MULTIPLE TECHNIQUES OF SOLVING LINEAR PROGRAMMING MODEL FOR THE OPTIMAL USAGE OF RAW MATERIALS AND PROFIT MAXIMIZATION IN A BAKERY

1.F.F Amurawaye,2. A.R Hassan, 3.A.O Ogunyale and 4.G. G Oyetoro.

1,2,3 Department of Mathematics,
Tai Solarin University of Education, Ijagun, Ijebu ode, Ogun state, Nigeria.
4. Department of Mathematics and statistics, Adeseun Ogundoyin polytechnic, Eruwa

Abstract
This research work examine the multiple techniques that can be used in solving linear programming model for the optimal usage of raw materials and profit maximization in a Bakery. The use of linear optimization techniques to solve the problem on the use of resources and profit to be maximized was considered with particular reference to Tai Solarin University of Education (TASUED) Ventures Limited, Ijagun, Ijebu ode, Ogun state, Nigeria. Data used for this study were collected from Bakery section of the organization. This research work utilized the concept of Simplex algorithm, Microsoft Excel solver, LINGO18.0 software and Graphical method to assign limited resources to competing decision variables such as (small loaf and big loaf) for the purpose of profit maximization. Based On the data collected on the amount of raw materials available, the result shows that more of small loaf should be produced to optimize the use of raw materials and to maximize profit for the organization.

Keywords: *Constraints, decision variables, linear programming, objective function, optimal solution.*

1. INTRODUCTION

The growth of every industry is made possible by its efficient and effective use of resources utilized during each stage of its production stage. Erinle Ibrahim *et al* (2020) affirm that limited resources are at disposal of every organization. In modern days, manufacturing industries and business enterprises are often confronted with challenges emanating from how resources can be well utilized to produce goods of exact quality and precise proportion, mainly to maximize profits for the organization. Titilayo *et. al* (2018) added that firms have been finding it difficult to allocate scare resources in a manner that will ensure profit maximization or cost minimization. However, the proficient utilization of the resources which are to be used is achievable by the decision making techniques

adopted by such organization. This is because the aims of every business organizations, companies or firms are to maximize profits and minimize costs as this will enhance their continuous survival and outputs.

Linear programming model otherwise known as linear optimization model is a specialized mathematical decision-making techniques that serves as a problem-solving approach developed to help managers in decision making. The word linear represents mathematical functions which are essential and can be expressed as linear functions, while programming represents the mathematical modeling which is used in solving problems related to how limited resources can be well utilized to their best advantage. Singh (2018) stated that if both objective function and constraint(s) are linear, then they can be framed as a linear programming problem. This has made linear programming model which is a mathematical tools used in the field of Operation Research for activities planning to considered as a technique that can be used to attain an optimal solution to most situations that are of great complexity.

The quantitative decision making tools called linear programming can be used for optimization problem of product mix (Woubante, 2017). This technique has helped most decision maker to improve the quality of their decisions. It has also been used extensively in solving problems related to resource allocation, products mix, transportation and assignment problems which allow choices to be made among alternative course of action as cited by (Yahya, 2004). Although many business organization see linear Programming as a new science or recently development in history of mathematics, but there is nothing new about the maximization of profit in any business organization (Akpan *et al*, 2016). However certain real-life problems can be represented as linear functions. The techniques of linear programming model has been applied in several fields such as mathematics, manufacturing industry, transportation optimization, military, agriculture and other relevant fields.

The Bakery Industry has been considered as one of the largest processed food industries in most countries.

Nwewi *et. al* (2017) reported that a lot of small and medium scale businessmen are shipping into and launching out different techniques, to take advantage of the industry at different location in the state. However, Bread which is one of popular bakery products in our society today can be used as an alternative food for rice (*Suryatna*, 2015). Bread is the product obtained by mixing, fermentation, forming and baking of dough obtained from basic raw materials (Aleksander *et al*, 2009). Raw materials used in producing bread include wheat flour, yeast, sugar, butter, salt, flavour, preservative, nutmeg, improver, vegetable oil, and water. Considering the significance and the timely supply of raw materials that would be needed for production, it is important to implement the concept of

linear programming model to the optimal usage of resources or raw materials. Citraresimi *et. al* (2016) established that the relevance of resources supply has made organizations concentrate on the correlation among the quantities of the resources that would be desirable for production.

However, the inferences drawn from various study, has revealed that most manufacturing industries are not familiar with the application of linear programming model to their operations. This has made most of the decisions taken by the management of such production companies and business enterprises to be based on trial and error method to determine the quantity of the raw materials that would be used and the amount of products or goods to be produced from using them, which might either be profitable or not. Linear programming has been demonstrated to be an alternative solution and plans that can be used to replace the traditional solutions which are based on trial and error (Cardoen *et. al*, 2010). One of the competent technique that help companies to efficiently improve the use of their resources to increase profit is linear programming (Gezahegn *et. al*, 2016). Therefore, this study has been undertaken to boast the efficiency of an institutional owned Bakery of Tai Solarin University of Education ventures limited by formulating a linear programming model that would suggest a viable product mix needed to ensure optimal usage of raw materials and profit maximization. Also, this study uses Simplex algorithm to determine the quantities of each product needed to maximize profit and comparing the result of the model by using Microsoft Excel solver, LINGO 18.0 software and Graphical method.

2. LITERATURE REVIEW

The concept of linear programming model has been considered as an important innovatory techniques which has given human the ability to set worthwhile goals and to state different line of actions that can be used in achieving their goals when their faced with real situations of life. In 1939, Russian mathematician called Leonid Kantorovich developed the first linear programming model which was used during the military operation of the World War II. However, the technique of linear programming model was published by a renowned American mathematician George B. Dantzig and John Neumann who propounded linear optimization solution called the theory of duality which was used for game theory. Ever since the time it was suggested in 1947 linear programming has been used tremendously in many fields by management scientist, data analyst, statistician, mathematician and academic researcher who have written numerous numbers of books and research article on it.

The simplex method/algorithm has however been considered as an efficient tools for deriving most theorem which involves series of steps with some number of decision

variables. In today society due to technological advancement, simplex algorithm has been developed in some computer software packages to solve thousands of variables. This refinement has increase the scope on the use of this technique to series of operations.

Many researchers have solved diverse practical problems using linear programming model. Some of their landmark works include. Balogun O.S *et al* (2012) in their study considered how linear programming techniques can be used in maximizing profit derived from the production of soft drinks by Nigeria Bottling Company using simplex method. They suggested that only two particular soft drinks should be produced to maximize profit.

Erinle-Ibrahim *et. al* (2020) develop an optimization scheme of using linear programming in a production line of rite foods limited Ososa. In their study using Simplex algorithm it is observed that the company's profits would be maximized if it produced more of Bigi Cola and Bigi Tropical soft drinks among those which were used for the analysis.

Oladejo N.K *et. al* (2019) in their studies on the use of optimization principle to optimize profits of a production industry using linear programming to determine the production cost and its optimal profit. From the data collected on the five types of bread which include Chocolate loaf, Family loaf, sliced family bread, medium size bread, and small size bread which are solved using AMPL software. The results obtained reveals that the bakery firm should concentrate more on the production of Family loaf and Chocolate loaf while others should be produced in less quantity.

Titilayo *et. al* (2018) studied how the Profits made by Lace Baking Industry in Lafia can be optimized using the techniques of Linear Programming Model. Analysis on the data collected on the six types of bread packages produce by the firm which includes Fancy bread (1kg), Family loaf (1kg), Banana bread (800g), Mini loaf (150g), Fruit bread (1kg) and Coconut bread (900g). Using R statistical software the solution reveals that the baking industry should produce more of Mini loaf, followed by Family loaf because they contributes more to the profit to be made by the baking industry.

3. MATERIAL AND METHOD

General Mathematical Model of Linear Programming

Generalized linear programming model having *q* constraints *and p* decision variables can be written in this form:

Optimize (Min or Max) $Z = c_1x_1 + c_2x_2 + ... + c_px_q$ subject to the linear constraints,

$$a_{11}x_1 + a_{12}x_2 + ...+ a_{1p}x_p \ (\leq, =, \geq) b_1$$
$$a_{21}x_1 + a_{22}x_2 + ...+ a_{2p}x_p \ (\leq, =, \geq) b_2$$
$$\cdot \qquad \cdot \qquad \cdot \qquad \cdot$$
$$a_{q1}x_1 + a_{q2}x_2 + ...+ a_{qp}x_p \ (\leq, =, \geq) b_q$$

and

$x_1, x_2, ..., x_n \geq 0$

The formulation above can also be written in a compact form below.

Optimize (Min or Max) $Z = \sum_{j=1}^{p} c_j x_j$ (Objective function) (1)

Subject to the linear constraints

$\sum_{j=1}^{p} a_{ij} x_j \ (\leq, =, \geq) b_i ; \ i = 1,2,....., q$ (Constraints) (2)

And $x_j \geq 0 ; \quad j = 1,2,....., p$ (Non –negativity conditions) (3)

Structure of Simplex tableau for Linear Programming model

Basis	x_1	x_2	x_p	k_1	k_2	k_q	B	Check
k_1	a_{11}	a_{12}	a_{1p}	1	0	0	b_1	
k_2	a_{21}	a_{22}	a_{2p}	0	1	0	b_2	
.	.	.	.	.	.	.	.	
.	.	.	.	.	.	.	.	
k_q	a_{1p}	a_{2p}	a_{qp}	0	0	1	b_q	
P	Z_1	Z_2	Z_p	0	0	0	Z_j	

Assumption of linear programming model

(i) It deals with only a single objective.
(ii) It assumes linear relationship among decision variable.
(ii) It does not take into consideration the effect of time and uncertainty.
(iv) Parameters in the model are assumed to be constant.

Data Presentation and Analysis

The table below shows the data collected from Bakery section.

Table 1: Amount of raw materials required to produce each loaf of Bread.

Raw materials	**Units**	**Products**		**Quantity Available**
		Small loaf	**Big loaf**	
Flour	Kg	0.23	0.25	200
Sugar	Kg	0.02	0.034	18.74
Salt	Kg	0.0035	0.0045	3.12
Butter	Kg	0.0020	0.0045	1.995

Flavour	Kg	0.000416	0.0008	0.4
Preservative	Kg	0.000416	0.0008	0.4
Nutmeg	Kg	0.00008804	0.000127	0.08
Improver	Kg	0.000416	0.0008	0.4
Yeast	Kg	0.000416	0.0008	0.4
Water	L	0.11104	0.152	100

Source: TASUED Bakery 2020.

Table 2: Average cost price and selling price of each loaf of Bread with their profit

Products	**Cost of production per loaf**	**Selling price per loaf**	**Profits**
Small loaf	₦70	₦ 80	₦ 10
Big loaf	₦200	₦ 220	₦ 20

Source: TASUED Bakery 2020.

4. RESULTS

Data collected from the Bakery was used in formulating, solving and analyzing linear programming model using Simplex Algorithm, Microsoft Excel solver, LINGO18.O software and Graphical method.

Model Formulation

Maximize $P = 10X_1 + 20X_2$

Subject to,

$0.23X_1 + 0.25X_2 \leq 200$

$0.02X_1 + 0.034X_2 \leq 18.74$

$0.0035X_1 + 0.0045X_2 \leq 3.12$

$0.0020X_1 + 0.0045X_2 \leq 1.995$

$0.000416X_1 + 0.0008X_2 \leq 0.4$

$0.000416X_1 + 0.0008X_2 \leq 0.4$

$0.00008804X_1 + 0.000127X_2 \leq 0.08$

$0.000416X_1 + 0.0008X_2 \leq 0.4$

$0.000416X_1 + 0.0008X_2 \leq 0.4$

$0.11104X_1 + 0.152X_2 \leq 100$

$X_1, X_2 \geq 0$

Where,

X_1 = quantity of small loaf.

X_2 = quantity of big loaf.

Result from the analysis carried out with linear programming model using Simplex Algorithm, Microsoft Excel solver, LINGO 18.0 software and Graphical method give the following results

Simplex Algorithm

Optimal solution

$X_1 = 749.999894604 \approx 750,$

$X_2 = 110.000046867 \approx 110,$

$P = 9699.99988295 \approx 9700.$

Microsoft Excel Answer Report

Target Cell (Max)

Cell	Name	Original value	Final Values
B19	Total profit for Small loaf	9700	9700

Adjustable Cells

Cell	Name	Original value	Final Value
B17	Small loaf produced	750	750
C17	Big loaf produced	110	110

Micro Excel Sensitivity Analysis

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B17	Small loaf Produced	750	0	10	3.864566929	1.111111111

C1	Big loaf					5.57473875
7	Produced	110	0	20	2.5	5

LINGO 18.0

Global optimal solution found.

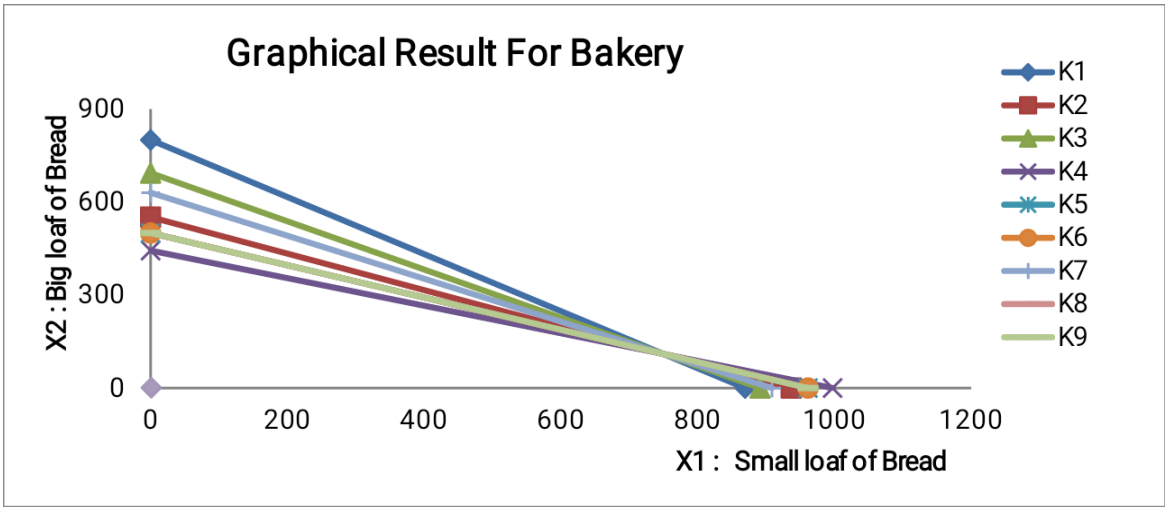
Objective value: 9700.000

Variables	Value	Reduced Cost
X1	750.0000	0.000000
X2	110.0000	0.000000

Rows	Slack or Surplus	Dual Price
1	9700.000	1.000000
2	0.000000	-97.33333

LINGO result indicates that the objective value P=9700, X1=750 and X2=110. This implies that in other to maximize profit of ₦9700. Small loaf of 750 units and big loaf of 110 units of bread should be produced.

GRAPHICAL SOLUTION



5. DISCUSSION

Results on the multiple techniques used in analysis of the data collected from the Bakery shows that the objective function to be maximized is P=9700, and the decision variables are $X_1 = 750$ and $X_2 = 110$. This implies that for the organization to have optimal utilization of her scarce resources in other to maximize profit, 750 units of small loaves and 110 units of big loaves of bread should be produced from the available raw materials.

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