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# APPLICATION OF LINEAR PROGRAMMING TO FIRM'S DECISION MAKING: HYPOTHETICAL EXAMPLE

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**ABSTRACT:** *The study investigated the application of linear programming to firm's decision making: Hypothetical example. The objective of the study was to apply linear programming for optimal use of time in hair and body cream production. The decision variables applied in the study are two different types of cream (hair cream and body cream) produced by Seun Cream factory limited. Simplex method of linear programming approach was employed and evidence from the finding indicated that 6.5 unit of hair cream and 27.7 unit of body cream should be produced respectively which will give a maximum profit of ₦1107.75. In respect to the emanating finding from the study, the study concluded that Seun factory should produce the two types of cream (hair cream and body cream) in order to satisfy her customers, however, more of body cream should be produce in order to attain maximum profit, because they contribute mostly to the profit earned by the company. Thus, it is recommended that business whether small family business or large corporate should adopt optimization technique to enhance the decision making and to enhance efficiency and effectiveness of firm's performance.*

**KEYWORD**: Linear Programming, Decision Making, Nigeria

## INTRODUCTION

Linear programming is a mathematical technique concerned with the allocation of scarce resources. It is a procedure adopted to optimize the value of some objectives subject to some constraints. The objectives may be to maximize profit or to minimize costs. The program is designed to help the production and operations manager in planning and decision making relative to resource allocation. The manager who is restricted in terms of solutions to be adopted is however expected by management to produce the best of optimal solutions. A linear programming model enables the manager to make optimal use of limited available resources. These scarce resources can be in form of manpower, money, materials, skills, time and facilities etc. The decision maker then aims at finding the best decision or outcomes with the scarce resources. The decision or outcome may be with respect to costs, profits, sales, return or investments, general welfare of the society etc. The technique involves formulating a given problem as a linear programming model with the variables clearly identified and using standard techniques to solve the problem. As is often formulated, linear programming seeks to find non–negative values of the variables $X_1$, $X_2$, $X_3$, $X_4$ $X_5$, $X_6$…., $X_n$ that satisfy the constraints: $a_{11}x_1 + a_{12}x_2 + ai_3x_3 + \ldots\ldots\ldots a_{in}x_n = b$, where I = 1,2,3...m, that maximizes or minimizes the linear form $C_1X_1 + C_2X_2 + \ldots.C_nX_n$ (Kanu, Ozurumba, & Emerole, 2014).

Research in the field of capital structure and corporate performance have drawn extensive debate as a result of the relevance of capital in the success and survival of business as a going concern. Abu-Tapanjeh (2006) reported that considerable amount of research has been conducted on the relationship between capital structure and performance of firms in developed and developing economies. These studies have documented several arguments on the need to improve the capital structure as a need to enhance the performance of firms (Abor, 2005; Carpentier, 2006; Abor, 2007; Madan, 2007; Chen, Firth & Zhang, 2008; Ahmad, 2012; Shubita & Alsawallah, 2012). Capital structure decisions represent another important financial decision of a business organization apart from investment decisions. Ali, Akhtar and Sadaqat (2011) stressed that the decision regarding the use of debt and equity modes of financing is not an easy job, with the fact that a number of benefits and costs are associated with the management decisions regarding the optimal use of capital structure. It is important because it involves a huge amount of money and has long- term implications on firms. Capital structure is one of the important financial decisions for any business organization. This decision is important because the organization need to maximize return to various organizations and also have an effect on the value of the firm (Ahmad, 2012). A new business requires capital and still more capital is needed if the firm is to expand. The required funds can come from many different sources and by different forms. Firms can use either debt or equity capital to finance their assets. The best choice is a mix of debt and equity. One of the most perplexing issues facing financial managers is the relationship between capital structure, which is the mix of debt and equity financing and stock prices (Azhagaiah & Gavoury, 2011). Al-Qudah (2011) explains that the relationship between capital structure and firm value, how firms choose their capital structure and how much they should borrow based on various trades off between the cost and benefit of debt versus equity.

## LITERATURE REVIEW

The theory of capital structure was pioneered by Modigliani and Miller (1958). They found that the value of a firm is not affected by its financing mix when the study of financing choices initially received little attention. Modiglian Miller concluded to the broadly known theory of "capital structure irrelevance" where the financial leverage does not affect the firm's market value under perfect market condition.

Pecking order theory is a capital structure model based on asymmetry of information amongst insiders and outsiders. This theory predicts that due to the information asymmetry between a firm and outside investors regarding the real value of both current operations and future prospects, debt and equity will always be relatively costly compared to retained earnings (Zurigat, 2009; Ebadi, Thim, & Choong, 2011). Azhagaiah and Govoury (2011) reported that the issue of external equity is seen as being the most expensive and also dangerous in terms of potential loss of control of the enterprises by the original owner-managers. The information advantage of the corporate managers will be minimized by issuing debt.

Optimistic managers, who believe the shares of their firms are undervalued, will prefer immediately to issue debt and to avoid equity issue. Ahmad, Akhtar and Sadaqat (2012) documents that firms that are profitable and therefore generate high earnings are expected to use less debt capital than those who do not generate high earnings. Hence, internal funds are used first, and when that is depleted, debt is issued, and when it is not sensible to issue any more debt, equity is issued (Ali *et al*, 2011).

Akpan and Iwok (2016) utilized the concept of Simplex algorithm; an aspect of linear programing to allocate raw materials to competing variables (big loaf, giant loaf and small loaf) in bakery for the purpose of profit maximization. The analysis was carried out and the result showed that 962 units of small loaf, 38 units of big loaf and 0 unit of giant loaf should be produced respectively in order to make a profit of ₦20385. From the analysis, it was observed that small loaf, followed by big loaf contribute objectively to the profit. Hence, more of small loafs and big loafs are needed to be produced and sold in order to maximize the profit

Fagoyinbo and Ajibode (2014) employed the application of linear programming in the area of personnel management in minimizing the cost of staff training. The method gives an integer optimum solution to all the models formulated. Data collected may not yield a feasible solution, when this occurs the model needs to be reformed to give an optimum solution. However, this study recommends 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.

Ezema and Amakom (2012) seek and arrive at the optimal product-mix of a productive firm-the Golden Plastic Industry Limited in the layout. The production problem of the firm was formulated as a linear programming problem and estimated as such. The result showed that only two sizes of the total eight "PVC" pipes should be produced. The study succeeded in establishing that Golden Plastic Industry Limited, Emene 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 ₦1,964,537 given the present level of available funds and the technical coefficients of the products. The study also shows that only two of the raw materials and two labour time were surplus, while the other six-resin, calcium carbonate, stabilizer, cast, carbon black and blend-were scarce in relation to the formulated model. The shadow prices of the raw materials obtained showed their unit contribution to the objective function (profits) and suggests to management the prices at which they should either be bought or sold.

Adeyemo and Otiero (2009) also tried to demonstrate that the linear programming model can be extended beyond the realms of Management Sciences and organizational decision departments to other areas such as Physical and Environmental Sciences. They used the application of Differential Evolution (DE) and Linear Programming (LP) to maximize total income (in South African Rand ZAR) of 2500 planting area where 16 crops are planted and constrained by water availability (using only 10mm3of irrigation water). It is found that a total income of ZAR 46,060,200 can be derived using linear programming. Ten strategies of DE are tested with this problem varying the population size (NP), crossover constant (CR) and weighing factor (F). It is found that strategy 1, DE/rand-1-bin, with values of NP, CR and F of 160, 0.95 and 0.5 respectively obtains the best solution most efficiently.

Murugan and Manivel (2009) tried to demonstrate the use of linear programming technique by using linear interactive optimizer (LINDO) software to maximise the profit of Khadi and Village Industries Commission (KVIC) affiliated to Servodaya Sangham, run by a non-governmental organization. Servodaya Sangham engages in the production of three textile products, namely; cotton Khadi, Khadi ready-made and silk Khadi. Account records indicate that total profit earned by Servodava and Sangham was INR.22.31 million for the year. To produce each unit of the products requires the unit of raw materials cost of INR.32.74 million for cotton Khadi, INR.24.64 million for Khadi ready-made and INR.36.9 million for silk Khadi. The unit labour cost of INR.7.36 million, INR.0.68 million and INR.7.58 million for cotton Khadi, Khadi ready-made and silk Khadi respectively is required while the unit overhead cost of INR.5.79 million, INR.0.49 million and INR. 6.78 million for cotton Khadi, Khadi ready-made and silk Khadi is incurred. The input availability of INR.94.28million, INR.15.62 million and INR.13.06 million for raw material, labour hour time and labour overhead time are used bearing in mind that each product will make a contribution of INR.9.23, INR.0.23 and INR.12.85 in million for cotton Khadi, Khadi ready-made and silk Khadi respectively. The application of linear programming suggests that the existing production volume would help to maximize the profit of Sanghan products to the tune of INR.24.752 million, noting that producing silk Khadi alone is economically profitable. The profit is INR.2.442 million higher than that of the present profit of INR.22.31 million.

Kareem and Aderoba (2008) tried to show the effectiveness of adopting the linear programming model in maintenance and manpower planning using data from a cocoa processing industry in Akure, Ondo State of Nigeria. The result shows that only four maintenance crew out of the 19 employees are needed in that section to effectively carry out maintenance jobs in the industry. But in their own contributions, Nedim (2002) tried to demonstrate that risk analysis is necessary in order to maximize resources allocation efficiency and minimize the effects of risk environment. They used data from a sample of a company's products taking risk into account as the objective function. The result suggests that producing 5 units of X1 generates 36% loss possibility. If decision makers aim risk not to exceed certain limits, then, variances should be used as constraints. The model suggests that producing 3 units of X1 will decrease the objective function from $432 to $287.

## RESEARCH METHOD

### Formulation of a Linear Programming Model

Many linear programming problems are not stated in mathematical forms. They will need to be formulated as a linear programming problem using the following steps: First, list and define the decision variables, second, State the objective function to be optimized and identify the constraints on one or more variable. Third, write the mathematical expression relating the terms and the constraints using the appropriate relational signs. Fourthly, express the non negativity constraints mathematically. This enhances the feasibility of the solution. Thus, the general form of a linear programming model with n decision variables and 'n' constants are given as follows:

Maximize $P = a_1 X_I + a_2 X_2 + \ldots\ldots\ldots\ldots\ldots a_n X_n$

OR

Minimize $C = a_1 X_I + a_2 X_2 + \ldots\ldots\ldots\ldots\ldots a_n X_n$

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Subject to $b_{11}X_I + b_{21}X_2 + \ldots\ldots\ldots\ldots + baiXn \leq d_1$

$b_{12}X_I + b_{22}X_2 + \ldots\ldots\ldots + b_{n2}X_n \leq d_2$

$b_{1m}X_I + b_{2m}X_2 + \ldots\ldots\ldots + b_{mn}X_n \leq d_m$

With $X_I$, $X_2$-……………………….. $X_n \geq 0$

**Methods of solving a Linear Programming Model**

There are two basic methods of solving a linear programming model. This includes the graphical and simplex methods. These are briefly reviewed below:

**Graphical Method**

This method involves plotting the constraints on a graph and identifying the region that satisfies all of the constraints. This region is called the feasible solution space. After plotting the constraints and identifying the feasible space the objective function is then plotted and used to identify the optimal point in the feasible solution space. This point may be read directly from the graph or determined by substituting all the coordinates of the joints into the objective functions as these joints form the feasible solution space of the linear programming problem. If it is a maximization problem, the highest of these values is the optimum solution. However, if it is a minimization problem, the smallest of the values give the optimum solution of the linear programming problems.

**The Simplex Method**

The Simplex method is a general purpose linear programming Algorithm widely used to solve large scale problems. It is an iterative procedure that progressively approaches and ultimately reaches an optimal to linear programming problems. In other words, in a maximization problem the last solution yields a total profit than yielded by the previous solution. The steps involved in a Simplex method include:

i. Formulation of the problem into an objective function and the constraints
ii. Setting up of an initial Simplex tableau.
iii. Selection of the key/ Pivot column
iv. Development of main row and balance for a new table.
v. Iterative process of the above steps until all index numbers (Not including the constraint column are positive) – An optimum solution then results.

Having undertaken a bird's eye view of what linear programming technique entails; the study will solve a problem on linear programming using the simplex method which is applicable in real life situations.

Seun cream factory produces two products: Hair cream and Body cream. The time in hours to produce a unit of each product, the weekly capacity of operations in hours and the net profit per unit of each product in Naira are as given in the table below.

| Operations | Time per unit in hours | | Operation capacity in hours/week |
|---|---|---|---|
| | Hair cream | Body cream | |
| 1 | 2 | 1 | 40 |
| 2 | 3 | 8 | 240 |
| 3 | 4 | 5 | 200 |
| Net profit per unit (₦) | 45 | 30 | |

Formulate the linear programming problem that will determine the optimum weekly production for the two products that will maximize the profit, using simplex method to solve the linear programming.

## ANALYSIS/SOLUTION

Let x units of Hair cream and y units of Body cream be produced. Observe from the last row of the given table that the Net profit per unit of Hair cream and Body cream are ₦5 and ₦30 respectively. Furthermore, since the problem talks about profit maximization, then the linear programming problem is that of maximization. Hence, the problem is to maximize the objective function **P = 45x + 30y**

Constraints

From the given table, formulate constraints for each of the three operations as follows:

Operation 1: 2 hours per unit of Hair cream for x units plus 1 hour per unit of Body cream for y units amounts to at most 40 hours per week = $2x + y \leq 40$

Similarly, for operation 2: $3x + 8y \leq 240$

And operation 3: $4x + 5y \leq 200$

Observe also that the units $x \geq 0$, $y \geq 0$ (non-negativity conditions).

Summarizing the above therefore, the linear programming problem can be formulated as follows:

Maximize $P = 45x + 30y$

Subject to:

$2x + y \leq 40$ = $2x + y + Z_1 = 40$

$3x + 8y \leq 240$ = $3x + 8y + Z_2 = 240$

$4x + 5y \leq 200$ = $4x + 5y + Z_3 = 200$

$x, y \geq 0$ Objective function $P = 45x + 30y$

**Solution table 1**

| Solution variable | Product | | Slack Variables | | | Solution Quantities |
|---|---|---|---|---|---|---|
| | X | Y | Z1 | Z2 | Z3 | |
| Z1 | 2 | 1 | 1 | 0 | 0 | 40 |
| Z2 | 3 | 8 | 0 | 1 | 0 | 240 |
| Z3 | 4 | 5 | 0 | 0 | 1 | 200 |
| P | 45 | 30 | 0 | 0 | 0 | 0 |

Steps by step procedure:

Select the highest positive figure in the objective function row i.e 45

Divide each of the solution quantity by their corresponding figures in column i.e.

40/2 = 20, 240/3 = 80, 200/4 =50

Select the row with the smallest value and with its correspondent figure as pivot number:. Hence, 20 is the smallest row and 2 is the pivot number.

Divide all the row in Z1 by the pivot element to generate a new row for Z1 and replace Z1 by x.

Old row 1: Z1 2/2 1/2 1/2 0/2 0/2 40/2

= 1 0.5 0.5 0 0 20

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Old row 1 | Z1 | 2 | 1 | 1 | 0 | 0 | 40 |
| New row 1 | X | 1 | 0.5 | 0.5 | 0 | 0 | 20 |

Thus, the initial simplex table is replaced by the following to form solution table 2

**Solution table 2**

| Solution Variable | Product | | Slack Variables | | | Solution Quantities |
|---|---|---|---|---|---|---|
| | X | Y | Z1 | Z2 | Z3 | |
| X | 1 | 0.5 | 0.5 | 0 | 0 | 20 |
| Z2 | 3 | 8 | 0 | 1 | 0 | 240 |
| Z3 | 4 | 5 | 0 | 0 | 1 | 200 |
| P | 45 | 30 | 0 | 0 | 0 | 0 |

To proceed to row by row operation, multiply all the figures in the solution quantity of pivot number by the number in the pivot column to make them equal to zero.

i.e. 3xRow 1

Row 1 = 1 0.5 0.5 0 0 20

x3 = 3 1.5 1.5 0 0 60

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Row 2-3 x Row 1 now i.e

| | | | | | | |
|---|---|---|---|---|---|---|
| Row 2 = | 3 | 8 | 0 | 1 | 0 | 240 |
| Subtract (-) | | | | | | |
| 3 x Row 1= | 3 | 1.5 | 1.5 | 0 | 0 | 60 |
| Row 2 (Z2) = | 0 | 6.5 | -1.5 | 1 | 0 | 180 |

Row 3 - 4 Row 1

| | | | | | | |
|---|---|---|---|---|---|---|
| Row 3 = | 4 | 5 | 0 | 0 | 1 | 200 |
| Subtract (-) | | | | | | |
| 4 x Row 1= | 4 | 2 | 2 | 0 | 0 | 80 |
| Row 2 (Z2) = | 0 | 3 | -2 | 0 | 1 | 120 |

Row 4 - 45 Row 1

| | | | | | | |
|---|---|---|---|---|---|---|
| Row 4 = | 45 | 30 | 0 | 0 | 0 | 0 |
| Subtract (-) | | | | | | |
| 45 x Row 1= | 45 | 22.5 | 22.5 | 0 | 0 | 900 |
| Row 2 (Z2) = | 0 | 7.5 | -22.5 | 0 | 0 | -900 |

**Solution table 3**

| Row Operation | Solution variable | Product | | Slack Variables | | | Solution Quantities |
|---|---|---|---|---|---|---|---|
| | | X | Y | Z1 | Z2 | Z3 | |
| Row 1 (Pivot row) | X | 1 | 0.5 | 0.5 | 0 | 0 | 20 |
| Row 2 – 3 Row 1 | Z2 | 0 | 6.5 | -1.5 | 1 | 0 | 180 |
| Row 3 – 3 Row 1 | Z3 | 0 | 3 | -2 | 0 | 1 | 120 |
| Row 4 – 45 Row 1 | P | 0 | 7.5 | -22.5 | 0 | 0 | -900 |

Select 7.5, the next highest positive figure in Row P in column Y.

Divide the solution quantity figures by their corresponding figures in column Y i.e.,

20/0.5 = 40, 180/6.5 = 27.69, 120/3 = 40

Select the row with the smallest value and with its correspondence figure as pivot number in Y. hence, 27.69 is the smallest row and 6.5 is the pivot number.

Divide all the row in Z2 by the pivot element to generate a new row for Z2 and replace Z2 by y.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Z2 | = | 0/6.5 | 6.5/6.5 | -1.5/6.5 | 1/6.5 | 0/6.5 | 180/6.5 |
| | = | 0 | 1 | -0.23 | 0.15 | 0 | 27.69 |

Old row 2: Z2 0/6.5 6.5/6.5 -1.5/6.5 1/6.5 0/6.5 180/6.5

= 0 1 -0.23 0.15 0 27.69

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Old row 2 | Z2 | 0 | 6.5 | -1.5 | 1 | 0 | 180 |
| New row 2 | Y | 0 | 1 | -0.23 | 0.15 | 0 | 27.69 |

**Solution table 4**

| Solution Variable | Product | | Slack Variables | | | Solution Quantities |
|---|---|---|---|---|---|---|
| | X | Y | Z1 | Z2 | Z3 | |
| X | 1 | 0.5 | 0.5 | 0 | 0 | 20 |
| Y | 0 | 1 | 0.23 | 0.15 | 0 | 27.69 =27.7 |
| Z3 | 0 | 3 | -2 | 0 | 1 | 120 |
| P | 0 | 7.5 | -22.5 | 0 | 0 | -900 |

To proceed to row by row Operation, multiply all the figures in the solution number in the pivot column to make them equal to zero.

Row 1 x 0.5 Row 2. i.e

Row 1 = 1 0.5 0.5 0 0 20

Subtract (-)

0.5 x Row 2 = 0 0.5 -0.12 0.08 0 13.85

Row 2 (Z2) = 1 0 0.62 -0.08 0 6.15

Row 2 = Pivot row

Row 3-3 Row 2

Row 3 = 0 3 -2 0 1 120

Subtract (-)

3 x Row 2= 0 3 -0.69 0.45 0 83.1

0 0 1.31 -0.45 1 36.9

Row 4 – 7.5 Row 2

Row 4 = 0 7.5 -22.5 0 0 -900

Subtract (-)

7.5 Row 2 0 7.5 -1.725 1.125 0 207.75

0 0 -20.775 -1.125 0 -1107.75

**Solution table 5**

| Row Operation | Solution variable | Product | | Slack Variables | | | Solution Quantities |
|---|---|---|---|---|---|---|---|
| | | X | Y | Z1 | Z2 | Z3 | |
| Row 1 – 0.5 Row 2 | X | 1 | 0 | 0.62 | -0.08 | 0 | 6.15 |
| Row 2 Pivot Row | Y | 0 | 1 | -0.23 | 0.15 | 0 | 27.7 |
| Row 3 – 3 Row 2 | Z3 | 0 | 0 | -1.31 | -0.45 | 1 | 36.9 |
| Row 4 – 7.5 Row 2 | P | 0 | 0 | -20.775 | -1.125 | 0 | -1107.75 |

Hence; since there is no positive figure in P any more, it implies that this is the end of the solution. Thus, the substituted new solution variable X and Y is now 6.5 and 27.7 which provide feasible solution point. On the other hand, the objective function P with value -1107.75 provides the maximum profit. The study ignores the negative sign and concludes that P = ₦ 1107.75.

Check:

Substitute X = 6.15, y =27.7 into the objective function

P= 45x + 30y

P = 45x6.15 + 30x27.7

276.75 + 831

P = ₦1107.75

**Interpretation of Result**

Based on the analyses of the result, the optimum result derived from the model indicates that hair cream and body cream should be produced. Their production quantities should be 6.5 and 27.7 units respectively. This will produce a maximum profit of ₦1107.75.

## CONCLUSION

The objective of this research work was to apply linear programming for optimal use of time in hair and body cream production. Seun Cream factory was used as our case study. The decision variables in this research work are the two different types of cream (hair cream and body cream) produced by Seun Cream factory limited. The researcher focused mainly on the two types of cream for production purposes and the unit involved producing each cream. The result shows that 6.5 unit of hair cream and 27.7 unit of body cream should be produced respectively which will give a maximum profit of ₦1107.75.

Based on the analysis carried out in this research work and the result shown, Seun factory should produce the two types of cream (hair cream and body cream) in order to satisfy her customers. Also, more of body cream should be produce in order to attain maximum profit, because they contribute mostly to the profit earned by the company. The study recommends that Business whether small family business or large corporate should adopt optimization technique to enhance the decision making and to enhance efficiency and effectiveness of firm's performance. It is therefore incumbent on management of a company to develop an appropriate capital structure. In doing this, all factors that are relevant to the company's capital decision should be properly analyzed and balanced.

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