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ENHANCED MANUFACTURING INDUSTRY SUPPLY CHAIN DISTRIBUTION NETWORK THROUGH TRANSPORTATION MODELLING

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Abstract:
This paper examined the physical distribution of finished product of a soap manufacturing company, with a view to improving its outbound logistics operations. This was achieved through a mathematical modelling of the company's product distribution. The proposed model established cheapest methods of transporting goods from various warehouses of the company to their various customers (destinations). The resulting solution using the Vogel Approximation Method (VAM), showed that the company could save about one million, nine hundred and forty thousand, and eighty naira (₦1,940,080.00) only from its transportation/product distribution cost if the company could adopt the suggested shipping arrangement. On the basis of the result achieved, it is envisaged that the integration of operation research techniques (such as optimization, transportation and logistics planning, production planning) in the decision-making process of company would minimise the occurrence of surpluses and associated costs, as well as the tendency to transfer these costs to consumers. The adoption of similar measures within the manufacturing industry sector would improve the contribution of the industry to the economy of the nation.

Key words:
Transportation model supply chain manufacturing optimization logistics transshiipment

INTRODUCTION

Manufacturing is traditionally viewed as a production process through which raw materials are transformed into physical products [1]. Manufacturing has been described, especially in development economics, as an engine of growth [2; 3], more especially for middle-income economies [4]. This probably explains why many governments give special their manufacturing sectors in their development plans [5]. Although the role of manufacturing in Nigeria's economic growth is currently limited, it has great potentials through the provision of linkages sectors of the economy. It is on the basis of this, that the stimulation of the sector to maximize its forward linkage with whole-sale and retail trades from a domestic production perspective becomes imperative [6]. The National Planning Commission [7] also observes that a strong and prosperous Nigeria, to a large extent, depends upon a vibrant and growing manufacturing sector as it represents the greatest opportunity for the transformation of the Nigerian economy from a mono-cultural economy to a diversified one, and a veritable antidote for unemployment, and undoubtedly an engine of growth.

However, according to [8], the management of today's supply chains has become a challenge as manufacturing and supply networks have expanded and serves an increasingly demanding set of customers in multiple markets. The coordination of material flow of product and the information flow across all tiers of the supply chain is essential for successful management these supply chain networks [8; 9]. Therefore, the extent to which products of the manufacturing sector can impact on the society is dependent on the efficiency of the sector's management of its supply chain and logistics services. The timely movement of materials needed for production requires the development of a good distribution network. It was concluded in earlier studies that while good distribution network minimises cost and maximises profit in the shipment of finished products to customers and consumers [10; 11], poor distribution caused by inefficient transportation system can disrupt the supply chain, lead to unavailability of either raw materials or finished products, and ultimately affect the economy both at national and individual levels [12]. This is probably because a good transportation system ensures high availability and low cost of transportation services relative to the cost of holding inventory, thus encouraging fast and frequent delivery through [13].

Given the low infrastructure development in the transport sector, most organisations rely on road transport for movement and distribution of good. However, earlies studies observe that the state of road infrastructure in Nigeria has negatively affected other sectors, and in particular, the manufacturing sector, such that the quality of road significantly affects manufacturing production index [14]. This keys into the views that an efficient transport system (an aspect of the logistics) is essential for economic development and growth [15], while the achievement and sustenance of development is impossible without cost effective and reliable infrastructure such as road [14]. In consideration of the distribution challenges (for instance, high distribution cost) experienced in the manufacturing sector and its impact on the wider economy, this study has been designed to quantitatively determine an optimal allocation and distribution of manufactured products from manufacturer's depots to the end users, in a way that offers god value for money using a case study company, Godrej Nigerian Ltd (a soap manufacturing company in Nigeria).

1 LITERATURE REVIEW

It has been noted that the expansion of manufacturing and supply networks has brought about increasingly demanding set of customers in multiple markets that must be served [8]. As a result of this, some sources argue that the coordination of material flow of product and the information flow across all tiers of the supply chain is essential for successful management the divergent needs of members of a supply chain networks [9], in a way that products and materials are shipped at minimal cost and lead-time to the next tier, or customer in the supply chain [8]. A supply chain is a conglomeration of independent firms (raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies) for the sole purpose of manufacturing product(s) and making these available to the end user(s) [16; 17]. Existing works on supply chain management [17-20] suggest it encompasses how an organisation fulfils customer demand through the management of efficient flow of information, material and services between it and its customers. Consequent to the above, Chiou [9] notes that effective SCM is a determinant to competitiveness and success of most manufacturing and retailing organizations, as its implementation impacts significantly on cost, service level, and quality. While the overriding aim of this study is the optimization of a supply chain, attention will be more on logistics, a subset of supply chain management [18], that is concerned with the management of flow of goods between the point of origin and the point of consumption in order to meet the requirements of customers or users [21].

Logistics, according to [22] involves activities such as warehousing and transportation that facilitate the movement of materials and products from point of origin to point of consumption, and vice versa as shown in Figure 1 below. To this extent, logistics management could lead to cost reduction, timely delivery, reduced lead time, demand realization, increased market share, quality products and customer service satisfaction [23].

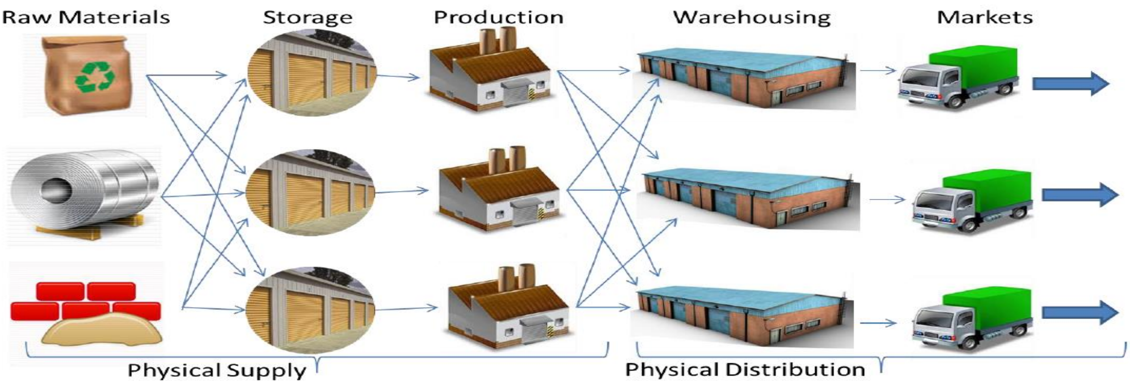

Fig.1 *Logistics Chain*
Source: [24]

While the broad view of logistics given above is acknowledged, this study concentrates more of logistics facility, transportation, and inventory planning which is the traditional meaning attached to logistics operations management as observed by [21]. This is in line with the definition of Logistics is the science that studies the movement of products from production to consumption [25]. It has been noted that the movement of item from the point of production to the point of consumption requires handling, holding loading and unloading, as well as transportation [25], and there are costs incurred holding and transporting these items [26]. Therefore, there are suggestions that the overall performance of the distribution network (whether evaluated in economic terms or in terms of customer service) can be improved if retailers collaborate whenever there is an unexpectedly high demand that may result in shortages in one or more retailing outlets [9]

The minimization of resources expended is a major motivation in logistics, and these resources which include both physical items (food, materials, animals, equipment, and liquids), and abstract items (time, information, particles, and energy) can be modelled, analysed, visualized, and optimized by dedicated simulation software [21]. Tayur, Ganeshan, and Magazine [27] note the existence of many quantitative models that could be used to provide decision support for the management of materials in supply chains, with a view to minimizing the costs in a logistics system. Generally, linear programming (transportation problem and its variants) is applied in the area of physical distribution or transportation of goods and services from several supply centres to several demand centres [28]. According to Winston [29], the study of the direct shipment of goods from a supply point to a demand point is known as a transportation problem, while the shipment of good made through a withholding before reaching the final demand point is referred to as transshipment problem. Chiou [9] while observing that transhipments is a popular strategy used to achieve basic logistics targets in multi-location supply chain systems facing stochastic demand (**Figure 2** below), equally argues that "transshipment policy can improve stock availability, i.e., customer service level, without increasing stock level which may induce higher inventory relevant cost."

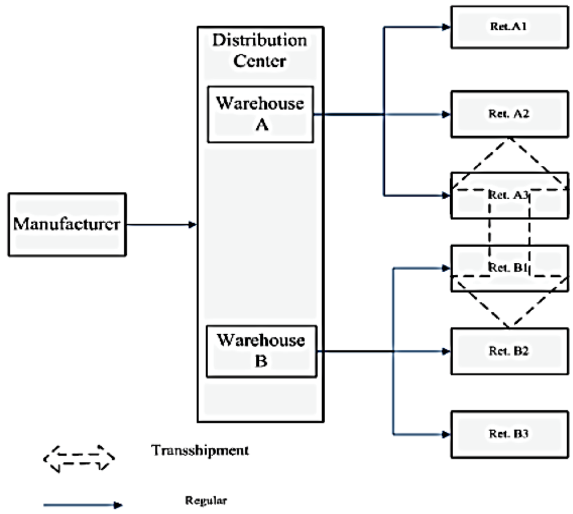

Fig.2 *Transshipment in Supply Chain System*
Source: [9]

A transshipment problem is a special type of linear programming problem in which the shipment of a commodity to a demand point from a supply point is done through one or more intermediate (trans-shipment) points [28; 30; 29]. For physical distribution (transportation) of goods, supply locations (called origins) and a specified order have to be matched with a variety of transportation routes and a variety of costs. The structure of a transportation problem involves a large number of shipping routes from several supply origins to several demand destinations [31].

The minimization of cost associated with transportation of materials/products to and from places of manufacture using linear programming methods have been the focus of many studies. For instance, [32] noted that introducing transshipment could reduce the request fulfilment costs scenarios, to the extent that the exchange of customer requests among carriers can obviously improve their routing decisions and reduce cost by up to 30% [33]. Nwaogbe et al. [12] in their study on cost minimization of product transshipment for physical distribution management concluded that one of the major tools for solving minimization and maximization problem in the logistics and supply chain management real life problem is transportation model. The study used the least cost method of transportation to minimize the cost of distribution. In another study of travelling salesman routing problems in Akwa Ibom State, Nigeria using dynamic programming approach, [34] not only established the optimal distance for the sales man's trip but also minimized the cost of transportation by deploying Floyd's shortest route algorithm. Galadima et al. [35] studied farm product distribution in Nigeria using transportation modelling and achieved a 16.10% saving in transportation cost.

2 MATERIALS AND METHOD

2.1 Study Area

The study was carried out Aba (5°07'23"N, 7°22'108"E), Abia State, South-East Nigeria (See **Figure 3** below). Aba, a cosmopolitan town located 64km from the state capital, Umuahia, has trading and other commercial activities as its predominant occupation [36]. Aba was chosen for the study because of the high commercial activity in the town as well as its social and ethnic diversity [37].

Aba is a commercial nerve centre of Eastern Nigeria, the home of Ariaria Market noted for home-made shoes, bags, soaps, palm oil and other household items. In addition, there are the Ngwa Road Market (New Market) and the Cemetery Market, while virtually every street in Aba has its share of the business activities for which the town is known. There are a good number of both public and private industrial establishments as well as financial institutions. Moreover, Aba is surrounded by oil wells which separate it from the city of Port Harcourt, a distance of about 30km away. Roads lead to Aba from Port Harcourt, Owerri, Umuahia, Ikot Ekpene and Ikot Abasi. Aba is served by a station and a halt (mini station) on the Nigerian railway. Aba is also a major hub for transport and logistics activities in the eastern region of Nigeria. A large number of logistics and transport companies operate coaches that transport people and freights daily to various parts of the country. The city is second to Onitsha in daily volume of mass transportation in the eastern part of the country.

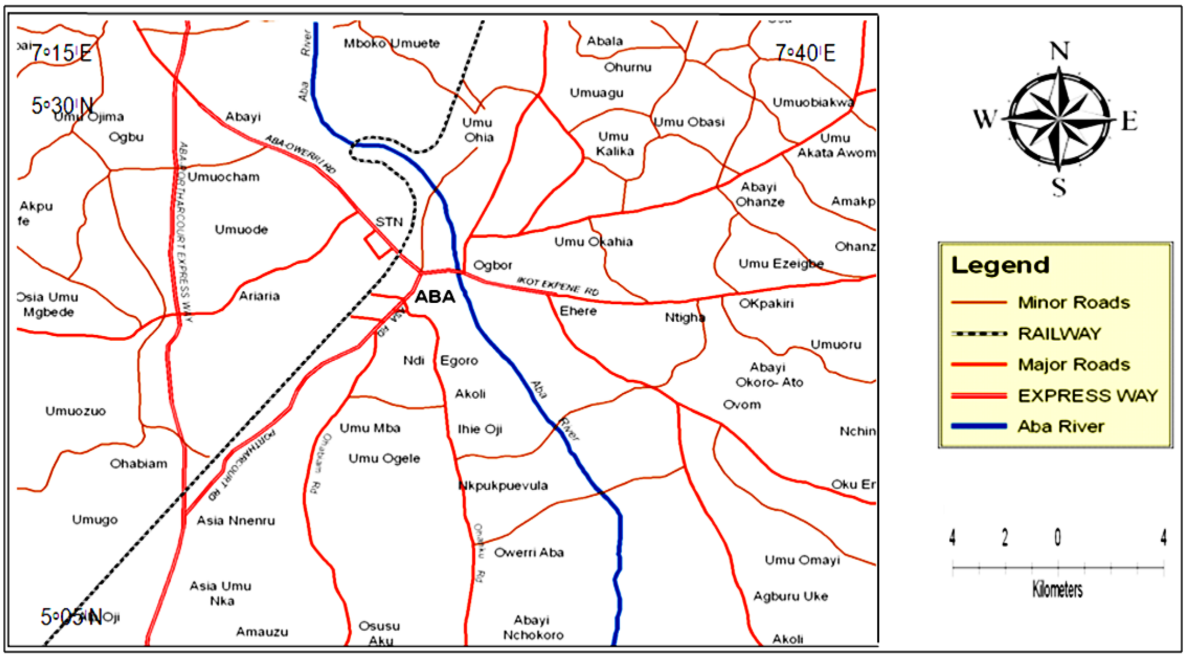

***Fig.3** Map of Aba, the Study Area*
Source: [9]

The case company is Godrej Group of Companies Aba, a leading soap manufacturing company in Nigeria, while the products considered are Tura Medicated and Tura Supreme soaps. Both primary and secondary data on the distribution of these produced were used in the research. The primary data were collected using questionnaires and interviews while the secondary data were collected from existing records about the company. The data on transportation costs incurred by the company in moving the product from one point to another, sales data, as well as quantities of products extracted were from the company's sales records at the depots in Aba, Calabar, Onitsha, Enugu, and Port Harcourt, as well as the main factory warehouse in Aba.

Although there are many methods that could be used to solve a transshipment problem, this study will use the Vogel Approximation Method (VAM), rather than the Northwest Corner Rule Method Least Cost Method, or the Simplex Method. This VAM model not only determines the initial solution and a feasible solution that satisfy all the supply and demand constraints, but also the optimal allocation of limited resources to meet the given objectives. The resources may be labour, materials, goods, machines, vehicles, etc [39]. The data will be analysed using TORA software, an algorithm used in optimization system [40].

2.2 Presentation of Data

Table 1 below shows the quantities of the products (Tura Medicated and Tura Supreme soaps) supplied within the year under consideration to the various warehouses of the company from the factory.

Tab. 1 *Quantity supplied from factory to Depot or Warehouse*

Depot/Warehouse	**Quantity Supplied (in Cartons per year)**		
	Tura Medicated	**Tura Supreme**	**Total**
Aba	12625	37375	**50000**
Calabar	4519	13298	**17817**
Enugu	3275	9200	**12475**
Onitsha	12445	22300	**34745**
Port Harcourt	6575	5700	**12275**
TOTAL	**39439**	**87873**	**127312**

Source: Godrej Group Nigeria Limited

Table 2 shows the quantities of the product demanded from the factory by the warehouses. The tables show that while the requirements of the depots were 95, 350 cartons of soap (25,184 cartons of Tura medicated and 70,166 cartons of Tura Supreme), they received a combined total of 127, 312 cartons of soap (39,439 cartons of Tura medicated and 87,873 cartons of Tura Supreme) from the factory. Table 3 below shows the cost (in naira) incurred, distributing the products from the depots to the distributors. This ranges between ₦15.00 and ₦160.00.

***Tab.** 2 Quantity supplied from factory to Depot or Warehouse*

	Quantity Demanded (in Cartons per year)		
Depot/Warehouse	**Tura Medicated**	**Tura Supreme**	**Total**
Aba	10935	22804	**33739**
Owerri	1690	3424	**5888**
Calabar	560	5328	**10315**
Port Harcourt	2375	1344	**5114**
Onitsha	6505	11900	**12332**
Ebonyi	230	1056	**3719**
Bayelsa	360	1528	**1888**
Enugu	934	11398	**1286**
Benue	600	2064	**18405**
Akwa Ibom	995	9320	**2664**
TOTAL	**25184**	**70166**	**95350**

Source: Godrej Group Nigeria Limited

***Tab. 3** Transportation cost from depots to distributors*

Depot	Transportation Cost (₦)									
	ABA	CAL	UY	OW	ENU	PH	YEN	EBO	ONI	BEN
ABA	15	70	30	30	60	45	90	90	40	120
CAL	70	15	35	100	90	90	105	100	100	110
ENU	60	90	85	105	15	100	140	50	40	90
ONI	40	100	65	60	40	90	120	80	15	80
PH	45	90	70	40	100	15	30	150	90	160

Source: Ugosylva Transport Services

2.3 Formulation of Model

In order to achieve the required objective (such as profit maximization or cost minimization), the model to be formulated must include origins (plants or factories where products are produced) and demands of the finished products made by customers at various destinations. In this model, let *m* factory (Aba) be the supplier of the products to n warehouses (Aba, Calabar, Enugu, Onitsha and Port Harcourt) as shown in **Figure 4** below.

Let the factory or source of supply $i(i = 1, 2, 3 \dots m)$ produce a_i units and the destination $j(j = 1, 2, 3 \dots n)$ require b_j units. Therefore, the cost of transportation from factory *i* to warehouse *j* is C_{ij}. The decision variable of this problem will be X_{ij}, which is the quantity of goods transported from factory *i* to warehouse *j*. The transshipment problem could be stated as:

$$Minimise\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}\, X_{ij} \tag{1}$$

Subject to:

$$\sum^{n} X_{ij} = a_i \qquad for\ i = 1, 2, 3\ \ldots, m \qquad (2)$$

$$\sum^{m} X_{ij} = b_i \qquad for\ j = 1, 2, 3\ \ldots, n \qquad (3)$$

$$X_{ij} \geq 0 \qquad for\ all\ i\ and\ j \qquad (4)$$

Where: $a_i = x_{ij}$ = quantity of soap produced in year i for $supply\ in\ year\ j$
b_i = quantity of commodity needed at source j,
C_{ij} = cost associated with each unit of X_{ij}
and X_{ij} = quantity transported from origin i to destination j

The feasible solution property: a transportation problem will have a feasible solution if, and only if:

$$\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} d_j \qquad (5)$$

Where: $S_i = a_i$ = quantity of commodity avialable at origin i,
$d_j = b_i$ = quantity of commodity needed at source j

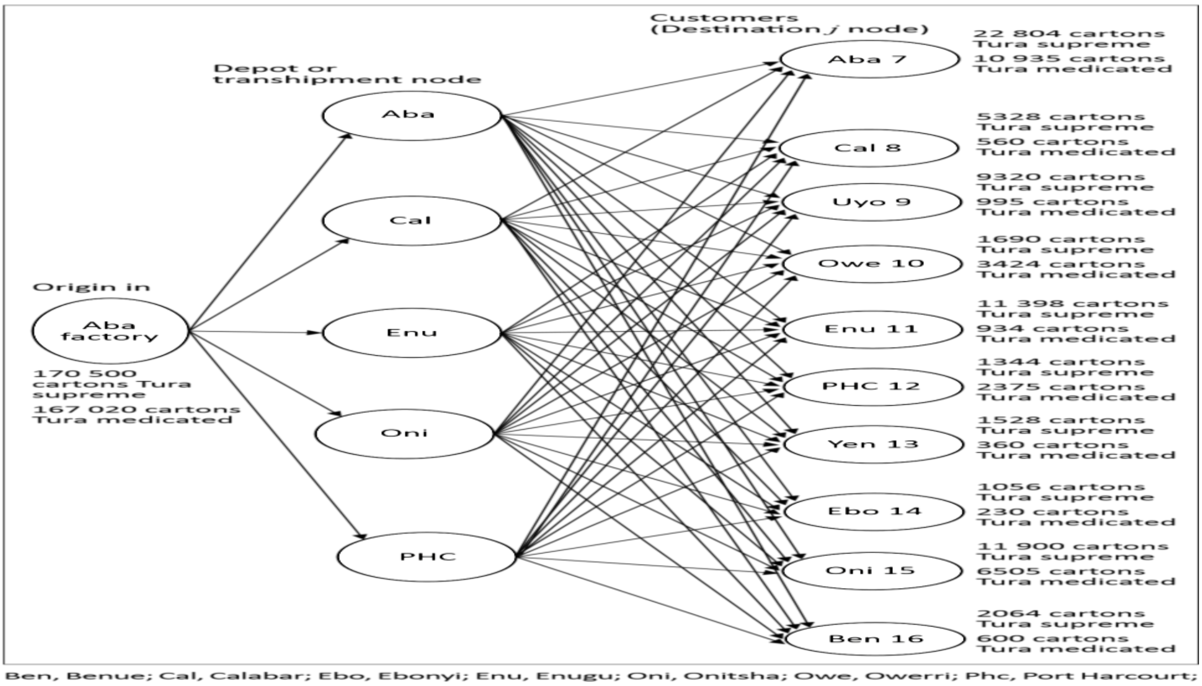

Fig.4 *Network model of the Distribution*
Source: [12]

The data presented on **Tables 1** to **3** above could be summarised in a transportation matrix (**Table 4** below), which summarises the data entered into the TORA software.

Tab. 4 *Input Grid of Transportation cost, Supply and Demand*

Source/Depot		Transportation Cost (₦)										Supply (Cartons/yr)
		D1 ABA	D2 CAL	D3 UY	D4 OW	D5 ENU	D6 PH	D7 YEN	D8 EBO	D9 ONI	D10 BEN	
S1	ABA	15	70	30	30	60	45	90	90	40	120	**50000**
S2	CAL	70	15	35	100	90	90	105	100	100	110	**17817**
S3	ENU	60	90	85	105	15	100	140	50	40	90	**12475**
S4	ONI	40	100	65	60	40	90	120	80	15	80	**34745**
S5	PH	45	90	70	40	100	15	30	150	90	160	**12275**
Demand (Cartons/yr)		**33739**	**5888**	**10315**	**5114**	**12332**	**3719**	**1999**	**1286**	**18405**	**2664**	

Source: Godrej Group Nigeria Limited

An optimal solution to the problem (with an objective value of **1940080.00**), using the Vogel Approximation Method, was arrived at, at the end of iteration 1. The result is shown on **Table 5** below.

Tab. 5 *Iteration 1 of Vogel Approximation Result*

Iter 1	ObjVal=	1940080.00	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Supply
	Name		ABA	CAL	UY	OW	ENU	PH	YEN	EBO	ONI	BEN	DummyD	
			v1=15.00	v2=15.00	v3=30.00	v4=30.00	v5=40.00	v6=15.00	v7=30.00	v8=75.00	v9=15.00	v10=80.00	v11=0.00	
			15.00	70.00	30.00	30.00	60.00	45.00	90.00	90.00	40.00	120.00	0.00	
S1	ABA	u1=0.00	33739		10315	5114							832	50000
			0.00	-55.00	0.00	0.00	-20.00	-30.00	-60.00	-15.00	-25.00	-40.00	0.00	
			70.00	15.00	35.00	100.00	90.00	90.00	105.00	100.00	100.00	110.00	0.00	
S2	CAL	u2=0.00		5888									11929	17817
			-55.00	0.00	-5.00	-70.00	-50.00	-75.00	-75.00	-25.00	-85.00	-30.00	0.00	
			60.00	90.00	85.00	105.00	15.00	100.00	140.00	50.00	40.00	90.00	0.00	
S3	ENU	u3=0.00					11189			1286				12475
			-70.00	-100.00	-80.00	-100.00	0.00	-110.00	-135.00	0.00	-50.00	-35.00	-25.00	
			40.00	100.00	65.00	60.00	40.00	90.00	120.00	80.00	15.00	80.00	0.00	
S4	ONI	u4=0.00					1143				18405	2664	12533	34745
			-25.00	-85.00	-35.00	-30.00	0.00	-75.00	-90.00	-5.00	0.00	0.00	0.00	
			45.00	90.00	70.00	40.00	100.00	15.00	30.00	150.00	90.00	160.00	0.00	
S5	PH	u5=0.00						3719	1999				6557	12275
			-30.00	-75.00	-40.00	-10.00	-60.00	0.00	0.00	-75.00	-75.00	-80.00	0.00	
	Demand		33739	5888	10315	5114	12332	3719	1999	1286	18405	2664	31851	

Source: Authors‘ Computation Using TORA Software Output

3 DISCUSSIONS

Based on the analysis given above, an optimal solution to the Godrej problem using the Vogel Approximation Method was achieved after one iteration as shown in **Table 5** above. Furthermore, the final optimal solution shows various objective coefficients with policy implications which can be derived from **Table 6** below. It could be seen from the transportation model output summary in **Table 6**, the total cost of transporting the products at minimal cost is ₦1,940,080.00. The result shows that the Aba depot has a surplus of 832 cartons of the product after supplying the quantity demanded by customers. A dummy variable is therefore introduced to balance the transportation model as the demand is not equal to supply of the product. The Aba depot is the most cost-effective supply point for Aba, Uyo and Owerri customers. The Calabar depot supplies Calabar and has a surplus of 11929 cartons of the product after fulfilling customers' demands. As a result of this, a dummy variable is introduced to balance the transportation model.

Tab. 6 *Transportation Model Output Summary*

From	To	Shipment	Cost per unit	Shipment cost
ABA	ABA	33,739.00	15.00	506,085.00
ABA	UY	10,315.00	30.00	309,450.00
ABA	OW	5,114.00	30.00	153,420.00
ABA	Dummy	832.00	0.00	0.00
CAL	CAL	5,888.00	15.00	88,320.00
CAL	Dummy	11,929.00	0.00	0.00
ENU	ENU	11,189.00	15.00	167,835.00
ENU	EBO	1,286.00	50.00	64,300.00
ONI	ENU	1,143.00	40.00	45,720.00
ONI	ONI	18,405.00	15.00	276,075.00
ONI	BEN	2,664.00	80.00	213,120.00
ONI	Dummy	12,533.00	0.00	0.00
PH	PH	3,719.00	15.00	55,785.00
PH	YEN	1,999.00	30.00	59,970.00
PH	Dummy	6,557.00	0.00	0.00

Source: Authors' Computation

Ebonyi and some Enugu customers are better served from the Enugu depot, while the Onitsha depot takes care of the customers in Onitsha, Benin and the remaining customers in Enugu. A dummy destination is also needed to absorb the 12533 surplus cartons of products from the Onitsha depot, thereby to balancing the model. Finally, the Port Harcourt depot after fulfilling the orders of customers in Port Harcourt and Yenagoa, is left with a surplus of 6557 cartons, hence the introduction of a dummy destination. Table 6 which is the final optimal solution shows how the company can make their distribution and minimize cost and time. Their policy on economic way of distribution can be achieved through this solution. Policy implication of the study is that the company should abide by this analysis to enhance their distribution so that they will not be having excess of the product at their various depot. The result also suggests that the company should project customer requirements using existing company data, in order to eliminate surpluses with their attendant costs, and improve the efficiency and effectiveness product distribution [12; 35].

4 CONCLUSIONS

This paper explored the use of transportation optimization model to solve the physical distribution problem of finished products from several depots (destination) in order to get a minimum cost and time for efficient distribution. The transportation problem which was formulated as a linear programming problem, and solved using Vogel's Approximation Method (VAM), showed that significant savings (in both time and cost) can be achieved using the model developed. Transportation modelling of could be employed by manufacturing companies to solve or optimise their production lines, logistic and supply chain management among others. Transportation modelling techniques are generally less complicated to use and give solutions that can be obtained through inspection. Specifically, the Vogel Approximation Method provides for a high utilisation of available facility through a better prediction of future transport plans.

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