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RESEARCH ARTICLE

APPLICATION OF LINEAR PROGRAMMING FOR PROFIT MAXIMIZATION: A CASE STUDY OF A COOKIES FACTORY IN BANGLADESH

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ABSTRACT

Linear programming is a mathematical method for choosing the best product combination to maximize profit or decrease cost within the limitations of available resources. In this article, we have proposed the linear programming application for profit Maximization of a Biscuit Factory in Bangladesh. For linear programming problems, the Simplex algorithm provides a powerful computational tool, able to provide fast solution to very large-scale application. The optimization principal examined unit cost of production, the selling price and the quantity of different raw materials used in production. A model for the problem was formulated and optimum results derived using software that employed simplex method. Our main goal is to emphasize the uniqueness of linear programming modeling at the business level as an optimization technique, and to encourage manufacturing companies to employ linear programming to determine their optimal profit.

KEYWORDS

Linear Programming Model, Simplex Method, Decision Variables, Optimal Results

1. INTRODUCTION

Linear programming (LP) is a mathematical technique for evaluating the most efficient use of a company's limited resources to achieve the optimum goal. It is also a mathematical method for choosing the best product combination to maximize profit or decrease cost within the limitations of available resources. The technique of LP is used in a wide range as applications, including agriculture, industry, transportation, economics, health system, social science and the military. Many business organizations see LP as a new science or recently development in mathematical history. Nowadays, Company managers are usually met with decisions relating to limited resources. These resources may incorporate men, materials, and money. There are not enough resources available to do everything that management wants. The problem revolves around deciding which resources should be assigned to achieve the optimal result, related to profit, cost, or both. Microeconomics and company management difficulties such as planning, production, transportation, technology, and other issues depend on linear programming.

Although management difficulties are constantly changing, most businesses would like to maximize earnings or reduce expenses with limited resources. As a result, many problems can be classified as LP problems. A group researchers used linear programming method in deriving the maximum gain from production of soft drink in Nigeria bottling company, Ilorin plant (Balogun et al., 2012). Linear programming of the operations of the company was formulated and optimum result obtained by using 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. Some researcher developed research to minimize the use of raw material by using simplex method in making loaf (AKpan and Iwak, 2016). Their results obtained showed that only two out of the five items they considered in their computational experiments are profitable.

Zangiabadi, and Maleki on their paper proposed several theorems which are used to obtain optimal solutions of linear programming problems with fuzzy parameters (Zangiabadi and Maleki, 2007). A group researchers proposed that profit can be maximized by applying linear programming in a chemical company (Maurya et al., 2015). Their data collection process is unclear. Some researchers have tried to study the linear programming approach to calculate the highest profit from the manufacturing of Feeds-by-Feeds Maters Limited in Kwara State but there is a lack of comprehensive control over the entire process (Balogun et al., 2013). Muhammad, Samson, and Hafisu, concentered on the use of linear programming methodologies in the industrial industry (Muhammad et al., 2015). Their results are very poor related to the industrial industry. A group researchers developed the applications of Linear Programming for profit maximization: a case of paints Company, Pakistan (Haider et al., 2016).

Some researchers developed that linear programming is used in a variety of power system economics, planning and operations (Delson et al., 2020). A new approach to the solution of game problems is suggested by Vaidya, N. V., and Khobragade, N. W., (Vaidya and Khobragade, 2013). The literature assessment of prior publications reveals that researchers are concerned about linear programming and other optimization methods. However, in several of these articles, the data collection process is unclear. Some of the studies are particularly lacking in future scope. In addition, there is a lack of comprehensive control over the entire process. The paper is structured as follows. In section 2, methodology of our research has been inserted. It has been used to conduct systematic research. In section 3, data presentation and analysis is discussed. Results of our paper contain in section 4. Finally in last section, the conclusion is given.

2. METHODOLOGY

Consider the objective function maximize $P = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \cdots + \gamma_n x_n$ subject to the constraints:

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$$\alpha_{11}x_1 + \alpha_{12}x_2 + \cdots + \alpha_{1n}x_n \le \beta_1$$
$$\alpha_{21}x_1 + \alpha_{22}x_2 + \cdots + \alpha_{2n}x_n \le \beta_2$$
$$\alpha_{31}x_1 + \alpha_{32}x_2 + \cdots + \alpha_{3n}x_n \ge \beta_3$$
$$\vdots$$
$$\alpha_{m1}x_1 + \alpha_{m2}x_2 + \cdots + \alpha_{mn}x_n \le \beta_m$$

where all $x_j \ge 0$ are variables, $\beta_i \ge 0$ and $\alpha_{ij} \ge 0$ are constants and $i = 1,2,3, \ldots \ldots \ldots \ldots, m$;

$j = 1,2,3, \ldots \ldots \ldots \ldots, n$.

To solve a standard maximization problem, we perform the following sequence of steps.

1. Rewriting each inequality as an equation by introducing slack variables. That is,
$$\alpha_{i1}x_1 + \alpha_{i2}x_2 + \alpha_{i3}x_3 + \ldots\ldots\ldots + \alpha_{in}x_n \le \beta_i$$
becomes
$$\alpha_{i1}x_1 + \alpha_{i2}x_2 + \alpha_{i3}x_3 + \ldots\ldots\ldots + \alpha_{in}x_n + s_i = \beta_i$$
where $i = 1,2,3, \ldots \ldots \ldots \ldots \ldots, m$ and s_i is slack variable.

2. Rewriting the objective function in the form:
$$P - \gamma_1 x_1 - \gamma_2 x_2 - \cdots - \gamma_n x_n = 0$$

3. For the simplex table creating an array containing the coefficients of our variables, slack variables and P.

x_1	x_2	… … … … ..	x_n	s_1	s_2	… … … … ..	s_m	P	Constant
a_{11}	a_{12}	… … … … ..	a_{1n}	1	0	… … … … ..	0	0	β_1
.	.	… … … … . .	.	0	1	… … … … . .	0	0	.
.	.	… … … … . .	.	0	0	… … … … . .	0	0	.
.	.	… … … … . .	.	0	0	… … … … . .	0	0	.
a_{m1}	a_{m2}	… … … … ..	a_{mn}	0	0	… … … … ..	1	0	β_m
$-\gamma_1$	$-\gamma_2$	… … … … ..	$-\gamma_n$	0	0	… … … … ..	0	1	0

4. Examining all items in the last row to the left of the vertical line to see if the best answer has been found. If all of these entries are nonnegative, we've found the best answer. Then we continue to Step 7. If one or more negative entries are present, the optimal solution has not been found. And we continue to Step 5.

5. Finding the highest negative number to the left of the vertical line in the last row to locate the pivot column. Then dividing each element in the constant column by the pivot column's corresponding entry. The pivot row corresponds to the ratio with the least value (we ignore this row if any of the quotients are negative or meaningless). The issue may not have an efficient solution if all of the rows are negative or meaningless.) The pivot location is where the pivot column and pivot row meet.

6. Now we scale the pivot element to 1 using simple row operations. Then making every other element in the pivot column zero by using this pivot one. A unit column is a column that has all zeros except one. Then we back to Step 4 now.

7. A fundamental variable is a variable that corresponds to a unit column. Non-basic variables are those that are not basic. The item in the constant column in the row containing the 1 determines the value of each fundamental variable. The value of non-basic variables is zero. This is the most suitable option.

3. Data Presentation and Analysis

Assumption for the problem:

- It is estimated that the total ingredients used is fixed.
- It is estimated that the total demand of Biscuits is limited.
- It is estimated that there is a linear relationship among the variables used in this paper.

Table 1: Quantity of raw materials available in stock

Raw Materials	Quantity Available (gm)
Sugar	2200
Flour	5000
Egg	3000
Salt	500
Vanilla Essence	600
Butter	2000
Flavor	1000

Table 2: Quantity of Raw Materials Needed to Produce Each Biscuit

Ingredients	Used Ingredients (in Gm) Per Packet of Biscuit							Available Ingredients (in gm)
	Energy Plus (80gm)	Lexus (20gm)	Orange (70gm)	Fit (70gm)	Dark Fantasy (80gm)	Grand Choice (70gm)	Dry Cake (100gm)	
Sugar	25.5	5	18.5	12.5	25	22.5	27.5	2200
Flour	34	9	31	33.5	28	25.5	44	5000
Egg	10	1.5	8.5	8	7	8	18	3000
Salt	3	1	2.5	6	5	4	3	500
Vanilla Essence	2.5	0.5	1.5	2.5	1	3	2.5	600
Butter	4	2	5	5.5	9	5	4	2000
Flavor	1	1	3	2	5	2	1	1000

Table 3: Average Cost and Selling Price of Each Biscuit

Product	Average Unit Cost (TK)	Average Selling Price (TK)	Average Unit Profit (TK)
Energy Plus	7.65	15	7.35
Lexus	2.25	5	2.75
Orange	4.3	10	5.7
Fit	7.2	15	7.8
Dark Fantasy	9.15	20	10.85
Grand Choice	9.85	20	10.15
Dry Cake	24.95	40	15.05

3.1 Model Formulation

Maximize $P = 7.35x_1 + 2.75x_2 + 5.7x_3 + 7.8x_4 + 10.85x_5 + 10.15x_6 + 15.05x_7$

Subject to

$$25.5x_1 + 5x_2 + 18.5x_3 + 12.5x_4 + 25x_5 + 22.5x_6 + 27.5x_7 \le 2200$$
$$34x_1 + 9x_2 + 31x_3 + 33.5x_4 + 28x_5 + 25.5x_6 + 44x_7 \le 5000$$
$$10x_1 + 1.5x_2 + 8.5x_3 + 8x_4 + 7x_5 + 8x_6 + 18x_7 \le 3000$$
$$3x_1 + 1x_2 + 2.5x_3 + 6x_4 + 5x_5 + 4x_6 + 3x_7 \le 500$$
$$2.5x_1 + 0.5x_2 + 1.5x_3 + 2.5x_4 + 1x_5 + 3x_6 + 2.5x_7 \le 60$$
$$4x_1 + 2x_2 + 5x_3 + 5.5x_4 + 9x_5 + 5x_6 + 4x_7 \le 2000$$

$x_1 + x_2 + 3x_3 + 2x_4 + 5x_5 + 2x_6 + x_7 \leq 1000$

$x_i \geq 0$ for $i = 1,2, \ldots, 7$

Now, introducing the slack variable to convert inequalities to equations, it gives:

$$P = 7.35x_1 + 2.75x_2 + 5.7x_3 + 7.8x_4 + 10.85x_5 + 10.15x_6 + 15.05x_7 + 0s_1 + 0s_2 + 0s_3 + 0s_4 + 0s_5 + 0s_6 + 0s_7$$

$$P - 7.35x_1 - 2.75x_2 - 5.7x_3 - 7.8x_4 - 10.85x_5 - 10.15x_6 - 15.05x_7 - 0s_1 - 0s_2 - 0s_3 - 0s_4 - 0s_5 - 0s_6 - 0s_7 = 0$$

Subject to

$25.5x_1 + 5x_2 + 18.5x_3 + 12.5x_4 + 25x_5 + 22.5x_6 + 27.5x_7 + s_1 = 2200$

$34x_1 + 9x_2 + 31x_3 + 33.5x_4 + 28x_5 + 25.5x_6 + 44x_7 + s_2 = 5000$

$10x_1 + 1.5x_2 + 8.5x_3 + 8x_4 + 7x_5 + 8x_6 + 18x_7 + s_3 = 3000$

$3x_1 + 1x_2 + 2.5x_3 + 6x_4 + 5x_5 + 4x_6 + 3x_7 + s_4 = 500$

$2.5x_1 + 0.5x_2 + 1.5x_3 + 2.5x_4 + 1x_5 + 3x_6 + 2.5x_7 + s_5 = 600$

$4x_1 + 2x_2 + 5x_3 + 5.5x_4 + 9x_5 + 5x_6 + 4x_7 + s_6 = 2000$

$x_1 + x_2 + 3x_3 + 2x_4 + 5x_5 + 2x_6 + x_7 + s_7 = 1000$

$x_i \geq 0$ for $i = 1,2, \ldots, 7$ and $s_i \geq 0$ for $i = 1,2, \ldots, 7$

where,

$x_1 =$ the number of Energy Plus packet

$x_2 =$ the number of Lexus packet

$x_3 =$ the number of Orange packet

$x_4 =$ the the number of Fit packet

$x_5 =$ the number of Dark Fantasy packet

$x_6 =$ the number of Grand Choice packet

$x_7 =$ the number of Dry Cake packet

Table 4: Final Iteration by Simplex Method

Row	Basis	x_1	x_2	x_3	$\boldsymbol{x_4}$	x_5	x_6	$\boldsymbol{x_7}$	s_1	s_2	s_3	s_4	s_5	s_6	s_7	BFS
1	$\boldsymbol{x_7}$	$\frac{77}{85}$	$\frac{7}{51}$	$\frac{319}{510}$	0	$\frac{35}{51}$	$\frac{2}{3}$	**1**	$\frac{4}{85}$	0	0	$\frac{-5}{51}$	0	0	0	$\frac{2780}{51}$
2	s_2	$\frac{-632}{85}$	$\frac{-11}{34}$	$\frac{-1}{340}$	0	$\frac{-633}{34}$	-15	0	$\frac{-109}{85}$	1	0	$\frac{-99}{34}$	0	0	0	$\frac{12290}{17}$
3	s_3	$\frac{-568}{85}$	$\frac{-179}{102}$	$\frac{1831}{510}$	0	$\frac{-473}{51}$	$\frac{-20}{3}$	0	$\frac{-56}{85}$	0	1	$\frac{2}{51}$	0	0	0	$\frac{80080}{51}$
4	$\boldsymbol{x_4}$	$\frac{4}{85}$	$\frac{5}{51}$	$\frac{53}{510}$	**1**	$\frac{25}{51}$	$\frac{1}{3}$	0	$\frac{-2}{85}$	0	0	$\frac{11}{51}$	0	0	0	$\frac{2860}{51}$
5	s_5	$\frac{2}{17}$	$\frac{-3}{34}$	$\frac{-11}{34}$	0	$\frac{-33}{17}$	$\frac{1}{2}$	0	$\frac{-1}{17}$	0	0	$\frac{-5}{17}$	1	0	0	$\frac{5500}{17}$
6	s_6	$\frac{2}{17}$	$\frac{31}{34}$	$\frac{131}{68}$	0	$\frac{121}{34}$	$\frac{1}{2}$	0	$\frac{-1}{17}$	0	0	$\frac{-27}{34}$	0	1	0	$\frac{25050}{17}$
7	s_7	0	$\frac{2}{3}$	$\frac{13}{6}$	0	$\frac{10}{3}$	$\frac{2}{3}$	0	$\frac{-1}{2147}$	0	0	$\frac{-1}{3}$	0	0	1	$\frac{2500}{3}$
8	P≥ 0	$\frac{5101}{767}$	$\frac{148}{255}$	$\frac{1588}{351}$	0	$\frac{842}{255}$	$\frac{149}{60}$	0	$\frac{223}{425}$	0	0	$\frac{211}{1020}$	0	0	0	$\frac{46538}{37}$

4. Analysis and Result

Objective functional value $P = \frac{46538}{37} = \mathbf{1257.78}$

Variables	Values
x_1	0.000
x_2	0.00
x_3	0.00
$\boldsymbol{x_4}$	**56.08**
x_5	0.00
x_6	0.00
$\boldsymbol{x_7}$	**54.51**

The optimal solutions are:

$\boldsymbol{P} = \frac{46538}{37} = \mathbf{1257.78}$

$x_1 = 0$; $x_2 = 0$; $x_3 = 0$; $\boldsymbol{x_4} = \frac{2860}{51} = \mathbf{56.08}$; $x_5 = 0$; $x_6 = 0$;$\boldsymbol{x_7} = \frac{2780}{51} = \mathbf{54.51}$,

and $s_1 = s_2 = \cdots = s_7 = 0$

4.1 Interpretation of the Result

The model indicates that the optimum result is derived from the data collected. Based on the analysis carried out in this project and the result shown, Biscuit factory should produce Energy Plus(80gm), Lexus(20gm), Orange(70gm), Fit(70gm), Dark Fantasy(80gm), Grand Choice(70gm), Dry cake (100gm) but more of Fit(70gm) and Dry cake(100gm) in order to satisfy their customers. This simply shows that x_4(the number of Fit packet) and x_7(the number of Dry Cake packet) contributed meaningfully to improve the value of the objective function of the LP model. Also, more of Fit(70gm) and Dry cake(100gm) should be produced in order to attain maximum profit because they contribute mostly to the profit earned. So, from the results of the LP model, it is desirable for Biscuit factory to concentrate on the sales of Fit and Dry Cake. This would fetch the company an optimal profit of about 1257.78 taka based on the uses of ingredients.

5. Conclusion

Linear programming is an area of applied mathematics that deals with a wide range of optimization issues. It's commonly utilized to solve production planning and scheduling issues. The most significant benefit of linear programming as an optimization method is that it always yields the best result. Linear programming appears to be a very effective means of transforming data into useful information to help daily production planning decisions. In this project a linear programming approach is developed to determine the best production plan for Biscuit items while optimizing profit. Also, the applicability of linear programming approaches for maximizing profit in a Biscuit factory is demonstrated. The Simplex Method, a well-known mathematical method, is utilized for this purpose. The research's main goal is to emphasize the uniqueness of linear programming modeling at the business level as an optimization technique and to encourage manufacturing companies to employ linear programming to determine their optimal profit. These insights will help the factory optimize its contribution not only now, but also in the future. In addition, this research suggests that other businesses use this strategy to improve their financial performance.

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