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Profit Maximization Through Linear Programming Problem: A Case Study Of Chocolate Making Industry In Karnataka, India

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Abstract:
Linear programming, a mathematical approach, aims to select the most optimal combination of products to either maximize profits or minimize costs while operating within the constraints of available resources. This article presents the application of linear programming specifically for maximizing profits in a chocolate factory situated in Bengaluru, Karnataka, India. When dealing with linear programming problems, the Simplex algorithm stands out as a robust computational tool, offering rapid solutions even for extensive applications. The focus of optimization in this study cantered on evaluating the unit cost of production, setting selling prices, and determining the quantities of various raw materials utilized in the production process. A model addressing these concerns was formulated, and optimal outcomes were derived through software employing the simplex method. The primary aim of this work is to u[1]nderscore the distinct advantages of employing linear programming as an optimization technique in business operations, specifically urging manufacturing enterprises to consider its implementation for determining the most advantageous path to optimal profits.

Keywords *LPP Model, Decision Variables, Objective function, Constraints, Optimal result*.

Introduction

Linear programming (LP) serves as a mathematical tool to assess the optimal utilization of a company's limited resources in pursuit of achieving specific goals. It is a methodical approach for selecting the most advantageous product combination to either maximize profits or minimize costs within the constraints of available resources. This technique finds diverse applications across various fields such as agriculture, industry, transportation, economics, healthcare, social sciences, and the military. Many businesses view LP as a contemporary scientific development in the realm of mathematics.

Modern-day managers frequently grapple with decisions involving constrained resources, encompassing factors like manpower, materials, and finances. Given the scarcity of resources to fulfil all managerial objectives, the crux of the issue lies in determining the allocation of resources that yields optimal outcomes, be it in terms of profit, cost reduction, or a combination of both. Microeconomic challenges and managerial tasks, spanning planning, production, transportation, technology, and other aspects, often rely on linear programming.

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Despite the dynamic nature of managerial challenges, the overarching goal for most businesses remains consistent—maximizing earnings or minimizing expenses within the confines of limited resources. Consequently, many problems encountered in business settings can be categorized as linear programming problems. For instance, researchers employed the linear programming method to maximize the profit from soft drink production at a Nigerian bottling company's Ilorin plant [1]. Formulating the linear programming model for the company's operations and utilizing the simplex method yielded optimal results, revealing that prioritizing the production of two specific products was more beneficial, even when there was demand for less profitable items in the vicinity of the plant.

In another study, researchers sought to minimize the use of raw materials in the production of loaves, employing the simplex method [2]. Their findings indicated that only two out of the five considered items in their computational experiments proved to be profitable.

A series of theorems aimed at deriving optimal solutions for linear programming problems with fuzzy parameters was also derived [3]. Another group of researchers [4] suggested that the application of linear programming in a chemical company could maximize profits, although their data collection process remains unclear. Similar attempts have been made to employ the linear programming approach to optimize profits in the manufacturing of confectioneries in the state of Gujrat, India, but the lack of comprehensive control over the entire process has been identified as a limitation.

Another researcher [5] indicated that linear programming finds applications in various aspects of power system economics, planning, and operations. However, a literature review of previous publications reveals concerns among researchers regarding the clarity of data collection processes in several articles. Some studies also lack a comprehensive overview of the entire process and future scope.

Methodology

The Simplex method functions as an iterative algorithm designed for the resolution of linear programming problems. It engages in a step-by-step approach to ascertain the optimal solution, progressing from one viable solution to another along the boundaries of the feasible region. Below is an all-encompassing procedure for implementing the Simplex method, specifically tailored for scenarios with seven variables:

Define the Linear Programming Problem:

- Determine the objective function, whether it involves maximization or minimization.
- Identify constraints on decision variables.
- Express both the objective function and constraints in standard form.

Set Up the Initial Simplex Tableau:

- Transform the linear programming problem into standard form if not already done.
- Introduce slack, surplus, or artificial variables as necessary.
- Construct the initial simplex tableau, incorporating coefficients of variables from the objective function and constraints.

Identify the Pivot Column:

- Choose the most negative coefficient in the objective function (the entering variable) as the pivot column.

Identify the Pivot Row:

- Calculate ratios of right-hand side values to coefficients in the pivot column.
- Select the smallest non-negative ratio as the pivot row (the departing variable).

Perform Row Operations:

- Utilize elementary row operations to set the pivot element to 1 and all other elements in the pivot column to 0.

Update the Tableau:

- Adjust the tableau by employing elementary row operations to nullify the coefficients in the pivot column of the objective function.

Repeat the Process:

- Assess if the solution is optimal by scrutinizing objective function coefficients.
- If negative coefficients persist, iterate through steps 3 to 6.
- When all coefficients are non-negative, the solution is optimal, and decision variable values are extracted from the tableau.

Handling Artificial Variables (if used):

- Confirm that artificial variables are all zero in the final solution.
- If any artificial variable remains in the basis, it indicates an infeasible problem.

Interpret the Results:

- Interpret the outcomes within the context of the original problem.
- Conduct sensitivity analysis if required to evaluate the impact of coefficient changes.

Conclude:

- Conclude the optimization process and present the ultimate solution.

It is crucial to recognize that this methodology necessitates iteration until an optimal solution is achieved. The iterative process continues until further enhancement in the objective function value becomes unattainable, signifying the attainment of the optimal solution.

Data arrangement and Analysis

The following are the assumptions made to get a feasible and optimal solution.

1. The total demand for the chocolates is fixed.
2. The ingredients used in the making of chocolates are fixed.

3. There exists a linear relationship among the variables.

Table 1. Raw material quantity in stock	
Particulars of the raw material	**Quantity in grams**
Cocoa beans	**2200**
Cocoa mass	**5000**
Sugar	**3000**
Aroma	**500**
Emulsifier	**600**
Butter	**2000**
Milk powder	**1000**

In the below table, C1, C2….C7 depicts the variants of the chocolate manufactured in the factory. These are coded as C1, C2, etc. due to copyright and other classified policies of the company.

Table 2. Raw material quantity to produce a chocolate							
Ingredients	**Ingredients used (in grams (gm)) per chocolate packet**						
	C1 (80 gm)	**C2 (20 gm)**	**C3 (70 gm)**	**C4 (70 gm)**	**C5 (80 gm)**	**C6 (70 gm)**	**C7 (100 gm)**
Cocoa beans	**25.5**	**5**	**18.5**	**12.5**	**25**	**22.5**	**27.5**
Cocoa mass	**34**	**9**	**31**	**33.5**	**28**	**25.5**	**44**
Sugar	**10**	**1.5**	**8.5**	**8**	**7**	**8**	**18**
Aroma	**3**	**1**	**2.5**	**6**	**5**	**4**	**3**
Emulsifier	**2.5**	**0.5**	**1.5**	**2.5**	**1**	**3**	**2.5**
Butter	**4**	**2**	**5**	**5.5**	**9**	**5**	**2**
Milk powder	**1**	**1**	**3**	**2**	**5**	**2**	**1**

Table 3. Average Profit, Selling price and Cost of each chocolate in ₹			
Product	**Average Selling price in ₹ (1)**	**Average cost in ₹ (2)**	**Average Profit in ₹ (1-2)**
C1	**15**	**7.65**	**7.35**
C2	**5**	**2.25**	**2.75**
C3	**10**	**4.3**	**5.7**
C4	**15**	**7.2**	**7.8**
C5	**20**	**9.15**	**10.85**
C6	**20**	**9.85**	**10.15**
C7	**40**	**24.95**	**15.05**

Linear Programming Problem Model

The Objective Function is defined below.

Maximize P=$7.35x_1+2.75x_2+5.7x_3+7.8x_4+10.85x_5+10.15x_6+15.05x_7$
The above Objective function is subject to the following constraints.

Subject to:

1. Ingredient of Cocoa beans; $25.5x_1+5x_2+18.5x_3+12.5x_4+25x_5+22.5x_6+27.5x_7 \leq 2200$
2. Ingredient of Cocoa mass; $34x_1+9x_2+31x_3+33.5x_4+28x_5+25.5x_6+44x_7 \leq 5000$
3. Ingredient of Sugar; $10x_1+1.5x_2+8.5x_3+8x_4+7x_5+8x_6+18x_7 \leq 3000$
4. Ingredient of Aroma; $3x_1+1x_2+2.5x_3+6x_4+5x_5+4x_6+3x_7 \leq 500$
5. Ingredient of Emulsifier; $2.5x_1+0.5x_2+1.5x_3+2.5x_4+1x_5+3x_6+2.5x_7 \leq 60$
6. Ingredient of Butter; $4x_1+2x_2+5x_3+5.5x_4+9x_5+5x_6+4x_7 \leq 2000$
7. Ingredient of Milk powder; $x_1+x_2+3x_3+2x_4+5x_5+2x_6+x_7 \leq 1000$
   Where $x_i \geq 0$, for i=1,2,3….,7

   Below is the conversion of inequalities to equations by introduction of slack variables.
   Maximize P=$7.35x_1+2.75x_2+5.7x_3+7.8x_4+10.85x_5+10.15x_6+15.05x_7$
   $+0s_1+0s_2+0s_3+0s_4+0s_5+0s_6+0s_7$

Subject to:

1. Ingredient of Cocoa beans; $25.5x_1+5x_2+18.5x_3+12.5x_4+25x_5+22.5x_6+27.5x_7+ s_1 = 2200$
2. Ingredient of Cocoa mass; $34x_1+9x_2+31x_3+33.5x_4+28x_5+25.5x_6+44x_7+ s_2 = 5000$
3. Ingredient of Sugar; $10x_1+1.5x_2+8.5x_3+8x_4+7x_5+8x_6+18x_7+ s_3 = 3000$
4. Ingredient of Aroma; $3x_1+1x_2+2.5x_3+6x_4+5x_5+4x_6+3x_7+ s_4 = 500$
5. Ingredient of Emulsifier; $2.5x_1+0.5x_2+1.5x_3+2.5x_4+1x_5+3x_6+2.5x_7 + s_5 = 60$
6. Ingredient of Butter; $4x_1+2x_2+5x_3+5.5x_4+9x_5+5x_6+4x_7 + s_6 = 2000$
7. Ingredient of Milk powder; $x_1+x_2+3x_3+2x_4+5x_5+2x_6+x_7+ s_7 = 1000$
   Where $x_i \geq 0$, for i=1,2,3….,7 and $s_i \geq 0$, for i=1,2,3….,7 and
   x_1 = Number of C1 type chocolate packet
   x_2 = Number of C2 type chocolate packet
   x_3 = Number of C3 type chocolate packet
   x_4 = Number of C4 type chocolate packet
   x_5 = Number of C5 type chocolate packet
   x_6 = Number of C6 type chocolate packet
   x_7 = Number of C7 type chocolate packet

   Table 4. Simplex Method Iterations

Row	Basis	x_1	x_2	x_3	x_4	x_5	x_6	x_7	s_1	s_2	s_3	s_4	s_5	s_6	s_7	BFS
1	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	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	$P \geq 0$	$\frac{5101}{767}$	$\frac{148}{255}$	$\frac{1588}{351}$	0	$\frac{842}{255}$	$\frac{149}{60}$	0	$\frac{223}{425}$	0	0	$\frac{211}{1020}$	0	0	0	$\frac{46538}{37}$

Result and Analysis

Table 5. Values of the variables	
Variables	**Solution**
x_1	0.00
x_2	0.00
x_3	0.00
x_4	56.08
x_5	0.00
x_6	0.00
x_7	54.51

The value of P obtained is 1257.78 (46538/37)

Analysis of the result

The model suggests that the optimal outcome is achieved through the gathered data. Based on the conducted analysis in this study and the resulting findings, the Chocolate factory should manufacture C1 (80gm), C2 (20gm), C3 (70gm), C4 (70gm), C5 (80gm), C6 (70gm), and C7 (100gm). However, there should be a greater emphasis on producing more units of C4 (70gm) and C7 (100gm) to meet customer satisfaction. This clearly indicates that x_4 (the quantity of C4 packets) and x_7 (the quantity of C7 packets) significantly contribute to enhancing the objective function value of the LP model. Additionally, prioritizing the production of more C4 (70gm) and C7 (100gm) is essential for maximizing profits, as they play a major role in the overall profitability. Therefore, according to the outcomes of the LP model, it is recommended that the Chocolate factory focuses its efforts on promoting the sales of C4 and C7. This strategic emphasis is projected to yield the company an optimal profit of approximately ₹1257.78, considering the utilization of ingredients.

Conclusion

Linear programming, a branch of applied mathematics, addresses a broad spectrum of optimization challenges, commonly finding application in solving issues related to production planning and scheduling. One of its primary advantages as an optimization method lies in its consistent ability to generate the best possible outcomes. Linear programming proves highly effective in converting data into valuable information, aiding in day-to-day production planning decisions. This study develops a linear programming approach specifically tailored to ascertain the optimal production plan for Chocolate products while maximizing profit. The study demonstrates the applicability of linear programming techniques in profit maximization within a Chocolate factory, employing the well-established Simplex Method for this purpose. The overarching objective of the research is to underscore the distinctive nature of linear programming modelling as an optimization technique at the business level, urging manufacturing companies to adopt linear programming for determining their optimal profit. These insights not only assist the factory in optimizing its current contribution but also lay a foundation for future optimization. Furthermore, the research advocates for the broader adoption of this strategy by other businesses to enhance their financial performance.

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