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APPLICATION OF LINEAR PROGRAMMING IN THE MINIMIZATION OF TRANSPORTATION COST IN DANGOTE CEMENT, PORT HARCOURT.

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ABSTRACT: *This study delved into the optimization of transportation expenses for Dangote Cement in Port Harcourt, Rivers State. It aligned the quantities of products required by national distributors with the supply available from their depots, employing linear programming techniques to achieve cost minimization. Three sources (depots) - Onne, Rumuodumaya and Trans Amadi as well as six destinations (national distributors) - Aluu, Bori, Elelewon, Omagwa, Oyibo and Rumuola were examined. The secondary data was obtained from a field survey and it contained the unit cost (in Naira) of transporting the products per bag from their various sources to various destinations as at October, 2023. Also, the data obtained from Dangote Cement National Consumer Promotion 2020 (Redemption Centres Detail) contained the list of eleven national distributors in Port Harcourt; however, only six of the national distributors were used in this research. Initial feasible solutions for the secondary data collected were determined through the application of the North-West Corner Method, the Least Cost Method, and the Vogel Approximation Method resulting in values of ₦452,000, ₦380,750, and ₦370,500, respectively. Upon analyzing the outcomes, it was established that the allocation strategy proposed by the Vogel Approximation Method is the most advantageous for optimizing the company's transportation costs. As such, it is recommended to the company as it offers the potential to reduce transportation expenses to a minimum of ₦370,500.*

KEYWORDS: Linear programming, Transportation problem, North-west corner, Least cost, Vogel approximation, Minimal cost, Feasible solution.

INTRODUCTION

Attempting to establish a clear definition of Linear Programming necessitates an initial exploration of the broader realm of Operations Research. This is because Linear Programming serves as a prominent technique within the domain of Operations Research. Operations Research, commonly referred to as “OR”, represents a systematic approach to making informed decisions. It is aimed at determining the most efficient way to design and manage a system, especially when faced with the challenge of allocating limited resources (Oyekan, 2019). Within the realm of Operations Research, one encounters a collection of algorithms that function as valuable problem-solving and decision-making tools in various application domains (Oyekan, 2019).

Linear programming (LP) can be described as a mathematical approach used to identify the most efficient way to allocate a company's finite resources in order to attain the best possible outcome. Another way to define linear programming (LP) is as the task of optimizing a linear function while adhering to linear constraints (Zakariya et al., 2022). Furthermore, it is worth noting that linear programming is a mathematical tool frequently employed within the field of Operations Research (OR). One of the earliest applications achieved a reduced cost of transportation of coking coal by ten percent (Land, 1957).

Manufacturers frequently encounter challenges when it comes to efficiently moving their products from origins to diverse destinations, primarily due to resource constraints. To address these logistical issues, Network Flow Programs offer a specialized category of models that fall under the broader framework of linear programming. This category encompasses a variety of problem types, including transportation dilemmas, assignment quandaries, shortest route conundrums, the minimum-cost-flow problem, and the maximum flow challenge, among others.

In the world of business and industry, organizations are confronted with a dual challenge: achieving economic optimization by minimizing costs while ensuring the efficient allocation of resources that are essential for their survival. Transportation models or issues primarily revolve around finding the most efficient method to transport products from various production facilities (referred to as supply origins) to multiple distribution points or customers (referred to as demand destinations). The ultimate goal in addressing transportation problems is to fulfill the destination demands while adhering to production capacity constraints and keeping costs as low as possible. The transportation problem falls under the category of linear programming and holds significant relevance in our daily lives, particularly within the realm of logistics. This essential function is instrumental in tackling issues associated with the distribution and transit of resources between different locations. The challenge at hand revolves around the effective movement of products from various starting points, such as manufacturing facilities, to designated endpoints, like storage facilities, to meet particular demands. Due to its extensive application in scenarios involving multiple sources of products and multiple destinations, it is commonly referred to as the transportation problem. Its name is derived from its primary role in addressing the transportation of goods from numerous sources to various destinations, although the underlying framework can also be adapted to address broader assignment, scheduling, and distribution challenges.

The term "Transportation theory" refers to the examination of the most efficient methods for allocating and transporting resources. This model is instrumental in guiding strategic decision-

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making, particularly when it comes to determining the best transportation routes for distributing products from multiple production facilities to various warehouses or distribution centers. Additionally, the transportation model can be a valuable tool for deciding on the optimal location for a new facility, whether it is a manufacturing plant or an office, especially when several potential locations are being considered. The transportation problem can be effectively represented through a mathematical model based on linear programming principles, often displayed in a transportation tableau. Linear programming has proven to be a versatile and successful approach in addressing a wide range of challenges. These include personnel assignment, as well as issues related to distribution, transportation, engineering, banking, education, and the petroleum industry, among others.

Minimizing transportation costs is a critical objective for many businesses and organizations, as it directly impacts their profitability and overall efficiency. Linear programming is a powerful mathematical tool that can be applied to optimize transportation logistics and reduce expenses. By formulating transportation problems as linear programming models, decision-makers can make informed choices on how to allocate resources and manage transportation routes effectively. In this essay, we will explore the related literature on minimizing transportation costs using linear programming.

LITERATURE REVIEW

Hitchcock first introduced the fundamental transportation problem back in 1941, however, an early study by Fulkerson and Dantzig in 1954 laid the foundation for using linear programming to solve transportation problems. Their work demonstrated that maximizing the cost efficiency of transportation networks could be achieved by minimizing total transportation costs while satisfying various constraints. This pioneering research paved the way for subsequent studies in the field.

Researchers have developed various linear programming models to address transportation cost optimization. For instance, the classical Transportation Problem (TP) model optimizes flow quantity from multiple origins to multiple destinations, considering cost, capacities, and demands. Also, the Vehicle Routing Problem (VRP) focuses on minimizing costs associated with routes, distances, and delivery demands. The application of linear programming in minimizing transportation costs has been widely demonstrated through case studies and real-world applications. For instance, the application in mining engineering, (Mahrous et al. (2012); in optimizing waste collection by reducing the route's length by up to thirty percent (Swapan & Bhattacharyya, 2015), thereby resulting in significant cost reductions. Zhang et al. (2015) in a similar study optimized a real-time feeder routing system for maritime containers, leading to improved delivery efficiency and reduced expenses.

Other notable studies in this field include a study by Ali et al. (2021) which concentrated on the development of three different Mixed Integer Linear Programming (MILP) models, where each model represented specific constraints; an exhaustive mathematical and an adaptable enormous neighborhood search to solve a two-tiered transportation problem which occurs in the distribution of goods in overcrowded cities chores (Renuad et al., 2015); application of the Modified Distribution (MODI) method to address transportation problems (Mallia et al., 2021); and harnessing the power of a transportation problem scenario minimized the cost of

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distribution of mosquito coils from a company's warehouse to distributor warehouses (Muztoba, 2014); and optimization of transportation cost using linear programming, (Khan, 2014). Excel Solver was leveraged to determine the optimal transportation cost in some context.

A comprehensive review of the linear programming techniques employed by Karsh R. Shah was carried out by Uwarani and Maslin (2022) to address the transportation challenges encountered by MITCO Labuan Company Limited. In Shah's research, he utilized the Vogel's Approximation Method (VAM) and the Modified Distribution (MODI) method to determine the most efficient distribution plan for polymer materials, minimizing shipping costs between four Petronas manufacturing plants and four demand destinations. However, the reviewed work took an innovative approach by recreating the network representation, mathematical model, and spreadsheet models to provide valuable comparisons. They employed the North West Corner Method (NWCM) and VAM to establish the initial Basic Feasible Solution (BSF). Subsequently, they applied sensitivity analysis to assess how fluctuations in unit shipping costs affected the total transportation expenses of the company. Remarkably, their findings revealed that when compared to VAM, the initial basic feasible solution achieved through NWCM resulted in the lowest shipping costs. Consequently, they subjected this solution to further optimization using the simplex method, a technique facilitated by Excel Solver. Additionally, a linear programming-based solution to the vehicle routing problem (VRP) which involves determining the optimal routes and schedules for a fleet of vehicles delivering goods to multiple locations was presented. The researchers developed a mixed integer linear programming model to minimize transportation costs by considering variables such as shipping capacities, time constraints, and fuel consumption. Their findings show that linear programming can provide efficient and cost-effective solutions to the VRP, leading to reduced transportation expenses and improved overall performance.

In the Nigerian context, an analysis of the transportation costs incurred by Nigeria Breweries Plc, situated in Ibadan, Oyo State was carried out by Olayiwola et al. (2022). The study focused on the relationship between the quantity of products demanded at different depots and the manufacturing capacity of the company. In considering five different starting points, namely; Ibadan, Osogbo, Ikeja, Oyo, and Ondo, the transportation of goods to twelve different destinations or warehouses, (Gbagi, Dugbe, Oje, Ikorodu, Mowe, Ife, Ilesa, Iseyin, Ogbomosho, Owode, Akure, and Ore) was examined. The analysis utilized both the North-West corner method and the Vogel Approximation Method to optimize transportation logistics. Additionally, a separate study conducted showcased the application of linear programming in solving transportation problems for products of Lubcon Limited. The study applied the simplex method, utilizing data extracted from the company's records concerning five distinct products and six district offices.

Overall, the literature on minimizing transportation costs using linear programming demonstrates its effectiveness in optimizing transportation logistics for various industries. By considering factors such as distances, capacities, demand fluctuations, and delivery frequencies, decision-makers can make informed choices on how to allocate resources and manage transportation routes efficiently. Through the application of linear programming techniques, transportation costs can be significantly reduced, increasing profitability and overall efficiency. As businesses and organizations continue to face the challenges of managing transportation logistics, utilizing linear programming can be a valuable tool in achieving cost-effective solutions.

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Linear programming has emerged as an effective tool for minimizing transportation costs. The literature review highlighted the significance of employing linear programming models to optimize transportation operations and reduce expenses in supply chain management. While existing research has provided valuable insights and techniques, ongoing advancements in algorithms and technological capabilities offer promising opportunities to further enhance the efficiency and cost-effectiveness of transportation networks. Continued research in this field will contribute to better decision-making, increased sustainability, and improved profitability in the transportation sector. This paper aimed at obtaining the minimum cost of transporting the products of Dangote Cement, Port Harcourt from the depots to some national distributors. The research modeled the distribution of Dangote Cement products as a transportation problem and obtained the minimum possible transportation cost. The secondary data obtained from the field survey contained the unit cost (in Naira) of transporting their products per bag from their various sources to various destinations as at October, 2023. Also, the data obtained from Dangote Cement National Consumer Promotion 2020 (Redemption Centres Detail) contained the list of eleven national distributors in Port Harcourt, however, only six of the national distributors were used in this research. The three depots (sources) are: Onne, Rumuodumaya and Trans Amadi while the six national distributors (destinations) are: Aluu, Bori, Elelewon, Omagwa, Oyigbo and Rumuola. The data set encompasses the specific needs at every destination and the available capacity at each source.

METHODOLOGY

Network Representation of Transportation Problem

In the network representation of transportation problems, a source or a destination is represented by a node while the route through which the commodity is transported is represented by an arc. A transportation problem of m sources and n destinations with X_{ij} units are transported from source i to destination j at a unit at a unit of transportation cost of C_{ij} is shown below.

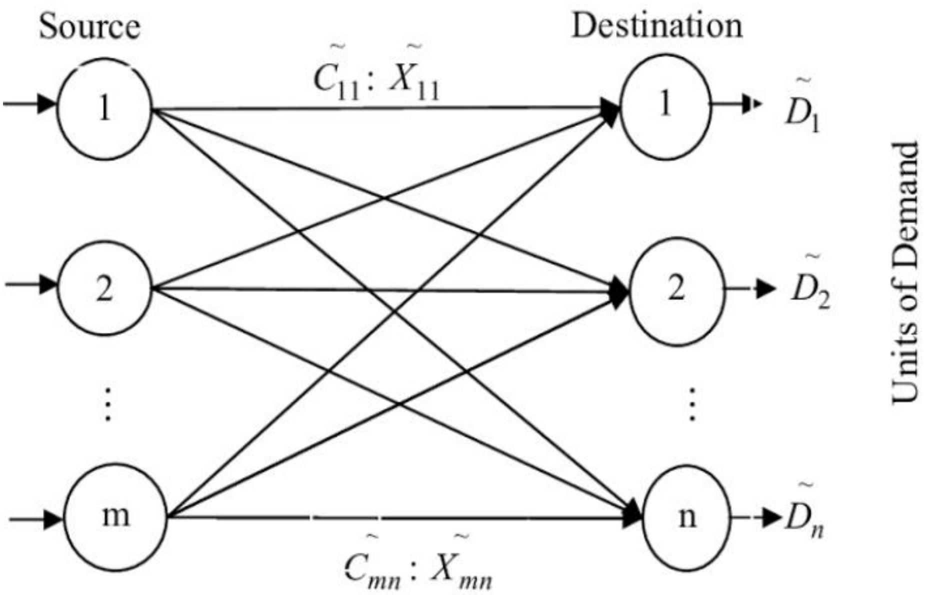

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Figure 1: Network Representation of Transportation Problem

Here a_i is the quantity of the commodity available at source i while b_i is the demand at destination j $(i = 1, 2, \ldots, m: j = 1, 2, \ldots, n)$.

Linear Programming Representation of Transportation problem

Let X_{ij} be the quantity of the commodity transported from source i to destination j. Let C_{ij} be the unit transportation cost from source i to destination j with the quantity available at source i being a_i while the demand at destination j is b_j. the linear programming presentation of this transportation problem is;

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

Subject to

$$\sum_{j=1}^{n} X_{ij} \le a_i, \qquad i = 1,2, \ldots, m \qquad (3.1)$$

$$\sum_{j=1}^{n} X_{ij} \ge b_j, \qquad j = 1,2, \ldots, n$$

$$X_{ij} \ge 0 \qquad \forall\, i, j$$

The first constraint means that the total quantity transported from source i cannot exceed supply while the second constraint means that the total quantity transported to destination j must satisfy demand.

Excluding the non-negative constraints $(X_{ij} \ge 0)$, the total number of constraints is $(m + n)$. (Inyama, 2007)

Balanced (Standard) Transportation Problem

The demand at the destinations can be met if and only if the total quantity at the sources is at least equal to the total demands, that is

$$\sum_{i=1}^{m} a_i \ge \sum_{j=1}^{n} b_j$$

when the total supply equals the total demand, that is

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

it yields what is called standard or balanced transportation problem. In this case all constraints would become equations. This will result in the following;

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

Subject to:

$$\sum_{j=1}^{n} X_{ij} = a_i, \qquad i = 1,2, \dots, m \qquad (3.2)$$

$$\sum_{j=1}^{n} X_{ij} = b_j, \qquad j = 1,2, \dots, n$$

$$X_{ij} \geq 0$$

The method of solving transportation problems called the Transportation Technique demands that a Transportation problem should be a standard or balanced form. This means that any Transportation problem that is not standard (where the supplies and demands are not equal) must be converted to a standard (balanced) Transportation problem. This is achieved by the use of a dummy source (warehouse) or dummy destination (market) (Inyama, 2007).

Table 1: Data on supply from depots (sources) in bags

Source	**Supply**
Onne	1250
Rumuodumaya	1750
Trans Amadi	2000

Source: Field Survey

Table 2: Data on demands from major distributors (destination) in bags

Destination	Aluu	Bori	Elelewon	Omagwa	Oyigbo	Rumuola
Demand	950	350	800	1250	1000	650

Source: Field Survey

Table 3: Average transportation cost (₦) per bag of cement

Sources (Depots)	**Destinations (National Distributors)**						**Supply**
	Aluu	**Bori**	**Elelewon**	**Omagwa**	**Oyigbo**	**Rumuola**	
Onne	145	60	85	150	125	120	1250
Rumuodumaya	65	170	95	75	120	70	1750
Trans Amadi	100	155	50	110	70	55	2000
Demand	950	350	800	1250	1000	650	

Source: *Field Survey*

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DATA ANALYSIS

The workable transportation expenses are determined through the following methodologies (as seen in Inyama, 2007).

1. North-West Corner Method

2. Least Cost Method

3. Vogel Approximation Method

North-West Corner Method (NWCM)

This method starts from the North-West corner of the transportation tableau that is as follows;

Step 1: Allocate the minimum amount allowable by the supply and demand to the variable X_{ij} that is occupying the North-West corner position in the transportation tableau. That is $X_{ij} = min\ (a_j, b_j)$.

Step 2: Eliminate the rows or columns that meet the criteria for satisfaction, indicating that all the remaining variables within the crossed-out row or column are zero. In cases where both a row and a column meet the satisfaction conditions simultaneously, it is necessary to choose and cross out only one of them.

Step 3: Modify the quantities of supply and demand for all rows and columns that have not been eliminated. In this adjustment, we allocate the minimum possible quantity to the first uneliminated element found in the new column or row, following the procedure discussed in step 1.

Step 4: The procedure is carried on until either all rows and columns have been eliminated or there remains just a single uncrossed-out row or column.

Least Cost Method (LCM)

The approach distinguishes itself from the North-West-Corner method solely in how it picks the next basic variables. In this method, the basic variable is selected based on the minimum unit cost within the transportation tableau.

Vogel's Approximately Method (VAM)

The basic step involved in this method are:

Step1: In the transportation tableau, analyze each row and pinpoint the lowest and the next lowest costs. Calculate the difference between these two values for every row, which is referred to as penalties. Additionally, calculate the penalties for each column.

Step 2: Determine the row or column with the most substantial penalty from among all the rows and columns. Within the chosen row or column, find the cell with the smallest cost, and allocate as many units as feasible to that particular cell.

Step 3: Decrease the available supply in the row and the demand in the column by the quantity of units allocated to the selected cell. Cross out the respective row's supply or column's demand

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once they have been satisfied. In cases where both a row and a column are satisfied at the same time, only one of them should be eliminated, and the remaining row or column is set to zero supply or demand. Rows or columns with zero supply or demand should be excluded from the penalty calculations.

Step 4: Recalculate the penalties for rows and columns, as previously explained in step 1. Then, proceed to step 2. Repeat this process until all the necessary conditions, including supplies and demands, have been fulfilled.

RESULTS/FINDINGS

Table 4: Allocation for the North-West Corner Solution

Sources (Depots)	Destinations (National Distributors)						Supply
	Aluu	Bori	Elelewon	Omagwa	Oyigbo	Rumuola	
Onne	(950) 145	(300) 60	85	150	125	120	1250
Rumuodumaya	65	(50) 170	(800) 95	(900) 75	120	70	1750
Trans Amadi	100	155	50	(350) 110	(1000) 70	(650) 55	2000
Demand	950	350	800	1250	1000	650	

NOTE: The allocations are in brackets

It is observed that this result in (m + n – 1) = (3 + 6 – 1) = 8

The basic feasible solutions to the transportation problem are;

$X_{11} = 145$, $X_{21} = 300$, $X_{22} = 170$, $X_{23} = 95$, $X_{24} = 75$, $X_{34} = 110$, $X_{35} = 70$, $X_{36} = 55$.

The total transportation cost for North-West Corner Method

= 145(950) + 60(300) + 170(50) + 95(800) + 75(900) + 110(350) + 70(1000) + 55(650)

= 137750 + 18000 + 8500 + 76000 + 67500 + 38500 + 70000 + 35750

= ₦452,000

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Table 5: Allocation for Least Cost Solution

Source (Depots)	Destinations (National Distributors)						Supply
	Aluu	Bori	Elelewon	Omagwa	Oyigbo	Rumuola	
Onne	145	(350) 60	85	(450) 150	(450) 125	120	1250
Rumuodumaya	(950) 65	170	95	(800) 75	120	70	1750
Trans Amadi	100	155	(800) 50	110	(550) 70	(650) 55	2000
Demand	950	350	800	1250	1000	650	

NOTE: The allocations are in brackets

It is observed that this result in (m + n – 1) = (3 + 6 – 1) = 8

The basic feasible solutions to the transportation problem are;

$X_{12} = 60$, $X_{14} = 150$, $X_{15} = 125$, $X_{21} = 65$, $X_{24} = 75$, $X_{33} = 50$, $X_{35} = 70$, $X_{36} = 55$.

The total transportation cost for Least Cost Method

= 60(350) + 150(450) + 125(450) + 65(950) + 75(800) + 50(800) + 70(550) + 55(650)

= 21000 + 67500 + 56250 + 61750 + 60000 + 40000 + 38500 + 35750

= ₦380,750

Table 6: Allocation for Vogel Approximation Solution

Sources (Depots)	Destinations (National Distributors)						Supply
	Aluu	Bori	Elelewon	Omagwa	Oyigbo	Rumuola	
Onne	(100) 145	(350) 60	(800) 85	150	125	120	1250
Rumuodumaya	(500) 65	170	95	(1250) 75	120	70	1750
Trans Amadi	(350) 100	155	50	110	(1000) 70	(650) 55	2000
Demand	950	350	800	1250	1000	650	

NOTE: The Note: The allocations are in brackets

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Observe that this result in (m + n – 1) = (3 + 6 – 1) = 8

The basic feasible solutions to the transportation problem are;

$X_{11} = 145$, $X_{12} = 60$, $X_{13} = 85$, $X_{21} = 65$, $X_{24} = 75$, $X_{31} = 100$, $X_{35} = 70$, $X_{36} = 55$.

The total transportation cost for Vogel Approximation Method

= 145(100) + 60(350) + 85(800) + 65(500) + 75(1250) + 100(350) + 70(1000) + 55(650)

= 14500 + 21000 + 68000 + 32500 + 93750 + 35000 + 70000 + 35750

= ₦370,500

DISCUSSION OF FINDINGS

The analysis yielded different transportation cost figures. The North West Corner Method resulted in a cost of ₦452,000, the Least Cost Method produced a total transportation cost of ₦380,750, and the Vogel Approximation method delivered the lowest cost at ₦370,500. Consequently, the minimal transportation cost, as per the Vogel Approximation Method, was determined to be ₦370,500. These findings suggest that by following the allocation provided by the Vogel Approximation Method, the management of Dangote Cement in Port Harcourt can effectively minimize their transportation expenses.

In light of the insights gained from the data analysis, this study therefore proposes the following in order to lower transportation costs, ultimately contributing to the goal of maximizing profits;

Assuming the transportation costs outlined in this dataset remain applicable, the leadership at Dangote Cement in Port Harcourt should consider the following actions:

- Allocate 100 units from Onne to Aluu;
- Allocate 350 units from Onne to Bori;
- Allocate 800 units from Onne to Elelewon;
- Allocate 500 units from Rumuodumaya to Aluu;
- Allocate 1250 units from Rumuodumaya to Omagwa;
- Allocate 350 units from Trans Amadi to Allu;
- Allocate 1000 units from Trans Amadi to Oyigbo;
- Allocate 650 units from Trans Amadi to Runuola.

In order to achieve the minimized transportation cost of ₦370,500.

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CONCLUSION

Linear programming is a pivotal tool in Operations Research. The transportation problem which is part of linear programming plays a significant role in our day to day lives. There is always the need for the movement and distribution of resources from one location to another. The transportation model becomes a viable tool especially when it has to do with logistics. This study focused on reducing the transportation expenses for Dangote Cement in Port Harcourt, encompassing shipments from different origins to diverse destinations. The secondary data, collected through field surveys, includes the cost per bag (in Naira) for transporting these products from various sources to different destinations, reflecting the conditions as at October 2023. Also, the data obtained from Dangote Cement National Consumer Promotion 2020 (Redemption Centres Detail) contained the list of some national distributors in Port Harcourt. The three depots (source) from where products were moved to the six national distributors (destinations) are: Onne, Rumuodumaya and Trans Amadi while the six national distributors (destinations) are: Aluu, Bori, Elelewon, Omagwa, Oyigbo and Rumuola. The dataset also encompassed the demand at each destination and the capacity of each source. To establish the initial workable solution, three methods were utilized: the North West Corner Method, the Least Cost Method, and the Vogel Approximation Method with the Vogel Approximation Method yielding the minimal cost.

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