

## TRANSPORTATION MODEL UNDER WEIGHTED INSECURITY

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**Abstract:** The conventional linear programming based transportation model in the previous studies was examined and found to be deficient in practice. Modified transportation model has been developed to include some predetermined salient factors such as road safety and security. In the real sense these factors are accidental and they can occur without prior notice. Besides, weather change is also critical to transportation insecurity. In this paper a new transportation scheme's model was developed to take into consideration the incidental occurrence nature of the insecurity factors as applicable elsewhere. The weighted loss cost function due to the insecurity factors on roads was formulated using Analytic Hierarchy Process (AHP) and its outcome was integrated into the conventional transportation model. The cost savings from three models namely conventional, modified-conventional, and the current (re-modified) were compared using the petrol's transportation schedule of the Nigerian petroleum industry. The results showed that the re-modified transportation model was not in good agreement with the other two in term of flexibility. The findings showed that the cost price of the item has a wide margin depending on the incidence and the weight of insecurity.

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## 1. INTRODUCTION

Transportation model in some quarters is defined as the most useful special-purpose algorithmic tool that is more efficient than the linear programming based simplex method (Taha, 2008; Gal & Nedona, 2001; Basu, 1989; Austin & Burns, 1985). In literature, transportation model has been described as a special case of linear programming model (Harold, 2006; Eckenrode, 2003; Levin et al., 1989). Previous studies have extended the use of transportation model in electronic computers in the areas of minimizing time and cost of locating processing units (Fernando et al., 2006; Goodman & Ralph, 2001; Feinberg, 1993; Arinze & Banerje, 1989). In transportation model total supplied is assumed to be equal to total demanded. Practically, this balanced condition is rare (Taha, 2008; Wheelwright, 2008; Grant & Eugene, 1989). However, the use of balanced system will enable a good idea of how best the cost of transportation can be minimized in the heterogeneous network flow problems (Grant & Eugene, 1989; Shepard, 2001). Transportation model has been proved reasonable and effective in minimizing the cost of transportation of goods (Shepard, 2001). However, the traditional Linear Programming, *LP* based transportation model, is highly engrossed with many unrealistic assumptions such as good road, guaranteed safety and adequate security networks. For instance, the previous studies have shown evidence of delays form road accidents due to bad-roads and road-insecurity in developing countries (Kareem et al., 2011; Kareem et al., 2012). In real-life situation many of these assumptions need to be relaxed when the model is to be applied to some strategic transportation problems (Kareem, 2012a; Kareem, 2012b). The unrealistic assumptions made in the formulation of conventional transportation model contributed to its deficiency in practice. In many developing countries including Nigeria there are evidence of bad roads, mounted security check-points, and sometimes, change in weather (poor weather) which are inimical to smooth transportation process. In such countries a promising transportation system should consider the salient constraints in arriving at a realistic judgement of fixing cost of transportation and price of goods. Though there exists a modified transportation model in previous studies that dealt with petroleum product transportation and distribution (Kareem, 2012a; Kareem, 2012b), and took salient factors such as road safety and security into consideration. The lapse in the model was its rigidity in predicting the cost of transportation, besides non-consideration of climatic change. In reality the road insecurity factors are incidental and they can sometimes occur at any time without prior notice. In order to achieve the objective of minimising the cost price of transporting a public goods and at the same time creating a flexibility in transportation cost determination, a new transportation model, that will take care of the salient incidental constraints is needed. In this paper, a new transportation model is developed to take into consideration the incidental insecurity factors as applicable elsewhere. The incidental factors are of different magnitude depending on the degree of occurrence. Based on

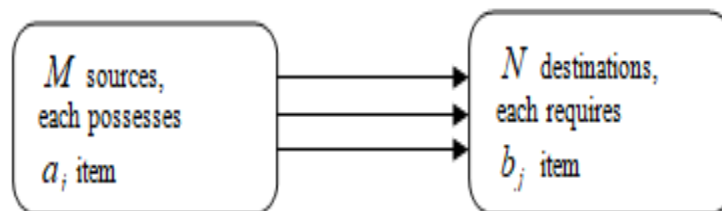
this Analytic Hierarchy Process (AHP) (Finnie et al., 1993) will be promising in formulating weighted loss cost function due to the insecurity factors on roads. The outcome will provide a good integration into the conventional transportation model.

The rest of the paper is presented thus: the conventional, the re-modified transportation model, the principle of AHP and the model implementation strategy are presented in Section 2; testing and evaluation of the model is detailed in Section 3; Section 4 presents results and discussion of the study; while conclusion and findings are in Section 5. The paper ends with acknowledgement and the list of references.

## 2. MATERIALS AND METHODS

### 2.1. Conventional transportation model formulation

The cost of distribution of products from the source (depot) to the destination (station) is minimized using linear programming based transportation model. In the transportation model, there are  $M$  sources and  $N$  destinations. Each source ( $i$ ) possesses  $a_i$  item, and each destination ( $j$ ) requires  $b_j$  item. The problem is how the item be distributed from the source to the destination such that the cost of transportation is minimized. Diagrammatic representation of the transportation problem is shown in Fig. 1.



**Fig. 1.** Representation of the Transportation Problem

Let,

$x_{ij}$  = the amount of item transported from depot  $i$  to station  $j$

$c_{ij}$  = unit cost of transporting an item from depot  $i$  to station  $j$

The mathematical statement of the transportation problem is,

Minimize (sum of transportation cost):

$$\sum_{i=1}^M \sum_{j=1}^N c_{ij} x_{ij}$$

Subject to:

$$\sum_{i=1}^M x_{ij} = b_j, \forall_j \text{ (all demands are met)}$$

$$\sum_{j=1}^N x_{ij} = a_i, \forall_i \text{ (all supplies are used)}$$

$$x_{ij} \geq 0, \forall_j$$

## 2.2. Transportation model and insecurity

The problem in Section 2.1. was re-modified to take care of how the item be distributed from the source to the destination such that the cost of transportation is minimized with due consideration of incidental insecurity factors namely bad road, poor weather, and security check-point which are principal elements of delays in transportation network. The insecurity factors or delay elements are said to be incidental because they can occur at any time with varying proportions. The delay elements are of different weights,  $W$ s depending on level of severity of contributions to the incidental insecurity on roads. The delays can be: equally severe, denoted by 1; moderately severe, 2; or strongly severe, 3. Diagrammatic representation of the re-modified transportation problem is shown in Fig. 2.

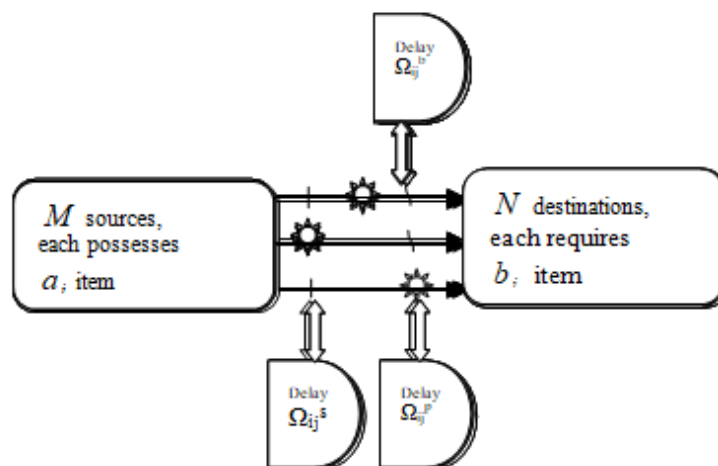


Fig. 2. Re-modified Transportation Problem

Let,

$x_{ij}$  = the amount of item transported from depot  $i$  to station  $j$

$c_{ij}$  = unit cost of transporting an item from depot  $i$  to station  $j$

$\Omega_{ij}^s$  = unit cost of security check-point delay of transporting an item from depot  $i$  to station  $j$

$\Omega_{ij}^b$  = unit cost of bad road delay of transporting an item from depot  $i$  to station  $j$

$\Omega_{ij}^p$  = unit cost of poor weather delay of transporting an item from depot  $i$  to station  $j$

$w_1$  = weighted security check-points vectorial relationship factor

$w_2$  = weighted bad road-segments vectorial relationship factor

$w_3$  = weighted poor weather vectorial relationship factor

The mathematical statement of the transportation problem based on the re-modification in Fig. 2 is,

Minimize (sum of transportation cost):

$$\sum_{i=1}^M \sum_{j=1}^N (c_{ij} + w_1 \Omega_{ij}^s + w_2 \Omega_{ij}^b + w_3 \Omega_{ij}^p) x_{ij}$$

Subject to:

$$\sum_{i=1}^M x_{ij} = b_j, \forall j \text{ (all demands are met)}$$

$$\sum_{j=1}^N x_{ij} = a_i, \forall i \text{ (all supplies are used)}$$

$$x_{ij} \geq 0, \forall j$$

The most paramount hypothesis is to test null hypothesis that there is a significant difference between the cost of transportation using the traditional method and the re-modified transportation method at first hand, and the modified transportation approach (Kareem, 2012a,b) and the re-modified approach on the other. The alternative hypothesis is that there is no significant difference between any of the two methods.

### 2.3. Weighted parameters by Analytical Hierarchy Process (AHP)

The weighted parameters,  $Ws (w_1, w_2, w_3, \dots, w_n)$  are evaluated using Analytic Hierarchy Process (AHP). The primary function of AHP is to help management

set priorities and make adaptive decisions in complex situations. The AHP is able to handle both qualitative and quantitative decision-making scenarios. The relative or specific weights of the incidental insecurity parameters were estimated using AHP as demonstrated by Finnie et al. (1993). In this process, any entry in the matrix will take the integer value of 1-5. Therefore, comparison of the two attributes (bad road, poor weather, or high security check-point) will take any of the following values: equally severe (1); moderately severe (2); strongly severe (3); very strongly severe (4); and extremely severe (5).

#### **2.4. Computer software development**

A new computer software was developed for the new model to replace the old, traditional-based model solution special algorithms in previous studies (Taha, 2008; Gal & Nedona, 2001; Basu, 1989; Yu & Zeleny, 2002). This was carried out for easy and rapid application of the new model in the industries. The modified linear programming based transportation model software package was developed using Microsoft Visual Basic 6.0 integrated development environment.

### **3. MODEL TESTING AND EVALUATION**

The model is tested using Nigerian petroleum industry as a case study. Data were obtained from a number of dependent and independent marketers sprang up across the country (PPMC, 2000). Petroleum products are mostly manufactured in the country's refineries located in Port-Harcourt, Warri and Kaduna cities. Piping systems of different capacities were used to facilitate distribution of petroleum products, through effective pumping, to twenty two (22) major oil depots spread across the country (PPMC, 2000). The major marketers loaded petroleum products from the depots in tankers, and transported them to their respective 37 retail stations. End-users buy the products from the stations based on pump price. Petroleum distribution inadequacy had led to demand bottleneck and high pump price. Data, including transportation cost per litre and road distances from depots to stations, were extracted from identified petroleum related publications including bulletin, annual reports and journals (PPMC, 2000; Green & Wind, 2007; Feinberg, 1993). The cost of transportation between the depots was estimated by calculating the average cost per kilometre (km) for selected depots from the average distances to the stations (Arinze & Banerji, 1989). Table 1 shows the cost of transporting a litre of petrol from the selected depots to station in Akure city, Nigeria, with the average distances (in km) apart. The cost of transportation to other depots was estimated from the product of average cost per km and the distance apart. The

optimal cost savings under this arrangement with respect to conventional and modified models (Kareem, 2012b) are shown in Table 3.

**Table 1.** Estimation of transportation cost of petrol

Depots	Station	Cost of transportation per litre (₦ / litre)	Cost of transporting 33,000 litres (₦)	Distance in km
Ore	Akure	0.80	26,400.00	92.00
Benin	Akure	1.00	33,000.00	171.00
Ibadan	Akure	1.00	33,000.00	200.00
<b>Average cost, and distance</b>			30,800.00	154.33
<b>Average cost per km (₦/km)</b>				199.57

Bias in the previous study (Kareem, 2012a,b) was eliminated by using data/information obtained from petrol transportation and road-users experts in Nigeria. The expert data were analysed using AHP (Finnie et al., 1993). Based on expert opinion the average costs per km of delays, due to bad road segments, poor weather condition and mounted security check-point are presented in Table 2. Besides, the expert opinion showed that three attributes of accidental insecurity (bad road, poor weather, or check-point) have the following relationships: poor weather is equally severe over mounted security check-point; bad road is strongly severe over poor weather; and bad road is moderately severe over mounted check-point. The order of the three attributes is: (1) bad road; (2) poor weather; and (3) security check-point. The 3x3 eigenvalue matrix for the preferences stated above takes the following form:

$$[A]_{3 \times 3} = \begin{bmatrix} 1.0 & a_{12} & a_{13} \\ a_{21} & 1.0 & a_{23} \\ a_{31} & a_{32} & 1.0 \end{bmatrix}$$

Here  $a_{12}$  refers to comparing bad road over poor weather. Similarly,  $a_{32}$  refers to comparing security check-point over poor weather. Based on the preferences of the attributes, the pair-wise comparison of the attributes would be as follows

$$= \begin{bmatrix} 1.0 & 0.5 & 1.5 \\ 2.0 & 1.0 & 3.0 \\ 1.5 & 0.25 & 1.0 \end{bmatrix}$$

The normalized matrix is determined by dividing the values in each column by the sum of the column:

$$= \begin{bmatrix} 0.22 & 0.29 & 0.23 \\ 0.44 & 0.57 & 0.62 \\ 0.33 & 0.14 & 0.15 \end{bmatrix}$$

Now, the eigenvector is formed as the average of each normalized row:

$$[W]_{3 \times 1} = \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix} = \begin{bmatrix} 0.25 \\ 0.54 \\ 0.21 \end{bmatrix}$$

**Table 2.** Experts' estimation of unit costs and weights of insecurity factors

Depots	Station	Security checkpoint	Bad road (₦)	Poor weather
		(₦) $\Omega_{ij}^s$	$\Omega_{ij}^b$	(₦) $\Omega_{ij}^s$
Ore	Akure	3,200.00	2,640.00	2,500.00
Benin	Akure	3,600.00	3,300.00	2,800.00
Ibadan	Akure	3,900.00	3,300.00	2,900.00
Average cost (₦)		3,633.00	3,080.00	2,733.00
Average distance (km)		154.33	154.33	154.33
Average cost per km (₦/km)		23.54	19.95	17.71
Weighted insecurity factor		0.21	0.25	0.54

Finally, the eigenvector is the weights of the three attributes where the weights of all the attributes sum up to 1. The different weights are: weighted (bad road/accidental insecurity) = 0.25; weighted (poor weather/accidental insecurity) = 0.54; and weighted (security checkpoint/accidental insecurity) = 0.21. These weights, along with the individual cost utilities are taken together or separately for calculating unit transportation cost (Table 2). This will lead to seven cost savings of transportation from which optimal saving(s) is selected based on road condition (Table 4).

**Table 3.** Optimal allocation of petrol using traditional and modified scheme; (Kareem, 2012a; Kareem, 2012b)

Sources / Depots	Destinations/ Stations	Optimal cost, ₦ (in Nigeria currency) (traditional)	Optimal cost, ₦ (in Nigeria currency) (new scheme)	Optimal item allocation (in '000) litres	Optimal distance (in km)	Minimum cost, ₦ of chosen wrong route	Minimum Cost savings, ₦(traditional)	Minimum Cost savings, ₦ (modified)
Aba	Owerri	20,356	20,399	245	102	24,000	3,644	3,600
	Port-Harcourt	12,772	12,815	89	64		11,228	11,184
	Uyo	20,356	20,399	11	102		3,644	3,600
Benin	Abakaliki	49,493	49,536	52	248	64,000	14,507	14,463
	Asaba	27,740	27,783	87	139		36,260	36,216
	Awka	33,129	33,172	150	166		30,871	30,827



<b>Enugu</b>	Umuahia	30,335	30,378	117	152	34,000	3,665	3,621
<b>Calabar</b>	Enugu	47,498	47,541	123	238	59,000	11,522	11,458
	Uyo	9,978	10,021	123	50		49,022	48,978
<b>Gombe</b>	Yola	52,686	52,729	218	264	60,000	7,314	7,270
<b>Gusau</b>	Birni-Kebbi	50,092	50,135	88	251	70,000	19,908	19,864
	Katsina	41,511	41,554	150	208		28,489	28,445
<b>Ibadan</b>	Abeokuta	15,367	15,410	234	77	106,000	90,633	90,589
<b>Ilorin</b>	Ibadan	31,732	31,775	87	159	62,000	30,268	30,224
<b>Jos</b>	Abuja	62,465	62,508	200	313	85,000	22,535	22,491
	Bauchi	26,343	26,386	212	132		58,657	58,613
	Kano	84,019	84,086	16	421		981	937
	Lafia	47,498	47,541	139	238		37,502	37,458
<b>Kano</b>	Bauchi	64,062	64,062	123	321	88,000	23,938	23,894
	Dutse	27,142	27,142	63	136		60,858	60,814
	Gusau	64,860	64,905	123	325		23,140	23,096
	Kaduna	52,287	52,330	125	262		35,713	35,669
	Katsina	34,526	34,569	220	173		53,474	53,430
<b>Lagos</b>	Birni-Kebbi	164,845	164,888	136	826	193,000	28,155	28,111
	Ibadan	29,337	29,380	16	147		163,663	163,619
	Ilorin	61,068	61,111	153	306		131,932	131,888
	Makurdi	163,647	163,690	275	820		29,353	29,309
	Sokoto	209,548	209,591	59	1,050		83,452	-16591
<b>Maiduguri</b>	Damaturu	25,944	25,987	400	130	174,000	148,056	148,012
	Gombe	95,993	96,036	246	481		78,007	77,963
	Kano	122,536	122,579	72	614		51,464	51,420
	Yola	81,624	81,667	27	409		92,376	92,332
<b>Makurdi</b>	Abakaliki	53,684	53,727	110	269	206,000	152,316	152,272
	Enugu	53,884	53,927	124	270		152,116	152,072
	Gudau	152,471	152,471	97	764		53,529	53,485
	Kano	151,673	151,716	48	760		52,327	52,283
	Lafia	19,957	20,000	150	100		186,043	185,999
	Lokoja	63,663	63,706	155	319		142,337	142,293
	Maiduguri	186,598	186,641	63	935		16,402	16,358
	Sokoto	196,576	196,619	150	985		9,402	9,358
<b>Minna</b>	Abuja	23,350	23,393	124	117	59,000	35,650	35,606
<b>Mosimi</b>	Abeokuta	12,772	12,815	217	64	16,000	3,228	3,184
	Ibadan	15,367	15,410	329	77		633	629
<b>Ore</b>	Ado Ekiti	27,940	27,983	256	140	39,000	11,050	11,016
	Akure	18,360	18,403	234	92		20,640	20,596
	Ilorin	38,118	38,161	47	191		889	885
	Osogbo	23,549	23,592	150	118		15,451	15,407
<b>Suleja</b>	Lokoja	27,541	27,584	95	138	35,000	7,459	7,415
	Minna	23,350	23,393	250	117		11,650	11,606
<b>Yola</b>	Jalingo	28,339	28,382	112	142	81,000	52,661	52,617
<b>Atlas-Cove</b>	Ibadan	29,337	29,380	200	147	47,000	17,663	17,619
<b>Port-Harcourt</b>	Abakaliki	13,770	13,813	50	69	19,000	5,230	5,186
	Yenegoa	8,981	9,024	150	45		10,019	9,975
<b>Kaduna</b>	Abuja	35,923	35,966	76	180	67,000	31,077	31,033
	Gusau	56,279	56,322	17	282		10,721	10,677
	Jos	55,880	55,923	107	280		11,120	11,076
<b>Warri</b>	Asaba	17,762	17,805	200	89	21,000	3,238	3,194

**Table 4.** Savings along the routes using the re-modified transportation model

Source/ Depot	Destina- tion/ Station(Ⓐ )	Security check Point(Ⓐ) (1)	Bad road (Ⓐ) (2)	Poor weather (Ⓐ) (3)	Inciden ce (Ⓐ)1 and 2	Inciden ce (Ⓐ)1 and 3	Inciden ce (Ⓐ)2 and 3	Inciden ce (Ⓐ)1, 2 and 3
<b>Aba</b>	Owerri	3,140	3,135	2,669	2,631	2,164	2,160	1,656
	Port- Harcourt	10,912	10,909	10,616	10,592	10,300	10,297	9,980
	Uyo	3,140	3,135	2,669	2,631	2,164	2,160	1,656
<b>Benin</b>	Abakaliki	13,281	13,270	12,135	12,044	10,909	10,898	9,672
	Asaba	35,573	35,567	34,931	34,880	34,244	34,237	33,550
	Awka	30,050	30,043	29,283	29,222	28,463	28,456	27,635
<b>Enugu</b>	Umuahia	10,325	10,315	9,226	9,138	8,049	8,039	6,862
<b>Calabar</b>	Enugu	48,775	48,773	48,544	48,525	48,297	48,294	48,047
	Uyo	6,009	5,997	4,789	4,692	3,484	3,473	2,168
<b>Gombe</b>	Yola	18,667	18,656	17,508	17,415	16,267	16,256	15,015
<b>Gusau</b>	Birni- Kebbi	27,461	27,452	26,500	26,423	25,472	25,462	24,434
	Katsina	90,252	90,249	89,897	89,868	89,516	89,513	89,132
<b>Ibadan</b>	Abeokuta	29,482	29,475	28,747	28,689	27,961	27,954	27,168
<b>Ilorin</b>	Ibadan	20,988	20,974	19,542	19,427	17,994	17,981	16,433
<b>Jos</b>	Abuja	58,004	57,999	57,395	57,346	56,742	56,736	56,084
	Bauchi	-1,100	-1,119	-3,045	-3,200	-5,126	-5,145	-7,226
	Kano	36,325	36,315	35,226	35,138	34,049	34,039	32,862
	Lafia	22,351	22,337	20,868	20,750	19,281	19,267	17,680
<b>Kano</b>	Bauchi	60,186	60,180	59,557	59,507	58,885	58,879	58,207
	Dutse	21,533	21,519	20,032	19,912	18,425	18,411	16,804
	Gusau	34,418	34,406	33,207	33,111	31,912	31,901	30,605
	Kaduna	52,619	52,611	51,820	51,756	50,964	50,957	50,101
	Katsina	24,072	24,035	20,256	19,952	16,172	16,136	12,053
<b>Lagos</b>	Birni- Kebbi	162,936	162,930	162,257	162,203	161,531	161,524	160,797
	Ibadan	130,419	130,406	129,006	128,893	127,493	127,479	125,967
	Ilorin	25,299	25,263	21,511	21,210	17,457	17,421	13,368
	Makurdi	-21,739	-21,785	-26,590	-26,975	-31,780	-31,826	-37,017
	Sokoto	147,413	147,408	146,813	146,765	146,170	146,164	145,522
<b>Maiduguri</b>	Damaturu	75,629	75,608	73,407	73,230	71,029	71,008	68,630
	Gombe	48,429	48,402	45,592	45,366	42,557	42,530	39,494
	Kano	90,354	90,336	88,465	88,314	86,443	86,425	84,403
	Yola	150,986	150,974	149,743	149,645	148,414	148,402	147,072
<b>Makurdi</b>	Abakaliki	150,781	150,769	149,534	149,435	148,199	148,187	146,853
	Enugu	49,752	49,719	46,223	45,942	42,446	42,412	38,635
	Gudau	50,570	50,537	47,059	46,780	43,302	43,268	39,511
	Kano	185,549	185,544	185,087	185,050	184,592	184,588	184,094
	Lafia	140,760	140,746	139,286	139,169	137,709	137,695	136,118
	Lokoja	14,780	14,739	10,460	10,117	5,838	5,797	1,175
	Maiduguri	4,555	4,511	4	-358	-4,865	-4,909	-9,778
	Sokoto	35,072	35,066	34,531	34,488	33,953	33,948	33,369
<b>Minna</b>	Abuja	2,912	2,909	2,616	2,592	2,300	2,297	1,980
<b>Mosimi</b>	Abeokuta	252	249	-103	-132	-484	-487	-868
	Ibadan	10,368	10,362	9,721	9,670	9,029	9,023	8,331
<b>Ore</b>	Ado Ekiti	20,185	20,181	19,760	19,726	19,305	19,301	18,847
	Akure	-62	-71	-945	-1,015	-1,889	-1,897	-2,841

	Ilorin	14,868	14,862	14,323	14,279	13,739	13,734	13,151
	Osogbo	6,777	6,771	6,139	6,089	5,457	5,451	4,769
<b>Suleja</b>	Lokoja	11,072	11,066	10,531	10,488	9,953	9,948	9,369
	Minna	51,959	51,953	51,303	51,251	50,601	50,595	49,893
<b>Yola</b>	Jalingo	16,936	16,930	16,257	16,203	15,531	15,524	14,797
<b>Atlas-Cove</b>	Ibadan	4,889	4,886	4,570	4,545	4,229	4,226	3,885
<b>Port-Harcourt</b>	Abakaliki	9,797	9,795	9,589	9,572	9,366	9,364	9,142
	Yenegoa	30,187	30,179	29,356	29,289	28,466	28,458	27,568
<b>Kaduna</b>	Abuja	9,327	9,315	8,024	7,920	6,630	6,618	5,224
	Gusau	9,736	9,724	8,442	8,339	7,058	7,046	5,662
	Jos	2,798	2,794	2,387	2,354	1,947	1,943	1,503
<b>Warri</b>	Asaba	3,140	3,135	2,669	2,631	2,164	2,160	1,656

#### 4. RESULTS AND DISCUSSION

The results obtained from application of conventional and modified models (Kareem, 2012a) to the transportation problem of distributing petrol from 22 depots to 37 stations in Nigerian cities are shown in Table 3, while that of the cost savings from the new model are detailed in Table 4. The results from the new model generally showed that there were appreciable transportation cost savings over traditional approach. This was an indicator of outstanding effectiveness of the new model in supplying petrol from available 22 depots to the 37 stations in major cities of Nigeria at reduced cost over the minimum cost of choosing a wrong route (Table 3). Explicitly, cost savings, ranging from 4% to 86% were achieved with the application of conventional model over unplanned choice of routes. There was slight reduction in savings when a modified model (Kareem, 2012b) was applied. This showed an improvement in cost estimation accuracy over the traditional approach. The results from the current approach (Table 4) produced seven different ranges of cost savings depending on the magnitude of delays by the environmental conditions. This indicated an outstanding flexibility in determining the cost of transportation. The savings (Table 4) were slightly lower or higher in varying proportions to the results of previous studies (Table 3). This flexibility in savings obtained from the new model was an indication of accuracy of determining possible ranges in prices of petrol with respect to environmental conditions.

#### 5. CONCLUSION

In this study a new transshipment model was developed by taking into consideration salient environmental factors. The weighted environmental factors

namely; bad road, poor weather, and mounted security check-point, were integrated into the conventional transportation model using Analytic Hierarchy Process (AHP) platform. The model was used to solve transportation problem of Nigerian petroleum product (petrol) distribution among existing depots and stations under incidental insecurity treats based on bad roads, poor weather and mounted security check-points, respectively. The re-modified transportation model was solved through developed computer software package using Microsoft Visual Basic (VB 6.0) integrated development environment (compiler) and its outcomes were compared with previous similar models. The model was applied to the Nigerian petroleum industry. It can be concluded from the results that the flexibility in savings obtained from the new model was an indication of accuracy of determining possible ranges in prices of petrol with respect to environmental conditions. The findings will be a veritable tool in determining the pump price of petrol which will be fair to all stakeholders involved in the petroleum sector based on prevailing environmental conditions. Future study may extend this model to aviation industries. The objective of such study will be to determine economic air-fare based on change in climatic conditions.

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## BIOGRAPHICAL NOTES

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