

# DEVELOPMENT OF A PRODUCT PRODUCTION RATE OPTIMIZATION MODEL USING BLOW FILM MOULDING MACHINE: A CASE STUDY OF THE BORNO STATE PLASTIC INDUSTRY (BOPLAST), MAIDUGURI

Abba-Aji, M.A.\*, Ibrahim, M.A. and Hammajam, A.A.

Department of Mechanical Engineering, University of Maiduguri, Borno State, Nigeria

\*Corresponding email: [birma4real2004@yahoo.com](mailto:birma4real2004@yahoo.com)

## ABSTRACT

*This study addresses the allocation problem of Borno Plastic Industry (BOPLAS), a plastic industry in Maiduguri, North-eastern Nigeria. The company employs Blow film moulding process; this is a high-speed production process to form plastic bottles and containers. The aim of the research is to develop an optimization model to maximize the company's profit. Linear programming was used to address the optimization problem. Data for model development were obtained through interactions with company personnel, verbal interviews, reviewing annual reports, and taking direct readings from the machine during operation. The simplex method was employed to formulate equations from the data obtained. MATLAB simulations was used to solve the equations and the value obtained from the objective function was 70.5146, with the production rate of 4, 569.6 units of PVC per month and 15, 716.88 units wash hand bowls per month yielding a profit margin of N2, 669,603 per month. The company is encouraged to adopt the developed model so that emphasis will be given to products that will generate more profit.*

**Key Words:** Linear Programming, Simplex Method, Blow Moulding

## 1 INTRODUCTION

The blow film moulding process is a pivotal method in plastic manufacturing industry that involves a series of intricate steps aimed at producing diverse plastic products. The process begins with the introduction of raw plastic material, often in the form of granules or pellets, into the hopper of the blow film moulding machine. This raw material is then heated until it reaches a molten state, forming a plasticized material ready for shaping. Subsequently, this molten plastic is extruded through a circular die, creating a continuous tube or bubble of plastic. The size of this bubble is controlled by various factors, including the speed of the extrusion process, air pressure, and the dimensions of the die. As the plastic bubble emerges, it is guided through a cooling process to solidify the material. The bubble is then flattened, creating a thin, continuous sheet of plastic film. This film can be further processed and shaped based on the specific requirements of the intended end product [1]. To optimize the production rates using the blow film moulding machine, the simplex method algorithm is employed. The simplex method is a mathematical technique used for linear programming, allowing for the maximization or minimization of an objective function while adhering to a set of linear equality and inequality constraints. In the context of this research, the simplex method is applied to formulate a model that optimizes production rates by adjusting variables such as machine settings and raw material properties. This algorithm aids in finding the most efficient combination of these variables to enhance productivity while considering the constraints imposed by the manufacturing process [2]. The fundamental challenges faced by Borno state plastic industry (BOPLAST) include fluctuating demand, uncertainties in raw material availability, variable energy costs, and the

dynamics of the workforce. These challenges have significant impact on the efficiency and economic viability of the plastic manufacturing process. To tackle these issues, this research aims to develop a comprehensive optimization model. To achieve this objective, MATLAB, a widely-used programming and numeric computing platform, has been employed as a tool for conducting independent price assessments and cost estimations. MATLAB is favoured by millions of engineers and scientists for its capabilities in data analysis, algorithm development, and the creation of costing models. In the course of the study, a production cost model was implemented to pinpoint specific expenses contributing to the organization's expenditure surpassing its revenue. This model not only identifies cost drivers but also assists the organization in devising strategies to curtail expenses [3]. The model's scope encompasses considerations for various elements such as production processes, machine capacities, labour availability, and market demand within the region. However, the effectiveness of the model is contingent upon the availability and accuracy of specific types of data and the assumptions made during its development. Jani [4] explains the role of optimization model as a mathematical representation of the system that aids in finding the best combination of input variables to achieve a specific objective. In the context of blow film moulding, an optimization model can help find the ideal combination of process parameters to achieve the highest production rate while meeting quality standards.

## **2 MATERIALS AND METHODS**

### **2.1 Materials and Equipment**

The raw materials used for the production of plastic product through blow film moulding by BOPLAST include: Recycled Materials obtained from sachet water nylon: This eco-friendly strategy not only promotes the reuse of resources but also significantly contributes to waste reduction within the state. Low-Density Polyethylene (LDPE): is a popular choice for blow film moulding due to its excellent flexibility and transparency. High-Density Polyethylene (HDPE): this material is known for its high tensile strength and chemical resistance. Polypropylene (PP): PP is a versatile material that can be used in blow film moulding to produce films with good clarity, strength, and chemical resistance. Stop Clock: Used for taking readings during the blowing, charging, and cooling phases of the plastic products. Modern Blow Film Moulding Machine Model 2000DH1: the machine is specifically designed for blow film moulding, ensuring precision and efficiency in the production process. Scale Balance: Utilized for accurately weighing the plastic products, ensuring consistency and quality control throughout the production cycle.

### **2.2 Methods**

#### *2.2.1 Research Design*

Following the international Organization for standardization (ISO 9001: 2008), a purposive sampling technique is employed in the participant's selection for interviews, ensuring representation from key roles within the production process, including machine operators, production managers, and quality control personnel. Additionally, a comprehensive review of historical production data has been conducted to form the quantitative analysis [5].

#### *2.2.2 Data Collection Methods*

Information regarding the cost of materials was obtained from the company's September 2023 report at BOPLAS, Nigeria. This data encompasses key financial aspects, including the selling price of finished products, initial costs of raw materials, overhead costs, power expenditures, and various fixed and variable costs. This information was gathered through verbal interviews with relevant participants of BOPLAST and direct machine readings, as duration of blow film, charge readings, cooling of plastic products.

### **2.3 Data Validation**

To ensure the accuracy of machine readings, cross-verification methods were employed, comparing direct readings with production records and operator feedback. Any discrepancies were addressed through additional checks and consultations with relevant personnel. Table 1 presents the bill of engineering

measurement and evaluation of products produced by BOPLAST using the blow film moulding machine, including associated quantities and the current selling price as per the company's report in September 2023. The demand for certain products listed in Table 1, which encompasses items produced at BOPLAST experiences periods of elevated demand throughout the preceding year. This cyclical pattern is recurrent. As a result, this study focuses on a short-term analysis spanning one month to capture and analyse these periodic fluctuations. The selected variables or products for a one-month analysis, based on market demand trends, are outlined below. These products were chosen with consideration for their measurements and recorded machine time during the process, excluding the use of a specific model. This approach aims to provide a clear examination of the factors influencing the production process over the specified timeframe.

Table 1. Bills of Engineering Measurements and Evaluation [6]

S/N	Products	Quantity (unit)	Current price (N)	Maximum rate (unit)
1	PP woven sack	500	160,000	2000
2	PVC pipe	1	3,700	120
3	Black shopping bag	1000	18,000	5000
4	Garden chair	1	8,500	120
5	Washing hand bowl	12	2,050	500
6	Armless chair	1	5,500	200
7	School desk	1	16,500	100
8	PP mat	1	4,000	100

## 2.4 Variables and Measurements

### 2.4.1 Key Variables

The key variables include (a) Polypropylene Woven Sack Production (PPWSP): The Company produce 4 bales (500 units in a bale and 40kg per bale) of Polypropylene woven sacks using blow film moulding process. (b) Garden Chair Production (GCP): The number of garden chairs produced through the blow film moulding machine is 120 units (2kg per unit). (c) Black shopping bag (BSB): The output of black shopping bags produced using the blow film moulding machine is 5 bales (1000 bags in a bale and 5.39kg per bale). (d) Polyvinyl chloride Pipe (PVCP): The quantity of PVC pipes manufactured through blow film moulding is 500 units (1.8 meters length). (e) Washing Hand Bowl Production (WHBP): The production volume of washing hand bowls produced in the blow film moulding process is 100 dozen (12 units in a dozen and 2.3kg per dozen).

### 2.4.2 Derived Variables

The derived variables include (a) Production Rate (PR): The rate at which products are manufactured per unit of time for each product are; 10,000 units (50 to 100kilograms) of each product per day. (b) Downtime Duration (DD): The cumulative time during which the blow film moulding machine is not operational was 4560 seconds. (c) Charge Time (CT): The time taken for the charge process, representing the introduction of raw materials into the machine was 70.3seconds. (d) Cooling Time (COT): The duration required for the cooling phase of the plastic products after the blow film moulding process was 94.2 seconds.

## 2.5 Measurement Tools

The measurement tools include (i) Direct machine readings: Sensors and monitoring systems were utilized for the collection of real-time data on production rates, downtime, charge and cooling times. (ii) Time tracking software: Stop clock was used in measuring time, such as duration of blowing, downtime duration, charge time, and cooling time. (iii) Weight Scales: Scale balance was used in measuring the weight of products. (iv) Counting System: Manual counting systems was implemented for accurate quantification of products, especially for items like chairs, desks, and bowls.

## 2.6 Historic Data Formulation

### 2.6.1 Raw Material Cost

In 2022, the cost of raw materials was 1,350,000 naira per ton. In September 2023, the cost increased to 1,950,000 naira per ton. The percentage increase as adopted from [6] is calculated as follows:

$$\text{Percentage increase} = \left( \frac{\text{new value} - \text{old value}}{\text{old value}} \right) \times 100 \quad (1)$$

The percentage increase is 44.44%, this means there was a 44.44% increase in the cost of raw materials from 2022 to September 2023. The production time is 4 hours per shift, and there are two shifts, making a total of 8 hours.

### 2.6.2 Labour Cost

The labour hours per shift is 8 hours. The monthly salary per worker is ₦30,000.

$$\text{Daily labour cost per worker} = \left( \frac{\text{monthly salary}}{\text{number of workdays in a month}} \right) \quad (2)$$

$$\text{Total labour cost per shift} = \text{number of workers per Shift} \times \text{Daily labor cost per worker} \times \text{number of shifts per Day} \quad (3)$$

$$\text{Total labour cost} = \text{Total labour cost per shift} \times \text{number of workdays in a month}$$

### 2.6.3 Maintenance Cost

The maintenance cost is reported to be 5% of the production cost, according to the company's report in September 2023. Similarly, the overhead cost is stated to be 10% of the production cost. Therefore, the maintenance cost can be calculated as 0.05 times the production cost and 0.10 times the production cost as the overhead cost [7].

$$\text{Production cost} = \text{cost of raw materials} + \text{cost of labour} + \text{overhead cost} + \text{power} \quad (4)$$

### 2.6.4 Power Consumption

In 2022, power consumption was 5% of production. In September 2023, due to an increase in fuel costs, power consumption is now 7% of production. Therefore, from equation 1, the percentage increase in power consumption is 40%. This means there was a 40% increase in power consumption from 2022 to September 2023. In the forthcoming one-month analysis, a comprehensive examination of the contribution to profit for each product was undertaken. This assessment aims to discern the financial impact of individual items, allowing for more understanding of their respective contributions. The products under consideration for this analysis include PP woven sack, PVC pipe, washing hand bowl, black shopping bag (BSB), and garden chair. To capture the essential details related to production constraints, specific parameters such as the duration of blowing, charge, and cooling were directly obtained from the machine as presented in the Table 2.

Table 2. Product and recorded machine time during process

Process time (sec)	Garden chairs	PP woven sack	PVC pipe	BSB	Washing hand bowl	Constraint (C)
Blowing	4	3	7	2	3	10
Charge	4	6	9	3	5	11
Cooling	6	6.6	11.5	5	5.7	12

## 2.7 Development of the Optimization Model

The objective is to maximize the total contribution to profit. The objective function is defined as:

$$Z = ax_1 + bx_2 + cx_3 + dx_4 + ex_5 \quad (5)$$

Subject to the following constraints;

$$\text{Blown: } \alpha_b x_1 + \beta_b x_2 + \gamma_b x_3 + \delta_b x_4 + \varepsilon_b x_5 \leq C_I \quad (6)$$

$$\text{Charge: } \alpha_c x_1 + \beta_c x_2 + \gamma_c x_3 + \delta_c x_4 + \varepsilon_c x_5 \leq C_{II} \quad (7)$$

$$\text{Cooling: } \alpha_G x_1 + \beta_G x_2 + \gamma_G x_3 + \delta_G x_4 + \varepsilon_G x_5 \leq C_{III} \quad (8)$$

Where  $x_1 x_2 x_3 x_4 x_5 \geq 0$  (*non – negativity constraint*) [7]. The decision variables are identified below: Let;  $x_1$  be the proportion of Garden chairs to be produced.  $x_2$  be the proportion of pp woven sack to be produced.  $x_3$  be the proportion of PVC pipe to be produced.  $x_4$  be the proportion of black shopping bag to be produced.  $x_5$  be the proportion of washing hand bowl to be produced. The constraints based on the duration of blowing (B), charge (C), and cooling (G) for each product. Let  $\alpha_b, \beta_b, \gamma_b, \delta_b, \varepsilon_b$  represent the respective durations for blowing,  $\alpha_c, \beta_c, \gamma_c, \delta_c, \varepsilon_c$  for charge, and  $\alpha_G, \beta_G, \gamma_G, \delta_G, \varepsilon_G$  for cooling.

$$\text{Blowing: } 4x_1 + 3x_2 + 7x_3 + 2x_4 + 3x_5 \leq CI \quad (9)$$

Here,  $CI$  represents the maximum available time for the Blowing process.

$$\text{Charge: } 4x_1 + 6x_2 + 9x_3 + 3x_4 + 5x_5 \leq C_{II} \quad (10)$$

Similarly,  $C_{II}$  represents the maximum available time for the Charge process.

$$\text{Cooling: } 6x_1 + 6.6x_2 + 11.5x_3 + 5x_4 + 5.7x_5 \leq C_{III} \quad (11)$$

Where  $C_{III}$  represents the maximum available time for the Cooling process.

## 2.8 Linear Programming Solution using MATLAB

The linear programming problem at hand, aimed at optimizing the production of various items subject to specific constraints, has been successfully solved using MATLAB. The problem involves maximizing the objective function  $Z = 6x_1 + 6.6x_2 + 11.5x_3 + 5x_4 + 5.7x_5$ , where  $x_1 x_2 x_3 x_4 x_5$  represent the production quantities of Garden chairs, PP woven sack, PVC Pipe, Black shopping bag (BSB), and Washing hand bowl, respectively. The constraints are determined by the durations of the Blowing, Charge, and Cooling processes for each item. The process times, represented by the coefficients in the constraints, are given for each item. The primary goal is to maximize profit while adhering to the time constraints for each process. Utilizing MATLAB's built-in linear programming function, "linprog", the following steps were undertaken. The coefficients of the objective function were defined in the MATLAB script as  $[-6; -6.6; -11.5; -5; -5.7]$ . The constraint coefficients and right-hand side values of the inequality constraints were organized into a matrix (A), and the right-hand side values were arranged into a vector (b). These coefficients and values correspond to the process times and available times for each process. MATLAB's linprog function was employed to solve the linear programming problem. The function returns the optimal solution (x), the optimal objective value (fval), the exit flag (exitflag), and additional output information. MATLAB's linprog function incorporates state-of-the-art optimization algorithms, including the simplex method, ensuring robust and reliable solutions. The solution vector 'x' satisfies the given linear constraints:

$$4x_1 + 3x_2 + 7x_3 + 2x_4 + 3x_5 = 10 \quad (12)$$

$$4x_1 + 6x_2 + 9x_3 + 3x_4 + 5x_5 = 11 \quad (13)$$

$$6x_1 + 6.6x_2 + 11.5x_3 + 5x_4 + 5.7x_5 = 12 \quad (14)$$

The obtained values for  $x_1, x_2, x_3, x_4, x_5$  optimize the objective function.

$$Z = 6x_1 + 6.6x_2 + 11.5x_3 + 5x_4 + 5.7x_5 = 12 \quad (15)$$

### 2.9 Difference in Sales Value (New - Initial)

The calculation below illustrates the difference in sales values between the new values and the initial values, considering the results obtained from the calculated sales values of PVC pipes and Washing Hand Bowls.

*New Total Sales Value of PVC pipes and washing hand bowls*

Therefore, the new total sales value can be obtained by adding the initial sales value to the difference in sales value: *New total sales = Initial total sales + Difference in sales*

*Gross Profit*

Gross profit is calculated as the difference between revenue (sales) and total costs of production: From the percentage increase in raw material cost (44.44%) and power consumption (40%) to the 2022 values [6], an estimate of the historic data for September 2023 can be obtained. *Estimated Raw Material Cost = 1,350,000 × (1 + 0.4444)* *Estimated Power Consumption = 5 × (1 + 0.4)*. Then, the estimated values along with the production time can be used to calculate the overall cost per ton.

### 2.10 Optimal monthly Production Quantity Calculations

The company operates 8 hours per day. In a month (24 working days), the total production time is:  $\frac{8\text{hours}}{\text{day}} \times \frac{24\text{days}}{\text{month}} = 192\text{hours/month}$ . The cycle time required to produce a single PVC Pipe is 30 seconds, while the production of one dozen Washing Hand Bowls takes 20 seconds. Given these cycle times obtained during machine operations, the optimal values derived from the MATLAB script will now be employed in the calculation of the production quantities for PVC Pipes and Washing Hand Bowls. The unit and monthly production of PVC and Wash hand bowls can be computed using equation 16 and 17 [9].

$$\text{Daily production} = \frac{60 \times 60 \times 8}{\text{cycle time} \times \text{unit production/day}} \quad (16)$$

$$\text{Monthly production} = \text{unit} \frac{\text{production}}{\text{day}} \times 24 \quad (17)$$

## 3 RESULTS AND DISCUSSION

After reviewing the derived variables considered for a one-month analysis, as outlined in section 2.4, the detailed measurements and recorded machine times is now presented in Table 3.

Table 3. Derived variables of products and recorded machine time during process

S/N	Products	Production rate (per day)	DD (sec.)	Charge (sec.)	time	Cooling time (sec.)
1	PP woven sack	2000 units	1200	10.2		16
2	PVC pipe	500 units	900	16.5		20
3	Black shopping bag	5000 units	300	7		8.2
4	Garden chair	120 units	1800	30.6		45
5	Washing hand bowl	1200 units	360	6		5

The blow film moulding machine's active production time was measured directly from the machine sensor, resulting in a rate of 85%. The proportion of defective products in relation to total production was 15%. Upon executing the MATLAB script with the linear programming problem, the following optimal solution and maximum profit were obtained: Optimal Solution:  $x_1 = 0.0001$  (Garden chairs),  $x_2 = 0.0000$  (PP woven sack),  $x_3 = 5.0418$  (PVC Pipe),  $x_4 = 0.0000$  (Black shopping bag),  $x_5 = 2.1989$  (Washing hand bowl). Optimal Objective Value:  $Z = 70.5146$ .

### 3.1 Analysis of Results

$x_1$ (Garden chairs) : A very small proportion.  $x_2$ (PP woven sack) : No production.  $x_3$ (PVC pipe) : A significant proportion.  $x_4$ (Black shopping back) : No production.  $x_5$ (Washing hand bowl): A moderate proportion. The Optimal solution prioritizes the production of PVC pipe( $x_3$ ) and Washing hand bowl ( $x_5$ ) while minimizing garden chairs ( $x_1$ ) and excluding PP Woven Sack ( $x_2$ ) and BSB( $x_4$ ). These values represent the proportions of each product to be produced for maximum profitability. Based on the data acquired from the BOPLAST industry, a comprehensive examination of sales and costs was conducted. This analysis involved a distinct effort to distinguish between variable costs and fixed costs. Subsequently, the profit statement for the month of September 2023 is presented in Table 4.

Table 4. Profit Statement for the Month of September 2023

N		
Revenue (sales);		6,080,000
Variable cost:		
Material	1,950,000	
Power	241,990	
Maintenance	202,250	
Overtime	100,000	
Total Variable cost		2,494,240
Fixed cost:		
Labour	1,507,000	
Courier service	6,000	
Communication	20,000	
Transportation	500,000	
Total fixed cost		2,033,000
Total cost		4,527,240
Gross profit		1,552,760

Table 5 presents the optimize production rates of PVC and WHB with monthly sales values

Table 5. Unit and monthly production rate of PVC and wash hand bowls (WHB) and sales value

S/No		Initial Prod Rate/Day (Units)	Initial Prod. Rate/Mont h (Units)	Final Prod. Rate/Day (Units)	Final Prod Rate/Month	Initial Sales Value/Unit (₦)	Initial Sales Value/Month (₦)	Final Sales Value/Unit (₦)	Final Sales Value/Month (₦)
1	PVC	150	3,600	190.4	4,569.6	3,700	2,049,600	3,700	16,907,520
2	WHB	500	12,000	654.87	15,716.88	170.8	2,049,600	170.8	2,684,443.10

The optimization efforts focused on the production of polyvinyl chloride (PVC) Pipes and Washing Hand Bowls have yielded substantial improvements in profitability when compared to the previous profit statement. Table 6 provides a detailed breakdown of the contribution to profit and the maximum production rate for both the optimized PVC Pipe and Washing Hand Bowl respectively, demonstrating positive impact of the optimization strategies on overall profitability.

Table 6. Contribution to Profit and Maximum Production Rate Comparison for one month

Product	Previous production rate (unit)	Max. production rate (unit)	Previous Profit (N)	Optimised production rate (unit)	Optimised Profit (N)
PVC pipe	3,600		1,055,876.80	4,569.60	3,587,520
W.H.B.	12,000		341,607.20	15,716.88	634,843.10

Note: W.H.B for washing hand bowl, max. for maximum.

Using the contribution to profit for the wash hand bowl and PVC, a new profit statement for the month of October is presented in Table 7. This detailed analysis shows the impact of optimizing production using the model on both quantity and revenue, resulting in a higher gross profit compared to the initial workflow without the model.

Table 7. New profit statement for the month of October using the model

N		
Revenue (sales);		8,749,603.10
Variable cost:		
Material	1,950,000	
Power	241,990	
Maintenance	202,250	
Overtime	100,000	
Total Variable cost		2,494,240
Fixed cost:		
Labour	1,507,000	
Courier service	6,000	
Communication	20,000	
Transportation	500,000	
Total fixed cost		2,033,000
Total cost		4,527,240
Total contribution:		
PVC pipe	3,587,520	
Washing hand bowl	634,843.10	
Gross profit		4,222,363.10

The optimal solution derived from the linear programming model prioritizes the production of polyvinyl chloride (PVC) pipes ( $x_3$ ) and washing hand bowls ( $x_5$ ), while minimizing the production of garden chairs ( $x_1$ ) and excluding PP Woven Sack ( $x_2$ ) and Black Shopping Bag ( $x_4$ ). This strategic allocation is carefully designed to maximize profitability. This result is in agreement with previous research work of Abba-Aji *et al.* [8]. Considering the operational context, BOPLAST industry operates for 8 hours per day, totalling 192 hours in a month (24 working days). The cycle time for producing one polyvinyl chloride (PVC) pipe is 30 seconds, and for one dozen washing hand bowls is 20 seconds. The profit statement for the month of October, utilizing the model, reports revenue (sales) and gross profit of ₦8,749,603.1 and ₦4,222,363.1, respectively. In comparison, the existing workflow without the model produces lower quantities and generates a gross profit of ₦1, 552,760 per month. The adoption of the linear programming model results in a substantial increase in both quantity and revenue, showcasing its effectiveness in maximizing profits. The results concord with the work of Krawjowski [9].

#### 4 CONCLUSIONS

In fulfilment of the primary aim to optimize the production rate in the plastic industry, the linear programming model developed for blown film moulding at BOPLAST has yielded significant insights and improvements. The model successfully allocated production resources, achieving an optimal solution that prioritizes polyvinyl chloride (PVC) pipes and washing hand bowls for maximum profitability. The optimal production plan minimizes garden chairs and excludes PP woven sacks and black shopping bags, aligning with the company's strategic objectives. The new profit statement, derived from the optimized production plan, projects a monthly revenue of ₦8, 749,603.1 and a gross profit of ₦4, 222,363.1. In comparison, the existing workflow without the model generates lower quantities and a gross profit of ₦1, 552,760 per month. The adoption of the linear programming model significantly enhances both quantity and revenue, demonstrating its effectiveness in maximizing profits. This demonstrates a considerable improvement over the initial workflow without the model and justifies why the company needs to emphasize the production of PVC pipes and wash hand bowls with regards to blow film moulding machine.

## REFERENCES

1. Laurence, W.M. (2017). the effects of creep and other time related factors on plastic and elastomers. *Chapter 2, a volume in plastics design library book. third edition. Science Direct*, pp. 41-60.
2. Ali, K.Y., Ahmed, K.J., Wanzuki, A.M., Mohammed, F.R., Najah, G. and Mo'ath, A. (2021). Simplex and Interior Point Methods for Solving Budgetary Allocation Linear Programming Problem as IR4.0 Strategy. *Journal of Theoretical and Applied Information Technology*, vol. 99, no. 22, pp. 5339-5350.
3. Amosun, S.T. and Muhammed, M.A. (2021). Optimization of the Production Capacity of a Manufacturing Company as Linear Programming Model. *Science and Technology Research*, vol. 4, no. 3, pp. 119-124.
4. Jani, S.P., Senthil, K.A., Adam, K.M. and Sujin, J.A. (2021). Design and Optimization of Unit Production Cost for Awj Process on Machining Hybrid Natural Fibre Composite Material. *International Journal of Lightweight Materials and Manufacture. Elsevier Science Direct*, vol. 4, no. 4, pp. 491-497.
5. Kendagor, J.R. (2021), Challenges that impede implementation of international Standard Organization (ISO) 900: 2008 In public organization in Kenya. *African Journal of Education Science and Technology*, vol. 6, no. 4, pp. 23-34.
6. Papka (2023). information retrieved from BOPLAST Checklist, Maiduguri.
7. Antonett, D.C. (2023). Study.com. Retrieved November Saturday, 2023, from <https://study.com/academy/lesson/production-costs-formula-examples.html>.
8. Abba-Aji, M., El-Jummah, A.M. and Ngala, G.M. (2009). Development of a product production rate optimization model. *Continental J. Engineering Sciences*, vol. 4 no. 2., pp. 26-31.
9. Krawjewski, J. (1987). Operations Management; Strategy and Analysis. *Addison-Wesley Publishing Company, Canada*, pp. 118-125.