INTEGRATION OF TRANSSHIPMENT IN THE TRANSPORTATION COORDINATION OF FERTILIZER FROM MANUFACTURER TO CONSUMERS IN A SUPPLY CHAIN SYSTEM

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ABSTRACT: *In Nigeria, fertilizer distribution has been fraught with deceit, inconsistencies and inefficiencies. This paper integrates transshipment in the transportation coordination of subsidized fertilizer from the manufacturer to the consumers in a supply chain system. It demonstrates that problems of this nature can be modelled in Excel and analyzed using the simplex option in Solver. The result of the analysis shows that appreciable transportation cost savings can be made by adopting the model presented in this paper. The actual cost of transporting 74800 bags of subsidized fertilizer from the manufacturer in Port Harcourt Nigeria to the redemption centres in Gombe State, Nigeria is ₦21,925,800.00. Using the transshipment model, the cost reduced to ₦ 21,368,400.00. The restriction on the number of bags of fertilizer to be deposited at the warehouses, at a fixed transportation cost, was easily accommodated due to the flexibility of modelling transshipment problems in Excel. The Excel output shows clearly the flow of the product from the manufacturer and the warehouses to the redemption centres.*

KEY WORDS: Transportation, Transshipment, Supply Chain, Excel Solver, Simplex, Fertilizer.

INTRODUCTION

A veritable strategy to reduce manufacturer's operational costs in addition to reducing the product cost for end users is the transportation coordination in a supply chain system. Supply chain management is a holistic cost reduction approach that encompasses inventory management, transportation and warehouse control. In a fertilizer industry, supply chain entails transportation of fertilizer from manufacturers or suppliers to storage facilities, agro input dealers and finally to consumers in known service regions.

Agriculture is a fundamental instrument for sustainable development, poverty alleviation and enhanced food security in developing countries. It is a vital development tool for achieving the Millennium Development Goals (MDG), one of which is to halve the share of people suffering from extreme poverty and hunger by 2015 [1]. The Federal Government of Nigeria (FGN) recognizes that the nation's food security can be improved mainly through increasing agricultural productivity, and has instituted various interventions aimed at precipitating widespread adaptation of intensive farming technologies. By scope and financial commitment, the most important intervention is the subsidization of inorganic fertilizer.

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Fertilizer is one of the most important inputs in increasing food production in Nigeria. Several policy approaches have been used to promote increased use of fertilizer in rural farming systems in order to boost the economy of the country. These have included the promotion of a state monopoly for fertilizer import and distribution, institution of price controls and subsidies at the fertilizer retail markets, provision of credit to farmers for the purchase of fertilizer, institution of import tariffs, decentralization of procurement and distribution, and deregulation of markets [2].

Fertilizer procurement and distribution in Nigeria has been fraught with fraud, discrepancies and inefficiencies [3]. Apart from the high cost of importing fertilizer, the challenge of its effective distribution to farmers across the country is enormous. Most of the time the fertilizer gets to the farmers at a cost they cannot afford or at a time they no longer need it - late deliveries [4].

To enhance increase in the utilization of fertilizers by the rural farmers and therefore ensure food security, the following measures are pertinent. The provision of subsidy by the government, close location of fertilizer purchasing centres, timely distribution of fertilizers, price reduction and improvement in extension services are mandatory [5].

In 2011, the Agricultural Transformation Agenda (ATA) was introduced to tackle the inefficiencies in the distribution of key inputs making them more readily available and affordable [6]. In this regard the private sector agro-input business enterprises (agro-dealers) are assigned a critical role especially in the implementation of the Growth Enhancement Support (GES) scheme which took off in 2012. They are involved in the procurement, distribution and delivery of inputs (fertilizers, improved seeds and agro-chemicals) to small-scale farmers. Under the scheme, farmers are to benefit directly from an innovative electronic system of delivering subsidized inputs in which the subsidy payments are delivered directly to the beneficiaries through mobile phones. With the GES in 2012, government sought to withdraw from direct fertilizer purchase and distribution and introduced an alternative system of distribution built on the voucher system. This system had been developed by International Fertilizer Development Centre (IFDC) and successfully implemented in 4 States at its inception. The Federal Ministry of Agriculture and Rural Development, as part of its mandate, monitors the implementation of the GES scheme.

In Gombe State Nigeria, some rural farmers find it difficult to access fertilizer through the scheme as a result of the channel inefficiencies; fertilizer typically does not reach the intended rural farmers at the right time because of delay in procurement and delivery. Many farmers therefore end up buying fertilizer at market rates or applying it late, a situation that inhibits the essence of applying fertilizer to crops.

In Nigeria, fertilizer distribution has been fraught with deceit, inconsistencies and inefficiencies. This paper therefore proposes a transshipment model for the transportation coordination of subsidized fertilizer from the manufacturer to consumers in a supply chain system in Gombe State, Nigeria. The policy of the State Government that fifty percent of the subsidized fertilizer be deposited at the warehouses before the commencement of the distribution programme is also considered. The paper aims to minimize total cost of transporting subsidized fertilizer from manufacture to consumers by determining the best supply arrangement to meet the demand at the redemption centres at a minimum transportation cost.

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The distribution network involves one manufacturer, three warehouses and five redemption centres. By the State Government policy, 50% of the required bags of subsidized fertilizer must be deposited at the three warehouses at a fixed transportation cost. This is to ensure reasonable availability of subsidized fertilizer at the flag off of its distribution to farmers even if there are delays in transporting the remaining 50%.

RELATED WORKS

Fertilizer subsidies have been one of the major policy instruments used to increase agricultural productivity in Nigeria, historically, fertilizer subsidies accounted for about 40 percent of the total federal budget for agriculture, although this was small given that FGN generally allocated less than 3 percent of its budget to agriculture [7].

Figure 1 represents the old fertilizer subsidy programme which has two distribution channels A and B [8].

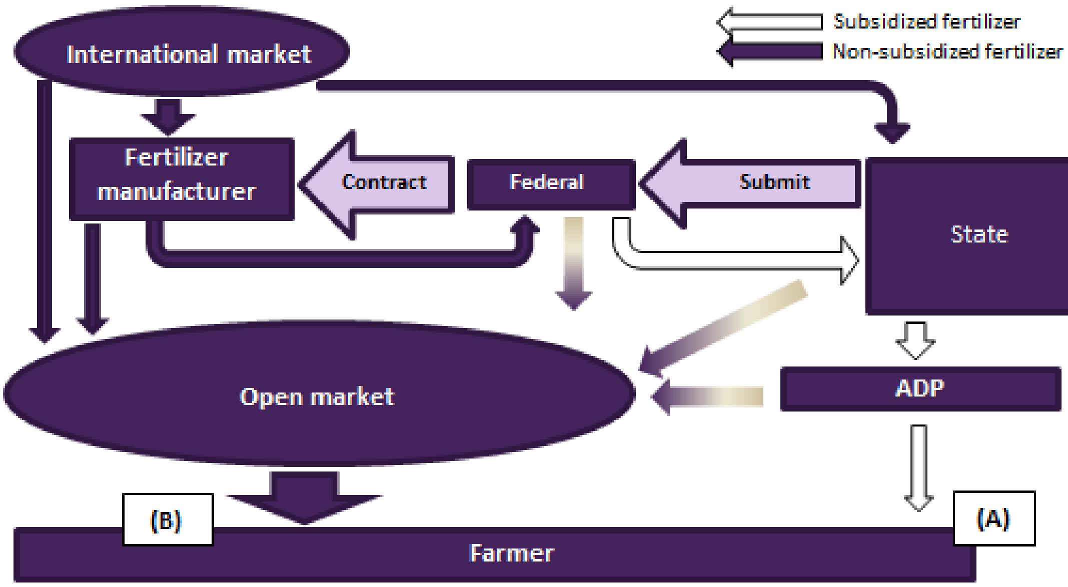

Figure 1: The Old Fertilizer Subsidy Program

The new fertilizer subsidy programme GES, under the ATA, sets ambitious goals of increasing fertilizer use from the current level of approximately 13 kg/ha to 50 kg/ha [9]. The main intended shifts in GES from previous subsidy schemes are to target beneficiaries through vouchers and to hand over the distribution of subsidized fertilizer to private dealers from the government. This contrasts with previous subsidy schemes in which the government directly participated in the procurement and distribution of subsidized fertilizer through the Agricultural Development Project (ADP) and other agencies [10].

The GES aims to benefit 20 million farmers by 2020 by providing subsidies equivalent to ₦5000 each year for four years. The plan, starting from 2012, is that the farmers will be divided into four cohorts of five million farmers. Each participating farmer is supposed to receive approximately100 kg of fertilizer each year during the four years of the subsidy programme.

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This will be implemented by providing a 50 percent subsidy throughout the country, in which the federal and state governments will each contribute 25 percent of the subsidy [8].

There are a few potential paths where the new subsidy scheme can help develop the private fertilizer sector. Handing over the distribution of fertilizer from the government to the private agro-dealers can potentially increase the quantity of fertilizer handled by these agro-dealers, enable an expansion of their business, and enable them to exploit economies of scale. In this context, the new fertilizer subsidy scheme may have more potential in developing the private fertilizer sector than previous subsidy schemes.

If farmers make sufficient savings from reduced production costs due to a fertilizer subsidy or increased sales from increased use of fertilizer, the subsidy could help farmers graduate into and sustain input-intensive production systems with high fertilizer demand, even after the withdrawal of the subsidy programme [11].

[12] observed that despite various efforts geared towards agricultural development, it has been established that majority indicated non commitment of the ADP and long distance to redemption centres as major constraints to the use of e-wallet. More than half had favourable attitude towards the e-wallet platform of the scheme. Despite the generous ratings of the effectiveness and successfulness of the scheme in getting subsidized fertilizers to the farmers, most agro dealers still faced some challenges. One major area of concern was the late delivery of inputs, both fertilizer and seeds.

[13] pointed out that, the primary constraint to fertilizer use in the country is the physical absence of the product at the time that it is needed, rather than problems of affordability or farmers' lack of knowledge about its importance. Late delivery and adulteration of fertilizer were common problems, potentially discouraging farmers from adopting subsidized fertilizer and reaping its benefits.

According to [14], most times the inputs were not distributed on time. Delayed input delivery was caused by lack of capital by agro dealers and long chain involved in the distribution of voucher. Bureaucracy existed in selection of agro dealers and independent monitoring and evaluation committee did not exist in the scheme.

[15] carried out a study on supply chain management performance of subsidized fertilizer in Indonesia: from perspective planning, distribution and human factor, they found out that the human factor plays an important role because they are critical subject to the success of the alignment plan and distribution. While factors such as alignment plan and distribution is a mediation between the human and supply chain management performance. To remain competitive in the global market environment, business enterprises need to improve their logistics operations performance. The improvement will be achieved when we can provide a comprehensive analysis and optimize its network performances. They developed mixed integer linear model for optimizing logistics network performance. It provides a single-product multi-period multi-facilities model, as well as the multi-product concept. The problem is modeled in form of a network flow problem with the main objective to minimize total logistics cost.

In this paper, we present transshipment model in which a manufacturer ships subsidized fertilizer to Agro dealers directly from plant or through warehouses by a fleet of vehicles. The objective is to minimize the total shipping cost. This study differs from prior studies in the following areas: it addresses the transshipment decision of subsidized fertilizer distribution

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area for an integrated decision of transportation problem with direct shipment and from manufacturer's plant to state warehouses and finally to redemption centres. The paper also integrates the government policy that 50% of the subsidized fertilizer must be deposited at the warehouses before the commencement of the distribution programme.

METHODOLOGY AND MODEL CONSTRUCTION

The analytical model adopted in this paper focuses on the concept of supply chain management, bothering on the coordination of transportation and distribution of subsidized fertilizer. The aim of supply chain is to minimize costs while keeping a reasonable service level, customer satisfaction/quality/on time delivery, etc. A transportation problem basically deals with finding the best way to fulfill the requirements of *n* demand points using the capacities of *m* supply points.

A transshipment model is a multi-phase transportation problem in which the flow of goods (such as raw materials) and services between the source and the destination is interrupted in at least one point. Product is not sent directly from the supplier (origin) to the point of demand; rather, it is first transported to a transshipment point, and from there to the point of demand (destination) [16]. Transshipments therefore serve as an emergency way to fill demands that would have otherwise gone unfilled.

The Transshipment Model

$$Minimize\ Cost = \sum_{i}^{m} \sum_{j}^{n} c_{ij}\ x_{ij} \qquad 1$$

Subject to:

$$\sum_{j}^{n} x_{ij} \leq s_i \qquad i = 1,2,3, \dots n \qquad 2$$

$$\sum_{i}^{m} x_{ij} \geq d_j \qquad j = 1,2,3, \dots, m \qquad 3$$

$$\sum_{j}^{n} x_{ij} - \sum_{i}^{m} x_{ij} = 0 \qquad 4$$

$$\sum_{j}^{n} x_{ij} \leq s_i = \sum_{i}^{m} x_{ij} \geq d_j \qquad 5$$

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

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Where

$m =$ The number of sources.
$n =$ The number of destinations.
$s_i =$ The capacity of i^{th} source (in bags).
$d_j =$ The demand of j^{th} destination (in bags).
$c_{ij} =$ The unit shipping cost between i^{th} source and j^{th} destination.

Model Assumptions

a. Fertilizer is always available for shipping at manufacturer's plant, no matter which distribution strategy is chosen.

b. Transportation cost from the warehouses to redemption centres is based on the distances between them in kilometer.

c. Fertilizer is delivered using a fleet of vehicles with known capacities.

DATA

The cost of shipping one bag of fertilizer from factory (plant) to each of the warehouses and to each of the redemption centres is ₦600. Table 1 shows the accredited Agro dealers, location, distance from the warehouses, and the demand at redemption centres. The demand is derived from the allocation given to Agro dealers from the Ministry of Agriculture in bags.

Table 1: Agro-Dealers, Location, Distance and Demand at Redemption Centers

Agro-Dealers	Location	Distance (Km)	Demand (bags)
Sadiku Shehu & Sons Ltd	Billiri	60	9000
Aliyu Abdu & Sons Ltd	Gadam	28.1	6000
ACL Interglobal Construction Ltd	Dadin Kowa	41.6	6000
Tradewaves Nigeria Ltd	Tongo	68.4	8400
Garbaba Global Resources Ltd	Mallam Sidi	31.1	5400

Source: Spring Field, Gombe State

Table 2 is the cost table for shipping a bag of subsidized fertilizer from each of the warehouses to each of the redemption centres.

Table 2: Warehouses, Redemption Centres and Unit Shipping Cost

From/To (per bag per km)	Billiri (₦)	Gadam (₦)	Dadin Kowa (₦)	Tongo (₦)	Mallam Sidi (₦)
Warehouse1	50	23	35	57	26
Warehouse2	50	23	35	57	26
Warehouse3	50	23	35	57	26

Source: A. U. Sambo De Trading and Company Ltd, Gombe State

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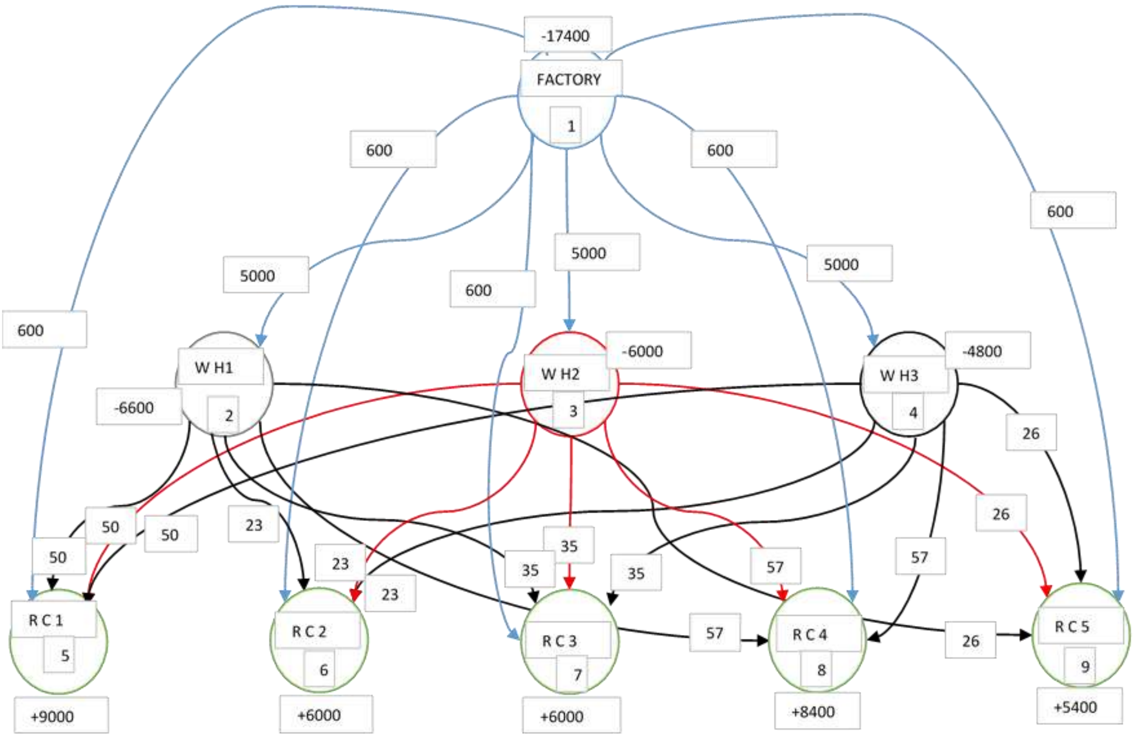

Fig. 2: Transshipment Network from Factory and Warehouses to Redemption Centres

In compliance with government directive, a very high transportation cost is placed between the factory and each of the warehouses. This is to ensure that further supplies are not made to the warehouses from the factory except the mandatory 50% of all subsidized fertilizer requirements.

MODEL FORMULATION

Let x_{ij} be the number of bags of fertilizer shipped from supply point *i* to destination *j* for some pairs of *i* and *j*.

Objective:

$$\begin{aligned} Min\ Cost = \ & 5000x_{12} + 5000x_{13} + 5000x_{14} + 600x_{15} + 600x_{16} + 600x_{17} + 600x_{18} \\ & + 600x_{19} + 50x_{25} + 23x_{26} + 35x_{27} + 57x_{28} + 26x_{29} + 50x_{35} + 23x_{36} \\ & + 35x_{37} + 57x_{38} + 26x_{39} + 50x_{45} + 23x_{46} + 35x_{47} + 57x_{48} + 26x_{49} \end{aligned}$$

Subject to:

$$-x_{12} - x_{13} - x_{14} - x_{15} - x_{16} - x_{17} - x_{18} - x_{19} \geq -17400$$

$$x_{12} - x_{25} - x_{26} - x_{27} - x_{28} - x_{29} \geq -6600$$

$$x_{13} - x_{35} - x_{36} - x_{37} - x_{38} - x_{39} \geq -6000$$

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$$x_{14} - x_{45} - x_{46} - x_{47} - x_{48} - x_{49} \geq -4800$$

$$x_{15} + x_{25} + x_{35} + x_{45} \geq 9000$$

$$x_{16} + x_{26} + x_{36} + x_{46} \geq 6000$$

$$x_{17} + x_{27} + x_{37} + x_{47} \geq 6000$$

$$x_{18} + x_{28} + x_{38} + x_{48} \geq 8400$$

$$x_{19} + x_{29} + x_{39} + x_{49} \geq 5400$$

$$All\ x_{ij} \geq 0$$

RESULTS/FINDINGS

Table 3: Excel Spreadsheet and Solver Output for the Transshipment Model

The Arcs (Decisions)							The Nodes (Constraints)			
Ship	From		To		Unit Cost (₦)		Nodes		Net Flow	Sup/Dem
0	1	Factory	2	WH1	5000		1	Factory	-17400	-17400
0	1	Factory	3	WH2	5000		2	WH1	-6600	-6600
0	1	Factory	4	WH3	5000		3	WH2	-6000	-6000
9000	1	Factory	5	RC1	600		4	WH3	-4800	-4800
0	1	Factory	6	RC2	600		5	RC1	9000	9000
0	1	Factory	7	RC3	600		6	RC2	6000	6000
8400	1	Factory	8	RC4	600		7	RC3	6000	6000
0	1	Factory	9	RC5	600		8	RC4	8400	8400
0	2	WH1	5	RC1	50		9	RC5	5400	5400
0	2	WH1	6	RC2	23					
1200	2	WH1	7	RC3	35					
0	2	WH1	8	RC4	57					
5400	2	WH1	9	RC5	26					
0	3	WH2	5	RC1	50					
1200	3	WH2	6	RC2	23					
4800	3	WH2	7	RC3	35					
0	3	WH2	8	RC4	57					
0	3	WH2	9	RC5	26					
0	4	WH3	5	RC1	50					
4800	4	WH3	6	RC2	23					
0	4	WH3	7	RC3	35					
0	4	WH3	8	RC4	57					
0	4	WH3	9	RC5	26					
		Total Transportation Cost (₦)			10928400					

Table 3 is the result obtained using the solver in Excel 2013 to analyze the transshipment model. Column 1 shows the flow of subsidized fertilizer from factory and warehouses to redemption centres. The total transportation cost is ₦10,928,400.00. This cost excludes the

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fixed cost of ₦10,440,000.00 representing the cost of shipping 50% of the subsidized fertilizer from the factory to the warehouses.

DISCUSSION

From Table 3, the demands at Redemption Centres 5 (9000 bags) and 8 (8400 bags) are satisfied directly from the Factory (Plant). Warehouse 1 supplied 5400 bags to Redemption Centre 9 to satisfy its demand. Warehouses 1 and 2 supplied 1200 bags and 4800 bags respectively to Redemption Centre 7 to satisfy its demand. Warehouses 2 and 3 supplied 1200 bags and 4800 bags respectively to Redemption Centre 6 to satisfy its demand.

The total transportation cost is made up of two cost components: The fixed transportation cost of transporting 50% (17,400 bags) at ₦600 per bag from the Factory (Plant) to the three Warehouses amounting to ₦10,440,000.00. The next is the cost of transporting all the 34,800 bags of subsidized fertilizer to the Redemption Centres from both the Factory and the Warehouses, using the transshipment model amounting to ₦10,928,400.00. The combined transportation cost amounts to an optimal shipping cost of ₦21,368,400.00.

Comparing the optimal shipping cost with the actual shipping cost of ₦21,925,800.00, gives a shipping cost saving of ₦557,400.00.

Implication to Research and Practice

Fig. 2 is the transshipment network for shipping subsidized fertilizer from factory and warehouses to the redemption centres. Warehouses served as both demand points and supply points, hence they constitute transshipment points. The peculiarity of this research stems from the fact that part of the transportation cost is determined by government policy (i.e. transportation subsidy). To accommodate the government policy therefore, a very high transportation cost was placed on all the links between the factory and the warehouses. The novelty of this paper is that it demonstrates the benefit of modelling problems of this nature in Excel where the output clearly shows the flow of subsidized fertilizer from the factory and warehouses to the redemption centres. Availabilities at the factory and warehouses are indicated by negative signs while requirements at redemptions centres are indicated by positive signs. This convention makes the model very suitable for analysis using the simplex option in Excel Solver.

CONCLUSION

The paper has demonstrated the use of Excel solver as an effective way of analyzing peculiar transportation problems in a supply chain system. The actual cost of transporting 34800 bags of subsidized fertilizer from factory and the warehouses to the redemption centres is ₦21,925,800.00. However, the transshipment model presented in this paper reduced the transportation cost to ₦21,368,400.00. The research therefore shows that reasonable cost saving can be achieved by adopting the transshipment model presented in this paper.

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Future Research

The model presented in this research and the method of analysis could be adopted to accommodate more manufacturers, more warehouses and more redemption centres.

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