# TRANSPORTATION UNDER DEPLORABLE ROAD SAFETY AND SECURITY MAINTENANCE

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**Abstract** The traditional linear programming model based on transportation system model seems impracticable in developing countries because of neglect of certain salient environmental factors such as deplorable state of road safety and security maintenance. A transportatioin system model is developed by taking into consideration the identified environmental constraints. The severity of the road safety and security deplorability was measured from pot-holes generation and check-points mounting rate. The loss cost function due to this deplorability was formulated and its outcome was integrated into the traditional transportation model. Transportation schedule from depots to the retail stations of the petrol product of the Nigerian petroleum industry was used to test the efficacy of the model. The results showed that the new scheme was not in good agreement with the traditional approach in some test cases. The findings showed that the cost price of the item can be affected by the degree of deplorability of road safety and security maintenance.

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## 1. INTRODUCTION

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. In real-life situation many of these assumptions need to be relaxed when the model is to be applied to some strategic transportation problems. In many developing countries including Nigeria there is evidence of neglect in road maintenance, safety, and security. In such countries a promising transportation system, that will consider the salient constraints, is needed in arriving at a realistic judgement of fixing cost of transportation and price of goods. In order to achieve this lofty objective of minimising the cost price of transporting a public goods such as petrol (product of petroleum), a new system-transportation model, that takes care of the salient constraints, is developed and its outcome is compared with the conventional transportation model.

Petroleum (crude oil) is generally defined as liquid combustible minerals occurring in the earth's sedimentary mantle (PPMC, 2000). The petrol is a product of crude oil (PPMC, 2000). Nigeria is blessed with abundant petroleum resources. Petroleum has attracted major oil companies including Texaco, Mobil, Agip, Total, National, Shell, Unipetrol, and Elf. A number of independent marketers were also sprung up across the country (PPMC, 2000; Green and Wind, 2007; Feinberg, 1993; Arinze and Banerje, 1989).

Independent marketers have complemented the marketing activities of the major oil dealers by allowing the petroleum products to get to the grass root. Petroleum products' retail stations were located in rural, semi-urban and urban centres. 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 pipeline systems' segment, length (km), diameter (inch), line-fill capacity ($m^2$) and flow-rate ($m^2/hr$) are adequate enough to provide required petroleum products (PPMC, 2000).

The independent marketers loaded petroleum products from the depots in tankers, and transported them to their respective retail stations. End-users buy the products from the stations based on pump price. Despite this holistic and effective distribution arrangement, the end-users are still suffering from products' high price as a result of inadequacy. Application of linear programming based transportation model will be a veritable tool in solving this lingering problem of transportation.

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 and Nedona, 2001; Basu, 1989; Austin and Burns, 1985). In literature, transportation model has been described as a special case of linear programming model (Harold, 2006; Eckenrode, 2003; Leven, Rubin, Simpson & Gardener, 1989). Previous work has extended the use of transportation model in electronic computers in the areas of minimizing time and cost of locating processing units (Fernando, Podrebarac & Sengupta, 2006; Goodman and Ralph, 2001; Feinberg, 1993; Arinze and 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 and 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 and Eugene, 1989; Shepard, 2001). Transportation model has been proved reasonable and effective in minimizing the cost of transportation of goods (Shepard, 2001). However, many of these models failed to consider many other possible constraints that may face transportation system. There is need for a study that will take care of this deficiency in order to arrive at a realistic cost of transportation. The rest of paper is presented thus: conventional and modified transportation models are presented in Section 2, validation procedures are presented in Section 3, results and discussion is in Section 4 while Section 5 presents conclusion. The paper ends with acknowledge and the list of references.

## 2. MATERIALS AND METHODS

### 2.1. Conventional transportation model formulation

The cost of distribution of petroleum 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 (petroleum product), 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.

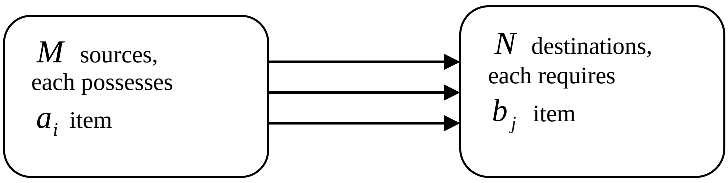


**Fig. 1** Representation of the Transportation Problem

Let,

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

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

The mathematical statement of the transportation problem is,
Minimize (sum of transportation cost):

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

Subject to:

$$\sum_{i=1}^{M} x_{ij} = b_j , \nabla_j \text{ (all demands are met)} \tag{2}$$

$$\sum_{j=1}^{N} x_{ij} = a_i , \nabla_i \text{ (all supplies are used)} \tag{3}$$

$$x_{ij} \succ 0, \qquad \nabla_j \tag{4}$$

## 2.1. Modified transportation system formulation

In the transportation model, there are $M$ sources and $N$ destinations. Each source ($i$) possesses $a_i$ item (petroleum product), 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 with the consideration of road security and safety (pot-holes) maintenance deplorability. Diagrammatic representation of the modified transportation problem is shown in Fig. 2.

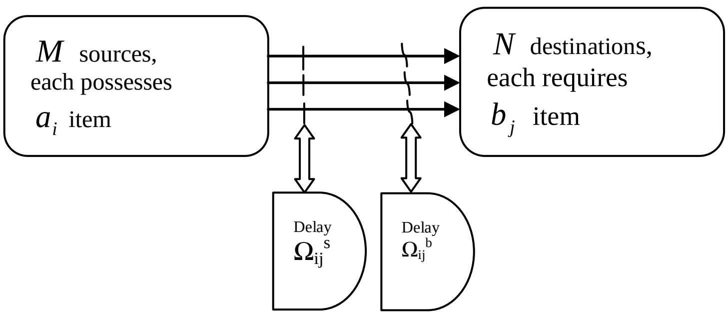


**Fig. 2** Modified Transportation Problem

Let,

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

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

$\Omega_{ij}^{s}$ = unit cost of security deplorability of transporting petroleum products from depot $i$ to station $j$

$\Omega_{ij}^{b}$ = unit cost of safety deplorability (bad road segiments) of transporting petroleum products from depot $i$ to station $j$

$k$ = number of security check-points predicted

$y$ = number of bad road-segments predicted

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

Minimize (sum of transportation cost):

$$\sum_{i=1}^{M}\sum_{j=1}^{N}(c_{ij} + k\Omega_{ij}^{s} + y\Omega_{ij}^{b})\ x_{ij} \tag{5}$$

Subject to:

$$\sum_{i=1}^{M} x_{ij} = b_j,\ \ \nabla_j \text{ (all demands are met)} \tag{6}$$

$$\sum_{j=1}^{N} x_{ij} = a_i, \nabla_i \text{ (all supplies are used)} \tag{7}$$

$$x_{ij} \succ 0, \nabla_j \tag{8}$$

The most paramount hypothesis is to test null hypothesis that there is a significant different between the cost of transportation using the traditional method and the modified transportation method. The alternative hypothesis is that there is no significant different between the two methods

## 3. SYSTEMS VALIDATION

Many studies have provided special algorithms that facilitate efficient solution to traditional transportation model (Taha, 2008); (Gal & Nedona, 2001); (Basu, 1989); (Yu & Zeleny, 2002). For easy and rapid application in industries the new model requires a modified computerized solution too. Therefore, a special linear programming based transportation model software package was developed using Microsoft Visual Basic 6.0 integrated development environment.

Data, including transportation cost per litre and road distances from depots to stations, used for model testing were extracted from identified petroleum related publications including bulletin, annual reports and journals (PPMC, 2000; Green and 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 and 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 solution of the transshipment (allocation) problem was shown in Table 3 using traditional/conventional transportation method.

**Table 1** Estimation of transportation cost per litre 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 | 92 |
| Benin | Akure | 1.00 | 33,000 | 171 |
| Ibadan | Akure | 1.00 | 33,000 | 200 |
| | Average cost, and distance | | 30,800 | 154.33 |
| | Average cost per km (₦/km) | | 199.57 | |

In Nigeria security check-points are mounted at varying distances but in most cases it was not less than 10 km interval. In order to limit the levels of bias in transportation cost estimate, it is reasonable to base the cost estimate on the minimum in order to allow for bargaining between the passenger and the transporter.

**Table 2** Estimation of unit cost of road deplorability

| Depots | Station | Cost incurred in checkpoint or bad road (₦) | Distance in km | Number of check point $k$ | Number of bad road segment $y$ | Unit cost per security check point $\Omega_{ij}^{s}$ | Unit cost per bad road segment $\Omega_{ij}^{b}$ |
|---|---|---|---|---|---|---|---|
| Ore | Akure | 2,640 | 92 | 9 | 12 | 2.21 | 1.66 |
| Benin | Akure | 3,300 | 171 | 17 | 23 | 1.17 | 0.86 |
| Ibadan | Akure | 3,300 | 200 | 20 | 26 | 0.99 | 0.76 |
| Average cost, and distance | | 3,080 | 154.33 | 15 | 20 | | |
| Average cost per km (₦/km) | | 19.95 | Average cost per km per check point or segiment | 1.33 | 0.99 | 1.45 | 1.09 |

This minimum security cost assumption will allow the transporter to be sure of delivering the goods without fair of loss, and at the same time allow the customer to know how much to charge the end-users in order to guard against any loss. In the case of bad road, similar condition was considered in estimating the cost incurred in transportation due to delay caused by bad road-segments. The difference between delays due to deplorable security and bad road-segiments maintenance is that the number of failed segments of road was more than number of mounted check-points. It was observed that the failed portions of roads are located between the ranges of 5 km to 10 km apart. Based on balanced probability, the average of these two extreme values (that is, 7.5 km) will be reasonably chosen as a good estimate for determining the cost of delay due to bad state of road. The cost of delay per security check-point was estimated by dividing the cost of transpor-tation per litre per km with the respective kilometre distances of location of security check-point (Table 2). The results of the analysis using the old and new schemes are presented in Table 3.

**Table 3** Optimal allocation of petrol using traditional and new schemes

| **Source / Depots** | **Destina tions/ Stations** | **Optimal cost, ₦ (in Nigeria currency) (traditi onal)** | **Optimal cost, ₦ (in Nigeria currency) (new scheme)** | **Optimal item allocatio n (in '000) litres** | **Optim al distanc e (in km)** | **Minim um cost, ₦ of chosen wrong route** | **Minimu m Cost savings, ₦(traditi onal)** | **Minimu m Cost savings, ₦ (new scheme)** |
|---|---|---|---|---|---|---|---|---|
| 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 |
| Enugu | Umuahia | 30,335 | 30,378 | 117 | 152 | 34,000 | 3,665 | 3,621 |
| Calabar | Enugu | 47,498 | 47,541 | 123 | 238 | 59,000 | 11,522 | 11,458 |
| | Uyo | 9,978 | 10,021 | 123 | 50 | | 49,022 | 48,978 |
| Gombe | Yola | 52,686 | 52,729 | 218 | 264 | 60,000 | 7,314 | 7,270 |
| Gusau | 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 |
| Ibadan | Abeokuta | 15,367 | 15,410 | 234 | 77 | 106,00 0 | 90,633 | 90,589 |
| Ilorin | Ibadan | 31,732 | 31,775 | 87 | 159 | 62,000 | 30, 268 | 30, 224 |
| Jos | 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 |
| Kano | 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 |
| Lagos | Birni-Kebbi | 164,845 | 164,888 | 136 | 826 | 193,00 0 | 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 |
| Maiduguri | 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 |
| Makurdi | 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 | 54,283 |
| | 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 | 19,358 |
| | Sokoto | 196,576 | 196,619 | 150 | 985 | | 9,402 | 9,380 |
| Minna | Abuja | 23,350 | 23,393 | 124 | 117 | 59,000 | 35,650 | 35,606 |
| Mosimi | Abeokuta | 12,772 | 12,815 | 217 | 64 | 16,000 | 3,228 | 3,184 |
| | Ibadan | 15,367 | 15,410 | 329 | 77 | | 633 | 589 |
| Ore | 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 | 838 |
| | Osogbo | 23,549 | 23,592 | 150 | 118 | | 15,451 | 15,407 |
| Suleja | Lokoja | 27,541 | 27,584 | 95 | 138 | 35,000 | 7,459 | 7,415 |
| | Minna | 23,350 | 29,393 | 250 | 117 | | 11,650 | 5,606 |
| Yola | Jalingo | 28,339 | 28,382 | 112 | 142 | 81,000 | 52,661 | 52,617 |
| Atlas-Cove | Ibadan | 29,337 | 29,380 | 200 | 147 | 47,000 | 17,663 | 17,619 |
| Port-Harcourt | Abakaliki | 13,770 | 13,813 | 50 | 69 | 19,000 | 5,230 | 5,186 |
| | Yenegoa | 8,981 | 9,024 | 150 | 45 | | 10,019 | 9,975 |
| Kaduna | Abuja | 35,923 | 35,966 | 76 | 180 | 67,000 | 31,077 | 31,033 |
| | Gusau | 56,279 | 52,322 | 17 | 282 | | 10,721 | 14,677 |
| | Jos | 55,880 | 55,923 | 107 | 280 | | 11,120 | 11,076 |
| Warri | Asaba | 17,762 | 17,805 | 200 | 89 | 21,000 | 3,238 | 3,194 |

## 4. RESULTS AND DISCUSSION

The results obtained using the 22 depots, spread all over the country, as the sources and the 37 stations in major cities as the destinations, are shown in Table 3. From the results, it was discovered that the available depots can supply petrol to the retail stations at minimum transportation cost. Based on traditional approach, a minimum cost required for the transportation of petrol in a unit month from the depots to the stations is ₦ 396,744,332. In this allocation, Markurdi recorded the highest supply while Warri depot had the least supply to the stations. Many routes were unused because they attracted high cost of transportation. A cost savings ranging from 4 to 86 % was achieved with the application of the conventional model over unplanned choice of routes. In the case of new scheme there was a slight decrease in percentage cost savings' results (Table 3). Application of the new model showed that there was some monetary sacrifice in the part of transporter which undermined the actual cost of the products. However, it was clearly shown form the new scheme that difference may be significant at high values of $k$ and $y$. Therefore, the concerned authority should limit the values of $k$ and $y$ such that the optimal cost of transportation would not be increased substantially. This would guard against shortage, and high cost of petrol.

## 5. CONCLUSION

In this study a linear programming based transportation model was used to solve transportation problem related to petroleum product distribution among Nigerian depots and stations with deplorable road safety and security maintenance. The traditional transportation model and its modified form were solved through computer software package in Microsoft Visual Basic (VB 6.0) integrated development environment (complier). The model was tested and implemented with data obtained from selected Nigerian depots and stations of the Petroleum Company. It can be concluded from the results that there were substantial cost savings from the use of the proposed models (new scheme) over the former unplanned (traditional) approach used by the company. Besides, good price per litre of petrol could be arrived at which will be fair for petrol dealers, transporters, customers and end-users.

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