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Optimisation Of Supply Chain Network Model for A Cement Manufacturing Company in Nigeria

Omonigho, Awele Vivian[1], and Otanocha, Omonigho Benedict[2]
[1,2]*Department of Mechanical Engineering, College of Engineering and Technology, Federal University of Petroleum Resources, Effurun (FUPRE), Uvwie LGA, Delta State, Nigeria.*
[1]*Corresponding Email: omonigho.awele@fupre.edu.ng*
[2]*Email: Otanocha.omonigho@fupre.edu.ng*

Abstract
Supply chain management is considered a topic of increasing interest worldwide and its focus has evolved over time. The design of a network for a productive and efficient supply chain is essential for every organisation as it aids in reducing the supply chain network's overall cost. Using the Dangote Cement Company as a case study, the supply chain network model for a Nigerian cement manufacturing company was optimised. To find the best capacity distribution, facility placement, transportation costs, and to improve network profitability overall while offering customers the right responsiveness, mixed integer linear programming (MILP) was developed. Based on the analytical estimation on the current supply chain network of Dangote Cement Manufacturing Plant across Nigeria. It was deduced that the initial estimation of using Dangote Cement Manufacturing Plants to distribute product across South-South and South-East was put at ₦1,875,453,000,000.00. After optimisation the overall cost of operating the supply chain network was reduced to ₦1,875,257,582,141.00 which translated to 0.0104% (₦ 195,417,859.00) annual saving cost reduction. In addition, a new optimise transportation route for distributing product was achieved.
Keywords: *Supply Chain Network, Cement Production and Distribution, Optimisation, and MILP Models.*

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I. Introduction

In today's 21st century economy, industries are faced with the increasing pressure to minimise costs while preserving levels of output and quality in order to produce results. To accomplish the goals of these, organisations must efficiently & effectively conquer series of obstacles. New demand and supply markets are emerging across the continent as a result of free, unregulated market economies and new innovation. For instance, many firms are looking for a fresh approach to enhance their supply chain architecture. Most manufacturing firms are still in the developing stage of effectively addressing the challenges of optimally utilising the efficacy supply chain network across each state. The supply chain's configuration and structure are determined by network design. Unfortunately, a good number of these firms lack the knowledge and information required to coordinate and drive most supply and production across the supply chain network (Meakem, 2003). The rapid increase in globalisation has expanded both the risk and opportunities for supply chains network. The 21st century has begun with huge fluctuation in exchange rates, increase in supply and demand and the rise in cost of raw material, these indicators affect network of the supply chain. Supply chain is designed to deal with these huge demand and supply, for the past several decades, most industries have become vertically less integrated. As organisations have shed noncore capacities, they have had the option to exploit customer and supplier competencies that they did not possess.

The supply chain network adjustment and management have become more challenging as a result of this new ownership structure. With the provide chain broken into numerous stakeholders, each with its own approaches and interests, the supply chain becomes more difficult to facilitate. This problem might actually make each stage of a supply chain network work for itself rather than the entire network, which would reduce the overall benefit of the supply network. A major obstacle to reaching a supply chain network goal is the unwillingness of all participants to cooperate. As consumer needs change, industry is compelled to continually re-examine their supply chain techniques. A technique that might have been extremely productive in one environment can be a weakness in different environment setting. Issues identified with the sustainability and environment have grown in relevance and should be considered when planning supply chain network methodology.

In certain instance, guideline has been driving changes; in others, change has been driven by the impression of the absence of manageability as a risk factor. (Mentzer, 2001). Environmental factors represent a huge opportunity to manufacturing firms that can add value to consumers and minimise their own expenses along the supply chain network. These issues additionally address a significant challenge since the most chances require coordination across various individuals from the provide chain network. To be successful, manufacturing firms will need to develop methodology that connects the whole members of the supply chain network to recognise and address opportunities for further sustainability. Coordinating and designing a supply chain network have become tasking because of the expanding market rivalry, increase in customer demand and fast improvement of the financial and globalisation technology.

The cement industry in Nigeria is highly fragmented, with numerous operating small and medium-sized producers in the industry. As of 2016, there were over 94 cement manufacturers in the country, with a total installed capacity of over 30 million tons per annum (MTPA). The majority of these producers are small-scale players, with a few large producers dominating the market. The largest producers include Dangote Cement, BUA Group, Ashaka Cement, Lafarge WAPCO and Ibeto Cement. The cement industry in Nigeria is characterised by high input costs and a highly competitive market. In order to remain competitive, cement producers must optimise their supply chain network to enhance efficiency and cut expenses efficiency. An efficient supply chain network is essential for reducing the time and cost of transporting raw materials to plants, as well as for transporting finished products to customers. An effective supply chain system responds to the rapid consumers demand with the goal of achieving the progress of the supply chain network. All these relies upon the participation and coordination among all individuals. Supply chain network configuration consolidates both tactical and strategic options on the location, quantity, capacity regarding the manufacturing, supply, and distribution Centres required to satisfy the base of consumers' needs for goods and services. (Klibi and Martel, 2012).

II. Literature Review

The origins of supply chain management can be found in the early 20th century, when businesses started concentrating on increasing productivity and cutting costs. During the early 1900s, companies began to use the concept of "just-in-time" inventory management, which allowed them to better anticipate customer demand and reduce inventory costs (Olhager, 2013). In the 1950s, the automobile industry started using a more integrated strategy for supply chain management that put an emphasis on streamlining everything from raw materials to final goods (Logmore, 2019). To maintain a smooth flow of supplies, information, and services along the entire supply chain, this strategy involves cooperation between manufacturers, distributors, and suppliers. By the 1980s, advances in technology allowed companies to further streamline their supply chain operations and automate many of the manual processes. Due to this, more advanced Supply Chain Management methods and software were developed, and they are still in use today (Logmore, 2019). In the 1990s, the emergence of the Internet revolutionised the way companies were able to manage their supply chains. Companies could now share information with suppliers, customers, and other partners in real time, allowing for more efficient tracking and management of the various components of the link chain. Today, Supply Chain Architecture is an integral part of many companies' operations, allowing them to monitor and manage their supply chains in real time, reduce costs, and improve customer service.

Haq et al. (1991) built a strong mixed-integer linear programming model with a coordinated distribution, production, and inventory model to reduce the overall cost of the supply chain system. They introduced various realistic constraints to determine the optimal distribution and production with respect to inventory level. Chandra and Fisher (1994) tried to address the coordination issue the distribution and production function for a unit plant that produces in a multi-period, multi-commodity setting. The research anticipated that goods would be produced and kept in the facility until they were delivered to the customer using truck fleets. The outcome of the computational investigation reviews that routing and planning could result to saving of approximately 20%.

Chan and Chung (2004) address the supply chain network problem for multiple items throughout a single period. The supply chain network was divided into three sub-networks: an inbound network system, a distribution-production supply chain network, and an outward supply chain network. To configure each sub-network organisation, a heuristic based on Lagrangian Relaxation was used. Perea-López et al. (2003) created a paradigm for mixed integer linear programming that three (3) plants with different product, four (4) distribution Centres, three (3) warehouses, twenty (20) customers and ten (10) retailers respectively. Taking into account a multiperiod, multi-distribution, and multi-product supply chain network. A single stage batch plant and a multiple centralised global approach was adopted. The solution technique they adopted was dynamic model predictive control (MPC) strategy. Yan et al. (2003) offered a methodology for a distribution and production model that included numerous distribution points, suppliers, manufacturers, and consumers to generate a number of goods at once. Kouvelis and Li (2012) introduced a mixed-integer program to investigate a single product's worldwide manufacturing network model for the introduction of a new product in several business sectors, a two-stage production procedure was examined. Their work amply demonstrates the value of incorporating obligations and local trading regulations into global manufacturing network plans, as they collectively alter the supply chain network structure. As per their key discoveries, expanded exchange taxes favours progressive decentralisation of manufacturing processes. Maqsood et al. (2005) developed a fuzzy two-stage stochastic programming method for water management system board planning in the presence of uncertainty.

Santoso et al. (2005) developed a stochastic programming model and a solution methodology for calculating issues with the supply chain network that are of a practical size. The stochastic supply chain network design problem had a large scope, and the solution method used sample average approximation techniques using an accelerated benders decomposition methodology to calculate quickly high-quality solutions. Altiparmak et al. (2006) developed a nonlinear for a plastics company, a mixed integer supply network model with many goals and a single product is presented. They created a process to estimate and resolve the issue using Genetic Algorithms. Sourirajan et al. (2009) investigated the structure a complicated network supply chain of an organization. The general goal was to design a multi-objective model by maximizing customers decreasing the number of partners included and demand. The problem was evaluated using a multi-stage numerical methodology based on Analytical Hierarchy Process, Genetic Algorithms, and Multi Attribute Utility Theory. Although their studies only took into account one product and one time period from the consumers, they neglected to account for how the product's structure influences customer happiness.

He et al. (2007) designed a production network configuration model to increase incomes before taxes' Net Present Value. The model was design to optimize the distribution production plan with respect to the plant capacity, plant allocation and plant location respectively. In view of the exceptional issue design of a synthetic chemical organization, across different supply network tiers, a single sourcing hypothesis was put forth. After one stage of production, the model includes a drawback for re-export and anticipates adjustments to permit drawback across higher number of production stages with respect to different supplies from multiple sub-assemblies. Tsiakis et al. (2001) recommended a mixed-integer deterministic model for optimization a global production network in-cooperating distribution centres, production plants with respect to different consumer zones. Although the model considered multiple products, only a single duty rate for all products was considered. Because of the essential point of the research work, choices on where to open distribution Centres and production plants, products are assigned to plants, and the work of distribution centres is divided between plants, centres, and consumer zones. Mula et al. (2010) presented an analysis of the use of numerical programming models for supply chain network planning and concluded that it is critical to integrate the suppliers' hubs into the supply chain optimisation network models. Hence, adopting a local strategy will not always increase the overall effectiveness of the multi-stage manufacturing chain network. As a result, creating an integrated model for cost-effective decision distribution and production optimisation becomes challenging for designers of manufacturing supply chains, especially when the products have intricate structures. El-Sayed et al. (2010) presented a thorough multi-echelon multi-period forward-reverse inventory logistics supply chain network using a risk analysis model to maximise the total cost of production. The supply chain topology that is being proposed takes into account first client zones where requests are assumed to be stochastic and second client zones where requests are assumed to be deterministic.

Paksoy et al. (2012) designed a mixed integer programming model with the goal of reducing production costs overall while putting some restrictions on the capacity of the production facility, suppliers, and distribution centers. Zapfel et al. (2010) created the ideal integrated production distribution network using a genetic algorithm. A single level BOM in the inbound sub-network and a double-level Bill of Material in the distribution and production network were found to be the product structures in the inquiry. The Bill of Material's fixed level was where the products were placed. Production facilities were divided into groups based on the structure of the Bill of Material, with each group manufacturing goods listed at the same level in the Bill of Material. Unfortunately, the process fails when the BOM structure is more complicated, such as when there are more than two layers and similar products exist at different levels.

Mezghani et al. (2012) built a mathematical Goal Programming model in an uncertain setting while explicitly incorporating the administrator's preferences into the optimisation model. Pishvaee and Razmi (2012) developed a nonlinear multi-objective numerical programming fuzzy model of a simulated environmental Supply Chain Network (SCN) is evaluated using an interactive fuzzy technique with the aim of minimising both the overall cost and the overall environmental effect.

Badri H. et al. (2013) introduced an interactive fuzzy technique is used to evaluate a nonlinear multi-objective numerical programming fuzzy model of a simulated environmental Supply Chain Network (SCN), with the goal of minimising both the overall cost and the overall environmental effect. Wang et al. (2014) investigated a non-linear multi-objective optimisation model was subsequently created to analyse the design of a supply chain under environmental conditions, highlighting the trade-off between environmental restrictions and total cost. Wu and Golbasi (2014) created a multi-objective model employing dynamic factory location methodologies and supply chain planning under demand uncertainty to minimise the total cost of factory site with respect to transportation and path selection. Xia et al. (2004) examined a retailer-supplier chain network that encounters supplier interruptions during planning. Alternative disruption should be taken into account while deciding the components, suppliers, cycles, and means of transportation to select at each stage of the supply chain network.

Margaretha (2015) introduced a investigating the impact of total aggregate planning under the Make-To-Order (MTO) condition using a hierarchical production planning (HPP) system. A linear mathematical model was formulated from the planning problem and evaluated to optimality by an optimisation software engine. The system performance was evaluated based on inventory levels and service. The data extracted from an automobile industry was utilised to characterise four demand situations. Adabi and Omrani (2015) developed two objective functions by formulating a mixed integer programming model, lowering the overall cost of facility layout in relation to the production of various products while increasing the effectiveness of the supply chain network. For a supply chain network, Serdar and Al-Ashhab (2016) theoretically created a mixed integer linear programming model that took into account deterministic demand in relation to overall profit

III. Methodology

3.1 Study Area

In this study, the South-East and South-South regions of Nigeria's Dangote Cement Company Supply Chain Network (SCN) were taken into account. In the South-East and South-South regions of Nigeria, a total of three production plant facilities (Dangote Cement Company), four warehouse facilities, and twenty-three (23) main distribution center facilities were taken into consideration

3.2 Nature/Source of Data

The research work deployed secondary data in its evaluation. Data was collected from the company's current Annual Reports and also from recent bulletin. A purposive sampling of staff of Dangote Management was conducted. The information contained were:

i. Transportation cost with respect to their distance across in Nigeria's south-south and southeast.
ii. Cost of production.
iii. Annual demand and supply from warehouse Facilities in Nigeria's south-south and southeast.
iv. Annual demand from distribution Centres Facilities in Nigeria's south-south and southeast.
v. Capacity of the warehouse and Distribution Centres. Nigeria's south-south and southeast.

3.3 Method of Data Analysis

A mathematical model was developed that examines the characteristics of the Dangote Cement Company's supply chain network. An evaluation of the created model was then performed utilising an Excel SOLVER.

3.4 Model Specification

The supply chain network (SCN) of the Dangote Cement Company was optimised using the established model, which took into account a number of important factors that have a significant impact on the business's profitability. Several factors, including product flow between each echelon, distribution centres, transportation costs, inventory levels, and warehouse and distribution centre capacity, made up the decision variables.

3.4.1 The Suppliers/ The Manufacturers (Dangote Cement Company)
3.4.2 The Warehouse
3.4.3 The Distribution Centres

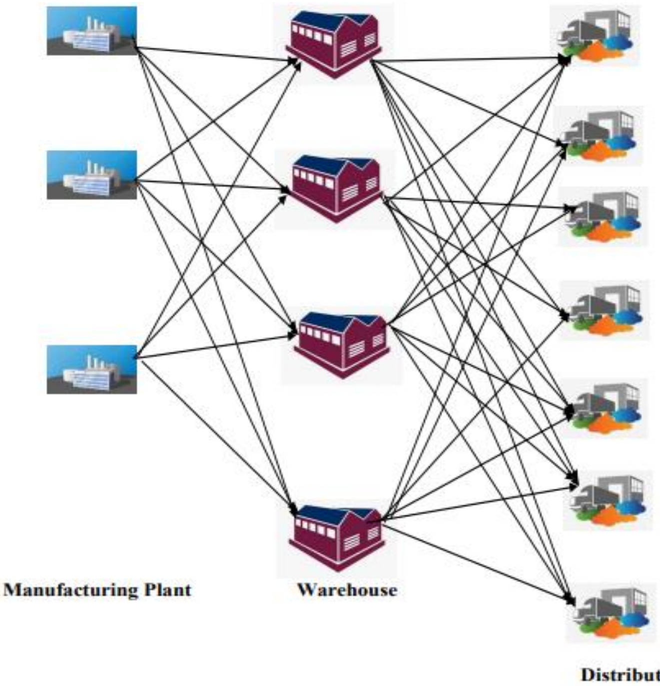


Figure 3.1: A Typical Supply Chain Network (SCN) including Manufacturing Plant, Warehouse and Distribution Centres.

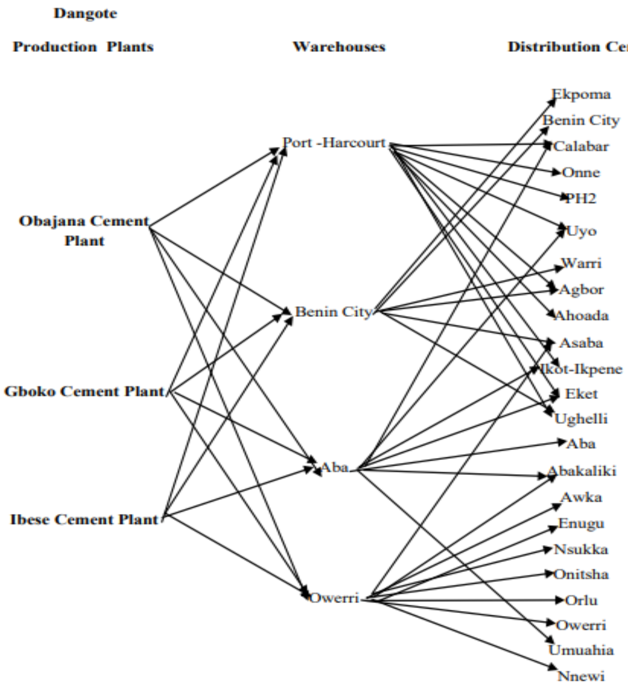


Figure 3.2: The current supply Chain Network for Dangote Cement Company across Nigeria's south-south and southeast

3.5 Model Formulation
Let n denotes number of Dangote Plant Facility in Nigeria.
Let t denoted number of warehouse Facility in South-South and South-East, Nigeria.
Let l denotes number of Distribution Centre's Facility in South-South and South-East, Nigeria.
Let K_P denotes supply capacity at Dangote Cement Plant **h** in South-South and South-East Nigeria.
Let K_W denotes ccapacity at Warehouse **i** in South-South and South-East, Nigeria.
Let D_w denotes annual demand from Warehouse Facility in South-South and South-East. Nigeria
Let D_d denotes Annual demand for Distribution Centre's Facility at site i in South-South and South-East, Nigeria.
Let F_h denotes fixed cost of locating/operating Dangote plant at site h
Let f_i denotes fixed cost of locating/operating a warehouse at site i in South-South and South-East, Nigeria.
Let c_{hi} denotes cost of producing and transporting one unit from Dangote Cement Plant h to warehouse i in South-South and South-East, Nigeria.
Let c_{ie} denotes cost of transporting one unit from warehouse i to distribution Centre's e
Hence the following decision variables are considered:
Let y_i = 1 if Dangote Cement Plant i, is open otherwise 0
Let y_e =1 if warehouse e is open otherwise 0
Let q_{hi} = represent the amount transported from Dangote Cement Plant h to warehouse at site i
Let q_{ie} = represent the amount transported from Warehouse at site i to Distribution Centre's e
From the condition placed on the decision variables, the problem can be formulated as follows:
The aim of this research is to minimise the overall cost associated with plant and warehouse location with respect to the amount of quantity transported.

Optimisation Model
Minimise Total cost (Fixed cost and Variable cost)

$$\sum_{i=1}^{n} F_h y_i + \sum_{e=1}^{t} f_i y_e + \sum_{h=1}^{n}\sum_{i=1}^{t} c_{hi} q_{hi} + \sum_{i=1}^{t}\sum_{e=1}^{l} c_{ie} q_{ie}$$

Subject to:

$$K_P y_i - \sum_{e=1}^{n} q_{hi} \qquad Sup \;\; \forall_i = 1, \dots\dots\dots, 3 \qquad (3.1)$$

The constraint expressed in Equation (3.1) requires that the total quantity transported from Dangote Cement Plant should not exceed its capacity

$$K_W y_e - \sum_{e=1}^{t} q_{ie} \qquad sup \quad \forall_e = 1, \dots\dots\dots, 4 \qquad (3.2)$$

The constraint expressed in Equation (3.2) requires that the total quantity transported from a warehouse should not exceed its capacity

$$D_w - \sum_{e=1}^{m} q_{hi} \qquad De \quad \forall_i = 1, \dots\dots\dots, 4 \qquad (3.3)$$

The constraint expressed in Equation (3.3) requires that the total quantity transported to Warehouse should cover the quantity demanded.

$$D_d - \sum_{e=1}^{l} q_{ie} \qquad De \quad \forall_i = 1, \dots\dots\dots, 23 \qquad (3.4)$$

The constraint expressed in Equation (3.4) requires that the total quantity transported to Distribution Centre's should cover the quantity demanded.

$$\sum_{e=1}^{n} q_{hi} - \sum_{e=1}^{l} q_{ie} \geq 0 \qquad \forall_i = 1, \dots\dots\dots, 4 \qquad (3.5)$$

The constraint expressed in Equation (3.5) requires that the total quantity transported out of the Warehouse should not exceed the amount received from Dangote Cement Plant.

$$y_i \in \{0|1\} \quad (Binary\ Constraint) \qquad (3.6)$$

The constraint expressed in Equation (3.6) requires that each Dangote Cement Plant and is either closed or open,

$$y_e \in \{0|1\} \quad (Binary\ Constraint) \qquad (3.7)$$

The constraint expressed in Equation (3.7) requires that each Warehouse is either closed or open,

$$q_{hi} \geq 0 \quad (Non\ negativity) \qquad (3.8)$$

The constraint expressed in Equation (3.8) requires that each quantity transported from Dangote Plant to Warehouse should not be more than the demand.

$$q_{ie} \geq 0 \quad (Non\ negativity) \qquad (3.9)$$

The constraint expressed in Equation (3.9) requires that each quantity transported from Warehouse to Distribution Centre's should not be more than the demand.

3.6 Input Data

Table 3.1A: Capacity of Dangote Cement Manufacturing Plants

S/N	State	Manufacturing Plant Location	Capacity (Million Tonnes)
1	Kogi State	Obajana Cement Plant	16.25Mta
2	Benue State	Gboko Cement Plant	4.00Mta
3	Ogun State	Ibese Cement Plant	12.20Mta
Total			32.30Mta

Source: Dangote Cement Annual Report Bulletin, (2020).

Table 3.1B: Cost of Establishing Dangote Manufacturing Plants

S/N	Cost (₦)/Km/30Ton	Manufacturing Plant Location	Fixed Cost (₦B)
1	Cost (₦)/Km/30Ton	Obajana Cement Plant (Km)	725,000,000,000
2	Cost (₦)/Km/30Ton	Gboko Cement Plant (Km)	400,000,000,000
3	Cost (₦)/Km/30Ton	Ibese Cement Plant (Km)	750,000,000,000

Source: Dangote Cement Company Logistics Department,2020.

Table 3.1C: Cost of Operating Distribution Centre's

S/N	Cost (₦)/Km/30Ton	Distribution Centres	Fixed Cost (₦M)
1	Cost (₦)/Km/30Ton	Port Harcourt Warehouse (Km)	55,500,000
2	Cost (₦)/Km/30Ton	Benin City Warehouse (Km)	40,000,000
3	Cost (₦)/Km/30Ton	Aba Warehouse (Km)	33,000,000
4	Cost (₦)/Km/30Ton	Owerri Warehouse (Km)	35,000,000

Source: Dangote Cement Company Logistics Department,2020.

Table 3.2: Average Capacity of each Warehouse in South-South and South-East Region.

S/N	State	Warehouse	Average Capacity per truck (800Bags = 30 Tonnes)	Annual Capacity (Million Tonnes)
1	Rivers State	Port - Harcourt	1650 truck/Week	1,782,000
2	Edo State	Benin City	1200 truck/Week	1,296,000
3	Abia State	Aba	1075 truck/Week	1,161,000
4	Imo State	Owerri	1150 truck/Week	1,242,000
Total				**5,481,000**

Source: Dangote Cement Company Logistics Department,2020.

Table 3.3: Average Capacity of each Distribution Centre's in South-South and South-East Region.

S/N	State	Distribution Centres	Average Truck Capacity (800Bags/30 Tonnes)	Average Capacity (Thousand Tonnes)
1	Edo State	Ekpoma	102 truck/Week	146880
2	Edo State	Benin City	132 truck/Week	190080
3	Cross Rivers State	Calabar	92 truck/Week	132480
4	Rivers State	Onne	118 truck/Week	169920
5	Rivers State	PH2	154 truck/Week	221760
6	Akwa Ibom State	Uyo	103 truck/Week	148320
7	Delta State	Warri	118 truck/Week	169920
8	Delta State	Agbor	96 truck/Week	138240
9	Rivers State	Ahoada	87 truck/Week	125280
10	Delta State	Asaba	113 truck/Week	162720
11	Akwa Ibom State	Ikot-Ikpene	92 truck/Week	132480
12	Akwa Ibom State	Eket	96 truck/Week	138240
13	Delta State	Ughelli	76 truck/Week	109440
14	Abia State	Aba	98 truck/Week	141120
15	Ebonyi State	Abakaliki	72 truck/Week	103680
16	Anambra State	Awka	78 truck/Week	112320
17	Enugu State	Enugu	93 truck/Week	133920
18	Imo State	Nsukka	102 truck/Week	146880
19	Anambra State	Onitsha	123 truck/Week	177120
20	Imo State	Orlu	82 truck/Week	118080
21	Imo State	Owerri	115 truck/Week	165600
22	Abia State	Umuahia	92 truck/Week	132480
23	Anambra State	Nnewi	102 truck/Week	146880
	Grand Total			**3363840**

Source: Dangote Cement Company Logistics Department, 2020.

Table 3.4: Distance from Dangote Cement Plants to Four (4) Warehouse in South-South and South-East Region.

S/N	Warehouse Location	Distance from Obajana Cement Plant (Km)	Distance from Gboko Cement Plant (Km)	Distance from Ibese Cement Plant (Km)
1	**Port - Harcourt**	417.4 Km	465.5 Km	587.6 Km
2	**Benin City**	287.3 Km	610.8 Km	285.2 Km
3	**Aba**	421.4 Km	415.4 Km	577.6 Km
4	**Owerri**	335 Km	377.4 Km	505.1 Km

Source: Nigeria Distance and Kilometer Map Calculation, 2020.

Table 3.5: Distance from Warehouse to various Distribution Centre's across South-South and South-East Region.

S/N	Distribution Centres	Distance from Port Harcourt Warehouse (Km)	Distance from Benin City Warehouse (Km)	Distance from Aba Warehouse (Km)	Distance from Owerri Warehouse (Km)
1	**Ekpoma**	359.4 Km	76.5 Km	301 Km	236.4 Km
2	**Benin City**	289.5 Km	0	292.5 Km	227.9 Km
3	**Calabar**	234.9 Km	475.9 Km	153.7 Km	224 Km
4	**Onne**	20.5 Km	304.5 Km	61.4 Km	118.3 Km
5	**PH2**	0	288.9 Km	57.9 Km	106.7 Km
6	**Uyo**	142.2 Km	348.9 Km	69.3 Km	139.7 Km
7	**Warri**	198.7 Km	96.2 Km	270.6 Km	206.1 Km
8	**Agbor**	281.2 Km	70.5 Km	230.2 Km	165.6 Km
9	**Ahoada**	67.6 Km	227.1 Km	139.5 Km	75 Km
10	**Asaba**	202.3 Km	130.3 Km	165.2 Km	100.6 Km
11	**Ikot-Ikpene**	149.2 Km	321.5 Km	41.9 Km	112.2 Km
12	**Eket**	114.1 Km	398 Km	108.6 Km	177.6 Km
13	**Ughelli**	196.8 Km	121.1 Km	268.7 Km	204.2 Km
14	**Aba**	58.2 Km	300.2 Km	0	74.7 Km
15	**Abakaliki**	272.6 Km	322.7 Km	223.9 Km	217.4 Km
16	**Awka**	221 Km	185 Km	207 Km	119.3 Km
17	**Enugu**	225.3 Km	252.7 Km	176.5 Km	147.4 Km
18	**Nsukka**	282.5 Km	279.5 Km	233.8 Km	204.7 Km
19	**Onitsha**	185.4 Km	144.2 Km	148.3 Km	83.7 Km
20	**Orlu**	150.2 Km	199.7 Km	117.6 Km	17.7 Km
21	**Owerri**	103.3 Km	226.6 Km	66.2 Km	0
22	**Umuahia**	108.2 Km	269.5 Km	59.5 Km	78.5 Km
23	**Nnewi**	176.3 Km	164.7 Km	134.8 Km	70.2 Km

Source: Nigeria Distance and Kilometer Map Calculation, 2020

Table 3.6: Haulage Cost from Dangote Cement Plant to four (4) Warehouse across South-South and South-East Region.

S/N	Warehouse Location	Cost (₦)/Km/30Ton from Obajana Cement Plant (Km)	Cost (₦)/Km/30Ton from Gboko Cement Plant (Km)	Cost (₦)/Km/30Ton from Ibese Cement Plant (Km)

1	**Port - Harcourt**	₦160,281.6	₦178,752	₦225.638.4
2	**Benin City**	₦1103,23.2	₦234,547.2	₦109.516.8
3	**Aba**	₦161,817.6	₦1595,13.6	₦221.798.4
4	**Owerri**	₦128,640	₦144,921.6	₦193.958.4

Source: Dangote Cement Logistics Department (₦12.8/Ton/Km)

Table 3.7: Haulage Cost from Warehouse to various Distribution Centre's across South-South and South-East Region.

S/N	Distribution Centres	Cost (₦)/Km/30Ton from Port Harcourt Warehouse (Km)	Cost (₦)/Km/30Ton from Benin City Warehouse (Km)	Cost (₦)/Km/30Ton from Aba Warehouse (Km)	Cost (₦)/Km/30Ton from Owerri Warehouse (Km)
1	**Ekpoma**	₦138,009.6	₦29,376	₦11,5584	₦90,777.6
2	**Benin City**	₦111,168	0	₦11,2320	₦87,513.6
3	**Calabar**	₦90,201.6	₦182,745.6	₦59,020.8	₦86,016
4	**Onne**	₦7,872	₦116,928	₦23,577.6	₦454,27.2
5	**PH2**	0	₦110,937.6	₦22,233.6	₦40,972.8
6	**Uyo**	₦54,604.8	₦133,977.6	₦26,611.2	₦53,644.8
7	**Warri**	₦76,300.8	₦36,940.8	₦103,910.4	₦79,142.4
8	**Agbor**	₦107,980.8	₦27,072	₦88,396.8	₦63,590.4
9	**Ahoada**	₦25,958.4	₦87,206.4	₦53,568	₦28,800
10	**Asaba**	₦77,683.2	₦50,035.2	₦63,436.8	₦38,630.4
11	**Ikot-Ikpene**	₦57,292.8	₦123,456	₦16,089.6	₦43,084.8
12	**Eket**	₦43,814.4	₦152,832	₦41,702.4	₦68,198.4
13	**Ughelli**	₦75,571.2	₦46,502.4	₦103,180.8	₦78,412.8
14	**Aba**	₦22,348.8	₦115,276.8	0	₦28,684.8
15	**Abakaliki**	₦10,4678.4	₦123,916.8	₦85,977.6	₦83,481.6
16	**Awka**	₦84,864	₦71,040	₦79,488	₦45,811.2
17	**Enugu**	₦86,515.2	₦97,036.8	₦67,776	₦56,601.6
18	**Nsukka**	₦108,480	₦10,7328	₦89,779.2	₦78,604.8
19	**Onitsha**	₦71,193.6	₦55,372.8	₦56,947.2	₦32,140.8
20	**Orlu**	₦57,676.8	₦76,684.8	₦45,158.4	₦67,96.8
21	**Owerri**	₦39,667.2	₦87,014.4	₦25,420.8	0
22	**Umuahia**	₦41,548.8	₦103,488	₦22,848	₦30,144

2 3	**Nnewi**	₦67,699.2	₦63,244.8	₦51,763.2	₦26,956.8

Source: Dangote Cement Logistics Department (₦12.8/Ton/Km).

IV. Computational Result

Table 4.1: Optimised Cost generated when **Obajana, Ibese** and **Gboko Cement Plant** was **OPEN**

Answer Report

Worksheet: [Final Vivian's Cost Analysis (Auto Recovered).xlsx] Sheet2

Report Created: 15/11/2021 1:11:24 pm

Result: Solver found a solution. All Constraints and optimality conditions are satisfied.

Solver Engine

Solver Options

Objective Cell (Min)

Cell	Name	Original Value	Final Value
M23	Cost of Operating Obajana, Ibese and Gboko Cement Plant (Trillion Naira)	**1,875,453,00 0,000**	**1,875,257,58 2,141**

Table 4.1 shows the result generated from the software which reviews total cost of operating the supply chain network of Dangote Cement plant at Obajana, Ibese and Gboko Cement Plant at Kogi, Ogun and Benue State respectively. The estimated cost optimisation of operating Obajana, Ibese and Gboko Cement Plant was estimated at **₦1,875,257,582,141** (One Trillion Eight hundred and seventy-five Billion two hundred and fifty-seven million five hundred and eighty-two thousand and one hundred and forty-one naira only

Table 4.2: Optimise Transportation Route and Capacity Allocation when **Obajana, Ibese** and **Gboko** Cement Plant were kept **OPEN** for Transporting Cement to Four Warehouse Location across South-South and South-East Region.

S/N	Destination		Capacity Allocation		Warehouse Demand
	Warehouse Location	**Obajana Cement Plant (Km)**	**Gboko Cement Plant (Km)**	**Ibese Cement Plant (Km)**	**Demand City (Million Tonnes)**
1	**Port -Harcourt**	1,782,000	0	0	1,782,000
2	**Benin City**	0	0	1,296,000	1,296,000
3	**Aba**	0	1,161,000	0	1,161,000
4	**Owerri**	1,242,000	0	0	1,242,000
	Supply	14,000,000	3,000,000	11,000,000	
	Plant(open/close)	**1 (OPEN)**	**1 (OPEN)**	**1 (OPEN)**	

Table 4.2 shows the capacity allocation of Dangote Cement Company from the three (3) Cement Plant to various Warehouse across South-South and South-East Region of Nigeria. Based on demand, Obajana Cement Plant supplied Port-Harcourt Warehouse with 1,782,000 million Tonnes of cement and Owerri Warehouse with 1,242,000 million Tonnes of cement. Gboko Cement Plant transported 1,161,000 million Tonnes of cement. Finally, Ibese Cement Plant delivered 1,296,000 million Tonnes of cement to Benin City Warehouse respectively. Furthermore, Obajana Cement Plant utilise the route to deliver product to Port Harcourt warehouse and Owerri Warehouse, Subsequently Gboko Cement Plant navigated through Aba warehouse while Ibese cement Plant transported to Benin City.

Table 4.3: Optimise Transportation Route and Capacity Allocation from Four (4) Warehouse to Distribution Centre's across South-South and South-East Region of Nigeria.

	Destination		Capacity Allocation			Average Demand
S/N	Distribution Centres	Port Harcourt Warehouse (Km)	Benin City Warehouse (Km)	Aba Warehouse (Km)	Owerri Warehouse (Km)	Capacity (Thousand Tonnes)
1	Ekpoma	0	146880	0	0	146880
2	Benin City	0	190080	0	0	190080
3	Calabar	0	0	132480	0	132480
4	Onne	169920	0	0	0	169920
5	PH2	221760	0	0	0	221760
6	Uyo	0	0	148320	0	148320
7	Warri	0	169920	0	0	169920
8	Agbor	0	138240	0	0	138240
9	Ahoada	125280	0	0	0	125280
10	Asaba	0	0	0	162720	162720
11	Ikot-Ikpene	0	0	132480	0	132480
12	Eket	0	0	138240	0	138240
13	Ughelli	0	109440	0	0	109440
14	Aba	0	0	141120	0	141120
15	Abakaliki	0	0	26000	77680	103680
16	Awka	0	0	0	112320	112320
17	Enugu	0	0	0	133920	133920
18	Nsukka	0	0	0	146880	146880
19	Onitsha	0	0	0	177120	177120
20	Orlu	0	0	0	118080	118080
21	Owerri	0	0	0	165600	165600
22	Umuahia	0	0	132480	0	132480
23	Nnewi	0	0	0	146880	146880
	Warehouse Inventory	**1,265,000**	**542,000**	**312,000**	**0**	
	Plant(open/close)	**1 (OPEN)**	**1 (OPEN)**	**1 (OPEN)**	**1 (OPEN)**	

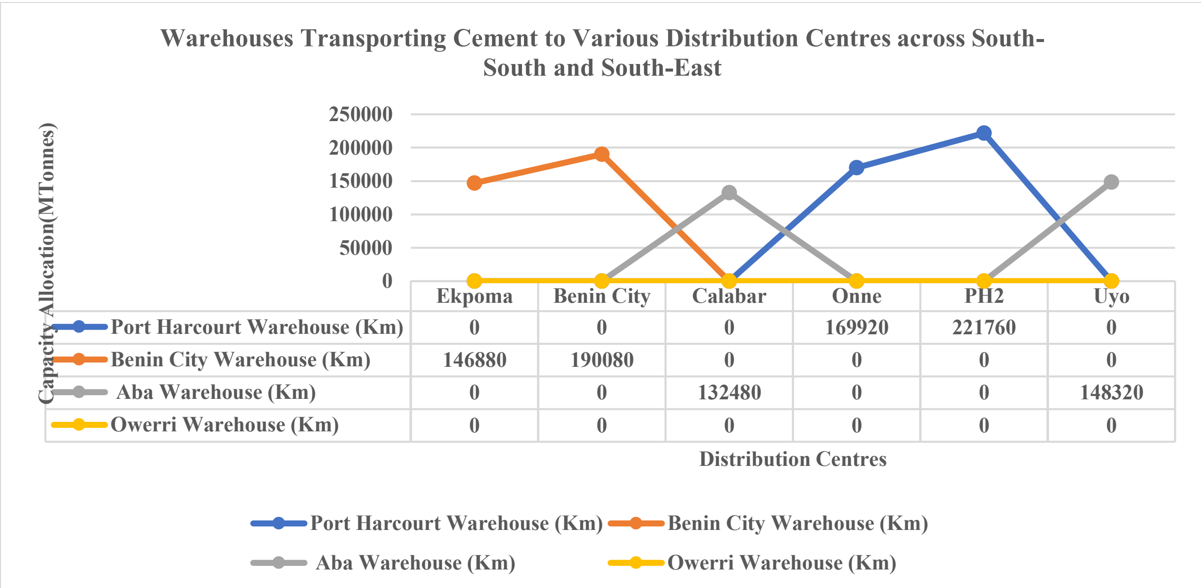
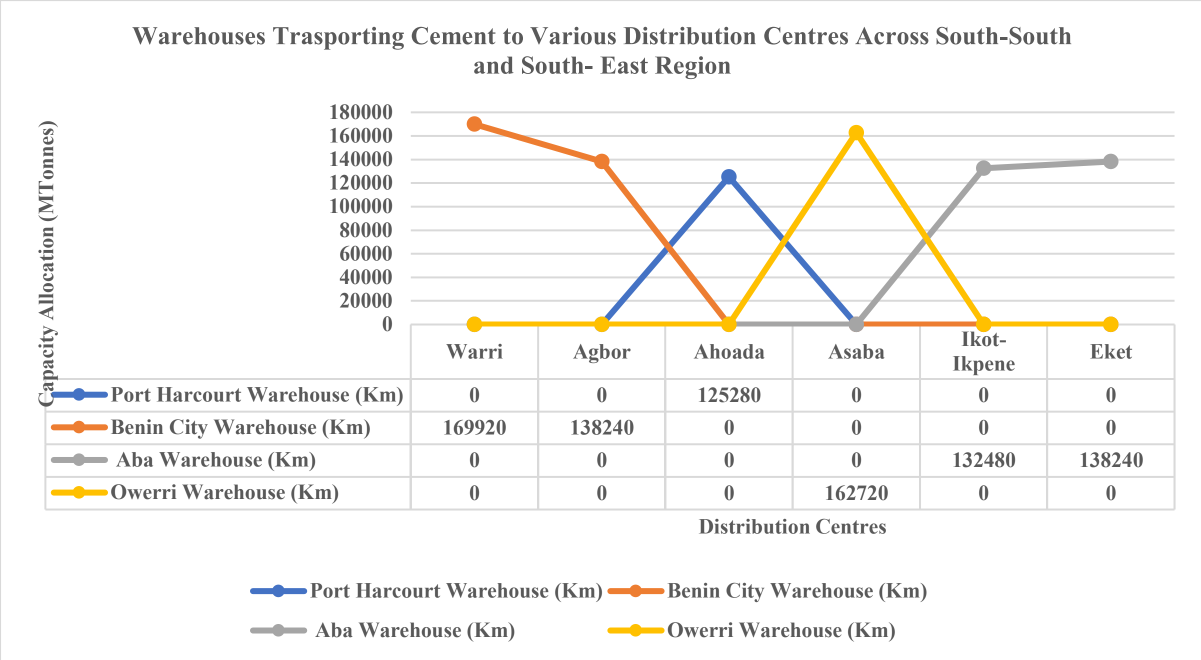
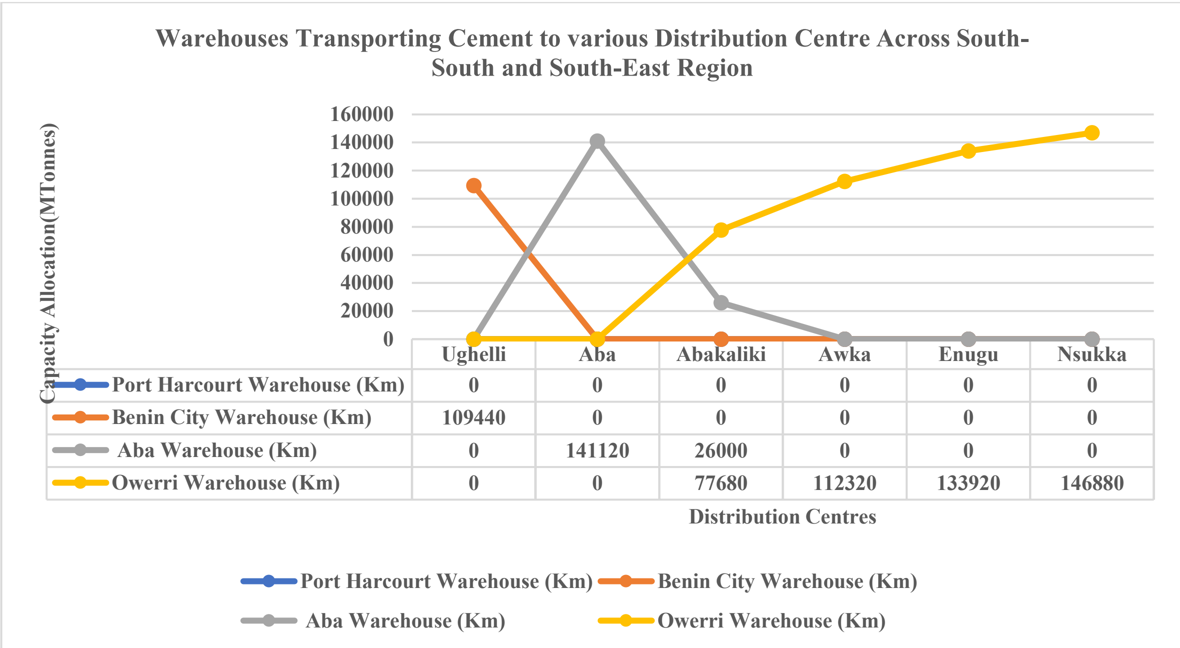


Figure 4.1: Graphical illustration showing Transportation Route and Capacity Allocation across Distribution Centre's in South-South and South-East, Nigeria.



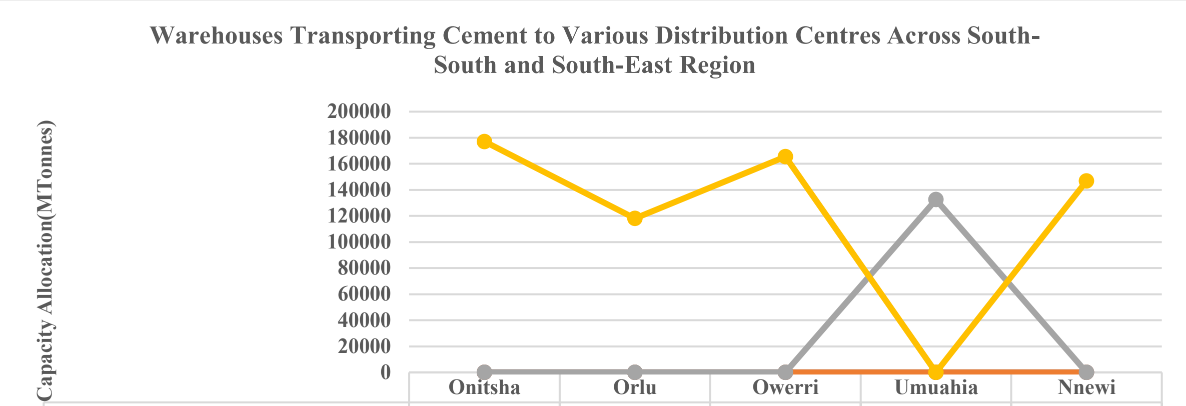
	Warri	Agbor	Ahoada	Asaba	Ikot-Ikpene	Eket
Port Harcourt Warehouse (Km)	0	0	125280	0	0	0
Benin City Warehouse (Km)	169920	138240	0	0	0	0
Aba Warehouse (Km)	0	0	0	0	132480	138240
Owerri Warehouse (Km)	0	0	0	162720	0	0

Figure 4.2: Graphical illustration of Transportation Route and Capacity Allocation across Distribution Centre's in South-South and South-East.



	Ughelli	Aba	Abakaliki	Awka	Enugu	Nsukka
Port Harcourt Warehouse (Km)	0	0	0	0	0	0
Benin City Warehouse (Km)	109440	0	0	0	0	0
Aba Warehouse (Km)	0	141120	26000	0	0	0
Owerri Warehouse (Km)	0	0	77680	112320	133920	146880

Figure 4.3: Graphical illustration of Transportation Route and Capacity Allocation across Distribution Centre's in South-South and South-East.



	Onitsha	Orlu	Owerri	Umuahia	Nnewi
Port Harcourt Warehouse (Km)	0	0	0	0	0
Benin City Warehouse (Km)	0	0	0	0	0
Aba Warehouse (Km)	0	0	0	132480	0
Owerri Warehouse (Km)	177120	118080	165600	0	146880

Figure 4.4: Graphical illustration of Transportation Route and Capacity Allocation across Distribution Centre's in South-South and South-East.

V. Result and Discussion

5,1 Optimisation and Re-design of Dangote Supply Chain Network with respect to Cost, Capacity and Transportation Route

The overall cost of operating the network using Obajana, Ibese and Gboko cement Plant was ₦1,875,453,000,000.00. After optimisation the cost of operating the network was reduced to ₦1,875,257,582,141.00 which translated to *0.0104% (₦ 195,417,859.00)*. Table 4.1 shows the result generated from the software which reviews total cost of operating the supply chain network of Dangote Cement plant at Obajana, Ibese and Gboko Cement Plant at Kogi, Ogun and Benue State respectively. The estimated cost of operating Obajana and Ibese Cement Plant is put at ₦1,875,257,582,141 (One Trillion Eight hundred and seventy-five Billion two hundred and fifty-seven million five hundred and eighty-two thousand and one hundred and forty-one naira only.

Secondly, Table 4.2 shows Capacity Allocation to Various Warehouse to distribute product across South-South and South-East, Nigeria was achieved. Hence, based on demand, the capacity allocation and distribution of Dangote Cement Company to various Warehouse across South-South and South-East Region of Nigeria are as follows, Port-Harcourt Warehouse was allocated 1,782,000 million Tonnes of cement, Benin City Warehouse was allocated 1,296,000 million Tonnes of cement, Aba Warehouse was allocated 1,161,000 million Tonnes of cement and Owerri Warehouse was allocated 1,242,000 million Tonnes of cement respectively. Furthermore, the transportation route followed by Port Harcourt Warehouse, Benin City Warehouse, Aba Warehouse, and Owerri warehouse is given below.

Thirdly, an Optimise route to eliminate travelling longer distance to distribute product across South-South and South-East, Nigeria was achieved.

i. Port-Harcourt Warehouse distributed to the following distribution Centre's Onne, 169920 thousand Tonnes, PH2, 221760 thousand Tonnes and Ahoada, 125280 thousand Tonnes.
ii. Benin City Warehouse distributed to the following distribution Centre's Ekpoma, 146880 thousand Tonnes, Benin City, 190080 thousand Tonnes, Warri, 169920 thousand Tonnes and Agbor, 138240 thousand Tonnes and Ughelli, 109440 thousand Tonnes.
iii. Aba Warehouse distributed to the following distribution Centre's Calabar, 132480 thousand Tonnes, Uyo, 148,320 thousand Tonnes, Ikot-Ikpene, 132,480 thousand Tonnes, Eket, 138240 thousand Tonnes, Aba, 141,120 thousand Tonnes and Umuahia, 141,120 thousand Tonnes.

iv. Owerri Warehouse distributed to the following distribution Centre's Asaba, 162720 thousand Tonnes, Awka, 112320 thousand Tonnes, Enugu, 133920 thousand Tonnes, Nsukka, 146880 thousand Tonnes, Onitsha, 177,120 thousand Tonnes, Orlu, 118,080 thousand Tonnes and Owerri, 165,600 thousand Tonnes.

5.2 Conclusions

The objective of this research work was to formulate a Mixed Integer Linear Programming Model (MILP) supply chain network for Dangote Manufacturing Plant. The developed model was design to tackle tactical and strategic decision such as facility role, facility location, capacity allocation and Transportation route. The work considered three Facility, which were Plant Facility, Warehouse Facility and distribution Centre's Facility. The aim was to minimise the total cost (Fixed cost and variable cost) of the supply chain network with the objective of considering capacity allocation, transportation cost and facility utilisation. Dangote Cement product was transported tthrough the various warehouses using road network as the primary means of transportation to meet the customer's demand. There were capacity constraints, supply constraint, demand constraints and facility location constraints using binary variables to determine which plant facility will give the minimum cost of operation. The essential target of the problem was to minimise cost, discover the shortest possible route at a lower cost and ultimately locate which warehouse facility should distribute product to the distribution Centre's facility across South-South and South-East region of Nigeria.

An optimisation software EXCEL SOLVER 12.0 was utilise to solve a set of real-world data. The computational results generated was validated accordingly. The model was subject to some constraints relative to real live event such as transportation route, capacity allocation facility function and supply allocation based on regional demands. The entire thought behind this research was to give an all-inclusive importance of the entire network design in order to achieve a more robust solution for logistics managers to adopted. This solution will also assist regional managers to adopt the optimisation techniques by practicaly incorporating the system into the organisation's framework to accomplish their annual goal.

VI. Recommendations

A Suppliers Disruption is recommended when considering capacity distribution across the four (4) warehouses in South-South and South-East region. Hence, the choice of facility allocation for supply of products greatly influences the cost of operation across the SCN and quick responsiveness to high demand. The Cost effect of disruption on Plant Facility allocation minimise the overall cost of the supply chain network when considering cost implication and plant Utilisation.

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