Profit Maximization through Linear Programming Model in a Mineral Water Manufacturing Company

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Abstract: In the 21st Century, efficiency plays a key role in increasing the profits earned by firms. This research aims at applying the linear programming model to a mineral water manufacturing company to maximize the profit that the company can earn. The data collected in this paper is of primary nature and has been collected from the management of the company. Two methods, Graphical method and Simplex method through Excel were used to solve the LPP and find an optimal solution. The results show that the company must produce 72,000 bottles of 500 ml and 24,000 bottles of 1 litre every day in order to earn a maximum profit of Rs 22,797.6.

Key words: Linear Programming, Optimal Solution, Maximization, Simplex Method.

I. INTRODUCTION

The subject of operations research deals with the creation and implementation of analytical techniques to enhance decision-making. It is a discipline that is used by management to enhance the effectiveness and efficiency of decision-making.

Organizational management can benefit from using operations research (OR) which is an analytical approach to problem-solving and decision-making. In operations research, issues are dissected into their fundamental elements and then resolved by quantitative analysis in predetermined processes.

The term "linear programming" (LP) which also known as Linear Optimization, is a technique for finding out the optimal result for a mathematical model whose criteria are represented by linear relationships, such as the largest profit or lowest cost. In commercial planning, industrial engineering, social and physical sciences, this method has proven helpful for directing quantitative decisions. The goal or aim of Linear Programming is to minimize or maximize the objective function. The LP model also consists of constrains that are in the form of linear functions which must be adhered to while finding the optimum solution for the objective function. The constraints can take the form of inequalities or linear equations. To determine the best resource use, linear programming is regarded as a crucial technique.

The Simplex Technique or Algorithm is a standard technique used to solve a linear programming problem (LPP). The vertices are systematically examined as potential solutions using the simplex method. Drawing the restrictions on a graph can help solve certain straightforward optimization issues. However, only two-variable systems of inequalities may be solved using this method.

Crystal Aqua Inc

Crystal Aqua Inc company is involved in the manufacturing of packaged drinking water. The company was founded by Dr Gopinath Muppiri in 1996 and was one of the earliest companies in the packaged water bottle industry in South India.

Crystal Aqua Inc is an important player in packaged drinking water industry providing services to large private organizations and government institutions apart from retail stores. The company currently has its manufacturing unit in the Harohalli Industrial Area, Bengaluru. The company primarily catered to the needs of the corporate companies in and around Bengaluru. In addition, it also supplies products to meet the needs of the local markets in Karnataka through its distributors. The company had some of the biggest companies as its clients such as HSBC, Hewlett Packard, Deutsche Bank, Tata B.P Solar, CISCO, Mindtree, G.E Groups, ABB Group, TCS, Oracle, J.P Morgan and many more. The company was also in a partnership with the United Breweries Group (UB) and was a franchisee of the McDowells packaged drinking water.

The company currently is operating with its own brand called Fontaine and is producing water bottles of different sizes mainly for commercial consumption. The company produces 200 ml bottles, 300 ml bottles, 500 ml bottles, 1

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litre bottles and 2 litre water bottles. The 500 ml water bottle is quite popular among the customers as it is considered to be an ideal size for a water bottle. The bottle is really convenient as people tend the finish the water quickly and do not have to store it. The 1 litre water bottle on the other hand is considered to be an ideal travel necessity as it contains enough water for an overnight travel.

II. LITERATURE REVIEW

The study conducted by [1] aimed to maximize the profits of Benin Bakery in the university of Benin using linear programming technique. The study aimed at finding the optimum production level of bread per day in order to find the maximum profits that can be earned by the firm subjected to the constraints in the production process. The result of the study shows that the bakery should eliminate or stop the production of medium and large bread as they do not contribute to the profits of the firm and produce 667 loaves of extra-large bread to earn a maximum profit of ₦1,00,000.

The study by [2] shows the application of linear programming technique to obtain optimal profit in a medicated soap manufacturing industry, Kasmo Industry Limited. Kasmo Ltd produces four types of sales packages of its medicated soap- 1 tablet per pack, 3 tablets per pack, 12 tablets per pack and 120 tablets per pack. On the application of linear programming technique, it is revealed that the company can earn an optimal profit of ₦2,71,296 by producing 18,893 units of 1 tablet pack and by not producing any other tablet package.

The study conducted by [3] aims at discovering the effectiveness of the application of LP (Linear Programming) in finding the optimal solution of various products that can be produced by an organization to maximize profits. The study involves applying linear programming model for one of the main products Plastic Emulsion produced by a paint company in Pakistan. The product is produced in three different sizes- quarter, gallon and drummy. The results of the study show that the company can earn a maximum profit of Rs 1,62,038 by investing all its resources in the production of only gallon.

The study conducted by [4] applies linear programming technique to determine the optimum production level of Usmer Water Company, Uyo. The company produces four different types of products- sachet bag of water, 50cl of water, 75 cl of water, 1.5 litres of water and 10 litres of refillable water. Upon applying the linear programming technique, it was revealed that the company should produce 45 units of sachet water, 0 units of 50cl water carton, 5.9 units of 75cl water carton, 10 units of 1.5 litre water carton and 17 units of 10 litre refillable water carton in order to achieve optimum production level.

The Simplex algorithm, a component of linear programming, was used in this work [5] to allocate raw materials. In order to maximise profits, bakeries compete by using competing factors (large loaf, huge loaf, and small loaf). The analysis was done, and the results showed that, in order to make a profit of ₦20,385, 962 units of small loaves, 38 units of huge loaves, and 0 units of enormous loaves should be created, correspondingly. Following the analysis, it was shown that the tiny bread, followed by the huge loaf, objectively contribute to the profit. Thus, more of small loafs and big loafs should be produced and sold to achieve maximum profit.

This study [6] aims to maximise profit from soft drink manufacturing for Nigeria Bottling Company's plant using linear programming techniques. The company's activities were given a linear programming formulation, and the best outcomes were obtained using software that used the simplex method. The outcome demonstrates that two specific products should be manufactured even though the corporation must meet demand for other, less profitable products in the area around the facilities. Based on the analysis done for this study and the results, Nigeria Bottling Company's Ilorin plant should produce more of Coke 50cl and Fanta Orange 50cl to satisfy their customers and to maximise profit as these two beverages make up the majority of the profit.

In this article [7], the author has suggested a linear programming application for the Bangladeshi biscuit factory's goal of profit maximisation. The raw materials, selling price, and the unit cost of manufacturing were assessed under the optimization principle. The software used the simplex approach to develop a model for the issue and get the best outcomes. The papers' objective is to highlight the distinctiveness of linear programming modelling as an optimization technique at the business level and to motivate manufacturing organisations to use linear programming to calculate their ideal profit.

This study [8] uses an Ethiopian garment manufacturing facility as a case study. Data such as product volume, resources required to manufacture 1 unit of the product, profit per unit for each product, monthly holding resources has been collected from the company. The parameters of the linear programming model were estimated using the data collected. LINGO 16.0 was used to solve the model. According to the study's findings, the company's profit can be increased by 59.84% i.e. from Birr 465,456 per month to Birr 777,877.3 per month by the application of linear programming model.

The research paper [9] is conducting research on the product mix optimization issue. The quantity of monthly held resources, the volume of the product, the resources needed to manufacture each unit of the product, and the profit per unit for each product have all been obtained from the company and are included in this article. The primary restriction identified was the underutilization of resources in the garment manufacturing sector. The profits comparison between the production carried out in accordance with LPP models and actual production reveals the significant variations. Therefore, we may draw the conclusion that the clothing sector should decide on their

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ideal product mix using quantitative research techniques developed by LPP. The company's monthly earnings can increase by 1926147.06 by applying the linear programming model. The application of LP helps the businesses in achieving its profit goals.

In this study [10], linear programming is used to model and improve energy use in the textile industry (LP). Under various operational restrictions, a linear programming model has been created that satisfies the requirements for the finished product at the lowest cost of energy utilised in the process. Data needed for the model's development were gathered through the plant's energy audit. This study aimed to reduce energy costs by applying linear programming techniques to optimise energy utilisation in the textile manufacturing sector. A simplex algorithm-based linear programming model has been developed to address this issue. In order to obtain the lowest cost, the linear programming technique found the best values for the process design variables.

In order to solve industrial problems, this study [11] uses the improved simplex approach, a component of linear programme with the intention of increasing profit. The business GEEPEE Nigeria Limited specialises in producing tanks of different types. According to the developed model and the analysis of the amount of polyethylene and oxyacetylene used in the production of various sizes of plastic material produced with the assigned time attached to each product, Combo Tanks guarantees a profit margin of $300 if the quantity produced stood at 5 within the designated period of time.

In order to identify the proper product and produce the right amount of paint in Nigeria for higher profit and optimum company performance, this research [12] focuses on linear optimization. Data analysis was performed using the LINDO 11 software and the linear programming model. Only two of the five goods under evaluation are profitable, according to the outcome. It also showed the rate at which the corporation must cut costs for the three additional items before they can be produced at a profit.

This article [13] depicts how to utilise linear programming to reduce the cost of producing cartons at Shree Lakshmi Craft. The primary data is collected from the owner of the company. The following constraints were used to frame a linear programming problem (LPP): raw materials, production capacity, and demand per month. Also, the LPP was resolved using the graphical and simplex method (excel solver). According to the findings, the company should produce 3,60,000 cartons every month in order to keep production costs to a minimum.

III. RESEARCH METHODOLOGY

The data that has been used in this study is of primary nature and has been collected from the management of the company, Crystal Aqua Inc.

Quantitative data has been collected for this study.

Non-probability sampling method has been used in this study. Non-probability sampling means that the data is selected on a non-random basis and is specifically selected for the sole purpose of conducting this study.

Convenience Sampling technique has been used in this study. It means that the data selected and collected in this study is according to the author's convenience.

IV. DATA ANALYSIS

Let the number of cases of 500 ml produced be x and the number of cases of 1 litre be y.

The objective function is to maximize the profit earned by the company by selling the two products. The profit per 500 ml bottle is Rs 0.2083 and profit per 1 litre bottle is Rs 0.325.

The constraints in the study are formed based on the information given below:

1. **Production Capacity Constraint-** The manufacturing unit has a completely automated machinery that does the job of filling up water bottles and capping them. The production capacity of this machinery is 10,000 litres per hour. In terms of number of 500 ml bottles the production capacity is 20,000 bottles per hour and for the 1 litre bottles, it is 10,000 bottles per hour. Therefore, the production capacity constraint for the plant is given below:
   $x + 2y \leq 2,40,000$.
2. **Raw Material Constraint-** A preform is made of Polyethylene Terephthalate also commonly known as PET. These preforms act as a raw material to the company as they purchase them for third party manufacturers. These preforms are blow-moulded according to the requirements of the company and customers. The raw material required per day is 60,000 preforms of 500 ml and 36,000 preforms of 1 litre. Therefore, the raw material constraint is as follows:
   $x + y \leq 96,000$
3. **Demand Constraint-** The demand constraint represents the amount of demand that is present in the market for the company's products. In other words, it represents the quantity of orders received by the company on a daily basis. The company receives an average order of 42,000 bottles of 500 ml and 6,000 bottles of 1 litre on a daily basis. Therefore, demand constraint is as follows:
   $x + 7y \geq 48,000$
4. **Storage Constraint-** The storage constraint represents the limited amount of area that is available with the company within its factory premises or godown to store its manufactured goods. The company has a storage

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facility that can store up to 2,10,000 bottles of 500 ml or 30,000 bottles of 1 litre.

x + 7y ≤ 2,40,000.

5. **Non-Negative Constraints-** The non-negative constraints are included in this study as the number of units manufactured cannot be 0.

x ≥ 0; y ≥ 0.

Linear programming problem is to maximise the profit earned by the company

Minimize Z = 0.2083x + 0.325y
Subjected to
x + 2y ≤ 2,40,000 (Production Constraint)
x + y ≤ 96,000 (Raw Material Constraint)
x + 7y ≥ 48,000 (Demand Constraint)
x + 7y ≤ 2,40,000 (Storage Constraint)
x ≥ 0; y ≥ 0 (Non-Negative Constraint)
The problem solved by Graphical Method:

Step 1: Converting the inequalities to equalities and finding ordered pairs:

- x + 2y ≤ 2,40,000 => x + 2y = 2,40,000

Solving the equation gives the following ordered pairs:

When x = 0, y = 1,20,000 (0,120000)
When y = 0, x = 2,40,000 (240000,0)

- x + y ≤ 96,000 => x + y = 96,000

Solving the equation gives the following ordered pairs:
When x = 0, y = 96,000 (0,96000)
When y = 0, x = 96,000 (96000,0)

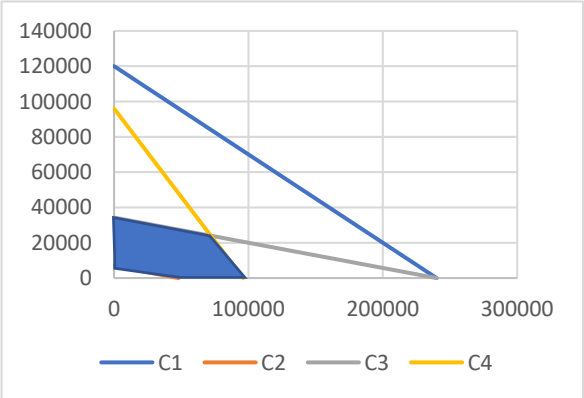
- x + 7y ≥ 48,000 => x + 7y = 48000

Solving the equation gives the following ordered pairs:
When x = 0, y = 6,857.14 (0,6857.14)
When y = 0, x = 48,000 (48000,0)

- x + 7y ≤ 2,40,000 => x + 7y = 240000

Solving the equation gives the following ordered pairs:
When x = 0, y = 34,285.71 (0,34285.71)
When y = 0, x = 2,40,000 (240000,0)

Step 2: Graphical Representation:



Graph 1: Shows the feasible points that are obtained by solving the LPP graphically.

Step 3: Feasible Points:

Feasible Points	Z = 0.2083x + 0.325y
(0,6857.14)	2,228.57
(0,34285.71)	11,142.625
(72000,24000)	22,797.6
(96000,0)	19,996.8

Table no 1: Feasible region points and their solutions as obtained from graphical solution.

Therefore, Max Z = 22,797.6 when x = 72,000 and y = 24,000.
The problem solved using the Simplex Method:
Solved in Excel using data solver

Decision Variables	x	y			
Values	72000	24000	22797.6		
Coefficients	0.2083	0.325			
			LHS		RHS
Constraint 1	1	2	120000	≤	240000
Constraint 2	1	7	240000	≥	48000
Constraint 3	1	7	240000	≤	240000
Constraint 4	1	1	96000	≤	96000

Table no 2: Solving the LPP using Simplex Method on Excel.

As we can see that the solution for the above Linear Programming Problem obtained is the same through the graphical method and Simplex method. Therefore, it can be concluded that the maximum profit that can be earned by the company is Rs 22,797.6 when x = 72,000 and y = 24,000.

V. CONCLUSION

The main aim of this paper was to apply the linear programming model to find the maximum profit that can be earned by the company along with constrains like raw materials, production capacity, demand constraint and storage constraint. The paper uses the Graphical method and the Simplex method to find the solution for the Linear Programming Problem that has been formulated. It has been found that Crystal Aqua Inc should manufacture 72,000 bottles of 500 ml and 24,000 bottles of 1 litre every day in order to earn a maximum profit of Rs 22,797.6.

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