

# Material Handling and Product Optimality of an Educational Institution Bakery Using Integer Programming

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## ABSTRACT

This study presents a numerical analysis for enhancing material handling allotment and deciding whether to produce or not in a bread production section of an educational institution. The study utilized 0/1 and real variables by the means of integer linear programming. In line with this, integer linear programming was applied in a bread production plant that produces three brands of bread, such as, medium size ( $x_1$ ), huge size ( $x_2$ ), and small size ( $x_3$ ). The discoveries using 0/1 variable shows that  $x_1 = x_2 = x_3 = 1$  while  $Z = 80$  Naira. Hence, the item mix of bread is optimal, and production can continue. The result obtained utilizing real variable demonstrated that  $x_1$  (medium-size bread) = 649,  $x_2$  (huge-size bread) = 0,  $x_3$  (small-size bread) = 145,  $Z=18,388$  Naira. In this manner the material handling allotment was optimized to obtain a profit of 18,388 Naira. Consequently, the organization should produce more medium-size bread ( $x_1$ ), more small-size bread ( $x_3$ ), and less huge-size bread ( $x_2$ ).

## KEYWORDS

Integer Linear Programming, Material Handling, Variable

## 1. INTRODUCTION

In a production framework, there are a lot of cycles and events that are sequentially arranged. One of the production frameworks is material handling. It is an integral aspect of production that decides the amount and place, which in turn will determine the product output. In line with this, there is need to optimize the interconnected production frameworks by applying optimization strategies to

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achieve product optimality (Ogunnaike, Bishop, Akinsulire, Kehinde, & Oreagba 2018). This model is employed to decide if an item will be produced or not due to limited resources. The high demand for raw materials require equivalent effectiveness in material handling proficiency and allocation in the manufacturing sector. Mathematical techniques are often proposed due to the need from organizations to respond to shortage or economic situations (Kallrath, 2005). These techniques investigate and measure the productivity and propose alternative solutions.

An optimal material handling framework is set to accomplish the profitability of an item. On the grounds that about 80% of the overall cost of an item is fundamentally based on the allocation and movement of materials (Kamble & Patil, 2019). While, 20% is associated with the procedure of production. According to (Noor, Omair, Maqsood & Zubairm, 2019) the cycle of material handling includes various capacities, such as, the conveyance and capacity in an assembling plant, the control and, security of crude materials and items. It also involves the allocation of materials and completed products, sorting, arrangement, fabricating and utilization. The most significant aspect of material handling process is the allotment of materials to a suitable location of utilization within any production facility (Mohite & Dongre, 2015). This will make the manufacturing procedure seamless and less time will be expended during production and product optimality will be achieved. Purnomo and Wiwoho (2019) asserted that an optimal material handling distribution framework and the determination of what to produce precipitate profitability.

The conveyance of materials within any production structure, for instance, the rate, quantity, and satisfying similar number of necessities are the objectives to optimize material allocation and item production (Adebayo, Kehinde, Ogunnaike, Olaoye, & Adesanya, 2019). In line with this, the technique of mixed-integer linear programming model was utilized to tackle a scheduling issue in a school which was an issue of allocation (Kristiansen, Sorensen & Stidsen, 2015). The utilization of integer mathematical models can be applied to portray decision issues based on the optimal utilization of resources in designing innovation, businesses and other various fields (Al-Shihabi & Aldurgam, 2020). A linear model with an integer limitation and decision factors is termed linear integer model. This class of mathematical model has a specific significance in organizations where the dynamic state of variables is engaged with numerous decision making circumstances i.e. production fields.

A mixed integer model was applied to address even harvest issues and the minimization of variables in the reap region and harvest quantity are consolidated as the objective function in order to obtain a moderate harvest (Demirci, Yesil & Bettinger, 2020). Oladejo, Abolarinwa, Salawu, Lukman and Bukari (2019) examined the total amount and quality mix of five items produced in an organization and the apportioning of materials to different products utilizing linear programming. This technique was utilized to obtain an optimal production. In business circumstance's there are scenarios where the variables of request are integers. Considering the product blend of the production firm that operates within limited resources and capacity, the organization will need decide the quantity of units of every item that will be produced in order to maximize profit. Therefore, this study explored integer Programming (IP) using a numerical model to optimize material handling distribution and determine the items that will be produced.

## **2. LITERATURE REVIEW**

A numerical formulation by (Kantor, Robineau, Butun & Marechal, 2020) was figured through the reconciliation of complex mechanical frameworks from the degree of unit activities to processes. The utilization of mixed-integer linear programming to helped to improve the cycle through the integration of various scale, and gives answers for the integration within the plant and potential mechanical interactive alternatives to attain optimality. Mageshvaran and Kumar (2020) formulated numerical steps, calculations, programming, and solvers to tackle a problem using mixed-integer linear programming. This includes problems that are constrained to be numbers, while different variables can be non-integers. The investigation by (Zhong, Zhang, Wang, Zhong, Wen & Peng,

2020) was based on a moving stock routing issue in a metropolitan travel line with different course plans, terminals, and moving stock sorts.

However, the issue is defined as a mixed integer model to limit movement. Patil and Kumanan (2015) utilized mixed-integer programming that has two objective functions, which is minimizing material cost and office building cost. They proposed a lexicographic strategy to deal with numerous objectives. A numeric iteration by (Ammar & Emsimir, 2020) utilizing integer linear model where all boundaries within the constraints and the objective is non-linear. Subsequently, integer linear procedure is introduced utilizing the slice sum strategy with the branch and bound method. Yami, Okafor, and Modibo (2020) utilized mixed integer linear programming to aid production outcomes and homogenous item, multi-item procedure routing issues. The model form considered the procedure, the conveyance necessities, various items, and distinctive stock levels. The goal is to reduce production quantity, transportation, and stock expenses. It produced a noteworthy value that shows the utilization of logical methodology is better than the current organization practice.

In the view of (Luo, Liu, Cui, Cheng, Yu, Li, Jiang & Tan, 2020) an efficient analysis of the components influencing the planning of medical attendants in a large medical clinics applying an adaptable scheduling model. Blood collection by medical attendants is set up utilizing mixed integer programming. This consolidated model determined the number of medical attendants needed during a specific period. According to (Takanoa & Nagano, 2019) a stream shop with obstructing, succession and machine dependent arrangement time bottleneck intending to minimize the make-span is considered. Two mixed integer models are proposed and two other models, are proposed for the no setup issue. The iterations shows a stream shop with blocking and machine dependent arrangement time optimization. The study by (Tantawy, 2014) presented another method for analyzing integer models issue with a linear function and constraints that are unequal. The proposed strategy depends on the gradient technique and the utilization of Gomory cut to apportion resources. Al-Rabeeah, Al-Hasani, Kumar, and Eberhard (2020) developed another calculation to track down the arrangement of a non-control focus for an integer model with multiple objectives.

The upgraded calculation is a better recursive strategy by utilizing a lexicographic technique to allocate resources. Kayode, Atsegameh, and Omole (2020) utilized linear model technique to a dynamic problem in an organization, and further decide the amount of materials that the firm should deliver in a day to optimize profit, that is subject to limitations in the production cycle. It was formulated using numerical analysis and solved utilizing linear programming solver (LIPS) to obtain resource optimality. Hecker, Hussein, Hussein, and Becker (2020) developed a model utilizing a manufacturing line with a restricted scope of data and information to match the real process utilizing a PSO calculation to optimize resources. Results show the high capability of this strategy to solve planning issues with less computational time.

### **3. JUSTIFICATION FOR THE STUDY**

The final decision of an educational institution bakery depends on the availability of material input and product profitability. The dynamics of this technique is constantly one-sided, for instance, the discrepancy in the accuracy of material handling allocation and the determination of what to produce. The organization is faced with the issue of lean resources. This is as a result of the economic downturn in Nigeria therefore, resource optimization is imperative. The educational institution bakery produces different sizes of bread at a large scale and it is confronted with two major issues. The issue of material handling allocation and determining whether to produce an item or not. This is a focal point in the organization because it determines the production rate and quantity. It is on this ground the study utilized integer programming to carry out a quantitative method of dealing with the dynamics of material handling distribution and determining whether to produce or not.

#### 4. OBJECTIVE OF THE STUDY

The objective of the study is the optimization of material handling distribution and determining whether to produce or not utilizing integer linear programming.

#### 5. METHODOLOGY

$$\text{Optimize: } \sum_{j=1}^n C_j X_j (x_1, x_2, x_3, \dots)$$

subject to:

$$\sum_j a_{ij} x_j = b_i, i = 1, 2, \dots, m$$

and:

$$X_j \geq 0, j = 1, 2, \dots, n$$

and  $x_j$  integer value:

$$j = 1, 2, \dots, h \leq n$$

$$X_j = j (1, 0)$$

An integer programming variable is limited to take discrete estimations within any formulation, the function (objective engaged with the limitations) in an integer programming. The  $C_j X_j$  is the cost and resources that will be optimized while,  $a_{ij} x_j$  implies to the decision constraints. There are two values for  $x_j = j(1, 0)$ . In the event that item  $x_j$  is 1, it means the product is profitable, optimal and production should proceed, if item  $x_j$  is 0 it is not profitable nor optimal and production should stop. Integer linear programming was utilized to model material handling, with an objective function  $C_j X_j$  representing the unit prices of each product such as  $x_1, x_2$  and  $x_3$  while,  $a_{ij} x_j$  the resources utilized to manufacture them. Integer linear programming is a subjective quantitative method that helps in making optimal decisions. The main advantage of this technique is the subjective insight in planning resources, and making decisions.

#### 6. DATA ANALYSIS AND PRESENTATION

The information for this study was gathered from a bread production plant in Nigeria via observation and archival documents. The information comprises of the aggregate sum of resources for the production of different sizes. They are white flour, salt, yeast, sugar, vegetable fat, and calcium propitiation accessible for making three distinct range of bread such as small, medium and large or huge size and the available space in the store per day. The information was analyzed using two variables real and 0/1 via QM software. The material per unit product of size (bread) produced is as shown in Table 1.

Table 1. Initial Model

	White flour(g)	Salt (g)	Sugar (g)	Yeast (g)	Fat (g)	Calcium (Litres)	Profit
Medium	0.2	0.00011	0.14	0.05	0.000231	0.012	25
Huge	0.34	0.0110	0.20	0.05	0.02	0.031	40
Small	0.14	0.00015	0.17	0.05	0.00012	0.015	15
Total	150g	10.5g	140g	50g	15.0g	8L	

### 6.1 Model Definition

The model was formulated based on the resources such as white flour, salt, yeast, sugar, vegetable fat, and calcium propitiation utilized to produce bread in the organization. Let the Medium size represent:  $x_1$ ; Let the huge size represent:  $x_2$ ; Let the small size represent:  $x_3$ ; Let Z signify maximization (see Table 2):

$$\text{Max } Z = 25 x_1 + 40 x_2 + 15 x_3$$

subject to:

$$0.2 x_1 + 0.34 x_2 + 0.14x_3 \leq 150$$

$$0.0011 x_1 + 0.01103 x_2 + 0.00015x_3 \leq 10.5$$

$$0.14 x_1 + 0.20 x_2 + 0.17x_3 \leq 140$$

$$0.05 x_1 + 0.05 x_2 + 0.05x_3 \leq 50$$

$$0.00231 x_1 + 0.002 x_2 + 0.00012x_3 \leq 15$$

$$0.012 x_1 + 0.031 x_2 + 0.0015x_3 \leq 8$$

$$X_j = (0,1), x_1, x_2, x_3 \geq 0$$

Table 2.

Materials	Medium Size ( $x_1$ )	Huge Size ( $x_2$ )	Small Size ( $x_3$ )	Available Materials
White Flour(g)	0.2	0.34	0.14	150
Salt(g)	0.0011	0.01103	0.00015	10.5
Sugar(g)	0.14	0.20	0.17	140
Yeast(g)	0.05	0.05	0.05	50
Vegetable fat(g)	0.00231	0.002	0.00012	15
Calcium propionate(L)	0.012	0.031	0.0015	8
Z	25	40	15	

## 7. RESULTS AND FINDINGS

### 7.1 0/1 Variable Output

The outcome from table 2 utilizing QM software indicated that  $x_1$  (Medium size) = 1 unit;  $x_2$  (Huge size) = 1 unit;  $x_3$  (Small size) = 1 unit and Z (optimal output) = 80Naira. The output utilizing the

framework of 0/1 variable indicated that  $x_1$ ,  $x_2$  and  $x_3$  product blend of 1 unit each is feasible for production to obtain at an optimal cost of 80 Naira. The results (see Table 3) further shows that item  $x_1$ ,  $x_2$ , and  $x_3$  is sustainable for production and profitable for the organization.

Table 3. Iteration result

Iteration	Level	Added Constraint	Solution Type	Solution Value	$X_1$	$X_2$	$X_3$
		0	Optimal	80	1	1	1
1	0	0	Integer	80	1	1	1

## 7.2 Real Variable Output

The iterative result from table 3 indicated that  $x_1$  (Medium size) = 649 units;  $x_2$  (Huge size) = 0 units;  $x_3$  (Small size) = 145 units and Z (Profits) = 18388Naira. The feasible optimal output utilizing real variable further shows that the organization should produce 649 units of  $x_1$  (Medium size), 145 units of  $x_3$  (Small size) and a minimal unit of  $x_2$  (Huge size) to yield at optimal profit of 18388 (Z).

Table 4. Iteration result

Iteration	Level	Added Constraint	Solution Type	Solution Value	$X_1$	$X_2$	$X_3$
		0	Optimal	18388	649	0	145
1	0	0	Integer	18388	649	0	145

## 8. DISCUSSION

In literatures, optimal planning of the amount of resources required for production and allocation has been discussed using various models. The study proposed an integer programming model that addressed resource allocation and product optimality, with the goal of optimizing profit. QM software was utilized to develop a linear integer model. The study utilized linear integer programming through a framework of 0/1 and real variable. Table 3 and 4 displayed the values of three decision variables respectively i.e.  $x_1$ ,  $x_2$ , and  $x_3$  as well as their outcome and objective function value. Table 3 utilized the framework of 0/1 where 1 means profitability and 0 indicates loss. It further shows that the organization can obtain an optimal cost of 80 Naira after satisfying the basic integer programming iterative conditions. The linear integer model output is  $x_1$  (Medium size) = 1;  $x_2$  (Huge size) = 1;  $x_3$  (Small size) = 1 which means the products are profitable. However table 4 utilized real variables and a feasible linear integer output was obtained i.e.  $x_1$  (Medium size bread) = 649 units,  $x_2$  (Huge Size bread) = 0units,  $x_3$  (Small size bread) = 145units, Z=18388 Naira. This means that the organization should prioritize the production of  $x_1$  (Medium size bread) and  $x_3$  (Small size bread) and minimize the production of  $x_2$  (Huge Size bread) = 0units to obtain a profit of 18388 Naira.

## 9. CONCLUSION

The study utilized 0/1 and real variable via integer programming. The optimum output utilizing 0/1 and real variable by the means of QM software for  $X_j = (0,1)$  with  $0 \leq X_j \leq 1$  for all  $j$  yields  $x_1 = 1$ ,  $x_2 = 1$ ,  $x_3 = 1$  and  $Z = 80$ . In view of the findings  $x_1 = x_2 = x_3 = 1$  unit with  $Z = 80$  Naira. In line with this, the integer model also utilized real variable and it shows that  $x_1$  (Medium size bread) = 649 units,  $x_2$  (Huge Size bread) = 0 units,  $x_3$  (Small size bread) = 145 units,  $Z=18388$  Naira. From the analysis the product blend of bread is optimal and profitable at  $x_1 = 1$  unit,  $x_2 = 1$  unit,  $x_3 = 1$  unit to yield a minimized cost of 80Naira which means production should proceed. Furthermore the material handling distribution has been optimized to produce a profit of 18,388 Naira however, the organization should produce more medium size bread( $x_1$ ) and small size bread( $x_3$ ), and less huge size bread( $x_2$ ). The model was formulated in the context of the organizations circumstance via integer programming and an optimal outcome was obtained. Additional techniques, for example, parametric model are proposed in future work that will consider numerous destinations and request fluctuation. In all the proposed integer programming is utilized to achieve resources optimization.

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