Development of Optimization Models for The Productive Capacity of Paint Manufacturing Company to Maximize Profit

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Abstract
The technology of paint manufacture is highly advanced. Paints are manufactured from synthetic materials. The art of paint manufacturing was dated back to prehistoric times. The prehistoric man-made paints by mixing clays, chalks, and animal fats. Then it was applied in designing their bodies during traditional festivals and coloring the walls of their caves. In present times, the chemistry of many aspects of paint manufacturing and its area of application is properly understood. The implication is that paint manufacturing has finally moved from being an art to being a science. In day to day engineering endeavors, paints are applied in coating pipes, building walls, automobiles, and aircraft body structures to guide against corrosion or avoid environmental degradation. In this research work, the authors developed mathematical optimization models to maximize the profitability index of the Academy Color Paint Company. The models are Linear Programming production-demand based models subject to a certain number of critical constraints to be handled by a computational approach using LINDO Computer Software.

Keywords: *Technology; Prehistoric; Paint Manufacturing; Environmental Degradation; Linear Programming; Production Based Models; Computational Approach; Lindo Computer Software*

I. INTRODUCTION

The paint was discovered 35000year ago by prehistoric men as they mixed clays, chalk and animal fats. This mixture was employed in painting their cave walls or design their bodies during local festivals [1]. By 2500BC Egyptians tremendously improved upon the technology of the paint manufacturing [1]. They produced blue pigment by grinding azurite and mixing it with gum, wax and if the need is albumen (egg white) as binders and solvents for their paints. Much later, purple color was developed from yellow earth by heating it till it turned to red and plunging it into vinegar[2, 3, 4]. In now the chemistry of paint manufacture has improved tremendously, such that paint manufacture is no longer an art but is a science.

The application of paints on product and structure is for a good number of reasons. It is used as protective coatings on pipes conveying oil, gas, water and other fluids to prevent rust formation or corrosion. It was applied to building walls for protection from the environment as well as to make the walls attractive. Bodies of automobiles, aircraft, even ships are painted for protection against the hazardous environments and also to create attraction.

University of Port Harcourt Academy color paint company manufactures three broad categories of paints, namely:

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

The different species of emulsion are as follows: Academy sik/rubber emulsion, Anti-fungus emulsion, Academy emulsion premium, Academy normal and Total contractors' emulsion. The different sub-categories of Texture paint are Academy sik/men, of paint, Academy normal tex/premium, Academy normal tex, and Total contractor's tex. Gloss paint grade is in two species, premium gloss, and Normal gloss.

Considering all the fantastic arrays of the products in place, this research endeavor is gear toward the production planning of the Academy Paint Manufacturing Company to maximize profit from sales subject to available resources.

The approach to profit maximization was by developing Linear Programming production-based models to maximize the profit of the concerns. The researchers advised the use of LINDO Computer Software in the computational analysis of the optimization models.

II. RESEARCH SIGNIFICANCE

The developed models are production-demand based models. It is designed to handle the available resources of concerns by effective workforce management, production, and demand schedule. Ultimately, this would culminate in maximizing the revenue base of the company, reduce expenditures in a bid to improve the profitability index of the establishment.

III. RELEVANT MATHEMATICAL MODELS

The different models applicable to paint production optimization subject to the type, quality of paint to be produced, moreover, available resources, and time outlay are as follows:

(i) Production Planning: Programming Models, this is applicable under the following operating conditions:
(a) Multiple items with independent demand
(b) Multiple shared resources
(c) Linear costs
The linear programming for the production planning optimization [5, 6,7] will be express as :

$$P1 = Min\sum_{i=1}^{T}\sum_{j=1}^{I}[cp_{it}p_{it} + cq_{it}q_{it}] \quad (1)$$
$$Subjectto:$$
$$q_{i,t-1} + p_{it} - q_{it} = d_{it} \quad (2)$$
$$\sum_{i=1}^{I} a_{ik}\, p_{it} \le b_{it} \quad (3)$$
$$p_{it}q_{it} \ge 0 \quad (4)$$

Where,
p_{it}—production of item i during period t
q_{it}—inventory of item i at the end of period 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 period t
d_{it}—demand for item i in period t

(ii) Demand planning: Lost sales
The Linear Programming for lost sales due to unmet demands goes thus :

$$P2 = Min\sum_{i=1}^{T}\sum_{j=1}^{I}\begin{bmatrix} r_{it}(d_{it} - u_{it}) - \\ cp_{it}p_{it} - cq_{it}q_{it} - cu_{it}u_{it}\end{bmatrix} \quad (5)$$
$$Subjectto:$$
$$q_{it} + p_{it} - q_{it} + u_{it} = d_{it} \quad (6)$$
$$\sum_{i=1}^{I} a_{ik}\, p_{it} \le b_{it} \quad (7)$$
$$p_{it}q_{it}u_{it} \ge 0 \quad (8)$$

Where,
u_{it}—unmet demand of item I during period t
r_{it}—unit revenue for the item I in period t
cu_{it}—unit cost not meeting the demand for an item I in period t

(iii) Demand planning: Backorders
Linear Programming models for a backorder or rescheduled demand will be express as :

$$P1 = Min\sum_{i=1}^{T}\sum_{j=1}^{I}\begin{bmatrix} cp_{it}p_{it} + \\ cq_{it}q_{it} + cv_{it}v_{it}\end{bmatrix} \quad (9)$$
$$Subjectto:$$
$$q_{i,t-1} - v_{i,t-1} + p_{it} - q_{it} + v_{it} = d_{it} \quad (10)$$
$$p_{it}q_{it}v_{it} \ge 0 \quad (11)$$

Where,
Vit—backorder level for item i at the end of period t
Cvit—unit cost of backorder for item i in period t

The emulsion paint produced by the color paint company is of five different species as earlier stated. In formulating the linear programming models, the data in Tables 1, 2, and 3 were used.

The system was modelled subject to profit maximization as an objective function, eleven constraints influenced the outcome of the objective function. The governing equations and inequalities expressions are as follows:

(iv) OBJECTIVE FUNCTION FOR PROFIT MAXIMIZATION
MAX=691.66*x1+435*x2+2188.74*x3+2037.7*x4+1400*x5;
Subject to the following constraints
WATER CONSTRAINTS
135000*x1+67020*x2+105000*X5<=300000;
TITAMIN DIOXIDE CONSTRAINTS
147150*x1+122850*x2+47880*x3+24750*x4+107100*x5<=450000;
CALCIUM CARBONATE CONSTRAINTS
1283040*x1+599280*x2+63360*x3+26400*x4+749760*x5<=2640000;
BINDER RESIN CONSTRAINTS
51000*x1+42000*x2+38100*x3+21000*x4+147000*x5<=300000;
ADDITIVES CONSTRAINTS
3570*x1+5355*x2+360*x2+360*x4+5356*x5<=15000;
COLOURING PASTE CONSTRAINTS
3000*x1+1500*x2+225*x3+150*x4+1125*x5<=7500;
SAND CONSTRAINTS
57750*x5<=57750;
KEROSENE CONSTRAINTS
779370*x1+346380*x2+135000*x3+90000*x4+62490*x5<=1413240;
LABOUR HOURS PER PRODUCT CONSTRAINTS
1985300*x1+882400*x2+343900*x3+229300*x4+15900*x5<=3600100;
PIGMENT COLOURING MATERIALS CONSTRAINTS
10800*x1+5400*x2+825*x3+540*x4+9450*x5<=27000;
DEMAND CONSTRAINTS
2950622*x1+1062270*x2+2709611*x3+2871119*x4+1178800*x5<=49172638;

Where,
X1—units of product 1 (Academic sik) produced per month
X2—units of p 2 (ANti-fungus emulsion) produced per month
X3—units of product 3 (Academy emulsion/premium paint) produced per month
X4—units of product 4 (Academy paint) produced per month
X5—units of product 5 (Texture paint) produced per month

Conclusions

Linear Programming optimization-based models had been developed to maximize the profitability index of the Academy Color Paint Company. It is believed that if the models are simulated in this regard, effective management of workforce, material resources, marketing, and sales would be the later promise of this research.

Recommendation

The developed profit maximization models should be simulated by a computational approach using LINDO Computer Software to evaluate the profitability index of the establishment.

Table 1: Table Showing Production Data and Unit Cost of Constraints Involved

	Products						
Variable Material Resources	x1 Unit price(N)	x2		x3	x4	x5	Maximum Available
Water(liters)	135,000	69,000	0	0	105,000	1	300,000
Titamin Oxide(kg)	9810	8190	3192	1650	7140	15	30,000
Calcium Carbonate(kg)	128304	59928	63360	2640	74976	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	11550	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 Hrs/month
PigmentCol0ring Material(kg)	720	360	54	36	630	15	
Demand for Products(liters)	4,266	2442	1238	1419	842	15	600,000

Table 2: Material Costing Table for the Various Emulsion Paint Species

	Products						
Variable Material Resources	x1 Unit price(N)	x2	x3		x4	x5	Maximum Available
Water(liters)	135,000	69,000	0	0	105,000	1	300,000
Titamin Oxide(kg)	147150	122,850	47,880	24,750	107100	15	450,000
Calcium Carbonate(kg)	1283040	599280	633600	26400	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	5,356	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 Hrs/month
PigmentCol0ring 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	2871119	1178800		49,172,638

Table: 3 Paint Species and Unit Contribution Margin per liter

Warehouse Capacity (liters)	X1	X2	X3	X4	X5	600,000
Unit Contribution Margin (N)	691.66	435	2,188.74	2,037.7	1,400	

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