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Application of Linear Programming for Profit Maximization in Shukura Bakery, Zaria, Kaduna State, Nigeria

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Abstract

Linear programming is an operation research technique which is widely used in finding solutions to managerial decision making problems of allocating scarce resources in order to maximize profit and minimize cost. This paper deals with the application of the optimization principle .It examined unit cost of production, the selling price and the quantity of different raw materials used in production and the available raw materials in stock weekly to determine the optimal profit of a popular local bakery Shukura Bakery, Zaria, Kaduna State, Nigeria using linear programming technique. Four types of bread produced by the bakery namely; small loaf, medium loaf, family loaf and slice family loaf were considered in the research. A model for the problem was formulated and optimum results derived using software that employed simplex method. The result shows that the family loaf x_3 contributes more to the profit made and therefore, should be produced more by the Bakery.

Keywords: Optimization, linear programming, constraints, Objective function

INTRODUCTION

Profit making is the goal of every industry, company or firm, as that will guarantees its existence. The key to making profits in manufacturing industries lies in production of goods at minimum cost and maximum profit that are of the right standard, quantity and at the right time and more especially for sustainability and growth (Oladejo *et al.* (2019)).

Linear programming (LP) is a technique used in determining the best allocation of a firm's limited resources mathematically to achieve optimum results. It is also a mathematical method or procedure employed in operations research or Management Sciences to deal with specific problems that allows a choice or selection between alternative courses of action. It is perhaps the most effective and widely used optimization technique.

LP is a way of obtaining the best outcome in a mathematical model whose requirements are represented by linear relationships. It is a technique for the maximization or minimization of a linear objective function subject to linear equality and inequality constraints. It has applications in various fields of study which include mathematics, business, economics and engineering. Industries that use linear programming models include transportation, energy,

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telecommunications and manufacturing. Its usefulness span into modeling diverse types of problems in planning, routing, scheduling, assignment and design.
Many researchers have studied linear programming and its real life application in recent years.

Balogun *et al.* (2012) used linear programming method in deriving the maximum gain from production of soft drink in Nigeria Bottling Company, Ilorin plant. Linear programming of the operations of the company was formulated and optimum results obtained using software that uses simplex method. Their results showed that two particular products should be produced even when the company should meet demands of the other-not-so profitable items in the surrounding of the plants.

Adebiyi *et al.* (2014) focused on linear programming for achieving product-mix optimization in and optimum firm performance. Their result obtained showed that only two out of the five items they considered in their computational experiment are profitable. Ibitoye *et al.* (2015) empirically examined the impact of linear programming in entrepreneur decision making process as an optimization technique for maximizing profit with the available resources.
Igbinehi *et al.* (2015) used linear programming to obtain optimal profit in production of local soap. Raimi *et al.* (2017) examined the optimization of bread production in Rufus Giwa Polytechnic Bakery, Owo, Ondo State, Nigeria using linear programming technique. Amit *et al.* (2020) also apply linear programming to maximize profit and minimize cost of transportation at Mascot Herbals Ltd and Ashwini Herbal Pharmacy, India.

In this work, the researchers, through observation noted that most works carried out on LP has to do with large or medium scale firms while the local or small-scale firms are left wit a trial and error method of production in order to minimize cost and maximize profit. This gap necessitated the need to practically demonstrate the reliability of LP model in Shukura bakery to enable the owner to improve his decision making capability. Therefore the researchers intend to demonstrate how the developed LP working model can assist the local bakery to optimize its resources for effective output decision.

MATHEMATICAL FORMULATION

A Linear Programming Problem (LPP) has the generic form
maximize/minimize the objective function (Amit *et al.* (2020)):

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + \cdots + c_nx_n \text{---------- (1)}$$

subject to the constraints:

$a_{11}x_{1+}a_{12}x_2{+}a_{13}x_3 + \cdots + a_{1n}x_n(\leq, =, \geq)b_1$
$a_{21}x_{1+}a_{22}x_2{+}a_{23}x_3 + \cdots + a_{2n}x_n(\leq, =, \geq)b_2$
$a_{31}x_{1+}a_{32}x_2{+}a_{33}x_3 + \cdots + a_{3n}x_n(\leq, =, \geq)b_3$
… … … … …
… … … … …
$a_{m1}x_{1+}a_{m2}x_2{+}a_{m3}x_3 + \cdots + a_{mn}x_n(\leq, =, \geq)b_m$

And the non-negative restrictions $x_j \geq 0,\ j = 1,2, \ldots, n$
where a_{ij} , b_i , and c_i are constants and x_j are variables.

METHODOLOGY

The information used for this research work was collected from Shukura Bakery in Zaria in October, 2021. The collected data was based on the different types of bread produced by the bakery which are small, medium and family loaves. The bakery makes production from eight 50kg bags of flour on all the seven days of the week from 9:00am to 4:00pm with the exception of Sundays that the bakery opens by 12:30pm and makes production at half capacity.

In Table 1, the various types of loaves produced by the bakery and the unit cost of production, market price and net profit are given. The raw materials used for the production, the raw material mix for each product (in grams), and the available amount of each raw material for weekly production is stated in Table 2.

Table 1: Types of Products Made by the Bakery, the Production cost per unit, market price and Profit

Product Type	Cost Price/loaf (₦)	Selling Price/loaf (₦)	Selling Price/loaf (₦)
Small loaf x_1	105	120	15
Medium loaf x_2	170	200	30
Family loaf x_3	290	350	60
Family(slice) loaf x_4	290	350	60

Source: Shukura Bakery Records 2021

Table 2: Raw materials used for the production of the different types of bread

Raw materials	Types of bread and their raw materials mix				Total quantity per week (grams)
	x_1	x_2	x_3	x_4	
Flour	170	285	500	500	2,800,000
Yeast	0.6	1.1	2	2	11,200
Milk	1	1.8	3	3	16,800
Egg	0.3	0.5	1	1	5,600
Water	60	100	180	180	1,008,000
Preservatives	1	1.5	3	3	16,800
Butter	13	20	40	40	224,000
Sugar	27	40	80	80	448,000
Salt	3.4	5	10	10	56,000

Source: Shukura Bakery Records 2021

FORMULATION OF THE LINEAR PROGRAMMING PROBLEM

Let x_1, x_2, x_3 and x_4 be the decision variables which represent the non-negative number of small loaf, medium loaf, family loaf and family slice loaf breads to be produced by the factory in a week. c_1, c_2, c_3 and c_4 are the respective profits for each unit of the various types of bread produced in the bakery. $a'_{ij}s$ represent the quantity of each raw material used in the production of the four types of bread. The objective is to maximize the weekly profit Z of the bakery and thus a linear programming model for the maximization of the objective function Z can be stated mathematically as follows:

Maximize the objective function:

$$Z = 15x_1 + 30x_2 + 60x_3 + 60x_4 \text{----------} \quad (2)$$

Subject to the constraints:

$170x_1 + 285x_2 + 500x_3 + 500x_4 \leq 2{,}800{,}000$
$0.6x_1 + 1.1x_2 + 2x_3 + 2x_4 \leq 11{,}200$
$x_1 + 1.8x_2 + 3x_3 + 3x_4 \leq 16{,}800$
$0.3x_1 + 0.5x_2 + x_3 + x_4 \leq 5{,}600$
$60x_1 + 100x_2 + 180x_3 + 180x_4 \leq 1{,}008{,}000$
$x_1 + 1.5x_2 + 3x_3 + 3x_4 \leq 16{,}800$

$13x_1 + 20x_2 + 40x_3 + 40x_4 \leq 224{,}000$
$27x_1 + 40x_2 + 80x_3 + 80x_4 \leq 448{,}000$
$3.4x_1 + 5x_2 + 10x_3 + 10x_4 \leq 56{,}000$
$0.07x_1 + 0.1x_2 + 0.2x_3 + 0.2x_4 \leq 1{,}120$
With: $x_1, x_2, x_3, x_4 \geq 0$

By introducing the slack variables $s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8, s_9, s_{10}$ to convert inequalities to equations, we have the standard form as follows:
maximize: $Z = 15x_1 + 30x_2 + 60x_3 + 60x_4$
subject to the constraints:
$170x_1 + 285x_2 + 500x_3 + 500x_4 + s_1 = 2{,}800{,}000$
$0.6x_1 + 1.1x_2 + 2x_3 + 2x_4 + s_2 = 11{,}200$
$x_1 + 1.8x_2 + 3x_3 + 3x_4 + s_3 = 16{,}800$
$0.3x_1 + 0.5x_2 + x_3 + x_4 + s_4 = 5{,}600$
$60x_1 + 100x_2 + 180x_3 + 180x_4 + s_5 = 1{,}008{,}000$
$x_1 + 1.5x_2 + 3x_3 + 3x_4 + s_6 = 16{,}800$
$13x_1 + 20x_2 + 40x_3 + 40x_4 + s_7 = 224{,}000$
$27x_1 + 40x_2 + 80x_3 + 80x_4 + s_8 = 448{,}000$
$3.4x_1 + 5x_2 + 10x_3 + 10x_4 + s_9 = 56{,}000$
$0.07x_1 + 0.1x_2 + 0.2x_3 + 0.2x_4 + s_{10} = 1{,}120$
With: $x_1, x_2, x_3, x_4, s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8, s_9, s_{10} \geq 0$
The optimal solution obtained using Solver (Microsoft Excel Tool) as follows:

Table 3: Optimal solution

Variables	Values
Z	336,000
x_1	0
x_2	0
x_3	5,600
x_4	0

RESULTS AND DISCUSSION

By applying simplex method on the linear programming model formulated, the optimum solution of the Linear programming problem is as follows:

$x_1 = 0, x_2 = 0, x_3 = 5{,}600$ and $x_4 = 0$ with $Z = N336{,}000$.

This solution simply shows that x_3 is the only product that contributes meaningfully to improve the value of the objective function of the linear programming model.
Considering the solution of the linear programming model obtained, it is therefore recommended and beneficial for shukura Bakery to give much more attention on the production of family loaf
at the moment due to instability of prices and availability of raw materials provided there is demand for the product. By this, total sales of 5,600 units would be sold per week. This would yield the Bakery an optimal profit of N336,000 per week based on the costs of raw materials to be used.

CONCLUSION

In this work, we have effectively considered the different types of products, amount of raw materials used and the production cost in Shukura Bakery weekly. Using the secondary data obtained from the sales department of the bakery on four types of bread produced, the optimal solution was obtained after a formulation of the linear programming problem. The solution obtained revealed that the management of the Bakery should focus more on the production

of the family loaf and produce less of the other products since they contribute less so as to realize a peak weekly gain of N336,000.

The study has shown that the Linear Programming Model can be applicable to small scale firms to substitute the trial and error method in finding optimal solutions to some decision-making problems.

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