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Application of Linear Programming for Optimal Use of Raw Materials in Bakery

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ABSTRACT

This is about utilization the concept of Simplex algorithm; a method of linear programming for allocating raw materials to corresponding variables (big loaf, giant loaf and small loaf) in bakery to maximize the profit. The analysis is made and the result shows that 962 units of small loaf, 38 units of big loaf and 0 unit of giant loaf shall be produced respectively for a profit of N20385.It was observed from the analysis that small loaf, followed by big loaf contribute objectively to the profit. So, more of small loafs and big loafs are required to be produced and sold for maximization of profit.

1. Introduction

Linear programming is a part of mathematical programming that is concerned with or useful for allocating limited resources to several competing activities on the basis of given criterion of optimality. In Operation Research, linear programming (LP) is a technique used for the objective of optimization of linear function subject to linear constraints. Linear programming tells us the way to achieve best outcome, such as maximum profit or minimum cost in a given mathematical problem and given some list of requirement as a linear equation. This technique of linear programming is used widely as applications, including agriculture, industry, transportation, economics, health system, social science and the military. Some business organization thinks that linear programming as a “new science” or recently development in mathematical history, but there is nothing new about the maximization of profit in any business organization. Linear programming was born during the Second World War for solving military logistics problems. The development of linear programming has been ranked among the most important scientific advances of the mid-20th century. Now, it is a standard technique that saves many thousands for most businesses of even moderate size in the various countries in the world. The report of various surveys shows that many production companies, particularly the ones operating in Nigeria are not conversance or yet to know fully the application of linear optimizations. Production companies had faced the problems of how to utilize the available resources for maximize profit; this is due to the use of linear programming that brought a suitable quantitative approach for decision-making had not been completely applied.

The decision of most of the production managers always based on the total input used in the production and output proceed. This method for decision making is always biased, that means it brings about reduction of accuracy for forecasting the future which includes price fluctuation and shortage of available resources. The problem of decision making based on the use of limited resource is the main factor that brings the application of linear programming model which is now one of the most powerful tools which all decision makers must apply before achieving effective decision.

2. Literature Review

According to miller (2007), linear programming is a generalization of linear algebra use in modelling of real life problems varies from scheduling airline routes to shipping oil from refineries to cities for the purpose of finding inexpensive diet capable of meeting daily requirements. Miller stated that the reason of great versatility of linear programming is because of the ease at which constraints can be incorporated into the linear programming model.

Ezema and Amaken (2012) says that the problems of industries are the result of shortage of production inputs which result in low capacity utilization and consequently low outputs. They apply lpp in optimization of profit in golden plastic industry for the purpose of seeking and arriving at the optimal product-mix of the golden plastic industry. This was done or achieve by formulating the linear programming problem for production of plastic and estimated as such, the company was initially producing eight pipes but from the data analysis and estimation it shows that only two size of the total of eight polyvinel chloride pipes shall be produce and they also succeed in establishing that 7,136.564 pieces of 20mm by 5.4m thick pressure pipe and 114317.2 pieces of 25mm by 5.4m conduct pipe shall be produced and 0 quantities of the remaining size for obtaining a monthly profit of N1,964,537. Igweet al (2011) reported that linear programming is a good technique for achieving efficiency in production planning, particularly in achieving increased agricultural productivity. It was observed when they carried out investigation on maximization of gross return from semi-commercial agriculture in Ohafia zone in Abia state. The general deterministic model is a gross margin maximization model designed to find out the optimum solutions, the decision variables for the model are numbers of hectares the farmer devoted to the production of crop and combination of crop produced by the farmer. Balogun et al (2012) reported that, the problem of managements the main problem in production sectors, which is faced by many companies with decision relating to the use of limited resources such as manpower, raw materials, capital etc. In their work titled “use of linear programming for optimal production” in the Coca-Cola Company, they were able to applied linear programming in obtaining the optimal production process for Coca-Cola Company. Firstly, in the process of formulating a lpp for the production process, they identified the decision variables to be

the following Coke, Fanta, Schweppes, Fanta tonic, Krest soda etc. that are total nine decision variables and the constraint are identified to be concentration of the drinks, sugar content, water volume and carbon (iv) oxide. The resulting model was solve using the simplex algorithm, after the data analysis they came to a conclusion that out of the nine product the company was producing only two contribute maximum to the profit maximization, that is Fanta orange 50cl and Coke 50cl with a fix quantity of 462,547 and 415,593 for obtaining the maximum profit of N263,497,283. The company were advised by them to focus in the production of the two products in order not to run into high cost. Snezanza and Milorad (2009) recognize linear programming as an important tool in energy management despite the non-linearity property of many energy system, they argue that the non-linearity property can be converted to a linear form by applying Taylor series expansion so that the optimization model could be applied to determine the best way to generate energy at a minimum cost. VeliUlucan(2010) reported that a mixed integer lpp plays a crucial role in aggregate production planning (i.e a macro production planning) which addresses the matter of deciding what percentage employees the firm should retain and for manufacturing company, the number and blend of products to be produced. Veili argue that the decision variables for an integer programming are requied to be

an integer so as to satisfy both the objective function and therefore the constraints. Fagoyinbo and Ajibode (2010) reported that the success and failure that a private or organization experience towards business planning depends to an outsized extent on the power of creating appropriate decision. They argue that a manager cannot make decision based on his/her personal experience, guesswork or intuition because the consequences of wrong decision is very costly, hence an understanding of the applicability of quantitative method to deciding is of fundamental importance to the decision maker. They described linear programming as one of the major quantitative approach to decision-making and hence applied it in effective use of resources for staff training, the decision variables for the model are the junior staff and senior staff and the constraints was the time available for training as the program is in-service training. According to Majeke (2013) commercial farmers are always confronted with the matter of finding the mixture of enterprises which will provide them with the very best amount of income through the best use of farm limited resources (constraints), he recognized the over-growing application of lpp in agricultural sector, particularly in optimization of obtainable farm resources so as to achieve an optimal income (profit). He formulated 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 for soya bean production and hectares allocated for tobacco production (i.e five decision variables) and also, six constraints were identified. The resulting model was solved employing a computer software (MS excel). Joly (2012) reported that, optimization may be a crucial science for high-performance refineries , its main purpose within the oil sector is to push production process or operation towards the maximal profit until it reaches the limit at which any further profitability increase depends on changes in the existing system. Stephanos and Dimitrios (2010), see lpp as an excellent revolutionary development which has given mankind the power to state general goals and to get out path of detailed decision to require so as to “best” achieve its goals when faced with practical problem of great complexity. They argue that an easy lpp begins determinedly of interrelationship of an objective function because the maximization of profit for one or more products (activities). Nabasirye et al (2011) argue that a lpp problem is made when the feasible region is subset of the non-negative portion of Rn, defined by linear equations and inequalities, and the objective function to be minimized or maximized is linear. They also argue that selecting the best alternative out of a large number of possibilities is called optimization. They successively applied linear programming in minimization of cost of animal feed since animal feed was identified as a major factor in the overall cost of animal production in order to maximize an optimal profits. According Mula et al (2005) production planning problem is one of the most important application of optimization tools using mathematical programming (linear programming). They argue that the idea of incorporating uncertainty in mathematical models is very important in order not to generate inferior planning decisions. This is known as sensitive analysis. According to Waheed et al (2012) lpp models are frequently utilized in operation research and management sciences to unravel specific problems concerning the utilization of scare resources. They demonstrated the appliance of lpp in profit maximization during a product-mix company, in selecting the simplest means for selling her medicated soap product which include 1 tablet per pack, 3 tablets per pack, 12 tablets per pack and 120 tablets per pack, which are subject to some constraints. The data analysis was carried out with R-statistical package, the result of the analysis showed that the company would obtain optimal monthly profitlevel of about N271,296 if she concentrates mainly on the unit sales (one tablet per pack)of her medicated soap product ignoring other kind of sales packages. Lenka (2013) argue that global economic crisis makes the business environment unfavorable for industries to survive or manage their resources optimally. Lenka formulated two lpp models where one among them maximizes the revenue of a corporation and therefore the other minimizes the value of operation respectively. Igbinehi et al (2015) applied lpp model to maximise profit during a local soap production company, the corporate produces three different sort of soap, 5g white soap, 10g white soap and 10g coloredsoap. From the info analysis it had been observed that the corporate spends more on colored soap and that they gets more take advantage of white soap than colored soap. So the company was advised to produce more of white soap (5g and 10g) than the colored soap in order to obtain an optimal profit. Maryam et al (2013) reported that, linear programming plays an important role in improving management decision despite it is still regarded as new science but has proven to be capable in solving

problems like production planning, allocation of resources, internal control and advertisement. Taha (2003) argue that the idea of differential calculus is required for optimization of objective function subject to constrained continuous functions. For Taha, Langrangean method is that the most appropriate method for solving optimization problem with equality constrained continuous functions, if the constraints were continuous and non-linear then the appropriate method was the Karush-Kuhn-Tucker method for system of non-leaner programming. This is called the classical optimization.

3. Linear Programming Model

The general linear programming model with *m* decision variables and *n* constraints can be stated in the following type of form.

Optimize (Max or Min) $Z = d_1y_1 + d_2y_2 \ldots\ldots\ldots\ldots\ldots\ldots + d_my_m$.

S.t

$b_{11}y_1 + b_{12}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{1m}y_m$ (≤, =, ≥) a_1.
$b_{21}y_1 + b_{22}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{2m}y_m$ (≤, =, ≥) a_2.
. . .
. . .
. . .
$b_{n1}y_1 + b_{n2}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{nm}y_m$ (≤, =, ≥) a_n.

This can be also written in the form of

$$OptimizeZ = \sum_{i=1}^{m} d_i y_j$$

Subject to the linear constraints

$$\sum_{i=1}^{m} b_{ji} y_i (\leq, =, \geq) a_j, j = 1, 2.....n \quad a_i$$

$$y_i \geq 0, i = 1, 2, ...n$$

Where $d_1, d_2, \ldots\ldots d_m$ represent the per unit profit (or cost) of decision variables $y_1, y_2, \ldots\ldots y_m$ to the value of the objective function. And $b_{11}, b_{12}, \ldots b_{2m}, \ldots\ldots\ldots b_{n1}, b_{n2}, \ldots\ldots b_{nm}$ represent the amount of resource consumed per unit of the decision variables. The a_j represents the total availability of the *jth* resource. Z represent the measure – of – performance which can be either profit, or cost or reverence etc.

Standard form of a Linear Programming Model

The use of the simplex technique to solve a linear programming problem needs that the problem be converted into its standard form. The standard form of a linear programming problem has the following properties.

1. All the constraints should be expressed as equations by adding slack or surplus variables.
2. The right-hand side of each constraint should be made of non-negative. That can done by multiplying both sides of the resulting constraints by -1.
3. The objective function should be of a maximization type.

For *m* decision variables and *n* constraints, the standard form of the linear programming model can be formulated as follows.

Max.$Z = d_1y_1 + d_2y_2 \ldots\ldots\ldots\ldots\ldots\ldots + d_my_m + 0s_1 + 0s_2 \ldots\ldots\ldots\ldots\ldots\ldots + 0s_n$.

Subject to constraints

$b_{11}y_1 + b_{12}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{1m}y_m = a_1$
$b_{21}y_1 + b_{22}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{2m}y_m = a_2$
. . .
. . .
. . .
$b_{n1}y_1 + b_{n2}y_2 \ldots\ldots\ldots\ldots\ldots\ldots + b_{nm}y_m + s_n = a_n$.
$y_1, y_2, \ldots\ldots y_m, s_1, s_2, \ldots s_n \geq 0$.

This can also be stated as .

$$MaxZ = \sum_{i=1}^{m} d_i y_j + \sum_{j=1}^{n} 0S_j$$

Subject to constraints

$$\sum_{i=1}^{m} b_{ij} y_i S_j = a_i, i = 1, 2, ...n. \ and$$

$$y_i, s_j \geq 0 (\forall \ j \ and \ i)$$

Assumptions

- It is assumed that the stuffs required for production of bread are limited
- It is assumed that an effective allocation of raw materials to the variables (big loaf, giant loaf and small loaf) will aid optimal production and at the same time maximizing the profit of then bakery.
- It is assumed that the qualities of raw materials used in bread production are standard (not inferior).

4. Data Presentation and Analysis

The data for this scientific research was collected from Gorretta bakery limited, Nigeria. The data contains total amount of raw materials (sugar, flour, yeast, salt, wheat gluten and soybean oil) available for daily production of three different sizes of bread (big loaf, giant loaf and small loaf) and profit contribution per each unit size of bread produced. The data analysis was carried out with TORA software(version 2.0). The content of every stuff per each unit product of bread produced is shown below.

Flour

Total quantity of flour available = 200kg
Every unit of big loaf needs s 0.2kg of flour
Every unit of giant loaf needs 0.24kg of flour
Every unit of small loaf r needs 0.14kg of flour

Sugar

Total quantity of sugar available = 160g
Every unit of big loaf needs 0.14g of sugar
Every unit of giant loaf needs 0.20g of sugar

Every unit of small loaf needs 0.16g of sugar

Yeast

Total quantity of yeast available = 20kg
Every unit of big loaf needs 0.02kg of yeast
Every unit of giant loaf needs 0.02kg of yeast
Every unit of small loaf needs 0.02kg of yeast

Salt

Total quantity of salt available = 8.5g
Every unit of big loaf needs 0.0011g of salt
Every unit of giant loaf needs 0.00105g of salt
Every unit of small loaf needs 0.00017g of salt

Wheat gluten

Total quantity of wheat gluten = 15.0g
Every unit of big loaf needs 0.000167g of wheat gluten
Every unit of giant loaf needs 0.002g of wheat gluten
Every unit of small loaf needs 0.00012g of wheat gluten

Soybean Oil

Total quantity (volume) of soybean available = 10.0L
Every unit of big loaf needs 0.0157L of soybean oil
Every unit of giant loaf needs 0.021L of soybean oil
Every unit of small loaf needs 0.0098L of soybean oil

Profit contribution per unit product (size) of bread produced

Every unit of big loaf = N30
Every unit of giant loaf = N40
Every unit of small loaf = N20
The above data can be summarized in a tabular form.

Raw material	Product			Total available raw material
	Big loaf	Giant loaf	Small loaf	
Flour (kg)	0.20	0.24	0.14	200.0
Sugar (g)	0.14	0.20	0.16	160.0
Yeast (kg)	0.02	0.02	0.02	20.0
Salt (g)	0.0011	0.00105	0.00017	8.5
Wheat gluten (g)	0.000167	0.002	0.00012	15.0
Soybean oil (L)	0.015	0.021	0.0098	10.0
Profit (N)	30	40	20	

Model formulation

Suppose the amount of big loaf to be produce = y_1
Suppose the amount of giant loaf to be produce = y_2
Suppose the amount of small loaf to be produce = y_3
Suppose Z denote the profit to be maximize
The linear programming model for the above production data is given by

$Max\ Z = 30y_1 + 40y_2 + 30y_3$
Subject to constraints are

$0.20y_1 + 0.24y_2 + 0.14y_3 \leq 200$
$0.14y_1 + 0.20y_2 + 0.16y_3 \leq 160$
$0.02y_1 + 0.02y_2 + 0.02y_3 \leq 20$
$0.0011y_1 + 0.00105y_2 + 0.00017y_3 \leq 8.5$
$0\ .00067\ y_1 + 0.002\ y_2 + 0.00012\ y_3 \leq 15$
$0.015y_1 + 0.021\ y_2 + 0.0098\ y_3 \leq 10$

$y_1, y_2, y_3 \geq 0.$

Converting the model into its corresponding standard form;

$Max\ Z = 30y_1 + 40y_2 + 30y_3 + 0s_1 + 0s_2 + 0s_3 + 0s_4 + 0s_5 + 0s_6$
Subject to constraints are

$0.20y_1 + 0.24y_2 + 0.14y_3 + s_1 \leq 200$
$0.14y_1 + 0.20y_2 + 0.16y_3 + s_2 \leq 160$
$0.02y_1 + 0.02y_2 + 0.02y_3 + s_3 \leq 20$
$0.0011y_1 + 0.00105y_2 + 0.00017y_3 + s_4 \leq 8.5$
$0\ .00067\ y_1 + 0.002\ y_2 + 0.00012\ y_3 + s_5 \leq 15$
$0.015y_1 + 0.021\ y_2 + 0.0098\ y_3 + s_6 \leq 10$

$y_1, y_2, y_3, s_1, s_2, s_3, s_4, s_5, s_6 \geq 0.$

The above linear programming model was solved by use of TORA software, which provides an optimal solution of:
$Y_1 = 38.0$, $Y_2 = 0.0$, $Y_3 = 962.0$
$Z = 20385.0$

Interpretation of Result

Based on the info collected the optimum result derived from the model indicates that two sizes of bread should be produced, small loaf and large loaf. Their production quantities should be 962.0 and 38.0 units respectively. This may produce a maximum profit of N20,385.0

5. Summary

The objective of this research work was to use lpp for optimal use of stuff in bread production. Goretta bakery limited was used as our case study. the decision variables during this research work are the three different sizes of bread (big loaf, giant loaf and small loaf) produced by Goretta bakery limited. The researcher focused mainly on six raw materials (flour, sugar, yeast, salt, wheat gluten and soybean oil)used within the production and therefore the amount of stuff required of every variable (bread size). The result shows that 962 unit of small loaf, 38 unit of big loaf and 0 unit of giant loaf should be produce respectively which can provides a maximum profit of ₦20385.0

6. Conclusion

Based on the analysis administered during this research work and therefore the result shown, Goretta bakery limited should produce the three sizes of bread (big loaf, giant loaf and small loaf) so as to satisfy her customers. Also, more of small loaf and big loaf should be produce so as to achieve maximum profit, because they contribute mostly to the profit earned by the corporate.

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