IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN:2278-487X, p-ISSN: 2319-7668. Volume 27, Issue 5. Ser. 8 (May. 2025), PP 13-18
www.iosrjournals.org

Cost Optimization For A Coffee Shop With Linear Programming And Scenario Comparison

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Abstract:
This article presents a case study focused on cost optimization in a small coffee shop, located in the city of Manaus-AM, using the Linear Programming (PL) technique. The objective was to mathematically model the coffee shop's production process, simulating scenarios and comparing the results between the current operation and the optimized proposal. Real data on costs, inputs, demand and operational capacity were collected, which served as a basis for the construction of the model in the Excel software with the Solver supplement. The results revealed a 21.6% reduction in monthly costs, a 55.56% drop in resource waste, and a 59.09% increase in profit margin. The research confirms the effectiveness of PL as a tool to support decision-making and highlights its potential to contribute to the financial sustainability of small businesses in the food industry.
KeyWords: *Linear Programming, Cost Optimization, Coffee Shop, Decision Making, Small Business.*

Date of Submission: 08-05-2025 Date of Acceptance: 18-05-2025

I. Introduction

Being the second most consumed beverage worldwide, second only to water, coffee has become a memorable drink in Brazilian homes, no wonder Brazil is the second largest consumer of coffee in the world, behind only the United States (Ministry of Agriculture and Livestock, 2023). Coffee is currently among the most consumed beverages by Brazilians, but this relationship began centuries ago, more precisely in the eighteenth century, in mid-1727, by Francisco de Melo Palheta, in Pará. Despite this, it was discovered that the climate of northern Brazil did not favor the growth of the plant, becoming popular only in 1770, when it reached the northeast, first to Maranhão and Bahia, respectively. After a few years, in 1774 it arrived in the state of Rio de Janeiro, the country's capital at the time, with which its cultivation spread throughout the Brazilian territory, becoming one of the country's main economies, so much so that in 1845 Brazil produced about 45% of the world's coffee (BEZERRA, 2020).

For the presentation of this article, a coffee shop located in the city of Manaus-AM, Brazil, was used as study material. On its menu it has a diversified menu. With this, an efficient management of resources is expected to obtain better performance, from the beginning to the end of the preparation for the product, as well as a better monthly billing, thus bringing a good profit margin for better future investments, despite this, inefficient, manual and simple methods are often used, which will eventually cause unnecessary increases in expenses and generating losses to the establishment, it can have a "Snowball" effect.

The mathematical methods that will be used focus on Linear Programming and the ability to optimize the entire process that involves from the purchase, storage, preparation and sale of a product from the menu of this cafeteria, showing that better results can be obtained by making use of PL. A comparison will be made using the scientific method between the way the cafeteria is managed before the application of the PL and how it will be after its implementation, aiming to cover the most diverse scenarios to obtain the best possible results.

II. Bibliographic Reference

Operations Research (OP) is an analytical methodology that uses quantitative techniques to assist in decision-making, aiming to optimize results in complex systems (SUNO, 2023).

Operations Research

According to Hillier and Lieberman (2013), due to the war enterprise, there was an urgent need to efficiently allocate scarce resources to the various military operations and internal activities of each operation. Operational Research is by necessity a method for decision making, every problem needs a solution and in the war period extensive research was carried out to understand the problem, the ideal objective, define restrictions and limits to find an optimal solution. As said, it is natural to conclude that OP from an organization's point of view aims to solve conflicts in the best way and with the greatest possible efficiency, so that within all the solutions studied, the one with the greatest positive impact is applied.

Linear Programming

The linear programming technique gets its name because the mathematical programming (PM) problems to which it applies are linear in nature. This means that all functions in a linear programming (PL) model must be able to be expressed as a weighted sum (or linear combination) of the decision variables (RAGSDALE, 2017). Therefore, every linear programming model follows this pattern in general.

$$
\begin{array}{ll}
\text{MAX (or MIN):} & c_1X_1 + c_2X_2 + \cdots + c_nX_n \\
\text{Subject to:} & a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n \leq b_1 \\
& \vdots \\
& a_{k1}X_1 + a_{k2}X_2 + \cdots + a_{kn}X_n \geq b_k \\
& \vdots \\
& a_{m1}X_1 + a_{m2}X_2 + \cdots + a_{mn}X_n = b_m
\end{array}
$$

Figure 1. General Structure of a Linear Programming Model
Source: Ragsdale, 2017.

Linear Programming is a mathematical technique that seeks to optimize resources through already defined constraints, either to maximize profits or minimize costs. The model is based on an objective function such as cost reduction and restrictions on the production time of a product, for example, solved by methods such as Simplex (HILLIER and LIEBERMAN, 2013). Applied in sectors such as logistics and production, PL allows for the efficient allocation of resources, as demonstrated in recent studies of inventory optimization in small businesses (SANTOS, et al. 2023).

Cost Optimization

Cost optimization is essential for a company, especially micro or small businesses, since better resource management means less unnecessary expenses, and better efficiency in the process as a whole. It aims to identify, analyze and solve bottlenecks from the beginning of the process to its end, always seeking to efficiently manage the available resources, proving to be a significant advantage over companies that manage their resources lightly.

Scenarios

The application of linear programming (PL) stands out as a strategic tool for resource optimization, whether in maximizing profits or minimizing costs, adapting to various contexts. Scenario analysis allows you to compare traditional and optimized strategies, evidencing the efficiency of mathematical modeling in decision-making. While scenarios that do not use PL have manual practices in micro-enterprises, which generate waste and excessive inventories, optimized scenarios use linear models that adjust critical variables, such as inventory, operating costs, and production volume.

In scenarios that do not use PL, the lack of control leads to unnecessary purchases of raw materials or exaggerated use of labor, expiration of inputs, and demands with many fluctuations. According to SEBRAE (2023), 30% of micro-enterprises close before two years due to inefficient management. In scenarios that use PL, operational bottlenecks are identified, such as production or inventory limitations, and alternatives are proposed to reduce costs and increase productivity. For example, the definition of ideal quantities of raw material can reduce operating costs by up to 15%, as demonstrated in practical cases, such as that of a hamburger restaurant analyzed by the author Almeida Silva et al. (2024).

Scenario simulation is essential for micro-enterprises, as it allows you to assess risks and opportunities without compromising real resources. By aligning with seasonal demands, adjusting prices, and testing operational variations through linear constraints, PL facilitates decisions, being crucial for competitive markets, such as food. Thus, the transition from traditional methods to optimized models not only avoids waste, but also strengthens adaptation and financial sustainability in environments with constant changes such as food.

III. Methodology

The objective of this study was to analyze and propose cost optimization solutions in a coffee shop located in the city of Manaus-AM, based on the Linear Programming (PL) technique. This section describes in detail the steps used for the construction, analysis and validation of the mathematical model applied to the reality of the coffee shop studied.

Type Of Research

This is an applied research, of quantitative character and with an experimental approach, as it aims to solve a practical problem of the company studied through mathematical and computational tools. The research also assumes an exploratory-descriptive design, seeking to understand the reality of current management and then propose an optimizing model.

Stages Of The Methodology

Data collection is a fundamental step in this study, as it provides the necessary basis for the formulation and validation of the linear programming model. For this, information was obtained directly from a coffee shop located in Manaus-AM, focusing on the inputs used for the preparation of products such as coffees, cakes, snacks and other menu items. The data includes, among other elements, the unit cost of each raw material, the preparation time of the products, the availability of resources (such as labor and equipment), and the average monthly demand per item. This information was collected through interviews with the owner, analysis of financial control spreadsheets and direct observation of the production process over a given period.

Internal data were also considered external variables, such as the cost of replacing inputs in the local market, seasonal variations in demand and limitations of physical space for storage. With this, the survey ensured a complete overview of the coffee shop's operating conditions, allowing the structuring of realistic constraints in the mathematical model. The quality and consistency of this information were essential to ensure the reliability of the simulated results in the scenarios optimized with the use of Linear Programming.

Research Timeline

To achieve the proposed objectives, the methodology of this study was organized into seven interdependent steps, each essential to ensure a robust analysis and the effective application of Linear Programming. The process began with the diagnosis of the current operation of the coffee shop, where relevant information was collected about the daily operation, including the flows of purchase, storage, preparation and sale of products. This stage also involved interviews with the manager of the establishment and on-site observations, allowing the identification of operational bottlenecks, waste and opportunities for improvement. Then, a clear definition of the problem and the objective function to be optimized was made, with the formulation of decision variables and operational constraints, respecting the limits of inventory, budget and production capacity.

Steps	Month 1	Month 2	Month 3	Month 4
Initial Survey and Diagnosis	X			
Problem Formulation and Modeling		X		
Implementation and Computational Testing		X	X	
Scenario Simulation and Comparative Analysis			X	
Validation and Final Writing				X

Figure 2. Research timeline
Source: Authors, 2025

With the information organized, we started the mathematical modeling based on the Linear Programming technique, using linear equations to represent both the objective function and the constraints. The model was computationally implemented in Excel, through the Solver add-in, which made it possible to perform tests and validations of the results obtained. Subsequently, different scenarios were simulated with and without the application of the model to analyze the impact of optimization on metrics such as costs, waste and profit margin. The results were compared quantitatively and presented through graphs and tables to facilitate understanding. Finally, the optimized results were submitted to validation by the cafeteria manager, who was able to evaluate their real applicability, propose adjustments and approve the adoption of the suggested model.

IV. Results

Next, the results obtained with the application of Linear Programming in the context of the coffee shop studied are presented. The analysis was divided into three sub-themes: operational indicators, percentage variations between scenarios and comparative graphic visualization.

Operational Indicators: Current Vs. Optimized Scenario

Based on the data collected and the mathematical model implemented, it was possible to compare the performance of the coffee shop before and after the application of Linear Programming. Table 1 presents the main indicators of the two scenarios analyzed.

Table 1. Comparative Indicators and Current Scenario vs. Optimized

Indicators	Current Scenario	Optimized Scenario (PL)
Monthly Cost (R$)	12.500	9.800
Waste (%)	18	8
Profit Margin (%)	22	35

Source: Authors, 2025

The analysis of the data shows significant improvements in the main operational indicators of the coffee shop after the application of Linear Programming (PL). The monthly cost suffered a significant reduction, from R$ 12,500 in the current scenario to R$ 9,800 in the optimized scenario, representing a saving of 21.6%. The waste index also showed a relevant drop, from 18% to only 8%, indicating a more efficient use of inputs and reduction of losses. The profit margin was increased from 22% to 35%, which demonstrates a direct impact on the profitability of the business. These results confirm that the use of mathematical optimization models can bring concrete and sustainable gains, making management more strategic and effective.

Percentage Change Between Scenarios

Table 2 presents the percentage variation between the two scenarios, demonstrating the practical benefits of the optimization performed with the use of Linear Programming.

Table 2. Percentage Change Between Scenarios

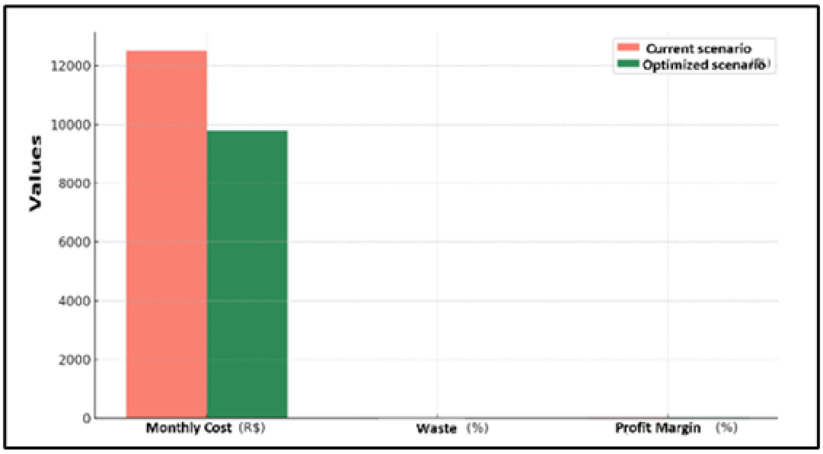
Indicators	Change (%)
Monthly Cost (R$)	-21,60%
Waste (%)	-55,56%
Profit Margin (%)	59,09%

Source: Authors, 2025

The percentage variation between the current and optimized scenarios reinforces the positive impacts of the application of Linear Programming in the operation of the coffee shop. The monthly cost showed a reduction of 21.60%, evidencing the efficiency in the allocation of resources and in the control of expenses. Waste was further reduced, with a drop of 55.56%, which indicates a substantial improvement in the use of inputs and inventory planning. The profit margin increased by 59.09%, demonstrating that the adoption of mathematical strategies not only cuts costs, but also enhances the financial gains of the business. These results validate the relevance of modeling as a decision-making tool in small enterprises.

Comparative Graphical Display

The following chart presents a comparative chart between the main indicators of the current scenario and the optimized scenario, with the labels in English to facilitate international understanding.



Graph 1. Comparative Chart: Current vs. Optimized Scenario
Source: Authors, 2025

Based on the data obtained, it is verified that the application of Linear Programming provided significant gains in the operational efficiency of the coffee shop analyzed. There was a significant reduction in monthly costs and in the percentage of waste, while there was a substantial increase in the profit margin. These results reinforce the practical feasibility and effectiveness of the mathematical model developed. The use of quantitative techniques for process optimization has proven to be an effective strategy, especially in small businesses that face constant financial and operational challenges (OLIVEIRA, 2021). Linear Programming contributes to more assertive and data-driven decisions, allowing the manager to visualize different scenarios and adopt continuous improvement strategies (SOUZA, 2020).

V. Conclusion

The main purpose of the research developed in this article was to demonstrate how the application of Linear Programming (PL) can contribute in a practical and effective way to cost optimization in a small coffee shop. From the detailed analysis of the company's operation, it was possible to identify bottlenecks and inefficiencies in the processes of purchasing, storage, production and sale, factors that directly compromised the profitability of the business. Based on the systematic collection and organization of real data, a mathematical model was built that respected the constraints of the operation, such as budget limit, production capacity and average monthly demand. The use of the Solver add-in in Excel allowed the simulation of optimized scenarios, presenting solid and measurable results regarding the operational and financial efficiency of the establishment.

The gains obtained with the application of Linear Programming were significant. There was a 21.6% reduction in monthly costs, a 55.56% cut in input waste and a 59.09% growth in profit margin. Such indicators are extremely relevant for micro and small companies, which often face difficulties in maintaining the balance between expenses and revenues due to the low operational room for maneuver and the lack of analytical instruments to support their decisions. Research has shown that even smaller-scale businesses can benefit from using sophisticated quantitative techniques, often restricted to large corporations. Contrary to common sense, the use of mathematical modeling does not require a complex infrastructure, but rather the organization of data and a commitment to continuous improvement.

The direct benefits in cafeteria numbers, this study also has important implications from an academic and practical point of view. Academically, he reinforces the importance of Operations Research as a tool to support decision-making in environments with multiple variables and constraints. Practically, it is evident that affordable and easy-to-implement solutions, such as Excel with Solver, can generate significant and transformative results. The applicability of the proposal was validated with the cafeteria manager, who recognized the value of the model and showed interest in continuing to use the methodology as support for future decisions. This adhesion reinforces the viability of Linear Programming as a strategic management tool, contributing not only to the reduction of waste and increased efficiency, but also to the sustainability and growth of the business in the medium and long term.

In the future, the model developed here can be adapted to include new variables, such as demand seasonality, sales promotions, changes in input prices or even the expansion planning of the coffee shop. Other optimization tools can also be explored, such as Integer Programming and Genetic Algorithms, for more complex problems. It is concluded, therefore, that the application of Linear Programming, combined with scenario analysis, not only solves immediate operational problems, but also offers a solid basis for managerial innovation and the construction of competitive advantage in highly volatile and challenging markets such as food.

VI. Agradecimentos

To FAMETRO University Center, Metropolitan Institute of Education (IME), and to the Postgraduate Program in Engineering, Processes, Systems and Environmental Management of the Galileo Institute of Technology and Education of the Amazon (PPG.EGPSA/ITEGAM)..

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