Computer Simulation Models for Profit Maximisation in a Paint Production Company

Shadrack Mathew Uzoma, and Tobinson A. Briggs (corresponding author)

Abstract—Paint manufacturing is an advanced area of technology in the world. Necessarily paints are applied to any structure or body for a virtuous number of reasons; corrosion protection, aesthetic features to create attractive colours on buildings to protect it from environmental degradation and none the less to protect the bodies of automobiles, aircraft, and ships from ecological damage; also to give the right shades of colours catching to the eyes and minds of customers. In this research work, mathematical models developed by the researchers were employed to maximise the profit margin of a painting Company. The mathematical optimisation models are Linear Programming production demand-based planning models. It is geared towards maximising the profit of the establishment subject to a certain number of critical constraints. Lindo computer software was employed in the simulation to access the profitability index of the company subject to demand constraints. Revenue accruable from sales of the items produced was ten million and six hundred and twenty-seven thousand sixty-two naira and fifty-three kobo (N10, 627,062.53). The different cost inputs resulted in the expenditure of ten million and six hundred and ten thousand and six forty naira (N10, 610,640.00). The profit margin is sixteen thousand four hundred and twenty-two naira and fifty-three kobo (N16,422.53). Profit optimisation maximisation procedure using Lindo Computer Software resulted in a profit margin of twenty-nine thousand one hundred and ten naira (N29,110.00). The percentage difference in profit margin is 77.26%. The simulation profit optimisation results revealed a tremendous difference in turnover margin and called for an interaction with the Academy Color Paint Company for enhancement in the turnover margin of their establishment.

Index Terms—Paint Manufacturing, Planning Models, Profit Margin, Linear Programming, Maximizing Profit, Simulation.

I. INTRODUCTION

This work is a follow up the research titled: “Development of Optimization Models for The Productive Capacity of Paint Manufacturing Company To Maximize Profit” by Briggs & Shadrack [5]. Linear programming optimisation models developed by the researchers was simulated by a computational approach to determine the margin of profit accruable operating optimally [2]. Lindo computer software was employed in the simulation to access the profitability index of the company subject to the demand constraints equations in the developed linear programming models [5, 6].

The Academy, a colour paint company, manufactures three broad categories of paints, namely [5]:

(i) Emulsion paint
(ii) Texture paint
(iii) Gloss paint

The focus of this study deployed software in the application of the proposed model to maximise profit in the planning of the Paint Manufacturing Company production [3,4].

II. RESEARCH SIGNIFICANCE

The developed Linear Programming models are easy to handle type. The Lindo Computer Software employed in processing the operational data generated optimal maximal profit margin in a few iteration steps.

III. APPLICABLE MATHEMATICAL MODELS

There is different application model for the planning and optimisation of the production of paint, which is subject to the type of paint, quality of paint to be produced, and the available resources and time spend such as [5, 1]:

A. Production Planning: Programming Models

These models are applicable under the following operating conditions:

(a) Multiple items with independent demand
(b) Multiple shared resources
(c) Linear costs

The linear programming for production planning maximisation is expressed as [3, 5]:

\[ P = \text{Min} \sum_{i=1}^{I} \sum_{j=1}^{J} (q_{ij}P_{ij} + c_{ij}q_{ij}) \]  

\[ \text{Subject to:} \]

\[ q_{ij+1} + p_{ij} - q_{ij} = d_{ij} \]  

\[ \sum_{i=1}^{I} a_{ik}p_{ij} \leq b_{it} \]  

\[ p_{ij}q_{ij} \geq 0 \]  

Where,

\( p_{ij} \)—production of item i during time t
\( q_{ij} \)—inventory of item i at the end of time t
\( T, I, K \)—number of periods, items, resources respectively
\( a_{ik} \)—the amount of resource k required per unit production of item i
\( b_{it} \)—the amount of resource k available in time t
\( d_{it} \)—demand for item i in time t

Published on January 14, 2020.

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DOI: http://dx.doi.org/10.24018/ejers.2020.5.1.1679
B. Demand planning: Lost sales

The Linear Programming for lost sales due to unmet demands goes thus [5, 7]:

\[
P_2 = \text{Min } \sum_{i=1}^{n} \sum_{t=1}^{T} [p_{it}(d_{it} - u_{it}) - c_p a_{it} u_{it} - c_{q_{it}} q_{it} - c_{u_{it}} u_{it}]
\]  \(5\)

Subject to:

\[
q_{it,t-1} + p_{it} - q_{it} + u_{it} = d_{it}
\]  \(6\)

\[
\sum_{i=1}^{n} a_{ik} p_{ik} \leq b_{it}
\]  \(7\)

\[
p_{it} q_{it} u_{it} \geq 0
\]  \(8\)

Where,

\( u_{it} \)—unmet demand of item \( i \) during time \( t \)
\( r_{it} \) —unit revenue for item \( i \) in time \( t \)
\( c_{u_{it}} \) —unit cost not meeting order for an item \( i \) in time \( t \)

C. Demand planning: Backorders

Linear Programming models for a backorder or rescheduled demand is expressed as [5, 8]:

\[
P_1 = \text{Min } \sum_{i=1}^{n} \sum_{t=1}^{T} [c_p a_{it} p_{it} + c_{q_{it}} q_{it} + c_{v_{it}} v_{it}]
\]  \(9\)

Subject to:

\[
q_{it,t-1} - v_{it,t-1} + p_{it} - q_{it} + v_{it} = d_{it}
\]  \(10\)

\[
p_{it} q_{it} v_{it} \geq 0
\]  \(11\)

Where, 

\( v_{it} \)—backorder level for item \( i \) at the end of time \( t \)
\( c_{v_{it}} \)—the unit cost of backorder for item \( i \) in time \( t \)

Equation 1 to 11 was revoked from the work of Briggs and Shadrach in modeling formulation [5]. In formulating the linear programming models, the data in Tables I, II and III were considered [5].

| TABLE I: PRODUCTION DATA AND UNIT COST OF CONSTRAINTS INVOLVED [5] |
|---------------------------------|
| **Products** | **Variable Material Resources** | x1 | x2 | x3 | x4 | x5 | Unit Price | Maximum Available |
| Water (liters) | 135,000 | 69,000 | 0 | 0 | 105,000 | 1 | 300,000 |
| Titanium Oxide (kg) | 9810 | 8190 | 3192 | 1650 | 7140 | 15 | 30,000 |
| Calcium Carbonate (kg) | 128,304 | 59928 | 63360 | 2640 | 14976 | 10 | 264,000 |
| Binder Resin (kg) | 10,200 | 8,400 | 7,620 | 4,200 | 29,400 | 5 | 60,000 |
| Additives (kg) | 357 | 535.5 | 36 | 36 | 535.6 | 10 | 1,500 |
| Coloring Paste (kg) | 200 | 100 | 15 | 10 | 75 | 15 | 500 |
| Sand (kg) | 0 | 0 | 0 | 0 | 11,550 | 5 | 11,550 |
| Kerosene (liters) | 0 | 0 | 4,500 | 3,000 | 0 | 30 | 75,000 |
| Labor Hours per Product | 19,853 | 8824 | 3439 | 2293 | 1592 | 150 | 36,000 Hours/month |
| Pigment Coloring Material (kg) | 720 | 360 | 54 | 36 | 630 | 15 | |
| Demand for Products (liters) | 4,266 | 2442 | 1238 | 1419 | 842 | 15 | 600,000 |

| TABLE II: MATERIAL COSTING TABLE FOR THE VARIOUS EMULSION PAINT SPECIES [5] |
|---------------------------------|
| **Products** | **Variable Material Resources** | x1 | x2 | x3 | x4 | x5 | Unit Price | Maximum Available |
| Water (liters) | 135,000 | 69,000 | 0 | 0 | 105,000 | 1 | 300,000 |
| Titanium Oxide (kg) | 147,150 | 122,850 | 47,880 | 24,750 | 107,100 | 15 | 450,000 |
| Calcium Carbonate (kg) | 128,304 | 59928 | 63360 | 2640 | 749760 | 10 | 2,640,000 |
| Binder Resin (kg) | 51,000 | 42,000 | 38,100 | 21,000 | 147,000 | 5 | 300,000 |
| Additives (kg) | 3,570 | 5,355 | 360 | 360 | 5,535 | 10 | 1,500 |
| Coloring Paste (kg) | 3,000 | 1,500 | 225 | 150 | 1,125 | 15 | 7,500 |
| Sand (kg) | 0 | 0 | 0 | 0 | 57,750 | 5 | 57,750 |
| Kerosene (liters) | 0 | 0 | 135,000 | 90,000 | 62,490 | 30 | 71,413,240 |
| Labor Hours per Product | 19,853 | 8824 | 3439 | 2293 | 1592 | 100 | 36,000 Hours/month |
| Pigment Coloring Material (kg) | 10,800 | 5,400 | 825 | 540 | 9,450 | 15 | 27,000 |
| Demand for Products (liters) | 2,950,622 | 1,062,270 | 2,709,611 | 287,1119 | 117,8800 | 49,172,638 |

| TABLE III: PAINT SPECIES AND UNIT CONTRIBUTION MARGIN PER LITRE [5] |
|---------------------------------|
| **Warehouse Capacity (litres)** | X1 | X2 | X3 | X4 | X5 | 600,000 |
| Unit Contribution Margin (N) | 691.66 | 435 | 2,188.74 | 2,037.7 | 1,400 |

The objective functions developed by Briggs and Shadrach in their work on the "development of optimisation models for the productive capacity of paint manufacturing company to maximise profit" [5] was deployed in developing the programme.

1) **Objective Function For Profit Maximization [5]**

\[
\text{MAX} = 691.66 x 1 + 435 x 2 + 2188.74 x 3 + 2037.7 x 4
\]

\[
+1400 x 5
\]  \(12\)

Subject to the following constraints

2) **Water Constraints**

\[
135000x1 + 67020x2 + 105000x5 \leq 300000
\]  \(13\)

3) **Titanium Dioxide Constraints**

\[
147150x1 + 122850x2 + 47880x3 + 24750x4 + 107100x5 \leq 450000
\]  \(14\)

4) **Calcium Carbonate Constraints**

\[
128304x1 + 59928x2 + 63360x3 + 26400x4 + 74976x5 \leq 2640000
\]  \(15\)

DOI: http://dx.doi.org/10.24018/ejers.2020.5.1.1679
5) Binder Resin Constraints
51000x1+42000x2+38100x3+21000x4 +147000x5<=300000
(16)
6) Additives Constraints
3570x1+5355x2+360x2+360x4+3536x5<=15000
(17)
7) Colouring Paste Constraints
3000x1+1500x2+225x3+150x4+1125x5<=7500
(18)
8) Sand Constraints
57750x5<=57750
(19)
9) Kerosene Constraints
779370x1+346380x2+135000x3+90000x4 +62490x5<=1413240
(20)
10) Labour Hours Per Product Constraints
1985300x1+882400x2+343900x3+229300x4 +15900x5<=3600100
(21)
11) Pigment Colouring Materials Constraints
10800x1+5400x2+825x3+540x4+9450x5<=27000
(22)
12) Demand Constraints
2950622x1+1062270x2+2709611x3+2871119x4 +1178800x5<=49172638
(23)

V. RESULTS AND DISCUSSIONS

Input data for the computational, algorithmic coding are in Tables II and III. Computational results are as shown below:

Global optimal solution found.
Objective value: 29110.00
Infeasibilities: 0.000000
Total solver iterations: 2
Elapsed runtime seconds: 0.11
Model Class: LP
Total variables: 5
Nonlinear variables: 0
Integer variables: 0
Total constraints: 12
Nonlinear constraints: 0
Total nonzeros: 53
Nonlinear nonzeros: 0

TABLE IV: Portraying the values generated for the difference for the different variables in the linear programming equations

| Variable | Value     | Reduced Cost |
|----------|-----------|--------------|
| X1       | 0.000000  | 4257.040     |
| X2       | 0.000000  | 3640.400     |
| X3       | 0.000000  | 1508.230     |
| X4       | 14.28571  | 0.000000     |
| X5       | 1.000000  | 12863.90     |

TABLE V: Displaying the surplus or slack and dual price for the linear programming equations

| Row | Slack or Surplus | Dual Price   |
|-----|-----------------|--------------|
| 1   | 29110.00        | 1.000000     |
| 2   | 300000.0        | 0.000000     |
| 3   | 96428.57        | 0.000000     |
| 4   | 2262857         | 0.000000     |
| 5   | 0.000000        | 0.9703333E-01|
| 6   | 9857.143        | 0.000000     |
| 7   | 5357.143        | 0.000000     |
| 8   | 57750.00        | 0.000000     |
| 9   | 12752.7         | 0.000000     |
| 10  | 324385.7        | 0.000000     |
| 11  | 19285.71        | 0.000000     |
| 12  | 815665.2        | 0.000000     |
Following the input data on tables I, II, and III, the accruable profit from the venture without profit maximisation were sixteen thousand four hundred and twenty-two naira and fifty-three kobo (N16,422.53). Optimising the factory production capacity by Linear Programming approach using Lindo Computer Software, the maximised profit was twenty-nine thousand and one hundred and ten naira (N29110.00). Regarding table IV, only \( x_i \) is the non-zero variable with the numerical value of 14.26571. Injecting this value into equation (1), generated the optimal margin of N29110:00. The results in table V confirmed the slack or surplus and dual price at the different rows being zero, except at row 1, thereby reaffirming the optimal profit being N29110:00. The improvement in profit margin is 77\%. The margin is of profit tremendous. The researchers would communicate the findings of this work to the case study company to enable them to adopt the results in their future production planning.

VI. RECOMMENDATION FOR FUTURE RESEARCH

The developed objective function is for-profit maximisation subject to certain critical constraints. Further research endeavours should be directed to resource planning, multiple production facilities and multiple distribution channels, and more so production planning with lot-size models.

VII. CONCLUSION

Profit maximisation of the Colour Paint Company using LINDO Computer Software revealed a staggering gain in the profit margin of about 77\%. The gain is so substantial enough to awaken the need to propagate the research findings to the same company to enable them to enjoy the promise of these findings.

ACKNOWLEDGEMENT

We especially thank the management and staff of the Academic Paint Company for allowing understudying the operational sequence of the factory, which enables us to formulate the computer simulation model for the factory to maximise the productivity of its operation. Furthermore, we appreciate the students that did the observation and data collection on our behalf.

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DOI: http://dx.doi.org/10.24018/ejers.2020.5.1.1679