International Journal of Applied Operational Research
Vol. 9, No. 3, pp. 11-19, Summer 2019

Journal homepage: ijorlu.liau.ac.ir

Application of linear programming techniques in production planning

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Received: 2 March 2019**;** **Accepted:** 15 June 2019

Abstract Optimum utilization of limited resources in the production floor demands that the production manager makes decisions on the best allocation of limited resources. Linear programming techniques are applied in this study to a production planning problem in a feed mill producing company. The linear Programming model was formulated based on data obtained from the company operations' diary. Data was processed with the help of Management Scientist Version 5.0. The study reveals improved profit through streamlining of the product range and cutting off the less productive products. This suggests the company may adopt the outcome of the linear programming techniques in production planning to improve monthly profit. This study has shown that linear programming techniques are powerful tools that can be of help to managers in decision making and allocation of limited resources and indicate operations and profit improvement.

Keyword: Production, Optimization, Planning, Feed, Linear Programming.

1 Introduction

Decision making is one of the major functions of managers; they are often faced with decisions relating to the allocation and use of scarce resources. Resources available for production, according to the classical economists, are limited and have multidimensional uses. This makes it pertinent for operations managers as decision makers to contemplate on allocation of resources in production planning. Poor resources allocation may result into

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operations failure and endanger the financial health and survival of organizations. In practice, firms often produce below the installed capacity of their plants, thus, there is a thoughtful need for an efficient and effective control of the firms' production capacity planning [4]. For organization to maximize the usage of resources must be efficient and effective in achieving the result with little or minimum resources.

Proper allocation of scarce resources enhances organizational efficiency and effectiveness in meeting profit goals. Indeed, there will be evident improvement in the economy if sectors maximize productivity with little resources. Akpan, and Iwok [3] opined that an economy can only grow if management decisions at the firm level result in boosted output through cost minimization or output maximization culminating in increased production in the real sector. Failure to minimize cost will make it more difficult for organization to maximize profit or benefit. However, in order to minimize cost, it is pertinent for a production manager to decide on the best way to allocate limited resources in such a manner that it will lead to higher output and profit. There is a need to identify products that maximally contribute to profit and those that yield zero or negative profit. Production manager must keep idle time in the production floor to the minimum, excess idle time tends to waste resources in the production floor.

Managers are apt to make decisions with the rule of thumb (experience, intuition) which tends to expose the organization to the danger of uncertainty. Adebiyi et al. [2] argued that organizational entities managed by non-professional, but experienced managers are more dependent on experience, intuition and knowledge in making decisions which expose organizations to danger of uncertainty in terms of result.

The rate at which production companies, especially feed mill producing companies liquidate in Nigeria is alarming which can be traced to wastage of production resources, high level of idleness on the production floor and inability of the production companies to maximize meaningful profit that will enable these companies to meet up with the expectations of its stakeholders. This is so because the majority of these companies make use of traditional techniques in production planning; only few of them are aware about the application of these techniques in production planning. Though different studies have been done in Nigeria to alert management of these companies about the importance of linear programming techniques in production planning, but there is a paucity of such study that address feed mill production planning problem in Nigeria.

This study is set to utilize linear programming in production planning in a feed mill company in Nigeria, realize the optimal profit and extent of resource utilization.

2 Literature review

2.1 Concept of production

Production is one of the key functions in organizations, and it is concerned with the transformation of input resources into required outputs (products). Production involves the conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the users. It is a value addition process. Buffa (nd) cited in [10] defined production as a process by which goods and services are created. Production is an activity that is primarily concerned with the transformation or conversion of inputs into finished goods and services [5]. Olamade and Oni [11] observed that economic growth is positively related to the growth of the manufacturing sector in Africa countries.

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Abiodun [1] was of the opinion that production activities are the life wires of a country's economy, which create present and future value in utility and exchange.

2.1.1 Production planning

Wild [13] defined production planning as the determination, acquisition and arrangement of all facilities needed for production of items. Production planning is a key activity of production manager; it is the determination of objectives to be achieved during production and combination of resources (input) to be used to achieve goals efficiently.

Production planning estimates the resources required and prepares a detailed plan for achieving the production goals efficiently and timely [4]. Production planning is a basic function of manufacturing management applicable in all manufacturing companies in which it shows the direction and coordination of firms' resources towards attaining their prefixed goals [10]. Achievement of efficiency and effectiveness in production floor, require planning [7].

It gives direction on what to achieve in the production, how we want to achieve it and materials needed for its actualization. Production planning involves the generation and identification of alternative courses of action and to select the optimum alternative. Goutham [7] argues that production planning improves the performance of the manufacturing entity, especially when an entity operates in an uncertain environment. Umoh et al. [12] posits that production planning enhances operational efficiency in the organization. Production planning helps managers to improve the system and production process in an uncertain environment. Higgins [8] reported that firms that effectively implement production planning to their operations performs better than those that make use of adhoc approach. Goutham [7] was of the opinion that production planning plays a significant role in ensuring optimization.

2.1.2 Production system

Production systems are methods and procedures used to produce goods for the market. Production systems utilize material, capital, transportation, and labour resources to produce and distribute products.

Production system can be categorized into continuous production, job shop production, batch production and mass production. It has the following characteristics; production system transforms various inputs to useful outputs, production system does not operate in isolation from the other organization system, production is an organized activity, so every production system has an objective.

Amole et al. [4] are of the opinion that a production system is considered to incorporate an organizational element in addition to physical facilities.

2.2 Linear programming

Linear Programming is that branch of mathematical programming which is designed to solve optimization problems where objectives and all the constraints involved can be expressed as a linear function. It was developed by George Dantzig, in 1947 for finding optimal solutions to problems of supplies to the Force during World War II. It is a powerful tool in management science and operations research for decision making under certainty. Linear Programming can also be used for verification and checking mechanism to ascertain the accuracy and the

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reliability of the decisions which are taken solely on the basis of manager's experience without the aid of a mathematical model [4]. It is useful in the allocation of scarce resources like materials, machine, man, time, etc.

2.2.1 Advantages of linear programming

i. **Quality Decision**: Linear Programming technique helps to decision makers in making quality decisions. With the help of this technique, decision makers are more objective in their decision.
ii. **Maximization of Resources**: This technique helps in maximization of resources that are limited in nature. Managers can deploy this technique in allocating limited resources
iii. **Complex Problem**: The technique has the ability to solve complex problem we encounter in real life.
iv. **Multiple Constraint:** These techniques are more suitable to solve problems with multiple constraints
v. **Simplicity:** Linear programming model can be solved with the help of a simple and straight method called simplex.
vi. **Multipurpose:** This technique can be employed to solve different real life problems

2.2.2 Limitations of linear programming

Linear programming techniques have been applied to real life problems to derive an optimal solution which aid decision making process but the techniques has some limitations:

i. It assumes parameters are constant in nature meanwhile it is not so in real life.
ii. There is no assurance that the value we will get will be an integer value. For instance, the linear programming solution might result in 4.2 machines which is not possible in real life.
iii. Linear programming deals with a single objective; it does not have the capacity to deal with a problem that has multiple objectives. In real life, decision makers at times encounter problem with conflicting objectives
iv. Linear programming is only can only be used in a situation whereby constraints and objectives can be expressed as straight line equations i.e. linear in nature.
v. This technique assumes a certainty, but in some situations, values in objective and constraint might not be known beforehand. In this case, this technique cannot be used.

2.3 Empirical framework

Adebiyi et al. [2] applied linear programming techniques to achieve optimal product mix to improve profit contribution of five products of a paint producing company in Nigeria. The obtained solution suggested that the company should produce only two of its products and drop other three products. Akpan, and Iwok [3] utilized Simplex algorithm in linear programming maximize the profit contribution in the bread producing company. Amole et al. [4] applied linear programming techniques to the production planning problem of the Detergent producing company in Nigeria The result suggested that the total monthly cost of production could be reduced up to ₦2 million on an average. Benedict and Uzochukwu [6]

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applied linear programming techniques to a plastic producing company and obtained the optimal solution to the company's production problem The study suggested the company should produce 114,317.2 pieces of 25mm by 5.4m conduit pipes and 7,136.564 pieces of 20mm by 5.4m thick pressure pipes, and zero quantities of the rest sizes of pressure pipes per month in order to obtain a maximum profit of N1, 964,537. Igbinehi et al. [9] formulated linear programming model of Local Soap Manufacturing Company and achieved optimum solution The result of the analysis showed that the company spends more on coloured soap and get more from. They suggested that the company should produce more of white soap and less of coloured soap. Yahya et al. [14] showed that linear programming techniques are useful in production planning by analyzing the production planning problem of KASMO Industry in Nigeria, the obtained solution suggested that the company should produce only two of its products and drop other three products. Despite the popularity of linear programming techniques and different studies done on linear programming, there is a paucity of study that address production planning of feed producing company especially in Nigeria which is the focus of this study. This study will demonstrate the relevance of linear programming techniques in any production planning problem and strengthen claims of previous authors.

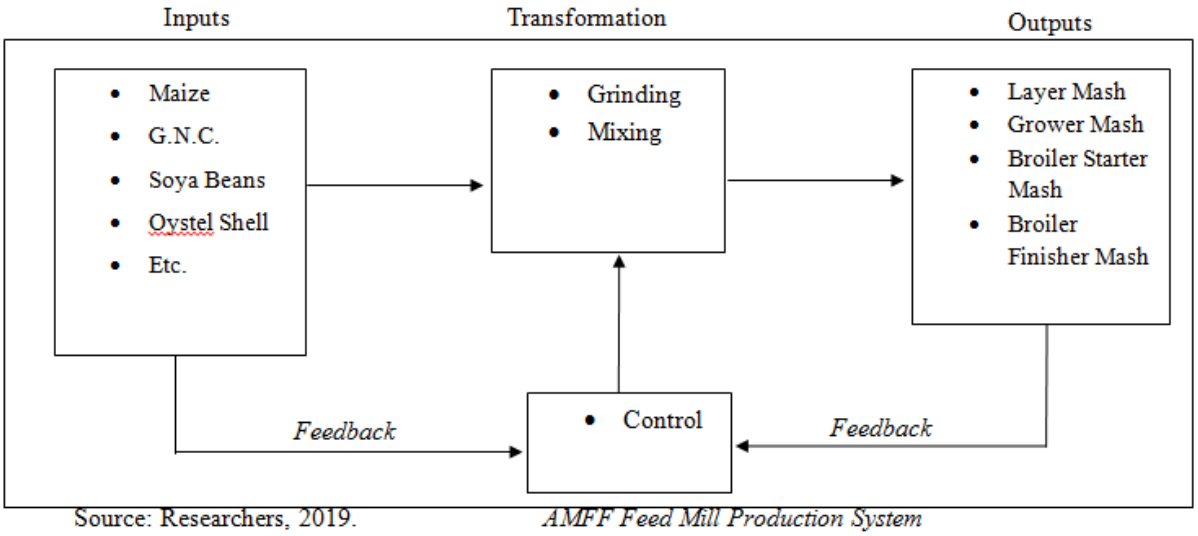


Fig. 1 Conceptual Model for the Study

The model above describes the generalized production process of the case organization. The process takes the inputs (Maize, G.N.C., Soya Beans, Oystel Shell Etc.) for conversion through the process of grinding and mixing using the right quantity of materials to generate the outputs or products that are marketed to the customers. The outputs consist of Layer Mash, Grower Mash, Broiler Starter Mash and Broiler Finisher Mash.

2.4 Case organization

The case organization produces animals' feeds in its factory located in Abeokuta. The organization is a medium sized organization and specializes in the production and selling of different kinds of animal feeds such as Layer Mash, Grower Mash, Broiler Starter Mash and Broiler Finisher Mash are the major products the company deals with. Administratively, the company is headed by a manager who oversees the operation of the firm**.**

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3 Materials and methods

Data for the study was obtained from the company's record book, clarification and explanation were obtained from the production manager in some aspect of the dataset. Data was obtained on the quantity of each raw material used per month as well mix of these basic raw materials and the costs. Finally, data were collected on the cost of production of the four products of the company.

3.1 Model formulation

The objective of the study was to maximize the profit.
Where Ci represents the profit derived from the sales of the products (i = 1,2,3,4) and Xi represents number of bags produced for each of the products (i = 1,2,3,4)

$Z = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4$

s.t.

$a_{11}x_1+a_{12}x_2+a_{13}x_3+a_{14}x_4 \leq b_1$

$a_{12}x_1+a_{22}x_2+a_{23}x_3+a_{24}x_4 \leq b_2$

$a_{13}x_1+a_{22}x_2+a_{33}x_3+a_{34}x_4 \leq b_3$

$a_{j1}x_1+a_{j2}x_2+a_{j3}x_3+a_{j4}x_4 \leq b_j$

Non Negativity = $X_1, X_2, X_3, X_4, X_5 \geq 0$

The model can be written in this Canonical form

$$Z = \sum_{j=1}^{4} c_j x_j$$

s.t.

$$\sum_{j=1,2\ldots,4}^{15} a_{ij}x_j \leq b_i$$

j = Layer Mash, Grower Mash, Broiler Starter Mash and Broiler Finisher Mash.
i = kg of materials to be used
bi = Resources available

3.2 Linear programming model of the company

Maximize $Z = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4$

Maximize $Z = 207.25X_1 + 97.75X_2 + 128.75X_3 + 153.5X_4$

s.t.

	Input Used
$13.5X_1 + 11.2X_2 + 15X_3 + 13X_4 \leq 11{,}700$	(Maize)
$6X_1 + 4.5X_2 + 6.5X_3 + 6X_4 \leq 2{,}600$	(Soya Beans)
$2X_1 + X_2 + 0.75X_3 + 2X_4 \leq 1{,}820$	(Lime Stone)
$0.65X_1 + X_2 + 0.5X_3 + 0.65X_4 \leq 1{,}820$	(Bone)
$2.75X_1 + 4.5X_2 + 2X_3 + 2.5X_4 \leq 7{,}800$	(Wheat Offal)
$0X_1 + 0X_2 + 0.5X_3 + 0.1X_4 \leq 50$	(Fish Offal)
$0.025X_1 + 0X_2 + 0.025X_3 + 0.025X_4 \leq 25$	(Lysine)
$0.025X_1 + 0X_2 + 0.025X_3 + 0.025X_4 \leq 25$	(Methionine)

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$0.1X_1 + 0.05X_2 + 0.075X_3 + 0.1X_4 \leq 100$ (Salt)
$0.075X_1 + 0X_2 + 0X_3 + 0X_4 \leq 39$ (Layer Premix)
$0X_1 + 0X_2 + 0.1X_3 + 0.075X_4 \leq 26$ (Broiler Premix)
$0X_1 + 0.063X_2 + 0X_3 + 0X_4 \leq 26$ (Grower Premix)
$0X_1 + 3X_2 + 0X_3 + X_4 \leq 3{,}900$ (P.K.C.)
$X_1, X_2, X_3, X_4 \geq 0$ (Non Negativity)

3.3 Techniques for Model Solution

The model was solved using The Management Scientist Version 5.0.

4. Result and discussion

The production planning problem of the feed producing company formulated into a linear programming model in this study covers a period of a month. The company produces a mix of 40 bags of layer mash, 100 bags of grower mash, 25 bags of broiler starter mash and 70 bags of broiler finisher mash with profit potential of ₦32,028.75 in a month.
The materials used for production of a bag of Layer Mash, Grower Mash, Broiler Starter and Broiler Finisher is presented in the table 1 below

Table 1 Materials used in the production

	PRODUCTS				
Materials	Layer Mash (kg)	Grower Mash (kg)	Broiler starter Mash (kg)	Broiler Finisher Mash (kg)	Available Quantity per month
Maize	13.5	11.2	15	13	11,700
Soya Beans	6	4.5	6.5	6	2,600
Lime Stone	2	1	0.75	2	1,820
Bone	0.65	1	0.5	0.65	1,820
Wheat Offal	2.75	4.5	2	2.5	7,800
Fish Offal	**	**	0.5	0.1	50
Lysine	0.025	**	0.025	0.025	25
Methionine	0.025	**	0.025	0.025	25
Salt	0.1	0.05	0.075	0.1	100
Layer Premix	0.075	**	**	**	39
Broiler Premix	**	**	0.1	0.075	26
Grower Premix	**	0.063	**	**	26
P.K.C	**	3	0	1	3,900

Source: Company's Record, 2019 **= Not use in feed

Table 2 shows the cost of producing, selling and expected profit from a bag of Layer Mash, Grower Mash, Broiler Starter Mash and Broiler Finisher Mash.

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Table 2 Average Cost of producing a kg of each product

Product	Parameter	Estimated Cost of Production a bag (₦)	Estimated Selling Price of a bag (₦)	Estimated Profit on a bag (₦)
Layer Mash	C_1	2,792.75	3,000	207.25
Grower Mash	C_2	2,502.25	2,600	97.75
Broiler Starter Mash	C_3	3,271.25	3,400	128.75
Broiler Finisher Mash	C_4	2,846.5	3,000	153.5
Total profit				**587.25**

Source: Computed from the Company's record, 2019

4.1 Optimal solution

The table below shows the optimal result obtained from the software employed to solve the model.

Table 3 Optimal solution

Variable	Product	Value
X_1	Layer Mash	433.33
X_2	Grower Mash	0
X_3	Broiler Starter Mash	0
X_4	Broiler Finisher Mash	0
Objective Function Value		**89,808.33**

Source: Researchers, 2019

Table 4 shows the optimal solution obtained from The Management Scientist Version 5. It suggests that the company in pursuit of profit objective, required to concentrate on the production of Layer Mash alone and other products are to be dropped by this solution. The company should produce 433.33 bags of Layer Mash which is approximately 433 bags, and drop other products which will enhance the profit potential of the company above the current operating profits. This will lead the company to profit maximization of ₦89, 808.33 against the current profit of ₦32, 028.75. This implies that if the company follows the solution from this study, there will be increase of ₦57, 779.58 in their monthly profit.

With the available resources, the company can improve their profit by producing 433 bags of Layer Mash and drop the production of other three products in order to attain maximum profit of ₦89,808 which is 80% increment.

5 Conclusions

The result of this study shows that application of heuristic approach in production planning can does not guarantee optimal solution, but facilitate wastage of resources in the production floor. Also, application of linear programming techniques is a powerful techniques production manager ought to adopt in production planning, this will increase improve the company's performance by enhancing total profit. The study further reveals that it is not enough for

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production companies to be after profit maximization alone, but resources optimization; this will be beneficial to the company rather than maximizing profit alone. The study concludes that linear programming can be used in solving any production planning problem. The study recommends that decision makers should not base their decision on experience and intuition, but on the analytical and scientific approach. Likewise, managers should learn to implement linear programming techniques in production planning.

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