Optimal Production Plan in Flour Mills of Nigeria Public Liability Company: Linear Programming and Sensitivity Analysis

OLUSEGUN Kazeem Lekan
Department of Business Management, Faculty of Management Sciences,
Federal University Dutsinma, Katsina,
P.M.B.5001, Katsina State.
kolusegun@fudutsinma.edu.ng

OLADEJO Lukman Gbolagade
Department of Business Management, Faculty of Management Sciences,
Federal University Dutsinma, Katsina,
P.M.B.5001, Katsina State.
loladejo@fudutsinma.edu.ng

SONNY Emmanuel Braide
Department of Business Management, Faculty of Management Sciences,
Federal University Dutsinma, Katsina, P.M.B.
5001, Katsina State.
sbraide@fudutsinma.edu.ng

Abstract

The insufficient or little attention given to sensitivity analysis (SA) approach in the extant literature prompted this study to incorporate both Linear Programming (LP) and Sensitivity Analysis (SA) techniques to determine segment that best contributes to the objective function in Flour Mills of Nigeria Plc. The study considered five main segments of the company namely; food, agro-allied, packaging, port operation and logistics and real state of the company and financial information extracted from the company annual report for the year ended March 31, 2017. Result from the LP analysis using simplex algorithm revealed that milling and sales of flour and rice and production and sales of pasta, snacks, sugar and noodles in the food segment contribute ₦72, 156, 441, 200 to profit representing 7.57% increase over the initial total contribution of ₦66, 689, 068, 000 with production of 1,250 units of the food items while each extra ₦'000 spent on the binding constraints (cost of sales), would produce ₦0.15 extra contribution. It was also found that SA analysis improves LP result by 1.34% and 0.88% respectively for units of production in the food segment and total contribution to profit. The study thus concluded that milling and sales of flour and rice and production and sales of pasta, snacks, sugar and noodles are more profitable to the company. For that reason and in order to maximize profit the management of FMN Plc should give more attention to the food segment.

Keywords: Optimal Production Plan, LP, SA, Food Segment and FMN PLC

1. Introduction

It is becoming increasingly difficult to ignore the roles of production planning in virtually every aspect of a company's operations as it serves as a useful tool to coordinate the activities of production system. It helps companies to supply good quality products to customers on the continuous basis at competitive rates (Rose, 2002). Planning, along with scheduling, provides the glue for bringing all the reliability processes together and maximizing the opportunity for more reliable production.

Production planning according to Robert (2013) and Saini (2008) is useful to accomplish production objective with respect to quality, quantity, cost and timeliness of delivery, and uninterrupted production flow in order to meet customers demand orders. It is needed to establish the production programme to meet target set for using and achieving effective utilization of firms' resources (Sujay & Abhijit, 2016).

Production planning systems can offer a multitude of benefits to manufacturing firms, but equally the potential exists to negatively affect organizations if not properly or optimally planned. The problem of decision making based on the use of limited resource is a major factor that brought the application of linear programming (LP) model which is now one of the most powerful tools which all decision makers (managers) must apply before achieving effective decision (Akpan & Iwok, 2016; Balogun, Jolayemi, Akingbade & Muazu, 2012; Moreno & Montagna, 2008; Yasser, Cesar, Rogelio, Carlos & Piero, 2015).

Most researches such as (Akpan et al., 2016; Al-kuhali, Zain & Hussein, 2012; Andrea & Adrian, 2012; Bergestorm & Smith, 1970; Goodman, 1975; Holt & Modigliani, 1960; Jones, 1967; Ishikawa, Inoguchi, Yang & Chang, 2007; Khan, Bajuri & Jadoon, 2008; Koltai & Terlaky, 2000) have proposed several quantitative models in an attempt to accomplish optimal production with limited available resources but with insufficient or little attention to sensitivity analysis (SA) approach. Realizing this gap in the extant literature, more researches are needed on optimal production plan with limited available resources using LP and SA algorithms. To our knowledge, this research is the first to address this gap in the Flour Mills of Nigeria Plc (FMN). For that reason, the present study is motivated by inclusion of sensitivity analysis (SA) approach and the need to take into consideration an exhaustive analysis of the segment that best contributes to the profit (objective function) within the limit of available resources (cost and expenses) using both LP and SA algorithms for optimal production plan in the study company.

2. Review of Related Literature

For every successful production process in a manufacturing industry, planning is inevitable and it has a direct impact on the quality of goods produced. According to Higle & Wallace (2003) linear programming model based work includes the post optimal solution and effects when data changes for the solution and the linear programming model is used for maximum profit output. Linear programming is a great revolutionary development which has given mankind the ability to state general goals and to lay out pith of detailed decisions to take in order to "best" achieve its goals when faced with practical problem of great complexity (Stephanos & Dimitrious, 2010).

The techniques of Linear Programming and sensitivity analysis were used by Izaz, Norkhairal and Imran (2011) to maximize the profit generated from the production patterns of the ICI Pakistan. Four different products manufactured at the company were taken into consideration. The result revealed that the production of soda Ash is contributing more than other products to the objective function and is more profitable to the company and that the company should give more attention to its production to maximize its profit. The work is significant in the sense that it will assist the top management of the company in making corrective decisions in good time using the method of linear programming. Similarly, Khan et al. (2008) used linear programming techniques and sensitivity analysis for the maximum profit in the products of ICI Pakistan. After applying the linear programming to different products they predicted that Soda Ash product showed more profit upon the application of Linear Programming.

Linear programming is used for the optimized allocation of the limited resources in order to maximize profits. Therefore, the programming approach to production is inevitable since supply of some inputs is limited and cannot be increased in the planning period being considered. The linear programming approach is an efficient and convenient method, which is used in the widespread manners (Can & Ozluer, 2012).The research of Balogun et al. (2012) on Nigeria bottling company Nigeria, Ilorin plant using linear programming revealed that two particular items should be produced i.e Coke 50cl and Fanta Orange 50cl in order to attain maximum profit. Al-kuhali et al. (2012) in their application of linear programming and sensitivity analysis methods to the production of Flat Panel Monitor of four Sizes observed that in all the three scenarios for the production of the LCDs the total profits is optimal and increases form scenario 1 to scenario 3. This made the authors to support decision maker with heuristics procedures to do better decision based on well-understood information in an efficient computation way. Adrea and Adrian (2012) also support that the linear programming is used to attain the best outcome or maximum profit.

Anieting, Ezugwu and Ologun (2013) applied linear programming techniques to determine optimum production of Usiner Water Company, in Uyo. Their results showed that linear programming method has proven, given the raw data the only way the company production problem can be addressed. Murugan, Choo

and Schombing (2013) in their study designed a linear programming model for palm oil mill processing in order to optimize the production planning related to the supply- demand patterns and minimize the cost of production. They reported that the test result of their model is close enough to real industry application (generated by Lingo) and the result obtained was considered promising.

Mayeke (2013) observed that commercial farmers are always confronted with the problem of finding the combination of enterprises that will provide them with the highest amount of income through the best use of farm limited resources (constraints), he recognized the over-growing application of linear programming in agricultural sector, particularly in optimization of available farm resources in order to attain an optimal income. After formulating a linear programming model that maximizes the income of farmers in rural area, the decision variables for the model was identified to be hectares allocated for maize production stored for family consumptions, hectares allocated in soya bean production and hectares allocated for tobacco production.

Haryadi, Mege and Adi (2015) concluded in their study of production of plates using de novo programming at Ceramics Company in Indonesia that the most appropriate forecasting method used to predict the sales quantity of each product for the company is linear regression, because it has the smallest mean Absolute Deviation of all the methods used in the study. Based on this, they advised that companies can use the methods of De Novo programming to assist decision makers, especially the production division in determining the right combination of products and allocation of overall resources effectively and efficiently, so that the company can maximize the production costs to be incurred..

Akpan and Iwok (2016) utilized the concept of simplex algorithm as an aspect of Linear Programming to allocate raw materials to competing variables in bakery for the purpose of profit maximization. Their results showed that 962 units of small loaf, 38units of big loaf and O unit of giant loaf should be produced respectively in order to make profit of N20, 385.00.

Hence, to the best of our knowledge none of the literature reviewed above dwelled on optimal production planning in FMN Plc, this makes the study inevitable.

3. Research Methodology

3.1 Modelling Approach

An exploratory research design which is quantitative in nature was used to provide a quantitative analysis of the segment that best contributes to the profit (objective function) within the limit of available resources (cost and expenses) in FMN Plc. This research takes into consideration five main segments of the company. The available data to analyse the research problem include cost of sales, expenses (interest, selling, distribution and administrative, capital expenditure), depreciation and amortization, and profits and loss. These data are readily objective in nature and were obtained mainly through secondary sources. LP and SA approaches were incorporated to analyze the secondary data generated from the keenly prepared annual report of the company for the year ended March 31, 2017. The main objective of the LP approach is the optimization of the objective function subject to a set of linear equalities and/or inequalities. Stated mathematically, the general production planning maximization models is (Higle and Wallence, 2003; Taha, 1975; Winston, 1995; Zeleny, 1982):

Objective Function:

Maximize $Z = c_1 x_1 + c_2 x_2 + \ldots\ldots + c_n x_n$

Subject to:

$a_{11} x_1 + a_{12} x_2 + \ldots\ldots + a_{1n} x_n \leq r_1$
$a_{21} x_1 + a_{22} x_2 + \ldots\ldots + a_{2n} x_n \leq r_2$
.. .. ..
.. .. ..
.. .. ..
$a_{m1} x_1 + a_{m2} x_2 + \ldots\ldots + a_{mn} x_n \leq r_m$
$x_1, x_2, \ldots\ldots\ldots\ldots\ldots\ldots x_j \geq 0$
$j = 1, 2, 3 \ldots n$

$i = 1, 2, 3 \ldots m$

Where:
Z= objective function that maximized profits

X_j = choice variable (production item) for which the problem is solved

C_j = coefficient measuring the contribution of the jth choice variable to the objective function.
r_i = constraint or restrictions placed upon the problem
a_{ij} = coefficient measuring the effect of the ith constraint on the jth choice variable.

The use of the simplex method to solve a linear programming problem requires that the problem be converted into its standard form. The standard form of a linear programming problem has the following properties.
- All the constraints should be expressed as equations by adding slack or surplus variables.
- The right-hand side of each constraint should be made of non-negative (if not). This is done by multiplying both sides of the resulting constraints by -1.
- The objective function should be of a maximization or minimization type.

For n decision variables and m constraints, the standard form of the linear programming model can be formulated as follows. This can be stated in a more compact form as:

$$\text{Maximize } Z = \sum_{j=1}^{n} c_j \; x_i \; \ldots\ldots\ldots \text{ (Objective function)}$$

Subject to the linear constraints

$$\sum_{j=1}^{n} a_{ij} \; x_i \; \ldots\ldots\ldots \leq r_i$$

$$x_j \geq 0 \ldots\ldots\ldots\ldots\ldots \text{ (Non-negativity condition)}$$

3.2 Model Assumptions

- It is assumed that the resources required for production are limited (scarce)
- It is assumed that an effective allocation of resources to the activity will aid optimal production and at the same time maximizing the profit of the company.
- It is assumed there is a linear relationship among the variables used in the model.
- All quantities and values are known with certainty.
- Consumption of resources and contribution by activities are additive and proportional to the level of decision variable.
- Activities are non negative.

4. Presentation of Results

This study focuses on Optimal Production Plan in FMN Plc. Analysis of LP approach on optimal production plan problem reveals in the fourth simplex tableaux (see appendix, table 4) that FMN plc can generate a profit of seventy-two billion one hundred and fifty-six million four hundred and forty-four thousand two hundred naira only (₦72, 156, 441, 200) representing 7.57% increase over the initial total contribution of ₦66, 689, 068, 000 with production of 1,250 units of the food items (milling and sales of flour and rice and production and sales of pasta, snacks, sugar and noodles). The negative values of (-4, 750, 419, 600), (-577, 787, 600), (-11, 092, 153) and (-257, 751, 600) under agro-allied, packaging, port operation and logistics, and real estate segments imply that if any unit of the segments were produced, then the overall contribution would fall by (₦4, 750, 419, 600), (₦577, 787, 600), (₦11, 092, 153) and (₦257, 751, 600) for each segment respectively.
In addition, there are ₦8, 883, 565, 800 unused interests and selling expenses, ₦29, 955, 463, 000 unused capital & administrative expenses and ₦4, 317, 444, 800 unused depreciation & amortization at optimum while cost of sales have no unused capacity at optimum and the constraints it represents is fully utilized at ₦0.15. The unused capacities of the slack variables at optimum mean that there is no value to be gained from increasing interests and selling expenses, capital & administrative expenses and depreciation & amortization. However, for each extra ₦'000 spent on cost of sales overall contribution would increase by ₦0.15. This is possible because the resource is a binding constraint as it is fully utilized and has non-zero shadow prices.
Corroborating the above analysis, the SA approach shows that if extra ₦4, 317, 444, 800 was available the solution is 1,267 units of food items giving a contribution of ₦72, 804, 057, 900. The SA improves the LP result by additional 17 units of food items and ₦647, 616, 000 of total contribution to the objective function. The other values in the solution column are the unused amounts of constraints of interests and selling expenses, capital & administrative expenses and depreciation & amortization represented by slack variables (see appendix, table 5).

5. Discussion of Findings

The study found from the result presented above that the milling and sales of flour and rice and production and sales of pasta, snacks, sugar and noodles in the food segment contribute most to the objective function. It is also found that each extra ₦'000 spent on the binding constraints (cost of sales), would produce ₦0.15 extra contribution. To improve on the initial LP result, SA is incorporated to maximize the profit and minimize cost and expenses with availability of least amount of unused slack variable that is depreciation & amortization at optimum which is ₦4, 317, 444, 800. Thus, the LP result was improved by 1.34% and 0.88% respectively for units of production in the food segment and total contribution to profit. The result of this study also confirmed the findings of previous studies carried out in this area. Al-kuhali et al (2012), Andrea & Adrian, (2012) and Robert (2013) affirmed that LP and SA are effective techniques for efficient production plan in an organization especially in the production division in determining the right combination of products and allocation of overall resources efficiently in order to maximize production objectives.

6. Conclusions and Recommendation

This study has successfully determined the segment that contributes most to the profit (objective function) within the limit of available resources (cost and expenses) in the company. The research takes into consideration five main segments of the company and financial information extracted from the company annual report for the year ended March 31, 2017. Based on the findings above it is concluded that milling and sales of flour and rice and production and sales of pasta, snacks, sugar and noodles in the food segment contribute most to the profit of the company. Thus, in order to maximize profit the study recommends that the management of FMN Plc should continue to give more attention to the listed products in the food segment.

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Appendix

TABLE 1: First Simplex tableau

Segments	Food	Agro-Allied	Packaging	Port operation & Logistics	Real Estate	Slack Variables				Solution Qty
Solution Variable	X_1	X_2	X_3	X_4	X_5	S_1	S_2	S_3	S4	
Cost of Sales	364,984,425	73,720,099	18,365,025	367,806	338,025	1	0	0	0	457,775,380
Interest & Selling Exp.	23,189,549	8,575,079	571,962	226,133	953,183	0	1	0	0	37,870,502
Capital & Admin Exp	8,974,256	12,813,264	771,046	153,774	23,136	0	0	1	0	41,173,283
Dep & Amortization Exp	9,218,165	3,316,239	1,414,227	1,507,329	384,191	0	0	0	1	15,840,151
Z	57,725,153	6,794,611	2,328, 470	46,633	(205,799)	0	0	0	0	0

Source: Adapted from FMN PLC Annual Report March 31, 2017

TABLE 2: Second Simplex tableau

Segments	Food (Pivot Column)	Agro-Allied	Packaging	Port operation & Logistics	Real Estate	Slack Variables				Solution Qty
Solution Variable	X_1	X_2	X_3	X_4	X_5	S_1	S_2	S_3	S 4	
Food (Pivot Row)	364,984,425	**73,720,099**	**18,365,025**	**367,806**	**338,025**	**1**	**0**	**0**	**0**	**457,775,380**
Interest & Selling Exp.	23,189,549	8,575,079	571,962	226,133	953,183	0	1	0	0	37,870,502
Capital & Admin Exp	8,974,256	12,813,264	771,046	153,774	23,136	0	0	1	0	41,173,283
Dep & Amortization Exp	9,218,165	3,316,239	1,414,227	1,507,329	384,191	0	0	0	1	15,840,151
Z	57,725,153	6,794,611	2,328, 470	46,633	(205,799)	0	0	0	0	0

Source: Authors' Computation, 2017

TABLE 3: Third Simplex tableau

Segments	Food (Pivot Column)	Agro-Allied	Packaging	Port operation & Logistics	Real Estate	Slack Variables				Solution Qty
Solution Variable	X_1	X_2	X_3	X_4	X_5	S_1	S_2	S_3	S4	
Food (New Element)	**1**	**0.20**	**0.05**	**0.001**	**0.0009**	**$2.7e^{-9}$**	**0**	**0**	**0**	**1.25**
Interest & Selling Exp.	23,189,549	8,575,079	571,962	226,133	953,183	0	1	0	0	37,870, 502
Capital & Admin Exp	8,974,256	12,813,264	771,046	153,774	23,136	0	0	1	0	41,173, 283
Dep & Amortization Exp	9,218,165	3,316,239	1,414,227	1,507,329	384,191	0	0	0	1	15,840, 151
Z	57,725,153	6,794,611	2,328, 470	46,633	(205,799)	0	0	0	0	0

Source: Authors' Computation, 2017

TABLE 4: Forth Simplex tableau

Segments	**Food (Pivot Column)**	Agro-Allied	Packaging	Port operation & Logistics	Real Estate	Slack Variables				Solution Qty
Solution Variable	**X_1**	X_2	X_3	X_4	X_5	S_1	S_2	S_3	S4	
Food (New Element)	**1**	**0.20**	**0.05**	**0.001**	**0.0009**	**$2.7e^{-9}$**	**0**	**0**	**0**	**1.25**
Interest & Selling Exp.	**0**	3,937,169.2	(587,515)	202,943	932,312	(0.06)	1	0	0	8,883,565
Capital & Admin Exp	**0**	11,018,413	322,333.2	144,799	15,059	(0.024)	0	1	0	29,955,463
Dep & Amortization Exp	**0**	1,472,606	953,318.7	1,498,110	375,894	(0.025)	0	0	1	4,317,444
Z	**0**	**(4,750,419)**	**(557,787)**	**(11,092)**	**(252,751)**	**(0.15)**	**0**	**0**	**0**	**(72,156,441.2)**

Source: Authors' Computation, 2017

TABLE 5: Sensitivity Analysis

Multiplier for S_1	Change in Constraint	Change in Solution	Original Solution	New Solution
$2.7e^{-9}$	× 4,317,444.8	= 0.017	+ 1.25	**= 1.267**
(0.06)	× 4,317,444.8	= (259,046.6)	+ 8,883,565.8	= 8,624,519.2
(0.024)	× 4,317,444.8	= (103,618.6)	+ 29,995,463	= 29, 851,844.
(0.025)	× 4,317,444.8	= (107,936.12)	+ 4,317,444.8	= 4,209,508.6
(0.15)	× 4,317,444.8	= (647,616.72)	- 72,156,441.2	**= - 72,804,051**

Source: Authors' Computation, 2017

Biographies

OLUSEGUN Kazeem Lekan is currently a lecturer in the of Department Business Management of the Federal University, Dutsin-Ma, Katsina State, Nigeria. He holds a Bachelor of Science degree in Business Administration and a Master of Science degree in Operations Research from the University of Lagos. He is an Associate Fellow of the Institute for Operations Research of Nigeria and a Chartered Member of the Nigerian Institute of Management. Mr. Kazeem gained wide experience of teaching and research in Quantitative Analysis, Production Management, Statistics and Social Research in particular and Operation Research in general. He has published several journal and conference papers.

OLADEJO Lukman Gbolagade is a full-time senior lecturer and Director of Entrepreneurship studies at the Federal University, Dutsin-Ma, Katsina State, Nigeria. He earned a Bachelor of Science degree in Business Administration, Master of Science degree in Accounting and PhD in Management studies from the Usmanu Danfodoyo University, Sokoto, Sokoto state, Nigeria. He is an Associate Member of the Nigerian Institute of Management. His areas of research interest include entrepreneurship and SME development, business communication and corporate planning.

SONNY Emmanuel Braide is a lecturer in the of Department Business Management of the Federal University, Dutsin-Ma, Katsina State, Nigeria. He holds a Bachelor of Science degree in Business Administration from the University of Port-Harcourt and MBA from Bayero University, Kano, Kano state, Nigeria. He is an Associate Member of the Nigerian Institute of Management. His areas of research interest cover SME development, business environment and international business.