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Linear programming and its applications in real-world decision making

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ABSTRACT

A basic mathematical optimisation technique, Linear Programming (LP) aims to maximise profit with minimum expenditure by efficiently allocating scarce resources. The linear functions are constrained by constraints expressed as linear equations or inequalities. This paper delves into the theoretical foundations of linear programming and explains how a business may put this technology to work for them to make lucrative decisions. To address this point, the article provides examples from a range of industries, such as manufacturing, agriculture, transportation, healthcare, and finance, to demonstrate the method's practical application..

Keywords: Mathematical optimisation, Resource allocation, Simplex Algorithm, Objective function, Decision variables

1. Introduction

Optimising operations and resource allocation is a continual challenge for many organisations in today's fast-paced, globally interconnected world. "An essential tool, linear programming not only offers a structured way to deal with these problems, but it also aids decision-makers in modelling real-world situations and finding the best answer within certain limits.

2. Literature review

After developing the first linear programming problems in 1939, Leonid Kantorovich deserves credit for introducing linear programming. The military forces utilised this method to maximise efficiency and reduce costs during World War 2. However, due to its military application, the Simplex method remained secret until its publication by George Dantzig. The Simplex Algorithm was created by George Dantzig, who is renowned as the father of linear programming, in 1947 while he was working on resource allocation for the US Air force. Computing optimisation has been transformed by this American mathematician. There has been a plethora of research, management science, agricultural, industrial, and engineering-related study and use of the method since then. It is still essential for quantitative analysis in making decisions within organisations.

3. Methodology and mathematical formulation

The linear programming is expressed as below:

Find the values of the decision variables like $x_1, x_2, x_3 \dots x_n$ to optimize (maximize or minimize) the objective function:

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + \dots + c_nx_n$$

Subject to the linear constraints:

$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n$ be either less than equal to or greater than equal to or equal to b_1

$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n$ be either less than equal to or greater than equal to or equal to b_2

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$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n$ be either less than equal to or greater than equal to or equal to b_m

And non-negativity restrictions:

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$X_1, x_2, x_3, \dots$ greater than equal to 0.

Explanation of key components

1. Decision Variables: An unknown quantities (x_1, x_2) representing the level of activity or choices to be determined.
2. Objective Function: A linear function (Z) representing profit to be maximized or cost/time to be minimized.
3. Constraints: Linear inequalities or equations defining the physical, operational or resource limits.
4. Non-Negativity Restrictions: Conditions ensuring variables which cannot be negative.

4. Real World Applications: Production Planning Problem: Manufacturers use this method to maximize their profit while reducing their cost and time

For Instance: A factory manufacturers sell two different types of the Products A and B, the cost of production of each units is rupees 150 and 100 respectively. Each unit generates a profit of 15 rupees and 10 rupees on selling. The factory estimates the monthly demand Of A and B be at a maximum of the harvested unit from all the production budget, which is set to be at rupees 30,000. With the help of this method,

We can easily find the number of units should the factory produce to earn high profit from its monthly sales of these products A and B.

Decision Variables: x =Product A, y = Product B.

Objective Maximize: $Z = 15x + 10y$

Subject to the Constraints:

$$150x + 100y = 30,000$$

$$y = 30000 - 150/100$$

$$y = 300 - 1.5x$$

x intercept when $y = 0$ and y intercept when $x = 0$

$$x = 200, y = 300$$

Now calculate profit at intercept points:

At (0,300)

$$Z = 15(0) + 10(300) = 3000$$

At (200,0)

$$Z = 15(200) + 0(300) = 3000$$

So, the maximum profit is Rs. 3000

Explanation: This illustration recommends the production of 15 units of Product A and 10 units of Product B because this combination maximizes profit while satisfying all the constraints.

2. Transportation and Logistics: Folks often use this method to determine the shortest delivery route for transporting the goods from one place to another at minimum cost

For instance: The company has 2 big warehouses and supply goods to 2 different retail stores in two different cities. Then, we can find minimum cost on moving goods from both supply units to demand units by taking the shortest route with the help of this method.

Variables: x, y, z and t represent 4 different routes.

Objective: Minimize $Z = 8x + 6y + 7z + 9t$

Constraints:

Supply Constraints:

$$x + y \leq 100; z + t \leq 80;$$

Demand constraints:

$$x + z = 90; y + t = 90; x, y, z, t \geq 0.$$

Explanation: The optimal shipment minimizes transportation cost while meeting supply and demand.

4.3 Agriculture

Farmers or agronomists use LP to maximize the crop yield based on land and water availability.

Variables: x =wheat acres, y =rice acres.

Objective: $Z = 40000x + 50000y$.

Constraints: $x + y \leq 100; 3x + 5y \leq 400; x, y \geq 0$.

Explanation: LP allocates land and water efficiently to maximize farmer income.

4.4. Healthcare

Hospitals use this method in optimizing staff scheduling to ensure adequate departmental coverage.

Variables: x =day nurses, y =night nurses.

Objective: $Z = 1200x + 1500y$.

Constraints: $x \geq 20; y \geq 15; x + y \leq 50; x, y \geq 0$.

Explanation: LP minimizes staffing cost while maintaining adequate healthcare services.

4.5. Finance

This tool helps to get high profit with minimum expenses and optimize investment decisions during the budget allocation and cost reduction".

Variables: x =investment in Asset A; y =investment in Asset B.

Objective: $Z = 0.10x + 0.12y$.

Constraints: $x + y \leq 1000000; 0.4x + 0.6y \leq 500000; x, y \geq 0$.

Explanation: LP determines the best investment allocation under budget and risk constraints.

5. Conclusion

Today, decision-makers in a wide variety of manufacturing and production units rely on linear programming as a crucial numerical tool. It aids businesses in being more efficient, which in turn helps them save money and make more money by translating complicated real-world problems into workable computational models. Despite previous discussions about evidence-based methods, analytics-driven strategies, and insights-led models, linear programming is becoming more important in the present situation.

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