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Optimizing Palm Oil Production Scheduling In Nigeria Using Balanced Transportation Problem

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Abstract:
This paper deal with optimizing palm oil production of a production firm in Nigeria using balanced Transportation problem in other to reduce or increase/ minimize the production cost and increase or maximize production, profit and efficiency. Here the scheduling challemnge is developed and modeled as a balanced of transportation problem as requires in creation of an optimum production schedule. This resulted in allocating optimal and maximum production level such that the given demand were meet at a minimum cost .
Keywords: *Optimal, Scheduling, Production, Maximize, Minimize, Transportation*

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I. Introduction

Production firm is a crucial and main sector of the economy which encompases of production planning as an essential aspect of business operations.According to Guo et al., (2021),planning involves the coordination of various activities, such as material procurement, production scheduling and delivery of finished goods and product to satisfy customer demands to maximize the production efficiency and minimize the costs of production.

According to Aldino and Ulfa, (2021) production industry produce distinct, separate products through a series of processes and operations, often involves assembly and fabrication These industries are characterized by the production of a limited range of prod-ucts, each of which has a unique set of requirements and specifications .

At every financial and fiscal year. It is necessary and important for any production firms to prepares their annual budget and production plan or schedules at the every financial period such that quantity of goods to be produced in each period of such financial year will be discussed in detailed depending on the products schedule or plans of the firm.

According to Grant(1973) production scheduling is critical procedure to analyze an existing production scheduling systems and establish ways and methods of improving on it.

Rayamajhee et al.,(2022), emphasis on many technical production challenges such poor quality, long lead times, high on-hand inventory, supply chain interruptions, quality problems,output problem and costing problems always hindered efficient productions in any given company

Lodre and Norman (2006) studied and advanced scheduling systems that rely on sophisticated algorithms. From their studies, both production schedulers, planner, engineers, and researchers were assisted to understand the true nature of production scheduling in dynamic production systems and encourage them to apply production scheduling systems in all their undertakings while emphasis and demonstrate its timeless importance.

Pfund and Scortt(2006) considered human performance limitations and personnel well-being in relation to scheduling personnel with the aims of optimizing system performance and emphasing on work as rest scheduling, job rotation, cross-training, and task learning and forgetting where they describe mathematical models and discuss the best of its applications.

Hermman(2006) studied and discussed production scheduling with dispatch on the most complex manufacturing environments-wafer fabrication facilities. The author considered the deterministic scheduling approach and presents a review of deterministic scheduling in a recent dispatching approacher and describe wafer fabrication and its operations which resulted on a survey of semiconductor manufacturer focus on the current state of the practice and future needs.

The author emphasis on the available production resources over time to best satisfy some criteria such as quality of goods, delivery time, demand and supply is well encompasses in production scheduling. The efficient allocation of resources at a given period to satisfy and meet some set criteria such that the plan to allocates the optimal production level and the resources required to meet a given particular demand at a minimum cost in an optimal production schedule is known as production schedule In this paper we develop some mathematical techniques to solve the transportation problem using Python Pulp Libraryn software.to optimize the production schedules of a palm oil company using the Transportation Techniques

II. Formulation Of Mmathematical Equations

Here we let our palm oil production problem be inform of a single product, which can be stored or supplied where both the production and the storage cost are well known. The addition of total cost of each unit of production and the cost of storage which is the cost of keeping or 9carrying a unit of good in a period such as insurance cost, cost of spoilage, theft and security cost, taxes level on the commodity is hereby referred to as the total cost of production

In forming our Mathematical model, we considered the following cogent assumptions:

i. Productin and Demand are fixed
ii. Transportation cost ate linear and constant
iii. Product are heterogenous
iv. Production and Demand points are mutually exclusive

In this case we consider the time and period of production since the goods is periodically produced and we modelled our production problem as a balanced transportation problem .

We let $p_1 p_2 \ldots\ldots\ldots p_n$ be the production sources and $z_1, z_2 \ldots\ldots\ldots z_n$ be the destination to be transported the goods to such that the product or good t_1 from the source p_1 is supplied at time i and d be good demanded or kept in store Z_i

In this case, we try to find the production pattern or schedule that satisfy all the consumers' demands at a bearable or minimum total cost so that all constraints of production capacity and demands were satisfied.

We let the production cost of a unit product at time i and total storage cost j be y_{ij} and we assume that the total number produced in time t be denoted by u_{ij} in the production source p_i and allocated or transported at time j to Z_n such that $\forall_{i,j} \geq 0$ such that $i = 1, 2\ldots.\mathrm{m}$, $j = 1, 2\ldots.n$

Hence,

We let p_i be the total quatity of good produced at each i be

$$\sum_{j=1}^{n} x_{i,j} \qquad (1)$$

For any set m of good produced and supply at points p_i from which a unit of the product is produced is given as:

$$\sum_{j=1}^{n} x_{i,j} \leq a_i, \forall i = 1, 2\ldots\ldots..m \qquad (2)$$

For any set of d demand points to which the products are allocated at the demand points z_n receives p_i units of the transported goods, then we have:

$$\sum_{j=1}^{n} x_{i,j} \leq d_{ij}, \forall_j = 1, 2\ldots\ldots..n \qquad (3)$$

Thus the total cost of production is giving as:

$$\sum_{ji=1}^{m}\sum_{j=1}^{n} c_{i.j} x_{i.j} \qquad (4)$$

Then, we determine the amount of goods allocated from production source to a destination such that the total production costs are minimized by applying the linear programming model given below:

$$Minimize\, P : \sum_{ji=1}^{m}\sum_{j=1}^{n} c_{i.j} b_{i.j} \qquad (5)$$

Subject to:

$$\left.\begin{aligned} &\sum_{j=1}^{n} x_{i,j} \le a_i, \forall i = 1,2,3........m \\ &\sum_{j=1}^{n} x_{i,j} \le d_{ij}, \forall_j = 1,2,3........n \\ &x_0 \ge 0 \quad j = 1,2,3......n \qquad i = 1,2,3........m \end{aligned}\right\} \qquad (6)$$

Where m and n is the supply and demand constraints respectively.

Since negative values for any $x_{i.j}$ have no physical meaning then then non-negativity condition $x_0 \ge 0$ is inclusive

The Modified Distribution Method (MODI): The Modified Distribution Method (MODI was applied to solve the above given equation. In this case,we consider the initial Basic Feasible solution (IBFS) by applying either the Northwest corner rule, Vogel's approximation method or the least cost method in solving the given problem and then implement our IBFS and the MODI by the Phyton Pulp Librarysoftware which helps in obtaining the optimal production solution as established by the following theorem.

Theorem:

Given a basic feasible solution containing $(m + n - 1)$ independent positive allocations with a set of arbitrary numbers u_i and v_j $(j = 1,2...n; i = 1,2....m)$ such that $C_n = u_i + v_j$ for all basic variables, then the evaluation corresponding to each non-basic variable (i, j) is given by $\bar{c}_{i,j} = c_{i,j} - (u_i + v_j)$

Proof:

From the above giving theorem

We let:

$$\sum_{ji=1}^{m}\sum_{j=1}^{n} c_{i.j} x_{i.j} = f \qquad (7)$$

$$\left.\begin{aligned} &\sum_{j=1}^{n} x_{i,j} \le a_i, \forall i = 1,2.,3.........m \\ &\sum_{j=1}^{n} x_{i,j} \le d_{ij}, \forall_j = 1,2,3..........n \end{aligned}\right\} \qquad (8)$$

From the equation (8) we multiply the i^{th} row by u_i and the j^{th} by v_j (u_i, v_j) arbitrary multipliers and constants are called simplex multiplier to obtain equation (9) below:

$$\left.\begin{aligned} \sum_{j=1}^{n} u_i x_j \le \sum_{i=1}^{m} u_1 a_1 \\ \sum_{j=1}^{n} v_i x_j \ge \sum_{i=1}^{m} v_1 d_j \end{aligned}\right\} \quad 9$$

We subtract each resultant equations (9) from the objective function equation (7) to obtain the modified objective function a shown in equation (10) below

$$\left.\begin{aligned} \sum_{i=1}^{m}\sum_{j=1}^{n} c_{i,} x_j - \sum_{j-1}^{n} u_i x_j - \sum_{i=1}^{n} v_j x_j - f - \sum_{i=1}^{m} a_i u_i - \sum_{j=1}^{n} d_j x_j \\ \sum_{i=1}^{m}\sum_{j=1}^{n} (c_{i,j} - u_i - v_j) x_{ij} = f - \sum_{i=1}^{n} a_i u_j - \sum_{j=1}^{m} d_j v_j \end{aligned}\right\} \quad (10)$$

This equation (10) can be written as:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij} = f - f_0 \quad (11)$$

Where

$$\left.\begin{aligned} \bar{c}_{ij} = c_{ij} - u_i - v \\ f_0 - \sum_{j=1}^{n} a_i u_i + \sum_{j=1}^{m} d_j v_j \end{aligned}\right\} \quad (12)$$

Since the relative cost coefficient $\bar{c}_{ij}$ corresponding to the basic variables (occupied the cells) have to be zero, we select u_i and v_j such that: $\bar{c}_{i,j} = c_{i,j} - u_i - v_j = 0$ for basis x_{ij}

Suppose equation (7) and (8) represent $(m+n)$ equations; totally $(m+n)$ arbitrary multipliers are to be defined. However only $(m+n+1)$ constraint equations are independent and so any one of the equation . (7) and (8) can be taken as redundant. Since redundant equations really do not exist, their arbitrary multiplier also does not exist. Hence, we have a total of $m+n+1$ arbitrary multipliers to determine. As the choice of the redundant equation is immaterial, we can set any one of the u_i 's or any one of the v_j 's to zero.

Once the multipliers u_i and v_j are determined, the relative cost coefficients corresponding to the non-basic variables (unoccupied cells) can be determined easily from equation (9) as proposed by (Amponsah, 2009).

Optimality Test:

Here we adopt the following procedures and step to test for optimality.

Step i: Llet IBFS with $(m+n+1)$ allocations be in independent cells.

Step ii: Determine a set of $(m+n+1)$ number $u_i(i = 1, 2.......m)$ and $v_i(j = 1, 2.......n)$ such that each occupied cells $(r,s) c_n = u_i + v_j$

Step iii: We calculate cell unit cost difference $\bar{c}_{ij}$ for ach empty cell (i, j) by using the formula $\bar{c}_{ij} = c_{i,j} - (u_i + v_j)$

Step iv:Examine the matrix of cell evaluation $\bar{c}_{ij}$ for negative entries and conclude as follows:

- If all $\bar{c}_{ij} > 0$ it implies the solution is optimal and unique
- If all $\bar{c}_{ij} \geq 0$ with at least one $\bar{c}_{ij} = 0$ it implies the solution is optimal and alternates
- If at least one $\bar{c}_{ij} < 0$ implies the solution is not optimal.

Data Collection and Analysis

Table 1 below contains the production and demamand capacity for the year 2020 .The cost per capacity and unit of the product of a barrel of palm oil ($15)and the unit cost of storage of ($2) were also given in each production period as obtained from a palm oil production firm in Nigeria as shown in table 1 below

Table1: Production and demand capacity of the palm oil production firm per barrel

Month	Demand capacity	Cost/ Production ($)	Storage cost/ production ($2)	Cost per unit of product ($)	Supply capacity
January	35000	15	-	15	35000
February	34700	15	2	17	34600
March	36200	15	2	19	36200
April	34750	15	2	21	34450
May	33400	15	2	23	33400
June	30600	15	2	25	30600
July	17800	15	2	27	17800
August	36850	15	2	29	36850
September	38300	15	2	31	38200
October	39400	15	2	33	39400
November	36450	15	2	35	35450
December	43400	15	2	37	43400
Total					

Table 2 below shows the production per hubs or plants, demamand point and demand capacity with the total cost of production in each production hurbs and supply capacity for the year 2020 extracted from table 1 above

Month	**Production Hubs/Plant**	**Demand point**	**Demand capacity(Barel)**	**Cost/unit produced($)**	**Supply Capacity**
Jan	Hub1	D1	35000	15	35000
Feb	Hub1	D2	34700	17	34600
Mar	Hub1	D3	36200	19	36200
Apr	Hub2	D1	34750	21	34450
May	Hub2	D2	33400	23	33400
Jun	Hub2	D3	30600	25	30600
Jul	Hub3	D1	17800	27	17800
Aug	Hub3	D2	36850	29	36850
Sep	Hub3	D3	38300	31	38200
Oct	Hub4	D1	39400	33	39400
Nov	Hub4	D2	36450	35	35450
Dec	Hub4	D3	43400	37	43400

Table 3 below shows the restructured and summarized palm oil production per hurbs from the firm in table 2 above as follows:

Hubs	**D1**	**D2**	**D3**	**Supply Capacity/barrel**
Hub 1	15 (35,000)	17 (34,700)	19 (36,200)	105,900
Hub 2	21 (34,750)	23 (33,400)	25 (30,600)	98,750

Hub 3	27 (17,800)	29 (36,850)	31 (38,300)	92,950
Hub 4	33 (39,400)	35 (36,450)	37 (43,400)	119,250
Dd Capacity/Barel	**126,930**	**141,420**	**148,500**	**416, 950**

Formulation of the Production Scheduling

Here we takes into account the unit cost of production plus the storage cost $C_{i,j}$, the supply a_i at source P_i and the demand d_j at destination for all $i.j \in (1, 2......12)$

Thus

We Minimize: $Y = \sum_{ji=1}^{m}\sum_{j=1}^{n} c_{i.j} x_{i.j}$

Subject to:

$$\left.\begin{array}{l} \sum_{j=1}^{n} x_{i,j} \leq a_i, \forall i = 1,2........m \\ \sum_{j=1}^{n} x_{i,j} \leq d_{ij}, \forall_j = 1,2........n \end{array}\right\}$$

Where m and n are the supply and demand constraints respectively with aim to determine the amount of x_{ij} allocated from source p_i to a destination j such that total production cost is minimized in line with the following assumptions:

Model Assumptions

The following assumptions were consider in this reseach paper

i. Productin and Demand are fixed
ii. Transportation cost ate linear and constant
iii. Product are heterogenous
iv. Production and Demand points are mutually exclusive

Thus:

It was deduced and discovered that the formulation of the optimal palm oil production planning problema and the decision variable will be transported from the designated Hub to the associated Demand point as shown in table 4 bellow:

Table 4.below shows the production hurbs with demand and supply capacity

Decision variable	Hubs	Demand points	Demand capacity	Supply Capacity/barrel
x_{11}	H1	D1	35,000	**105,900**
x_{12}	H1	D2	36,200	
x_{13}	H1	D3	17,800	
x_{21}	H2	D1	34,750	**98,750**
x_{22}	H2	D2	33,400	
x_{23}	H2	D3	30,600	
x_{31}	H3	D1	17,800	**92,950**
x_{32}	H3	D2	36,850	
x_{33}	H3	D3	38,300	
x_{41}	H4	D1	39,400	**118,250**
x_{42}	H4	D2	36,450	
x_{43}	H4	D3	43,400	

	Total		**415, 350**

III. Formulation Of Objective Function

Here we minimize the total costs of production given by finding total cost of transporting each barel of oil palm from each production point i to demand point j) + (total cost of transporting each unit of palm oil barel from each production point i to demand point j) + (total cost of transporting each barel of palm oil from each production point i to demand point j) + (total cost of transporting each barel of palm oil from each production point i to demand point j

Thus:

$$Minimiz : Y = \sum_{ji=1}^{12}\sum_{j=1}^{12} c_{i.j}\, x_{i.j}$$

Subject to demand and production contraints given

$$Minumize : Y = \begin{Bmatrix} (d_{11}x_{11} + d_{12}x_{12} + d_{13}x_{13}) + (d_{21}x_{21} + d_{22}x_{22} + d_{23}x_{23}) + \\ (d_{31}x_{31} + d_{32}x_{32} + d_{33}x_{33}) + (d_{41}x_{41} + d_{42}x_{42} + d_{43}x_{43}) \end{Bmatrix}$$

This implies that:

$$Minumize : Y = \begin{Bmatrix} (15_{11}\, x_{11} + 17_{12}\, x_{12} + 19_{13}\, x_{13}) + (17_{21}\, x_{21} + 23_{22}\, x_{22} + 29_{23}\, x_{23}) + \\ (27_{31}\, x_{31} + 29_{32}\, x_{32} + 31_{33}\, x_{33}) + (33_{41}\, x_{41} + 35_{42}\, x_{42} + 37_{43}\, x_{43}) \end{Bmatrix}$$

Subject to:

(i) Demand Constraints satisfies each demand capacity at the demand point

$$X_{11} + X_{21} + X_{31} + X_{41} = 126{,}950$$
$$X_{12} + X_{22} + X_{32} + X_{42} = 141{,}400$$
$$X_{13} + X_{23} + X_{33} + X_{43} = 148{,}500$$

(ii) Production Constraints:This satisfy the production capacities in each production Hubs

$$X_{11} + X_{12} + X_{13} \le 105{,}900$$
$$X_{12} + X_{22} + X_{23} \le 98{,}750$$
$$X_{31} + X_{32} + X_{33} \le 92{,}950$$
$$X_{41} + X_{42} + X_{43} \le 119{,}250$$

(iii) With the Non negativity constraints

$$x_{11}, x_{12}, x_{13}, x_{21}, x_{22}, x_{23}, x_{31}, x_{32}, x_{33}, x_{41}, x_{42}, x_{43} \ge 0$$

Hence:

The production problem is given as follows:

$$Minumize : Y = \begin{Bmatrix} (15_{11}\, x_{11} + 21_{12}\, x_{12} + 27_{13}\, x_{13}) + (17_{21}\, x_{21} + 23_{22}\, x_{22} + 29_{23}\, x_{23}) + \\ (19_{31}\, x_{31} + 25_{32}\, x_{32} + 31_{33}\, x_{33}) + (33_{41}\, x_{41} + 35_{42}\, x_{42} + 37_{43}\, x_{43}) \end{Bmatrix}$$

Subject to:

$$X_{11} + X_{21} + X_{31} + X_{41} = 145300$$
$$X_{12} + X_{22} + X_{32} + X_{42} = 135200$$
$$X_{13} + X_{23} + X_{33} + X_{43} = 136350$$
$$X_{11} + X_{12} + X_{13} \leq 105800$$
$$X_{12} + X_{22} + X_{23} \leq 98400$$
$$X_{31} + X_{32} + X_{33} \leq 92850$$
$$X_{41} + X_{42} + X_{43} \leq 118250$$
$$x_{11}, x_{12}, x_{13}, x_{21}, x_{22}, x_{23}, x_{31}, x_{32}, x_{33}, x_{41}, x_{42}, x_{43} \geq 0$$

Solution to the Problem

Here we apply the transportation problem to solve for the optimal production planning of a palm oil company in Nigeria using Python Pulp Library software using the secondary data collected as shown in table 1. We also employ the Modified Distribution (MODI) method to optimized the productin planning techniques in the context of production firms such as the palm oil production company in Nigeria by following the step below:

Steps in solving Transportatin Problem

Step i. Formulate the initial Basic Feasible solution using Vogel.s approximation technique
Step ii.Evaluate the initial Basic solution being formulated
Step iii.Check for optimality using Modified Distribution (MODI)
Step iv.Identify and implement MODI foe final implementation
Step v.Re evaluate and iterates to get optimal value
Step vi.Finalize ad determine optimal solution

Following the above steps and apply Pyton Pulp Library software,we had following results:

$$X_{11} = 0.0, X_{12} = 0.0, X_{13} = 105900$$
$$X_{21} = 126950.0, X_{22} = 56150.0, X_{23} = 42600.0X, _{31} = 0.0$$
$$X_{32} = 85250.0, X_{33} = 0.0X_{41} = 0.0, X_{42} = 0.0, X_{43} = 0.0$$

With minimum total cost of 9,506,750.0

Apply the Modified Distribution (MODI) method gives the following results.

$$X_{11} = 126850.0, X_{12} = 42600.0, X_{13} = 0.0$$
$$X_{21} = 0.0, X_{22} = 56150.0, X_{23} = 0.0, X_{31} = 0.0$$
$$X_{32} = 85250.0, X_{33} = 0.0, X_{41} = 0.0, X_{42} = 0.0, X_{43} = 0.0$$

With minimum total cost of 9,346,945.0

Feasibility checking

Here we test and verify the feasibility of the solution in other to ensure that total production matches the total good demanded and satisfied using the given Basic feasible solution method i.e $(m+n-1) = (4+3-1)$ to be the same as the number of demand and supply made such that it can be satisfy and verified:

Thus:

Total Demand is giving as:

$$(X_{11} + X_{21} + X_{31} + X_{41}) + (X_{12} + X_{22} + X_{32} + X_{42}) + (X_{13} + X_{23} + X_{33} + X_{43}) = 416950$$

(0 + 126950 + 0 + 0) + (0 +56150 + 85350 + 0) + (105900 + 42600 + 0+0) = 416950

And the Total Production

$$(X_{11} + X_{12} + X_{13}) + (X_{21} + X_{22} + X_{23}) + (X_{31} + X_{32} + X_{33}) + (X_{41} + X_{42} + X_{43}) = 416950$$

(0+ 0 +105900)+(126950+56150 42600) + (0 +85350 + 0) + (0+0+0) = 416950

While the Objective Function:

(15(0)+17(126950)+19(0))+(21(0)+23(0)+25(56150))+ (27(85350) + 29(0) + 31(105900)) + (33(42600) + 35(0.0) + 0.0)) = $9,805,000.00
This mean that it can be verified that all the demand and production capacity constraints are satisfied.

Sensitivity Analysis

We perform a sensitivity analysis to evaluating the robustness of the optimal production plan-ning decisions based on the transportation model by considering several factors that can influence the optimal solution obtained, and understand the sensitivity of the model to changes in these factors as essential for making best decisions.

The impact of a small perturbations in transportation costs were assessed. Each of the trans-porting cost values was changed(decreased and increased) by 5%, and 10% and the impacts on the total transportation cost and the optimal solution were analysed where it was observed that changes in the unit of production does not have significant changes in the optimal solution but changes linearly as the total production cost.

IV. Discussions Of Results

The given optimal solution represents the outcome of applying a transportation model for optimal production planning in a palm oil production firm in Nigeria

The minimum total cost of $9,346,945.is achieved through strategic decisions on the production of oil palm from production hurbs (H1, H2, H3, H4) to the specific demand points (D1, D2, D3) by considering the production costs, supply and demand constraints such that total production cost can be minimized as well as satisfying production and demand requirements.This optimal solution helps to enhanced operational efficiency, reduced costs of production, and improved overall production performance wher and provide a roadmap for decision-making in the production network.where the managers can make decisions about how much to produce at each production hurbs and how to satisfy the consumer demand at a bearable cost

The Sensitivity Analysis of the research reveal that a simple alterations in the unit of production exhibit minimal impact on the optimal solution and proportional changes in the total production cost.Meanwhile a small changes (1%) variation in both demand and production capacities significantly affect and influences the optimal solution and total production cost thereby gives the manager and the decision-makers in the oil palmproduction company a comprehensive understanding of the reliability and flexibility of the transportation model and helps making valuable adjustments to the production planning strategy by ensuring its effectiveness under various conditions and uncertainties.

V. Conclusion And Recommendation

Many production managers or production schedulers go through the process of creating optimum production schedules in an intuitive manner using little or no mathematics ideas which provides a more scientific way of obtaining the optimum schedule. The usage of the scheduling mathematical model to optimize a production schedule is important since production schedulers cannot rely on intuition alone.

The modelling of the production problem as a balanced transportation problem and its specialized methods of solution such as the Northwest corner rule, the least cost method and the Vogel's approximation method developed by Dantzig and Wolfe (1951), which are modifications of the parent simplex algorithm have proven worthwhile in obtaining the optimal solution

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