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Optimization of Production Plan of Hebron Drinks using Operational Research Technique

Agarana M. C[1], Oguntunde P. E[2] & Hammed A. H[3]

[1, 2, 3] Department of Mathematics, Covenant University, Ota, Ogun State, Nigeria
[1]michael.agarana@covenantuniversity.edu.ng
[2]pelumi.oguntunde@covenantuniversity.edu.ng
[3]habobo67@gmail.com

Abstract: Manufacturing companies frequently face challenging operational problems. In such business environment, operations that compete for the same resources must be planned in a way that deadlines are met. Certain expertise in optimization is often required for successful solution of these problems. In this paper, we attempted to optimize the production plan of a manufacturing company - Hebron Drinks, by minimizing the Labour hours, Marching hours and Materials used in producing six different types of products. Linear programming technique was use to model the production plan of Hebron Drinks. The resulted model was solved using simplex method with the aid of computer software (LIP Solver 1.11.1 and 1.11.0). The optimal value obtained shows a reduction in the total cost of production for the period considered.

Keywords: Linear programming, Simplex method, Optimization, Operational research, Production plan.

1. Introduction

Production systems are area of operations research that concentrates on real-word operational problems. Production planning is concerned primarily with the adaptation of the industrial limited resources of the firm in order to satisfy demand for its product. (Bruce R. Feiring, 1991; Shapiro, J.F., 1993). The following settings, among others, usually produce production systems problems: manufacturing, telecommunications, health-care delivery, facility location and layout, and staffing (Hillier, F., & Lieberman, G., 2001). Operations research fundamentals are required to solve production problems since they are operations research problems. Additionally, the solution of production systems problems frequently draws on expertise in more than one of the primary areas of operations research, implying that the successful production researcher cannot be one-dimensional (Banks, J., Carson II J., & Nelson, B., 1995: Taha, H. A., 2002).. In order to solve production problems, an in-depth understanding of the real problem is required, since invoking assumptions that simplify the mathematical structure of the problem may lead to an elegant solution for the wrong problem. Common attributes of successful production planners are common sense and practical insight (Hillier, F., & Lieberman, G., 2001; Epply, T., 2004). Design objective could be simply to minimize the cost of production or to maximize the efficiency of production (Agarana, M.C. Anake T.A., and Adeleke O.J., 2014).

An optimization algorithm is a procedure which is executed iteratively by comparing various solutions till an optimum or a satisfactory solution is found. Optimization or mathematical programming is the selection of a best element (with regard to some criteria) from some set of available alternatives (Ofori S., 2013). In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function (Voss, C., Tsikriktsis, N. & Frohlich, M. 2002). The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding "best available" values of some objective functions given a defined domain (or a set of constraints), including a variety of different types of objective functions and different types of domains (Fagotinbo, I. S., Akinbo, R. Y., Ajibode, I. A., Olaniran Y. O. A., 2011) A production plan is the administrative process that takes place within a manufacturing business and which involves making sure that sufficient raw materials, staff and other necessary items are procured the schedule specified (Graves, C. S., 1999)..

The Hebron drinks is a unit under Strategic Business Unit (SBU) of Covenant University Consultancy Services. It was established in December 2005, to cater, primarily, for worshippers at Canaan land and Covenant University students. The unit adequately provides Sachet water and Bottle water to Canaan land community. Hebron drinks is driving towards having distributors nationwide and maintaining high quality products at all times. Products range from Sachet water, Bottle water, Black currants flavour drink, Orange flavour drink. In March 2014, new products were added to the production line, these are: Hebron yoghurt and apple drink. In the near future, more products are expected to be added to the production, this will include pineapple drink and kola drink which are already being experimented to determine its demand and acceptance. (Covenant

University Student Handbook, 2013-2017). A typical manufacturing business engaging in production planning would usually aim at maximizing profit while maintaining a satisfied customer base (Voss, C., Tsikriktsis, N. & Frohlich, M., 2002). A planning problem exists because there are limited production resources that cannot be stored from period to period. Choices must be made as to which resources to include and how to model their capacity, behavior, and their costs (Unti, J. G., 1968). Also, there may be uncertainty associated with the production function, such as uncertain yields or lead times. One might only include the most critical or limiting resource in the planning problem, e. g., a bottleneck (Unti, J. G., 1968). Alternatively, when there is not a dominant resource, then one must model the resources that could limit production. We describe two types of production functions can be described as follows: The first assumes a linear relationship between the production quantity and the resource consumption. The second assumes that there is a required fixed charge or setup to initiate production and then a linear relationship between the production quantity and resource usage (Voss, C., Tsikriktsis, N. & Frohlich, M. 2002; Unti, J. G., 1968). In this paper attempt is made to maximize the production plan of Hebron drinks using Linear programming model.

2. Model Formulation

Production plan of Hebron Drinks is modeled using linear programming technique. The model include the objective function, the constraints; including the non-negativity constraints. Decision variables, constraints, per unit usage of resources. The available resources are labour hours, machine hours and materials. They are represented by the variables and parameters involved in the model formulation.

2.1 Decision Variables

Decision variables are a set of quantities that need to be determined in order to solve the linear programming problem. They are so called because the problem is to decide what value each variable should take. Typically, the variables represent the amount of a resource to use or the level of some activity. (Agarana, M. C., Anake T.A., and Adeleke O.J.,2014)

For this paper, let the decision variables be represented as follows:

x_{ij} : Number of product j produced by employing resource i

x_{1j} : Number of product j produced by employing resource 1

x_{2j} : Number of product j produced by employing resource 2

x_{3j} : Number of product j produced by employing resource 3

Specifically, we have the following representations:

x_{11}: Number of sachet water produced by employing machine hour.

x_{12}: Number of bottle water produced by employing machine hour

x_{13}: Number of apple juice produced by employing machine hour

x_{14}: Number of orange juice produced by employing machine hour

x_{15}: Number of yoghurt produced by employing machine hour

x_{16}: Number of communion drink produced by employing machine hour.

x_{21}: Number of sachet water produced by employing labour hour.

x_{22}: Number of bottle water produced by employing labour hour.

x_{23}: Number of apple juice produced by employing labour hour.

x_{24}: Number of orange juice produced by employing labour hour.

x_{25}: Number of yoghurt produced by employing labour hour.

x_{26}: Number of communion drink produced by employing labour hour.

x_{31}: Number of sachet water produced by employing material.

x_{32}: Number of bottle water produced by employing material

x_{33}: Number of apple juice produced by employing material

x_{34}: Number of orange juice produced by employing material

x_{35}: Number of yoghurt produced by employing material

x_{36}: Number of communion drink produced by employing material

x_{32}: Number of bottle water produced by employing material

x_{33}: Number of apple juice produced by employing material

x_{34}: Number of orange juice produced by employing material

x_{35}: Number of yoghurt produced by employing material

x_{36}: Number of communion drink produced by employing material

2.2 Resources Utilization

The resources used for production are represented as follows:

a_{ij}: Amount/Number of resource i used to produce a unit of product j

a_{1j}: Number of labour hour used to produce one unit of product j

a_{2j}: Number of machine hour used to produce one unit of product j

a_{3j}: Amount, in kilogram, of material used to produce one unit of product j

2.2.1 Labour Hours used:

a_{11} : Number of labour hour used to produce one unit of sachet water = 1.5seconds

a_{12} : Number of labour hour used to produce one unit of bottle water = 7.083seconds

a_{13} : Number of labour hour used to produce one unit of apple juice = 8.5714seconds

a_{14} : Number of labour hour used to produce one unit of orange juice = 8.5714seconds

a_{15} : Number of labour hour used to produce one unit of yoghurt = 75seconds

a_{16} : Number of labour hour used to produce one unit of apple juice = 14.094 seconds

2.2.2 Machine Hours used:

a_{21} : Number of machine hour used to produce one unit of sachet water = 1 second

a_{22} : Number of machine hours used to produce one unit of bottle water = 5 seconds

a_{23} : Number of machine hours used to produce one unit of apple juice = 8.75 seconds

a_{24} : Number of machine hours used to produce one unit of orange juice = 8.75 seconds

a_{25} : Number of machine hours used to produce one unit of yoghurt = 50 seconds

a_{26} : Number of machine hours used to produce one unit of apple juice = 12.5 seconds

2.2.3 Amount of Materials used:

a_{31} : Amount of material used to produce one unit of sachet water = 0.12

a_{32} : Amount of material used to produce one unit of bottle water = 0.34kg

a_{33} : Amount of material used to produce one unit of apple juice = 3.49kg

a_{34} : Amount of material used to produce one unit of orange juice = 2.01kg

a_{35} : Amount of material used to produce one unit of yoghurt = 1.24kg

a_{36} : Amount of material used to produce one unit of communion drink = 3.40kg

Table 1: Hebron Drinks' Daily Production Data

Days	x_1 (bag)	x_2 (tray)	x_3 (tray)	x_4 (tray)	x_5 (tray)	x_6 (tray)	Available resources
Day I	700	700	41	80	240	260	2400
Day II	600	600	79	84	240	149	2000
Day III	500	300	39	99	-	220	1700

Day IV	700	700	26	64	215	190	2125
Day V	750	600	60	100	200	149	2318
Cost per week	#85427	#664.630	#185,220	#240,828	#676,620	#789,880	#2,629,565.40

Where $x_1, x_2, x_3, x_4, x_5, x_6$ are defined as follows:

x_1: Number of sachet water produced per day using labour hour, machine hours and materials

x_2: Number of bottle water produced per day using labour hour, machine hours and materials

x_3: Number of apple juice produced per day using labour hour, machine hours and materials

x_4: Number of orange juice produced per day using labour hour, machine hours and materials

x_5 : Number of yoghurt produced per day using labour hour, machine hours and materials

x_6: Number of communion produced per day using labour hour, machine hours and materials

Table 2: Cost of Producing One Unit of Product at Hebron Drinks

c_j	cost per unit of producing product j	Cost in naira(#)
c_1	cost per unit of producing sachet water	1.314
c_2	cost per unit of producing bottle water	19.1
c_3	cost per unit of producing apple juice	51
c_4	cost per unit of producing orange juice	47
c_5	cost per unit of producing yoghurt	63
c_6	cost per unit of production communion drink	68

From the information gathered at Hebron Drinks, the total cost of producing all the products, on a weekly basis, is 2.63 million naira. Also the minimum required capacity, in terms of, labour hour, machine hour and material are 12600 minutes, 2160 minutes and 149 kilograms respectively.

2.1 The Model

The resulting linear programming model from the above representations and formulation is as follows:

$$\text{Minimize } Z = \sum_{j=1}^{6} c_j x_j$$

Subject to

$$\sum_{j=1}^{6} a_{1j}x_j \geq 12600$$

$$\sum_{j=1}^{6} a_{2j}x_j \geq 2160$$

$$\sum_{j=1}^{6} a_{3j}x_j \geq 149$$

$$\sum_{i=1}^{3} a_{i1}x_1 \geq 65000$$

$$\sum_{i=1}^{3} a_{i2}x_2 \geq 34800$$

$$\sum_{i=1}^{3} a_{i3}x_3 \geq 4165$$

$$\sum_{i=1}^{3} a_{i4}x_4 \geq 5124$$

$$\sum_{i=1}^{3} a_{i5}x_5 \geq 10740$$

$$\sum_{i=1}^{3} a_{i6}x_6 \geq 11580$$

$$x_j \geq 0,\ j = 1, 2, \ldots, 6$$

Substituting the values of Cj's and a_{ij}'s, the model becomes;

$$Minimize\ Z = 1.314x_1 + 19.1x_2 + 51x_3 + 47x_4 + 63x_5 + 68x_6$$

$$0.025x_1 + 0.118x_2 + 0.143x_3 + 0.143x_4 + 1.25x_5 + 0.235x_6 \geq 12600$$

$$0.016x_1 + 0.083x_2 + 0.146x_3 + 0.146x_4 + 0.83x_5 + 0.21x_6 \geq 2160$$

$$0.12x_1 + 0.39x_2 + 3.49x_3 + 2.01x_4 + 1.24x_5 + 3.4x_6 \geq 149$$

$$0.1617x_1 \geq 65000$$

$$0.540x_2 \geq 34800$$

$$5.114x_3 \geq 4165$$

$$3.634x_4 \geq 5124$$

$$3.32x_5 \geq 10740$$

$$3.843x_6 \geq 11580$$

$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

2.3 The Dual

In this section we find the dual of the above minimization problem, resulting in the following maximization problem, with A,B,C,D,E,F,G,H,I,J,K,L,M,N,O as the new decision variables.

$$\text{Max}\,imize\ P = 12600A + 2160B + 149C + 65000D + 34800E + 4165F + 5124G + 10740H + 11580I$$

$$Subject\ to:$$

$$0.025A + 0.016B + 0.12C + 0.1617D \quad 34$$

$$0.118A + 0.083B + 0.39C + 0.54E \leq 19.1$$

$$0.143A + 0.146B + 3.49C + 5.114F \leq 51$$

$$0.143A + 0.146B + 2.01C + 3.634G \leq 47$$

$$1.25A + 0.83B + 1.24C + 3.32H \leq 63$$

$$0.235A + 0.21B + 3.4C + 3.843I \leq 68$$

$$A, B, C, D, E, F, G, H, I \geq 0$$

2.4 The Standardized Form of the Dual Problem

In order to form the initial tableau, we standardized the above dual problem by introducing slack variables as follows (M.C. Agarana and T.O. Olokunde, 2015)

$$\text{Max}\,imize\ P = 12600A + 2160B + 149C + 65000D + 34800E + 4165F + 5124G + 10740H + 11580I$$

$Subject\ to:$

$$0.025A + 0.016B + 0.12C + 0.1617D + J = 1.314$$

$$0.118A + 0.083B + 0.39C + 0.54E + K = 19.1$$

$$0.143A + 0.146B + 3.49C + 5.114F + L = 51$$

$$0.143A + 0.146B + 2.01C + 3.634G + M = 47$$

$$1.25A + 0.83B + 1.24C + 3.32H + N = 63$$

$$0.235A + 0.21B + 3.4C + 3.843I + O = 68$$

$$A, B, C, D, E, F, G, H, I, J, K, L, M, N, O \geq 0$$

Table 3: Initial Simplex Tableau

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
J	0.025	0.016	0.12	0.1617	0	0	0	0	0	1	0	0	0	0	0	1.314
K	0.118	0.083	0.39	0	0.54	0	0	0	0	0	1	0	0	0	0	19.1
L	0.143	0.146	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
M	0.143	0.146	2.01	0	0	0	3.634	0	0	0	0	0	1	0	0	47
N	1.25	0.83	1.24	0	0	0	0	3.32	0	0	0	0	0	1	0	63
O	0.235	0.21	3.4	0	0	0	0	0	3.843	0	0	0	0	0	1	68
P	12600	2160	149	65000	34800	4165	5124	10740	11580	0	0	0	0	0	0	0

This initial simplex tableau was solved using computer application software (LIP SOLVER), and the following results obtained. It was observed that six (6) iterations were involved. The tables resulting from the iterations give better results as the iterations progresses. The sixth iteration therefore gives the best result shown in table 9.

Table 4: Simplex Tableau 2 (First iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	16/1617	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
K	0.219	0.083	0.39	0	0.54	0	0	0	0	0	1	0	0	0	0	19.1
L	0.143	73/500	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
M	0.143	73/500	2.01	0	0	0	3.634	0	0	0	0	0	1	0	0	47
N	1.25	0.83	1.24	0	0	0	0	3.32	0	0	0	0	0	1	0	63
O	0.235	0.21	3.4	0	0	0	0	0	3.843	0	0	0	0	0	1	68
P	2550.53	-4271.66	-48088.5	0	34800	4165	5124	10740	11580	-401979	0	0	0	0	0	528200

Table 5: Simplex tableau 3 (Second Iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	0.099	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
E	0.219	0.083	0.722	0	1	0	0	0	0	0	1.85	0	0	0	0	35.37
L	0.143	0.146	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
M	0.143	0.146	2.01	0	0	0	3.634	0	0	0	0	0	1	0	0	47
N	1.25	0.83	1.24	0	0	0	0	3.32	0	0	0	0	0	1	0	63
O	0.235	0.21	3.4	0	0	0	0	0	3.843	0	0	0	0	0	1	68
P	-5053.92	-9620.55	-73221.8	0	0	4165	5124	10740	11580	-401979	-64444.4	0	0	0	0	1759090

Table 6: Simplex tableau 4 (Third Iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	0.099	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
E	0.219	0.154	0.722	0	1	0	0	0	0	0	1.85	0	0	0	0	35.37
L	0.143	0.146	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
M	0.143	0.146	2.01	0	0	0	3.634	0	0	0	0	0	1	0	0	47
N	1.25	0.83	1.24	0	0	0	0	3.32	0	0	0	0	0	1	0	63
O	0.235	0.055	0.88473	0	0	0	0	0	1	0	0	0	0	0	0.26	17.6945
P	-5762.04	-10253.3	-83466.9	0	0	4165	5124	10740	0	-401979	-64444.4	0	0	0	-3013.27	1963990

Table 7: Simplex tableau 5 (Fourth Iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	0.099	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
E	0.219	0.154	0.722	0	1	0	0	0	0	0	1.85	0	0	0	0	35.37
L	0.143	0.146	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
M	0.143	0.146	2.01	0	0	0	3.634	0	0	0	0	0	1	0	0	47
N	0.377	0.25	0.373	0	0	0	0	0	0	0	0	0	0	0.3012	0	18.9759
I	0.061	0.055	0.88473	0	0	0	0	0	1	0	0	0	0	0	0.26	17.6945
P	-9805.71	-12938.3	7478.3	0	0	4165	5124	0	0	-401979	-64444.4	0	0	-3234.94	-3013.27	2167790

Table 8: Simplex tableau 6 (Fifth iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	0.099	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
E	0.219	0.154	0.722	0	1	0	0	0	0	0	1.85	0	0	0	0	35.37
L	0.143	0.146	3.49	0	0	5.114	0	0	0	0	0	1	0	0	0	51
G	0.143	0.0402	0.55311	0	0	0	1	0	0	0	0	0	0.2752	0	0	12.9334
H	0.377	0.25	0.373	0	0	0	0	0	0	0	0	0	0	0.3012	0	18.9759
I	0.061	0.055	0.88473	0	0	0	0	0	1	0	0	0	0	0	0.26	17.6945
P	-10007.3	-13144.2	-90312.4	0	0	4165	0	0	0	-401979	-64444.4	0	-1410.02	-3234.94	-3013.27	2167790

Table 9: Simplex tableau 7 (Sixth iteration)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	RHS
D	0.155	0.099	0.742	1	0	0	0	0	0	6.18429	0	0	0	0	0	8.1262
E	0.219	0.154	0.722	0	1	0	0	0	0	0	1.85	0	0	0	0	35.37
F	0.027	0.02855	0.68244	0	0	0	0	0	0	0	0	0.195	0	0	0	51
G	0.039	0.0402	0.55311	0	0	0	1	0	0	0	0	0	0.2752	0	0	12.9334
H	0.377	0.25	0.373	0	0	0	0	0	0	0	0	0	0	0.3012	0	18.9759
I	0.061	0.055	0.88473	0	0	0	0	0	1	0	0	0	0	0	0.26	17.6945
P	-10123.8	-13263.1	-93154.8	0	0	0	0	0	0	-401979	-64444.4	-814.423	-1410.02	-3234.94	-3013.27	2,275600

4. Interpretation of Result and Discussion

From the final tableau, the decision variables values are as follows:

$x_1 = 401979$

$x_2 = 64444.4$

$x_3 = 814.431$

$x_4 = 1410.02$

$x_5 = 3234.94$

$x_6 = 3013.27$

Substituting these values into the objective function of the primal problem, we have:

$$1.314(401979) + 19.1(64444.4) + 51(814.431) + 47(1410.02) + 63(3234.94) + 68(3031.27)$$
$$= 2{,}276{,}822.947 naira$$

This value is approximately the same as the optimal feasible solution shown in the final tableau (the sixth iteration). This means that the cost of production of the six (6) products in HEBRON DRINKS can be reduced to 2.276822.947 million naira as against the prevailing total cost of production of 2.63million naira per week. This implies that if the management of Hebron Drinks actually wants to maximize their profit, by efficiently putting the scarce available resources into use, the following must be put into consideration: Number of sachet water produced per day using labour hour, machine hours and materials must be 401979. Number of bottle water produced per day using labour hour, machine hours and materials must be 64444. Number of apple juice produced per day using labour hour, machine hours and materials must be 814. Number of orange juice produced per day using labour hour, machine hours and materials must be 1410.

Number of yoghurt produced per day using labour hour, machine hours and materials must be 3235.

Number of communion produced per day using labour hour, machine hours and materials must be 3013.

Looking at the values of the decision variables closely, we realized that less of apple juice should be produced while more of sachet water and bottled water should be produced. Doing this will minimize the usage of the available resources and maximize the company's profit.

4.1 Sensitivity Analysis

Sensitivity analyses were performed to identify key factors affecting the behaviour of the model. The sensitized parameters include:

- C_J's and
- a_{IJ}'s

We had a new set of decision variables, as a result of varying the sensitized parameters, which when substituted into the objective function gave 2,037,604 and 2,168,249 respectively.

We can see that both the C_J's and a_{IJ}'s are sensitive to the result of the model. The management of Hebron Drinks can manipulate these parameters to their benefit without necessarily altering their organizational policy or set goals in terms of expected income.

5. Conclusion

The data collected from HEBRON DRINKS was modeled into a Linear Programming Problem.

A primal problem was formed, and being a minimization case that would be solved using simplex method, it was imperative to find the Dual of the primal problem; hence a dual problem was developed out of the Linear Programming Problem. Upon obtaining the initial simplex tableau, the data was then run on a lip solver (linear integer problem solver) software application. The analysis done, using operations research technique (the linear programming problem, solved by using the simplex method) showed that average weekly cost of production at Hebron Drinks was 2,629,565.40 naira. Based on this research work, the company can reduce its weekly cost of production to 2,227,822.95 naira, which represents 13.41% decrease in the weekly production cost. The results also revealed that, for the decrease to be achieved there has to be an adherence to a new production routine. We can see that both the C_J's and a_{IJ}'s are sensitive to the result of the model. The management of Hebron Drinks can manipulate these parameters to their benefit without necessarily altering their organizational policy or set goals especially as it affects the contributions and amount of resources used in producing one unit of each of the products in order to maximize their expected income.

References

Hillier, F., & Lieberman, G. (2001). Introduction to Operations Research, Holden-Day.

Banks, J., Carson II J., & Nelson, B. (1995). Discrete-Event System Simulation. Prentice Hall.

Taha, H. A., (2002). Operations Research: An Introduction. Englewood Cliffs: Prentice Hall.

Epply, T., (2004). The Lean Manufacturing Handbook, (Assisted by Judy Nagengast), Second Edition

Ofori, S., (2013). Optimal Revenue Generation using Linear Programming, a case study of rmaa East District Assembly, Thesis submitted to the Department of Mathematics, Kwame Nkrumah University of Science and Technology

Voss, C., Tsikriktsis, N. & Frohlich, M. (2002). Case research in operations management. Inter. J. of Operations and Production Management, 22 (2) 195-219

Graves, C. S., (1999). Massachusetts Institute of Technology, Manufacturing Planning and Control

Unti, J. G., (1968). Use of a dynamic linear program for selecting optimum cropping patterns, Oregon State University, Corvallis

Covenant University Student Handbook (2013-2017). Revised Edition, a publication of dominion publishing house (DPH), Ota, Ogun State, Nigeria

Agarana, M. C., Anake T.A., and Adeleke O.J., (2014). Application of Linear Programming Model to Unsecured Loans and Bad debt Risk Controls in Banks, *Best;* International Journal of Management, Information Technology and Engineering. Vol. 2, Issue 7, pp. 93-102

Fagotinbo, I. S., Akinbo, R. Y., Ajibode, I. A., Olaniran Y. O. A. (2011) Maximization Of Profit In Manufacturing Industries Using Linear Programming Techniques: Geepee Nigeria Limited, Mediterranean Journal Of Social Sciences

M.C Agarana and T.O. Olokunde, (2015),

Optimization of Healthcare Pathways in Covenant

University Health Centre Using Linear
Programing Technjque, Far East journal of
Applied Mathematics Volume 91, number 3,

Shapiro, J.F. (1993). Mathematical programming methods for production planning and scheduling. Elsevier publishers, B.V, 371-443.

Bruce R. Feiring (1991), Production planning in stochastic demand environment, Mathematical and Computer Modelling, Volume 15, issue 10, Pp 91-95