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Modeling of Production Plan and Scheduling of Manufacturing Process for a Plastic Industry in Nigeria: A Case Study

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ABSTRACT

This research work seeks to model a production plan and scheduling of manufacturing process for a plastic industry in Nigeria using Indorama Petrochemical & Plastic Industry, Rivers State, Nigeria, as case study. The flow chart of operations in the production process of plastic was assessed, the different raw materials and production inputs for the production of plastics were analyzed, and a linear programming model based on the production variables and constraints with objective function of maximizing profit, was developed. Ultimately, an optimal schedule of raw material for the variables in the production industry that maximizes profit was determined. Data of raw materials available for daily production of five parts (Handle of paint bucket, Cover of paint bucket, Body of paint bucket, Cover of ice cream container and Body of ice cream container) of two particular plastic products (paint bucket and ice-cream container) and profit contribution per each unit brand of plastic produced was collected and Linear Programming method was employed to analyze the production data collected from the plastic industry. TORA computer software was applied to simulate the linear programming model developed and Broad based result for the optimum solution of the LP model showed a profit [z (max)].

Keyword: Production Plan, Manufacturing Process, Production of Raw Material

1. INTRODUCTION

Investigation conducted have shown that manufacturers have to be abreast of the growing demand of consumer needs and reduction of cost of production in a place where more products are produced, high competition and variety of choices to be made has made the planning of production activities more complicated to execute.

The research work carried out on the manufacturing industries have grown rapidly over the years in Nigeria and competition among manufacturer is so high that planning and scheduling of resources must be efficient for any of these industries to be profitable and able to survive competition.

Researchers considered production planning is one of the most important activities in a production factory. Production planning represents the heartbeat of any manufacturing process.

In this research work, the production processes of plastic in Indorama Petrochemical & Plastic Industry in Rivers State, Nigeria were studied in order to obtain its production inputs and to assess the raw materials available. This research work applied linear programming model for production planning and scheduling so as to realize the optimal profit and the extent of production resource utilization in a plastic manufacturing company in Nigeria. Linear programming is a family of mathematical programming that is concerned with production plan optimization or useful for allocation of scarce or limited resources to several competing activities on the basis of given criterion of optimality.

The analytical models used for production planning and scheduling mainly involved linear programming, stochastic programming, mixed integer programming, Markov decision process and multi-objective programming while linear programming was applied in this case.
There are quite a number of computer programs for production optimization such as: LINDO, MOSEK, LiPs, GAMS, CPLEX, TORA, QSB, and LINGO to mention but a few.

In this research, evaluated an application of linear programming techniques in production planning. They stated that the optimum utilization of limited resources in the production floor demanded that the production manager makes decisions on the best allocation of limited resources. Linear programming techniques were applied in their study to a production planning problem in a feedmill producing company.

2. MATERIALS AND METHOD

2.1 Materials

The materials data for the study was obtained from the company's record book, clarification and explanation was obtained from the production manager in some aspect of the dataset. The data for this research were obtained from production information of the products made available by the management of the Indorama Petrochemicals and Plastic Company Limited, Rivers State. Data of the product variables in the industry, quantity of raw material used daily for each variable, the quantity of raw material available as well as the mix proportion of the basic raw materials for the production of plastic will constitute the requisite production data obtained.

2.2 Methods

The following methods were considered

i. TORA computer program is menu-driven and Windows-based which makes it very user friendly.

ii. TORA computer program software offers solutions to various models in operational research, but however for the purpose of this study, 'linear programming' model is selected.

iii. Then the 'input mode' and 'input format' of the linear program be selected and encoded.
iv. After which, the objective function of the problem title (Maximization or Minimization) is selected and entered.
v. The number of variables and constraints in the linear model is also selected and entered.

2.3 Defining Variables and Parameters Alternative Variables:

X_{ij}	=	No of part(s) i produced at shift j
i	=	5 parts of 2 products
j	=	2 shifts of day (11 hours) and night (13 hours)

since the spends all his income purchasing the two commodities, the budget constraints is as follows:

$$(T - L)w = X P_1 + YP_2 \quad (1)$$

The utility U of the individual is given by a utility function *u* unique to him, as a function of X, Y, and L.

$$U = u(X, Y, L) \quad (2)$$

Certain general conditions on the function u as follows (where a subscript denotes partial derivative with respect to the subscript:

$$u_X \rangle 0 \qquad u_Y \langle 0 \qquad u_L \rangle 0, \qquad (3)$$

The problem to be maximized can be put into an equation in terms of a single Lagrange multiplier λ by defining the Lagrange function as follows:

$$v(X, Y, L, \lambda) = u(X, Y, L) + \lambda[(T - L)w - XP_1 - YP_2] \quad (4)$$

Maximization of utility occurs or values X*, Y*, L*, λ* of X, Y, L, λ that must satisfy the following equations:

$$v_\lambda = (T - L)w - XP_1 - YP_2 = 0 \quad (5)$$

We can represent variables X, Y, L the ones selected by the customer while P_1, P_2 and w are to be found using the current market conditions .Hence X, Y, L can be called endogenous variables, while P_1, P_2 and w are known as exogenous variables. If P_1 were to increase with P_2, w remaining fixed, we can conclude that a customer is likely to decrease X and increases Y or decrease L, hence when there is an increase in income or financial saving the more the expenses of x. mathematically, we can write twelve partial derivatives as follows:

$$\begin{bmatrix} X_{P1} & Y_{P1} & L_{P1} & \lambda_{P1} \\ X_{P2} & Y_{P2} & L_{P2} & \lambda_{P2} \\ X_W & Y_W & L_W & \lambda_W \end{bmatrix} (6)$$

Equation (6) has 12 partial derivatives which are called comparative statics of the problem. So we can add three explicit models (A), (B), and (C) as follows:

Model (A): $u_{XY} > 0$

Consider the function *u* is given by;

$$u(X, Y, L) = u_0 X^a Y^b L^c \quad (7)$$

Where u_0, a, b, c are constants. Taking partial derivative, we get,

$$u_X = u_0 a X^{a-1} Y^b L^c, \ u_Y = u_0 b X^a Y^{b-1} L^c, \quad u_L = u_0 c X^a Y^b L^{c-1} \tag{8}$$

If we now assume the constants, a, b and c to satisfy the following inequalities:

$$0 \langle a \langle 1, \quad 0 \langle b \langle 1, \quad 0 \langle c \langle 1 \tag{9}$$

And assume X, Y, L to be positive, as is required by the nature of the problem.

Model (B): $u_{XY} < 0$

Consider the function *u* is given by;

$$u(X, Y, L) = u_0 [(A(1 - e^{-aX - bY}) + CXYe^{-f(L)}] \tag{10}$$

Where u_0, a, b, A, C are positive constants and f (L) is a function of L and is given by:

$$f(L) = c(L_0 + L)^{-1} \tag{11}$$

With c, L_0 positive constants are distinct to those of Model (A). Taking partial derivative of (11) we get;

Taking the second partial derivative of (11) we have;

$$u_{XX} = -u_0 a^2 Ae^{-aX-bY}, \ u_{YY} = -u_0 b^2 Ae^{-aX-bY}, \ u_{LL} = -u_0 CcXY\{f''(L) - [f'(L)]^2\}e^{-f(L)} \tag{12}$$

$$u_{XL} = -u_0 Cf'(L)Ye^{-f(L)}, \ u_{YY} = -u_0 Cf'(L)Xe^{-f(L)}, \ u_{XY} = -u_0(-abAe^{-aX-bY} + Ce^{-f(L)}) \tag{12}$$

With $f''(L) = 2c(L_0 + L)^{-3}$ (13)

Since u_{XX} and u_{YY} given in (12) are clearly negative as required by (3), and again u_{LL}, given in (12), to be negative, the quantity on the right hand side of (13) must be positive, so that;

$$2(L_0 + L) > c$$

Model (C): $u_{XY} = 0$

It is similar to Model (A), but the function *u* consists of two parts as follows;

$$u(X, Y, L) = u_1 X^a L^c + u_2 Y^b L^c \tag{14}$$

Where u_1, u_2, a, b, c are new constants. Taking partial derivative of (14), we get,

$$u_X = u_1 a X^{a-1} L^c, \ u_Y = u_2 b Y^{b-1} L^c, \quad u_L = c(u_1 X^a + u_2 Y^b) L^{c-1} \tag{15}$$

Analysis of Models using TORA Software

The data obtained from the company must go through some computational analysis and the results would be placed as the coefficients of the variables in the various equations. Our objective function equation now becomes:

Max: P_T (K_{IJ} K_2) = 1.11 [X_{11} + X_{12}] + 6.67 [X_{21} + X_{22}] + 15.78[X_{31} + X_{32}] + 2.47 [X_{41} + X_{42}] + 7.70 [X_{51} + X_{52}] – 1146250 (16)

Max: P_T (K_{IJ} K_2) = [1.11 X_{11} + 1.11 X_{12}] + [6.67 X_{21} + 6.67 X_{22}] + [15.78 X_{31} + 15.78 X_{32}] + [2.47 X_{41} + 2.47 X_{42}] + [7.70 X_{51} + 7.70 X_{52}] – 1146250 (17)

3. RESULTS AND DISCUSSION

Table 1: Results collected from TORA software analysis

Z(Max)	X9
0	0.17
0.1	0.19
0.2	04.03
0.3	0.58
0.4	0.64
0.5	0.79
0.6	14.06

The summary of Simplex tableau Iteration of 13 for Optimum of the Original Linear Programming Model using the TORA software for the production optimization of plastics produced.

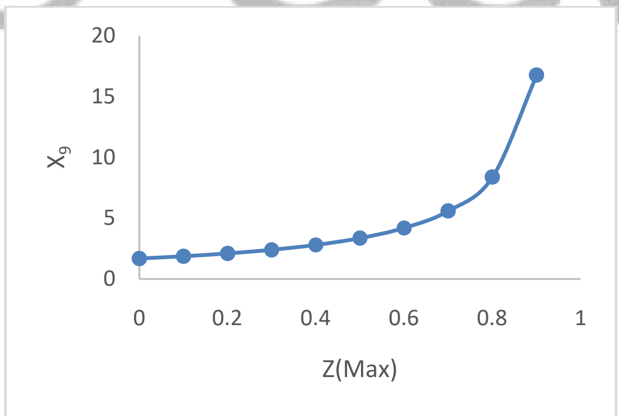


Figure 1: Graph of Z(max) versus X_9

The results of the linear programming were display based on the data inputted.

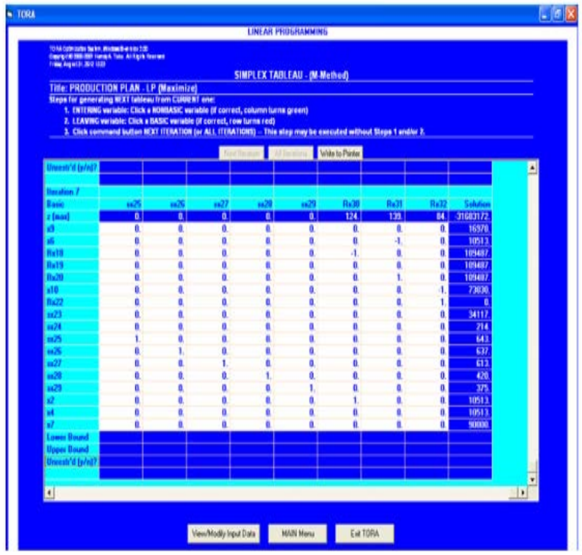


Plate 1: Summary of Simplex tableau Iteration of 7 for Optimum of the First Post Optimal Analysis using TORA software.

Table 2: Results from the TORA Software

Z(Max)	X3
0.383	0.285
0.3828	0.290
0.3826	0.295
0.3824	0.30
0.3834	0.0305
0.7756	0.0308
0.8422	0.0316
0.9230	0.0567

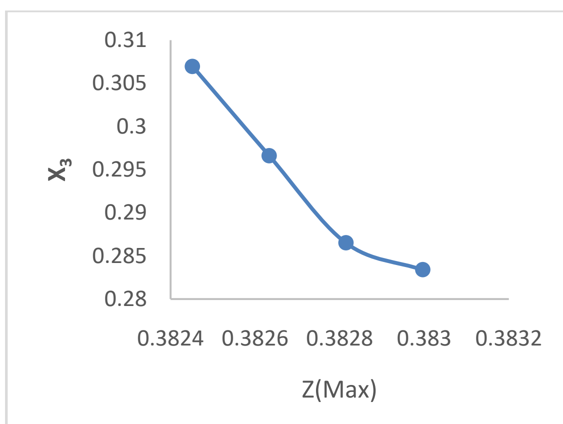


Figure 2: Graph of Z(max) versus x_3

The results of the linear programming were display based on the data inputted.

The Summary of Simplex Tableau Iteration of 14 for Optimum of the Original Linear Programming Model using the TORA software for the production optimization of plastics produced.

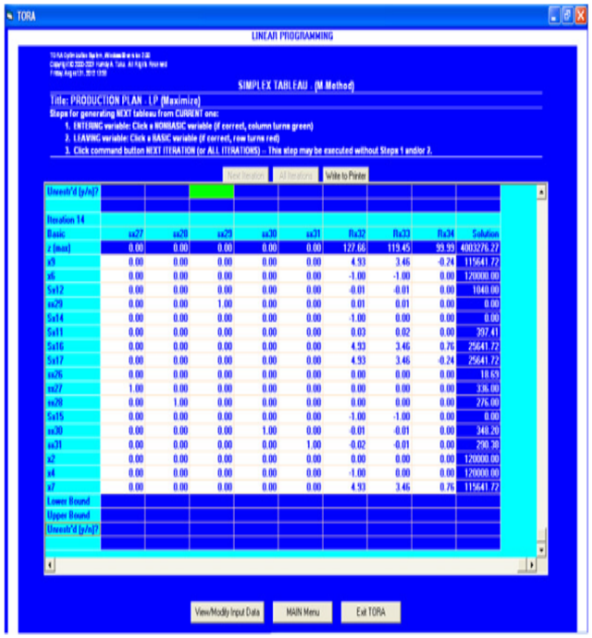


Plate 2: Summary of Simplex tableau Iteration of 14 for Optimum of the Second Post-Optimal Analysis.

Table 3: Results collected from TORA software analysis

Z(Max)	X6
0.32	0.25
0.335	0.26
0.35	0.27
0.367	0.28
0.372	0.29
0.389	0.30
0.387	0.32
0.367	0.34

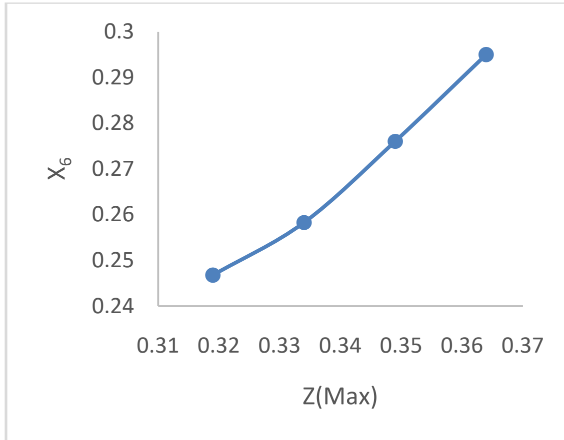
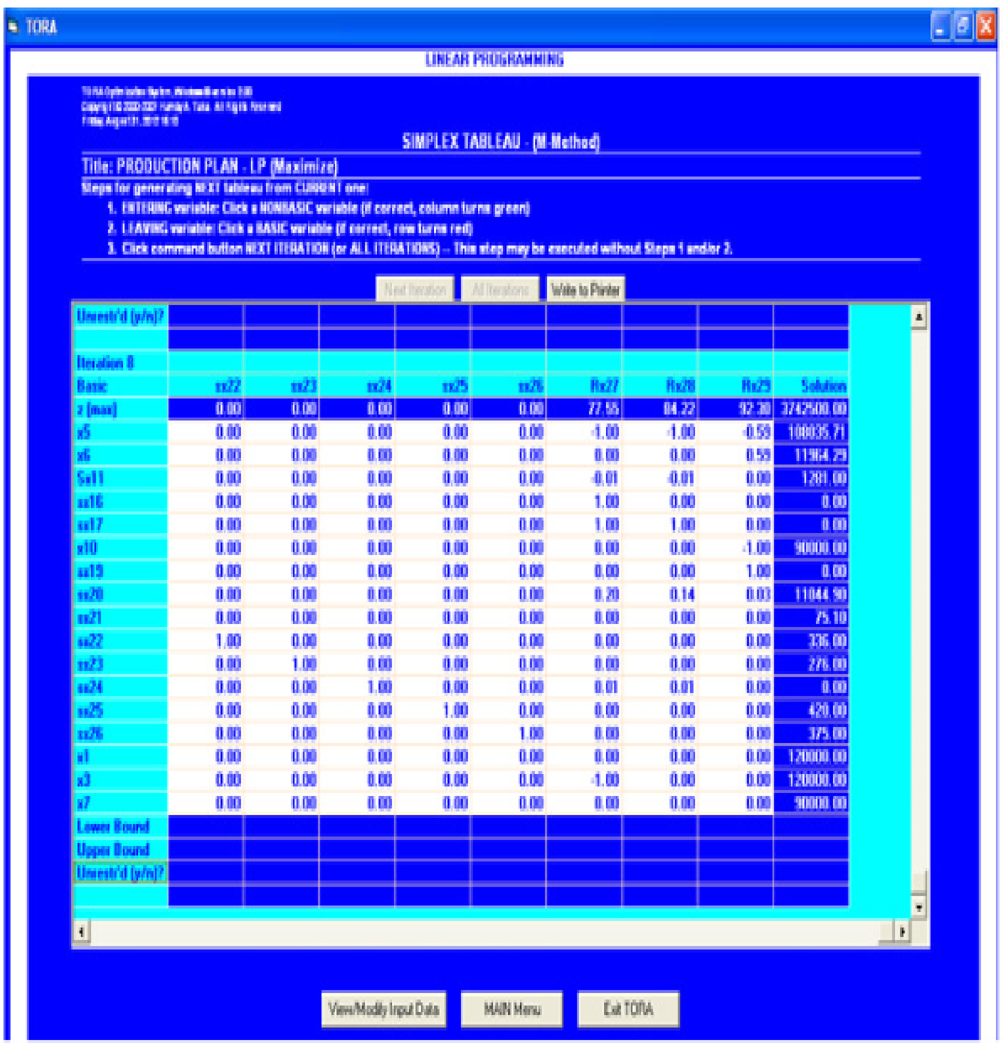


Figure 3: Graph of Z(Max) versus X_6

The results of the linear programming was display based on the data inputted.



Unrestr'd (y/n)?									
Iteration 8									
Basic	sx22	sx23	sx24	sx25	sx26	Rx27	Rx28	Rx29	Solution
z (max)	0.00	0.00	0.00	0.00	0.00	77.55	84.22	92.30	3742500.00
x5	0.00	0.00	0.00	0.00	0.00	-1.00	-1.00	-0.59	108035.71
x6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	11964.29
Sx11	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00	1281.00
ax16	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
ax17	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
x10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	90000.00
ax19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
sx20	0.00	0.00	0.00	0.00	0.00	0.20	0.14	0.03	11044.90
sx21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.10
sx22	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	336.00
sx23	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	276.00
sx24	0.00	0.00	1.00	0.00	0.00	0.01	0.01	0.00	0.00
sx25	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	420.00
sx26	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	375.00
x1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	120000.00
x3	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	120000.00
x7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90000.00
Lower Bound									
Upper Bound									
Unrestr'd (y/n)?									

Plate 3: Summary of Simplex tableau Iteration of 8 for Optimum of the Third Post Optimal Analysis.

4. CONCLUSION

The monthly production plan for Indorama Company limited was developed in this work. The company produces 5 distinct commodities and two products were manufactured using 3 kinds of injection machines. The materials needed are: Production (unit) time and order dependency. For purpose of understanding of the problem, linear programing model was formulated. TORA (optimization software) method was used to solve the developed model. It gave the products quantity which should be produced in each machine during each shift and expected profit if the optimum production plan for the month was adhered to. It is apparent that the original linear programming (LP) model produced the optimum solution that will give the best production plan and the maximum profit, hence it is recommended for application.

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