	45	80	35	200	95	135

SC: Supplier code; DQ: Demand quantity (piece/day); 1 Batch of Maize = a Tonne

According to Chandrakantha [8], for optimization problems with more than two variables, we need to use complex techniques and tedious calculations to find the optimal solution. The spreadsheet and solver approach simplifies solving optimization problems as it organizes the spreadsheet to represent the model. Then it separate cells to represent decision variables; create a formula in a cell to represent the objective function and create a formula in a cell for each constraint left hand side. Once the model is implemented in a spreadsheet, next step is to use the Solver to find the solution [8].

4.2 Objective function Definitions

The next step in the modeling process is to express the feasible region as the solution set of a finite collection of linear inequality and equality constraints. The objective function could be to minimize or maximize as per the equation below.

$$Min\ Objective\ Z = C \qquad (5)$$

The function to be minimized or maximized is called the objective function and the set of alternatives is called the feasible region (or constraint region).

4.3 Constraint Definition

This was done by setting a maximum allowable time limit and optimizing the cost for that given time constraint. In order to keep the time and the cost at their optimal point, constraint must be set. There are five constraints that have been generated from the study and these are:

- Transportation time cannot exceed the decided Maximum reaction time
- Transportation cost must be minimized
- The transportation quantity has to exceed or equal the demand.
- The transportation quantity from each country cannot exceed its own supplier quantities.
- The transportation time must exceed zero

As per Table 1, disaster happen only one area in the country and all affected areas have international airport access. All landlocked countries are connected with a rail access and all 15 countries will be shipping countries and receiving countries with cost multiply by time (C X T= V).

With 15 variables (countries) as mentioned above (D1, D2, D3, D4, etc…), Baraka, Yadavalli and Ranil [29] indicated the equations below to embrace the above constraints. The finding of minimal transportation cost using different time constraints is highlighted on the Equation (5).

Subject to:

$$C = \sum_{1}^{15}(S_i) \quad \textbf{(6)}$$

$$T = Max\ (M_i) \quad \textbf{(7)}$$

$$M_i = d_i\ x\ E_i \quad \textbf{(8)}$$

$$S_i = d_i\ x\ O_i \quad \textbf{(9)}$$

$$S_i > CD \quad \textbf{(10)}$$

$$Q \geq T \quad \textbf{(11)}$$

$$S_i \geq 0 \quad \textbf{(12)}$$

Constraint (6) denote the optimal cost of transportation from supply points i to a demand point j while constraint (7) denote the maximum time it take for a supply to reaches it demand point. Constraint (8) denote a calculated time per country (in hours) by considering the given time per ton for countries and the quantity of aid (tons) shipped from countries. Constraint (9) denote a calculated cost per country by considering the given time per ton for countries and the quantity of aid shipped from countries. With Constraint (10) denote that the calculated cost per hour is superior to the country demand, while constraint (11) clarify that the maximum given allowable time (in hours) is superior to maximum transportation time. Lastly, constraint (12) specifies that the calculated cost per countries is superior to zero.

With

M_i: Calculated Time per country (in hours) $i \in I$

C: Optimal transportation Cost (in dollars)

T: Maximum transportation time (in hours).

S_i: Calculated cost per country (\$)$i \in I$

d_i: Variable quantity of aid (in tons) shipped from countries $i \in I$

E_i: Given average time per ton for countries $i \in I$ to country with disaster

O_i: Given cost per ton to countries $i \in I$ to country with disaster

CD: Given country demand

Q: Maximum given allowable time (in hours)

4.4 Interpretation of the Model

With the assumed demand and supply quantity, the assumed cost per tonnes for transportations and the time and distant; the following decision scenarios were developed Figure 2 and Figure 3. With the known supply and demand quantities, transportation costs as well as traveling times and distances between countries, this model goal is to identify which scenario gives the research an optimal point or the most valuable decision to make between the cost/time/country involved in the trade-off. The three scenarios are **a)** dividing the cost x time by the number of countries involved (Figure 2) **b)** multiplying the cost by the time (Figure 2), and **c)** dividing the cost by the number of countries involved (Figure 3).

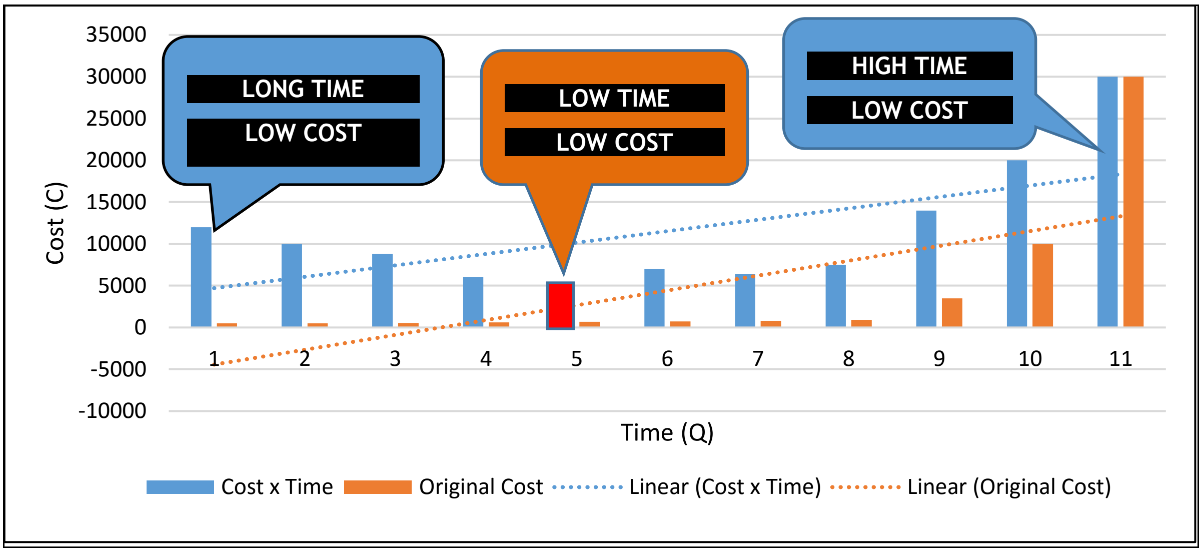

Figure 2: Original cost and Cost multiply by time

4.4.1 Decision 1: The variation of time for Original cost optimization

Figure 2 shows a visual illustration of the results obtained in the model. It is logical that the urgent the disaster, the quicker relief is required, the more expensive the transportation cost is. This method is unfavourable because the transportation time and cost increases simultaneously.

4.4.2 Decision 2: Cost x Time trade-off

Cost x Time equation gives the researcher an understanding of the best possible decision. Looking into the graphical representation in Figure 2, the yield shows the following: (1) longer times with lower costs are unfavourable for disaster such earthquakes, cyclones, etc, but favourable for disaster such as drought (2) higher costs with lower times are also unfavourable and that (3) a point near the optimal time can be achieved by minimizing cost and maximizing reliefs supply at an allowable time.

4.4.3 Decision 3: Time versus Cost

This is derived from value generated from Cost x Time divided by the number of countries involved and cost divided by the number of countries involved. This process gives this study a clear numerical view of the best possible decision to be made in the best possible time and in a cost effective way. Figure 3 shows in this scenario that increase the cities or countries involved simultaneously decrease the response time and cost. Under this scenario, the optimization of time and cost is reached.

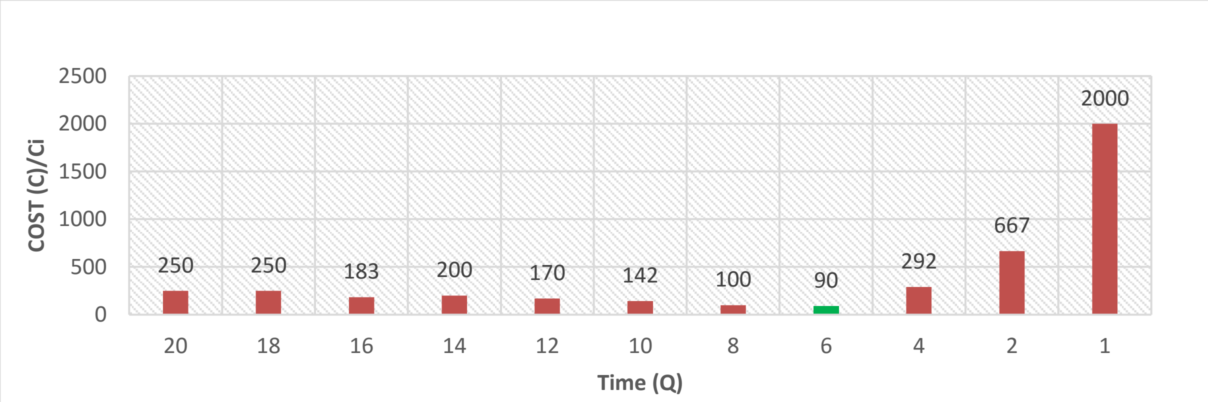

Figure 3: Time vs. Cost for countries involved ratio Result using EXCEL optimization tool

5 CONCLUSION

This study has used a quantitative analysis approach to determine the various decision making steps and procedures humanitarian logistics and supply chains. This research has highlighted locations for supply and demand, quantity to be supply, the cost, the time and the distance for the operation to be completed. Such operation has proven costly and time consuming, especially in a region with minimal infrastructure and preparedness for such events. The use of Excel Solver assisted decision maker to make cost effective decisions by calculation the feasible point especially for problems of more than two variables. With the minimization objective, the most feasible transportation point will be one that minimizes the transportation time and cost simultaneously.

6 REFERENCE

[1] **Strawderman, L., and Eksioglu, B. 2009.** The role of intermodal transportation in humanitarian supply chains final report.

[2] **Centre of research on the Epidemiology of Disasters Website (EM-DAT CRED) 2013.** *Southern Africa disasters Database*. 26/09/2013. http://www.em-dat.net.

[3] **EM-DAT 2014.** *The International Disaster Database*: http://www.emdat.be/glossary/9#letterd (last access: 13 January 2014).

[4] **Masih, I; Maskey, S; Mussá, F. E. F and Trambauer, P. 2014.** A review of droughts on the African continent: a geospatial and long-term perspective. *Hydrology and Earth System Sciences, 18* (1), pp. 3635–3649, 2014. www.hydrol-earth-syst-sci.net/18/3635/2014.

[5] **USAID/OFDA (U.S Agency of International Development/Office of U.S Foreign Disaster Assistance) 1996.** *Disaster history*, USAID/OFDA, Washington DC.

[6] **Chandrakantha, L. 2014.** Using excel solver in optimization problems. https://www.researchgate.net/publication/267557388_USING_EXCEL_SOLVER_IN_OPTIMIZATION_PROBLEMS.

[7] **Benson, C. and Clay, E. 1998.** The Impact of Drought on Sub-Saharan African Economies. *A Preliminary Examination, World Bank –Technical Papers*, 1998.

[8] **Oseni, T.O. and Masarirambi, M.T. 2011.** Effect of Climate Change on Maize (Zea mays) Production and Food Security in Swaziland. *American-Eurasian Journal of Agricultural and Environmental Sciences*, 11 (3), pp. 385-391.

[9] **Bilal, M. 2010.** The role of supply chain in Humanitarian Logistics. pp. 47.

[10] **Hamedi, M., Haghani, A., and Yang, S. 2012.** Reliable Transportation of Humanitarian Supplies in Disaster Response: Model and Heuristic. *Procedia-Social and Behavioral Sciences*, 54 (1), pp. 1205-1219.

[11] **Tatham, P. and Houghton, L. 2011.** The wicked problem of humanitarian logistics and disaster relief aid. *Journal of Humanitarian Logistics and Supply Chain Management*, 1(1), pp. 15-31.

[12] **Nikolic, I. 2006.** Total Time Minimizing Transportation Problem. *Yugoslav Journal of Operations Research*, 17 (1), pp. 125-133. DOI: 10.2298/YUJOR0701125N.

[13] **Rekha, S; Srividhya, B & Vidya, B., 2014.** Transportation Cost Minimization: Max Min Penalty Approach. *IOSR Journal of Mathematics (IOSR-JM)* e-ISSN: 2278-5728, p-ISSN:2319-765X. 10 (2), pp. 06-08.

[14] **Vukadinović, S. 1985.** Transportation Problem in Linear Programming, Naučna knjiga, Belgrade, Yugoslavia.

[15] **Barasov, A.S., 1961.** Linear Programming, Fizmatgiz, Moskva. (in Russian)

[16] **Barbarosoğlu, G., Özdamar, L., and Cevik, A. 2002.** An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations. *European Journal of Operational Research*, 140 (1), pp. 118-133.

[17] **Foster, V., and Ranganathan, R. 2011.** The SADC's infrastructure: a regional perspective.

[18] **Curtis, B. 2009.** The Chirundu Border-Post. Sub-Saharan Africa Transport Policy Discussion Paper, 10.

[19] **Africa Infrastructure Country Diagnostic (AICD) 2013.** World Bank website. http://data.worldbank.org/data-catalog/africa-infrastructure.

[20] **United States International Trade Commission (USITC) 2009.** Property and casualty insurance services: Competitive conditions in foreign markets. (Investigation No. 332-499, USITC Publication 4068). Washington, DC: United States International Trade Commission.

[21] **Drewry (Ocean) Shipping Consultants Limited 2010.** Container Forecaster, 2Q 2010, Quarterly Forecasts of the Container Market.London: Drewry Shipping Consultants Ltd.

[22] **Thomas, A., and Mizushima, M. 2005.** Logistics training: Necessity or Luxury? *Forced Migration Review*, 22(22), pp.60-61.

[23] **Taha. H.A. 2004.** Operations Research- Introduction, Prentice Hall of India (PVT), New Delhi.

[24] **Hamdy, T. 2002.** Operations Research- An Introduction (Sixth Edition). *Pearson Education Inc.*

[25] **Shore, H.H. 1970.**The Transportation Problem and the Vogels Approximation Method, *Decision Science,* 1(3-4), pp. 441-457.

[26] **Vignaux, G. A., and Michalewicz, Z. 1991.** A genetic algorithm for the linear transportation problem. Systems, Man and Cybernetics, *IEEE Transactions online*, 21(2), pp. 445-452.

[27] **Prasad, V. R., Nair, K. P. K., and Aneja, Y. P. 1993.** A generalized time-cost trade-off transportation problem. *Journal of the Operational Research Society*, pp. 1243-1248.

[28] **Balcik, B., Beamon, B. M., and Smilowitz, K. 2008.** Last mile distribution in humanitarian relief. Journal of Intelligent Transportation Systems, 12(2), pp. 51-63.

[29] **Baraka, J.C.M., Yadavalli, V.V.S., & Singh, R. 2017.** A transportation model for an effective disaster relief operation in the SADC region, South African Journal of Industrial Engineering, 28(2), pp. 46-58.