Jewel Journal of Scientific Research (JJSR) 7(2): 268–278, 2022
©Federal University of Kashere-Nigeria (Print ISSN: 2384 – 6267, Online ISSN 2756-651X)
jjsr.fukashere.edu.ng

Application of Linear Programming Model for Optimal Production Planning: A Case Study of Adama Beverages, Jimeta Yola, Adamawa State, Nigeria

***[1]Danfulani, U. B.; [2]Joshua, A. Y.; [1]Oludele, R. A.; [3]Hassan M. and [3]Jonathan T.**

[1]Department of Operations Research Modibbo Adama University, Yola Adamawa State, Nigeria
[2]Department of Statistics Air Force Institutes of Technology, Kaduna; Kaduna State Nigeria
[3]Department of Mathematics Adamawa State Polytechnic. Yola Adamawa State, Nigeria
***Corresponding Author:** bitrus@mau.edu.ng; +2347039798031

Abstract

The Linear Programming Problem (LPP) as an applied mathematical model has been applied in business related problem for optimization purposes (maximizing profit or minimizing cost of production). This study applied linear programming model as an optimal model on the production planning for the maximization of profit in Adama Beverages, Jimeta Yola, Adamawa State Nigeria. We adopted exploratory research designed because the study was designed in order to determine 750ml of bottle water, 1000ml of fruit juice and 250ml of sachet water that a company can produce on a weekly basis in order to maximize profit and minimize production cost given the quantity of each resource consumed by each product. The data for the study were secondary data collected from the company. The variables of the study were the concentrate, sugar, distilled water of the precise quantity often used by the firm and flavour. These data were formulated into the linear programming model and analyzed using Temporary Ordered Routine Algorithm (TORA) software. The optimal tableaus of the TORA iterations were obtained in Iteration four (4). The results revealed that the company should produce 571 quantities of bottle water (X_1) and 2,143 quantities of fruit juice (X_3) on a weekly basis in order to yield weekly profit of $Z^* =$ ₦835,714.29k while neglecting the production of sachet water as it profit contribution is 0 (X_2). We recommend that the company should produce above quantities of bottle water and fruit juice in order to gain much profit.

Keywords: Linear Programming Model, Optimal, Profit, Production

Received: 16th Oct., 2022 *Accepted:* 24th Dec, 2022 *Published Online:* 27th Dec., 2022

Introduction

Linear programming (LP) is the branch of applied mathematics that deals with a class of business-related problems for optimization. Linear programming (LP) is a widely used mathematical modeling technique developed to help decision makers in planning and decision making regarding optimal use of scarce resources. It contains a linear objective function which is to be optimized (maximize or minimize) subject to a certain number of constraints. The constraints are also linear inequalities or linear equation in the variables used in objective function (Amit *et al*, 2020; Akpan and Iwok, 2016). This (LP), is a constrained optimization technique, which optimize some criterion within some constraints. In Linear programming the objective function (profit, loss or return on investment) and constraints are linear. The essence of the application of linear programming technique in business and any other field of its applicability is to maximize the total profit, to minimize the total cost, to arrange the best times to start and finish project etc. It is a technique for finding the best optimal solution of a company (Sharma, 2016).

Despite the benefits of increased and investment for companies including access to more customers and cheaper resources, there is still need to put effort in this global era as globalization increases competition. Companies need to have long-term plans and manage their operations and logistics efficiently to remain competitive in a global market place (Uko, 2017).

Linear programming is a considerable field of optimization for several reasons. Many practical problems in Operations Research, Mathematics, Economics, Statistics, Agriculture, Engineering, etc. can be expressed as linear programming problems. It is heavily used in microeconomics and economics as production economy as well as company management duties, such as planning, production, transportation, technology etc. Although the modern management issues are ever-changing, most companies would like to maximize profits or minimize costs with limited resources. Therefore, many issues can be characterized as linear programming problems. In nowadays industrial lay out and structure, operating firms face two major problems; designing production plans which optimizes the production capacity for rapidly changing market demands and how to maximize their income. Industry and firms operate under price, quality, time, production capacity, raw material etc. thus, facility settlement and production technology as well as the products to be produced and production cycle has to be determined. Production planning helps managers give rational decision regarding resources allocation. Good production planning is considered essential to successful production-based businesses to management. Planning of Production is crucial and highly important in a manufacturing facility so as to ensure efficient and effective utilization of resources (Ramaraj *et al,* 2017). LP typically involves sequencing and scheduling the production batches to determine the optimal batch quantities and prioritizing the batches. In reality, the planning of the production processes is often conducted under a variety of uncertainties: such as demand, machine availability, worker's efficiency, etc. Therefore, it is always important to take the uncertainties into consideration when making the production decisions (Ramaraj and Hu, 2017).

For instance, there is always a need to identify products that optimally contribute to profit and those that yield zero or negative profit. Those that maximally contributed to profit are often prioritized while those that yield zero or negative profit are either work to improve upon or discard them so as to minimize cost of productions, distributions wastage of time and valuable resources (Uko, 2017). At the onset of production, the production manager must take into cognizance in order to keep idle time in the production floor to the minimum, this is because, excess idle time tends to waste resources in the production floor. Decision that are often taking by managers with the use of rule of thumb (experience, intuition) at time expose organization to the danger of uncertainty and resulting to the huge loss of resources and time wastage, which may equally ruin the organization.

Production is the core process of every manufacturing organization, and so the efficiency and quality of decisions taken on the shop floor determines the performance of the organizations quality management system (Akpan and Iwok, 2016). At planning level, a good production manager must be able to identify probable limitations in order to establish, prior to product realization processes the appropriate preventive measures. The ultimate in every production scheduling solution must affect the provision and control of specific resources to accomplish the required manufacturing tasks with due considerations to right sequence of job methods and timing parameters. An optimized production scheduling process is therefore characterized by the availability of desired output of products in type and quantity within the planned time at minimum costs.

Production planning managers are required to find a suitable balance between all of the production needs and objectives. Typical goals of any production planning process are to find the optimal amount of part to produce, and the optimal time needed to produce them, to maximize profit. Because of its role in business management and profitability, production planning has been the focus of significant research over the last century. More recently, linear Programming has employed computational optimization as a means for production planning. Many researchers have individually considered some of the many aspects associated with production planning.

Decision making is one of the major functions of managers; they are often faced with decisions relating to allocation and use of scarce resources. Resources available for production, according to the classical economists, are limited and have multidimensional uses. This makes it apropos for operations managers as decision makers to contemplate on allocation of resources in production planning (Magalhaes and Shah, 2003). Poor resources allocation may result into operations failure and endanger the financial health and survival of organizations. For organization to maximize resources, usage must be efficient and effective in achieving result with little or minimum resources (Solajo *et al*, 2019).

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 (2016) opined that an economy can only grow if management decisions at the firm level result in boosted output through cost minimization or output maximization emerging or arising in increased production in the real sector. A failure to minimize cost will make it more difficult for organization to maximize profit or benefit. On the other hand, in order to minimize cost, it is apropos for production manager to decide on the best way to allocate limited resources in such manner that it will lead to greater output and profit. Higher level of idleness and the inability of the production companies to effectively use the resources available in order to maximize profit will lead to loss of their stakeholders, this is so because majority of these companies make use of traditional techniques in production planning; only few of them are aware about the application of this techniques in production planning.

Though different studies have been done in Adama Beverages on how to improve the production in order to maximize profit and minimize cost of production using linear programming techniques in production planning yet there is few of such study that address Beverages planning problem in Adama Beverages. Most of the studies also consider one or two products being produced by Adama Beverages. Hence, this study applied LP as an optimal tool in maximizing profit in the study area taking three products

Overview of Adama Beverages.

We know that company operates in order to make profit, for example Adama Beverages Ltd FARO is an industry that engages in daily production and distribution of sachet water pouches, table water, 20 litters dispenser jar bottles and fruit juice. Patronage of its product depends on how much it distributes it and how accessible a customer has when he/she demands the product. In recent times Adama beverages faces challenges as there are other company that produces similar products which lead to loss of customers. This loss of customers is due to either the company is not supplying product in or on time to customers hence they resort to other products of it competitor. Despite having their products available, some customers still experience unsatisfied demand due to insufficient production; this leads to skepticism between what will be produced and what the market will require. Although series of studies have been conducted in Adama beverages using linear programming model but no studies considers three (3) variables mentioned earlier.

This study therefore seeks to employ the use of linear programming model taking three (3) variables in order to ascertain which of these variables when produce will yield higher profit at a minimum cost. We aimed at using Linear Programming to formulate product mix of Adama Beverages with a view of matching customer's demand to optimize profit.

Literature Review

Beverages are drinks which are in a liquid form usually produced for human consumption. A part from their basic function in satisfying thirst of human, they (drinks) have vital roles that they perform in human culture. Common types of drinks include plain drinking water, milk, juice and soft drinks (Oladejo, Olusegun and Jibril, 2018; Solajo *et al*, 2019). Traditionally warm beverages include coffee, tea, and hot chocolate. Caffeinated drinks that contain the stimulant caffeine have a long history.

A drink is a form of liquid which has been prepared for human consumption. The preparation can include a number of different steps, some prior to transport, others immediately prior to consumption (Osuolale, 2016).

In recent times due to globalization and technology advancement, companies experience more game of competition than ever before in a global field, in such a way that those who know how to play the game very well will succeed; while those who don't are dooming themselves to failure (Uko *et al*, 2017).

When a company has a sister(s) company that are producing same goods and or provide similar services as her, and that sister company happen to turn out product/services better, cheaper and faster that spells real trouble for the factory that is performing at lower levels. The trouble can be turn layoffs or even shutdown, if the management is unable to turn things around. The bottom lines therefore are better quality, highe productivity and lower costs, and the ability to quickly respond to the customer needs is more important than ever (Uko *et al*, 2017; Adebiyi *et al*., 2014).

Linear Programming was developed by Dantzig in 1947 as a product of his research work during World War II when he was working in the pentagon with the military. The model uses Simplex Method (SM) to iteratively optimize (Maximize or Minimize) as the case may be the objective function in a competing environment of a scarce resources. He extended his research work to solving problems of planning or scheduling dynamically overtime, particularly planning dynamically under uncertainty. Concentrating on the development and application of specific numerical values, a need arises to construct or formulate mathematical model (Ajibode, 2010; Mohammad *et al.*, 2015). Thus, the development of linear programming has been ranked among the most important scientific advances of the mid, 20th century, and its assessment is generally accepted. Its impact since 1950 has been extraordinary. Today it is the standard tool that has saved cost of many production companies.

For instance, Benedict and Uzochukwu (2012), applied linear programming techniques to a plastic producing company and obtained 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.

Fagoyinbo and Ajibode (2010) opined that the success and failure that an individual or organization experiences depends to a large extent on the ability of making appropriate decision. Making of a decision requires an enumeration of feasible and viable alternatives (course of action or strategies). They reported in their studies that, for one to embark on the developments or application of specific Operations Research (OR) techniques in order to determine the optimal choice among several courses of action, which will include numerical values (if required), linear programming as a tool of OR may be employed where there is a need to formulate a mathematical model to represent the problem at hand and allocate the scarce and or limited resources to several competing activities for optimality. Their work employed the application of linear programming in the area of personnel management in minimizing the cost of staff training, a method that gave an integer optimum solution to all the models formulated. They observed that data collected may not yield a feasible solution; when this occurs, the model needs to be reformed to give an optimum solution. Their study recommended to the management of the Federal Polytechnic Ilaro, the number of staff (junior and senior) to be sent for training program when there is need for such in the academic and non-academic sections of the institution.

Amit *et al* (2020) used the application of linear programing in Pharma Company where type A and B packed of medicine were collected and solved iteratively using LP. Their results indicate that by manufacturing 400 packet of type A and 20 packet of type B medicine; the maximum profit of company will be stood at Rs. 11,760 and a minimum transportation cost a company will incur is Rs. 19,200. Their results further revealed that by transporting the syrup packet from factory P to customer C_2 is 70, from factory P to customer C_3 is 50, from factory Q to customer C_1 is 60, from factory Q to customer C_2 is 20 and none of the packet should be transport from factory P to customer C_1 and factory Q to customer C_3. The optimum result is derived from the data collected by the pharma company.

Uko *et al* (2017) applied linear programming in assessing the performance of employees. It is stated that performance evaluation is an important process for achieving excellence. Since in many evaluation processes, an employee's annual composite score is a weighted average of performance scores of several roles and weights chosen by the employee within bounds stipulated by the administration for each role. They proposed a modified process based on Linear Programming (LP) that assigns to employees the optimal weights that are compatible with their supervisor-assigned scores in each role. The LP model was designed to assign role weights, within predefined ranges, such that the composite score is maximized. The overall score depends on the supervisor's assessment of performance alone, eliminating the need for the employee to correctly choose weights. Their modified approach resulted in more valid evaluations of performance and improved employee satisfaction with the annual performance review process.

Materials and Methods

We adopted exploratory research design for this study. This method is considered appropriate because the study is designed to determine the 750ml of bottle water, 1000ml of fruit and 250ml of sachet water that ADAMA Beverages Nigeria Limited should manufacture on weekly basis in order to minimize production cost given the quantity of available resource consumed by each product and constraint posed in the production process.

The statistical data used for the study were collected from the Adama Beverages company LTD, Jimeta Yola Adamawa State, Nigeria. The variables collected were concentrate, sugar, distilled water of the precise quantity often used by the company and flavor (see Table 1). Other data collected were the average prices of fruit juice, bottle water and sachet water as depicted in Table 2. The firm strategy of marketing her products is to necessitate the selling of her products in competitive environments with a maximum profit in per capital of each product being produced with relative loss of customer's goodwill. Some 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 as a mix of these basic raw materials and the costs (depicted in Tables 1 and 2). Since the study was conducted in a mixture of man machine system such data as labour cost, sales and marketing expenses, overheads cost as well as machine cost were ignored. Hence, there effects were not considered in the analysis. We only considered the cost elements of raw materials which are the driven forces in any manufacturing industry.

Assumptions of the Linear Programming Model

For us to evaluate how best Linear Programming applies to any given problem, the underlying assumptions of linearity should be satisfied to a large extent by the problem. The four main assumptions of linearity are proportionality, additivity, divisibility and certainty**.** What the assumptions tell us are seen asunder:

i. Proportionality: Proportionality assumption implies that the rate of change or slope of the functional relationship is constant, and therefore changes of equal size in the value of a variable will result in exactly the same relative change in the functional value.

ii. Additivity: Additivity assumes that there are no interactions between any of the activities, so that there are no cross-product terms in the model. This implies that, for each function, the total function value can be obtained by adding the individual contributions from respective activities.

iii. Divisibility: Divisibility assumes that activity units can be divided into any fractional levels, so that non-integer values for decision variables are permissible.

iv. Certainty: Certainty assumes that all parameters of the model ($a_{ij}, b_i c_j$) are known constants. There is however a degree of uncertainty especially as the parameters would be used to predict future conditions. Sensitivity analysis is normally conducted as one means of accounting for uncertainty in the assumed parameter values.

The generalized Martix LP model is stated below

Optimize (Maximize or Minimize) $Z = C^T X$ (Objective function)

Subject to the structural constraints:

$$\mathbf{AX}_i = \mathbf{b} \tag{1}$$

$$\mathbf{X}_i \geq 0 \tag{2}$$

$X_i \geq 0$ (Meaning all constraints must not have negative values)

where :

$$c = \begin{pmatrix} c_1 \\ c_2 \\ . \\ . \\ . \\ c_n \end{pmatrix}, b = \begin{pmatrix} b_1 \\ b_2 \\ . \\ . \\ . \\ b_m \end{pmatrix}, X = \begin{pmatrix} x_1 \\ x_2 \\ . \\ . \\ . \\ x_n \end{pmatrix}$$

are column vectors, C^T denote the transpose of the vector c, and $\mathbf{A} = (a_{ij})$, whose i, j element is a_{ij}

Definition of Variables as used in the objective and constraints equations is stated below:

X_1 =Bottle water

X_2 =Sachet water

X_3 =Fruit juice

Model Formulation of the Problem

Maximize Z= $C_1 X_1 + C_2 X_2 + C_3 X_3$ (3)

Subject to:

$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 \le b_1$ (4)

$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 \le b_2$ (5)

$a_{31}X_1 + a_{32}X_2 + a_{33}X_3 \le b_3$ (6)

$a_{41}X_1 + a_{42}X_2 + a_{43}X_3 \le b4$ (7)

$X_1, X_2, X_3 \ge 0$ (8)

Table1: Quantity of Raw Materials available.

Raw materials	Resource available
Concentrate	210 Units
Sugar	450 Kg
Water	40000 litters
Flavor	200 litters

Source: Records from Adamawa Beverage Company LTD, Jimeta, Yola Adamawa State (2022)

Table 2: Product and their Prices (in naira) Per Packet.

Product type	Average cost price	Average selling price	Profit contribution
Fruit juice	₦ 1550.00	₦ 1950.00	₦ 350.00
Bottle water	₦ 950.00	₦ 1050.00	₦ 150.00
Sachet water	₦ 1600.00	₦ 1800.00	₦ 200.00

Source: Source: Records from Adamawa Beverage Company LTD, Jimeta, Yola Adamawa State (2022)

Formulation of the Products Mix Model

$$\text{Maximize } Z = 150X_1 + 200X_2 + 350X_3 \tag{10}$$

Subject to:

$$0.012X_1 + 0.014x_2 + 0.031x_3 \leq 210 \text{ concentrate} \tag{11}$$

$$0.00X_1 + 0.00x_2 + 0.210x_3 \leq 450 \text{ sugar} \tag{12}$$

$$10.721X_1 + 13.958x_2 + 6.539x_3 \leq 40000 \textit{ water} \tag{13}$$

$$0.048X_1 + 0.56x_2 + 0.077x_3 \leq 200 \text{ flavour} \tag{14}$$

$$X_1,\ X_2, \textit{and } X_3 \geq 0 \tag{15}$$

Where,

X_1=Bottle water

X_2=Sachet water

X_3=Fruit juice

Z=total profit from product X_i and i=1,2,…,n

C_1= the per unit profit contribution of decision variable X_1 to the value of the objective function

C_2 = the per unit profit contribution of decision variable X_2 to the value of the objective function

C_3 = the per unit profit contribution of decision variable X_3 to the value of the objective function

a_{ij} = the input coefficients that represents the amount of resources consumed per unit of variable X and i= 1, 2,…,n

b_1= the available resource of bottle water

b_2 = the available resources of sachet water

b_3= the available resources of fruit juice

Data Analysis

The formulated mathematical problem was analyzed using Temporary Ordered Routine Algorithm (TORA) Software in order to get feasible optimal value of the three products being considered so as to recommend to the management of the Adama Bevarages which of the products to produce in large quantity, which one to produce in small quantity and which one to discontinue it production or make improvement on it so as to yield maximum profit to the factory. Four iterations were made by TORA and the fourth iterations was the optimal tableau as seen in the plate 1 and 2.

Iteration 1	bottle	sachet	fruit					
Basic	x1	x2	x3	sx4	sx5	sx6	sx7	Solution
z (max)	-150.00	-200.00	-350.00	0.00	0.00	0.00	0.00	0.00
sx4	0.02	0.01	0.03	1.00	0.00	0.00	0.00	210.00
sx5	0.00	0.00	0.21	0.00	1.00	0.00	0.00	450.00
sx6	10.72	13.96	6.54	0.00	0.00	1.00	0.00	40000.00
sx7	0.05	0.56	0.08	0.00	0.00	0.00	1.00	200.00
Lower Bound	0.00	0.00	0.00					
Upper Bound	infinity	infinity	infinity					
Unrestr'd (y/n)?	n	n	n					
Iteration 2	bottle	sachet	fruit					
Basic	x1	x2	x3	sx4	sx5	sx6	sx7	Solution
z (max)	-150.00	-200.00	0.00	0.00	1666.67	0.00	0.00	750000.00
sx4	0.02	0.01	0.00	1.00	-0.14	0.00	0.00	145.71
x3	0.00	0.00	1.00	0.00	4.76	0.00	0.00	2142.86
sx6	10.72	13.96	0.00	0.00	-31.14	1.00	0.00	25985.71
sx7	0.05	0.56	0.00	0.00	-0.38	0.00	1.00	28.57
Lower Bound	0.00	0.00	0.00					
Upper Bound	infinity	infinity	infinity					
Unrestr'd (y/n)?	n	n	n					

Plate I: Showing iterations 1 and 2 of the TORA Output

Iteration 3	bottle	sachet	fruit					
Basic	x1	x2	x3	sx4	sx5	sx6	sx7	Solution
z (max)	-132.14	0.00	0.00	0.00	1530.61	0.00	357.14	760204.08
sx4	0.02	0.00	0.00	1.00	-0.14	0.00	-0.02	145.20
x3	0.00	0.00	1.00	0.00	4.76	0.00	0.00	2142.86
sx6	9.47	0.00	0.00	0.00	-21.65	1.00	-24.93	25273.47
x2	0.09	1.00	0.00	0.00	-0.68	0.00	1.79	51.02
Lower Bound	0.00	0.00	0.00					
Upper Bound	infinity	infinity	infinity					
Unrestr'd (y/n)?	n	n	n					
Iteration 4	bottle	sachet	fruit					
Basic	x1	x2	x3	sx4	sx5	sx6	sx7	Solution
z (max)	0.00	1480.00	0.00	0.00	523.81	0.00	3000.00	835714.29
sx4	0.00	-0.21	0.00	1.00	0.01	0.00	-0.40	134.29
x3	0.00	0.00	1.00	0.00	4.76	0.00	0.00	2142.86
sx6	0.00	-106.10	0.00	0.00	50.53	1.00	-214.40	19860.00
x1	1.00	11.20	0.00	0.00	-7.62	0.00	20.00	571.43
Lower Bound	0.00	0.00	0.00					
Upper Bound	infinity	infinity	infinity					
Unrestr'd (y/n)?	n	n	n					

Plate II: Showing iterations 3 and 4 of the TORA Output

The above Plates are the results of the analyses obtained iteratively by TORA software. We saw that Plates 1 to 3 were all feasible Plates but non-optimal. However, iterations 4 gave the optimal Plates and the iterations terminated on it with $X^*_1 = 571.43$; $X_2^* = 0.00$; $X_3^* = 2{,}142.86$ and the objectives (Z) function value $Z^* = N835{,}714.29$ respectively. These results show that variable two does not contribute profit to the production while variables one three does.

Results

The study aimed at applying linear programming for the optimal production planning in maximization of profit in Adama Beverages in Jimeta Adamawa State, Nigeria. The raw data collected were subjected into analysis using TORA software. The results obtained shows that the profit contribution for the three variables X_1, X_2, *and* X_3 are ₦ 571.43k, 0.00 and ₦ 2,142.86k respectively. This shows that by using the above profit contribution in the productions of three variables measured a firm (Adama Beverages) can make weekly profit of ₦ 835,714.29k. This shows that a firm producing five hundred and seventy-one ($X^*_1 = N571.43$) bottle water and two thousand one hundred and forty-two fruit juice ($X_3^* = N2,142.86$) weekly can end her

₦ 835,714.29k weekly income. The decimal part of the optimal results was truncated (see Plate I and II) because there cannot be fractional production of bottle and fruit juice. The results further revealed that production of sachet water does not significantly contribute to profit nor does it cost factory any lost as their profit contributions are 0. In Table 1 Sugar and

Flavor, are the scarce resources i.e. they have been used up completely in the production process ($Sx_5 = 0$, $Sx_7 = 0$). While Concentrate and Water are the abundant resource i.e. it's in excess of ($S_{X4} = 134.29$ and $Sx_6 = 19,860$). Since Concentrate and water are in excess of 134.29 and 19,860 respectively, the firm can only purchase some certain quantities that will be used in production, while the amount for the remaining quantities should be added more in purchasing the other materials i.e. Sugar and Flavor for a better production.

Conclusion

Application of Linear Programing to a production company is very important as its guide the management of the company to make optimal decision and maximize profit. In this study, we applied linear programming problem to Adama Beverages and found out that if the management of the firm can use the model in her production process and in consideration of the three variables measured; the firm can make weekly profit of ₦ 835,714.29k while holding other variables constant. Therefore, we recommend that the firm should produce 571.143 quantity of bottle water and 2,142 quantity of fruit juice weekly in order to earn a weekly profit of ₦ 835,714.29k. There is no need for producing sachet water as there is no any profit contribution from sachet water to the firm. The amount uses to purchase concentrate and chemical for water treatment should be reduced and buy more quantitates of sugar and flavour as they seen to be a scarce resource (there slack variables indicate zero returns).

References

Adebiyi, S. O., Amole, B. B., and Soile, I. O. (2014). Linear Optimization Techniques for Product Mix of paints production in Nigeria. *Acta Universitatis Danubius Æconomica*, 10(1): 181-190.

Ajibode, I. (2010). Application of Linear Programming for Effective use of Resources and Staffing. *Journal of Emerging Trend in Engineering and Applied Sciences* 1(2): 127-132.

Akpan, N. P. and Iwok, I.A., (2016). Application of Linear Programming for Optimal use of Raw Materials in Bakery. *International Journal of Mathematics and Statistics Invention (IJMSI)*, 4(8): 51-57

Amit, K. J., Hemlata, S. R., Bhardwaj, G. V.V. Jagannadha R., and Siddharth, C. N. (2020). Application of Linear Programming for Profit Maximization of a Pharma Company. *Journal of Critical Review* 7(12): 213-235.

Benedict M. Y. and Uzochukwu M. M (2020). An Optimal Warehouse Management for Production Companies. *Journal of Scientific and Engineering Research*, 7(3): 238-243

Fagoyinbo, I. S and Ajibode, I.A. (2010). Application of Linear Programming Techniques in the Effective Use of Resources for Staff Training. *Journal of Emerging Trends in Engineering and*

Applied Sciences (JETEAS), 1(2): 127-132.

Magalhaes, M. V., & Shah, N. (2003). *Crude Oil Scheduling*. Foundations of Computer-Aided Operations (FOCAPO), pp 323-325

Muhammad, U., Samson, O., and Hafisu, R. (2015). Profit Maximization in a Product Mix Company Using Linear Programming Approach to Resource Allocation. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, 24(4): 46-52.

Oladejo L. G, Olusegun K. L. and Jibril N. S (2018). Application of Linear Programming for Optimum Production Planning in Maidabino Investment Nigeria Limited Katsina, Katsina State. *International Journal of Operational Research in Management, Social Sciences and Education* 4(1): 35-43

Osuola E.C. (2016). *Introduction to Research Methodology*: Onitsha Nigeria, African Publishers Ltd :179-182

Ramaraj H. and Hu, Z. (2017). A two-stage Stochastic Programming Model for Lot-sizing and Scheduling under Uncertainty. *International Journal of Production Economics*, 180: 198–207

Sharma J.K (2017). *Operations Research, Theory and Applications, 6th Edition*, Trinity Press, Boston (USA).

Solaja, O. A., Abolaji, J. A., Abioro, M. A., Ekpudu, J. E., Olasubulumi, O. M (2019). *Application of Linear Programming in Production Planing:* Munich Personal RePEc Archive (MPRA). Retrieved on the 20th July, 2022, from: https://mpra.ub.uni-muenchen.de/98226/

Uko L.U., Lutz R.J, Weisel J.A. (2017). An application of Linear Programming in performance Evaluation. *Academy of Educational Leadership Journal* 19: 1712-1721