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INCBAC INSTITUTE
Institute of Czech-Brazilian
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UNIGOU Remote 2024
Czech-Brazilian Academic Program

Optimizing Production Mix: Case Study of Independent Saleswoman in Belo Horizonte

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Abstract. The significant increase in self-employment in Brazil, particularly in the food sector, highlights the importance of exploring the application of advanced operational research techniques. These techniques aim not only to improve the performance of self-employed workers but also to quantify the manufacturing costs of their products and maximize their profits. Furthermore, given the complexity of the market and the constantly changing demands, it is essential to rely on effective analytical methods to guide decisions related to production and management of autonomous businesses. In this context, the present study utilizes a comprehensive bibliographic framework to underpin the creation and optimization of a mathematical model tailored to the specifics of a self-employed candy vendor in the Belo Horizonte region. Through linear programming techniques, the aim is not only to define a production mix that maximizes profits but also to identify efficient strategies to address market challenges and ensure the long-term sustainability of the enterprise.

Keywords. Linear Programming; production mix; simplex; profit maximization.

1. Introduction

The increase in self-employment, especially in the food sector in Brazil, highlights the need to explore advanced operational research techniques. According to data from the Continuous National Household Sample Survey (PNAD) in November 2018, around 35 million informal workers are in the country, many of whom start their own businesses without adopting basic production control practices. Jensen (1988) emphasizes that planning in most production systems is based on sales forecasts, and decision-making challenges often arise from market fluctuations and supply chain management. Slack et al. (2013) stress the importance of production management, even in smaller companies, and optimization techniques such as linear programming (Arenales et al., 2015) are widely applied to solve production problems. Silva et al. (2010) highlight the role of linear programming in decision-making to maximize resource efficiency and achieve business goals. Melo et al. (2018) and Oliveira et al. (2015) used linear programming to reduce production costs and improve route planning, respectively. Thus, this study, based on bibliographic references, aims to optimize the production of a self-employed candy vendor in Belo Horizonte (MG), aiming for maximum profit through linear programming (Passos, 2008).

1.1 Optimization of processes in logistic decision-making.

Improving processes through the simplex method aims to efficiently control the logistics chain. This includes managing acquisition, inventory, and transportation costs, as well as optimizing storage operations. Additionally, the method aims to enhance sales strategies by analyzing territories and defining target markets more accurately. An additional benefit is the reduction of losses by minimizing the risks of losses and theft throughout the supply chain. This systematic and analytical approach offered by the simplex method is essential for promoting efficient and profitable logistics management.

2. Theoretical foundation

Operations research (OR) emerged during World War II when mathematicians and scientists applied mathematical techniques and statistical analysis to solve complex logistical and military problems faced by the Allied and Axis forces (ARENALES et al, 2015). During this period, the need to optimize resources such as supplies, transportation, and troop allocation led to the development of advanced analytical techniques to improve operational efficiency. After the war, operations research expanded into various

fields, including industry, transportation, finance, healthcare, and management, where it is used to solve a wide range of decision-making and optimization problems (ANDRADE, 2012).

2.1 Linear programming

Linear programming is a mathematical method used to optimize the allocation of limited resources to achieve a specific outcome. It involves maximizing or minimizing a linear objective function subject to linear equality and inequality constraints. Simply put, linear programming aims to find the best solution (maximum profit or minimum cost) given a set of linear constraints. It has various applications in areas such as economics, finance, engineering, operations research, and management, where resources need to be allocated efficiently to achieve desired goals. According to Colin (2007), a model is a simplified simulation of reality described in the form of mathematical equations. Variables are elements of the model that can be controlled by the decision-maker. The objective function is a mathematical function that relates the variables representing the decision-maker's objective, which can be maximized (to generate profit) or minimized (to reduce costs). A parameter is a constant associated with a variable that cannot be controlled by the decision-maker. Constraints are the limiting rules for the resources needed to achieve the objective.

According to Melo et al. (2018), a linear programming model can be defined as follows:

Maximum or Minimum f (x1,x2,x3,x4.........................,xi)

K1x1 + K2x2+ .... +kixi {≤ ,=, ≥ } b1

K1x1 + K2x2+ .... +kixi {≤ ,=, ≥ } bj

$\quad$ x1,x2,.....,xi ≥ 0

Where: k is a parameter, x is a variable, and bj represents the resource limitations.

The objective function is therefore constrained by the limitations. In the model presented in this work, the variables will represent the quantity of each flavor of candy produced, the parameters will be the profit per unit of candy, and the objective function will be the sum of the parameters multiplied by the variables.

2.2 Simplex method

The simplex method is an algorithm employed to solve linear programming problems. Developed by George Dantzig in the 1940s, it's an iterative procedure that starts from a feasible basic solution and, at each iteration, enhances this solution by moving along the edges of the polyhedron formed by the problem's constraints. The aim is to find the optimal solution that maximizes or minimizes the objective function, subject to the linear constraints of the problem. The simplex method is widely used due to its efficiency and versatility in addressing a broad range of linear optimization problems.

In this context, Andrade (2012), Hillier et al. (2013), and Moreira (2017) advocate for the use of specific software and computational tools to work with the simplex algorithm. These programs require manual data input, while calculations are automatically performed, delivering the optimal solution. For this study, the Linear Optimization Lite application will be utilized to simplify the maximization calculations of the linear programming model.

3. Case study

A case study was conducted with an independent candy vendor in the Belo Horizonte region of Minas Gerais, Brazil, who produces fondue in different flavors. The study began with a personal interview with the vendor to gather data such as candy manufacturing costs, target audience size for sales, and materials needed to produce one unit, among others. Based on this interview, it was possible to model the problem, identifying the objective function and its respective constraints.

The vendor produces four flavors of fondue, which are primarily made with fruits and chocolate coating: strawberry, banana, grape, and kiwi. The capital to be invested for the next day of sales is R$ 100. Manufacturing costs and profits can be seen in Table 1:

Table 1. Profit withdrawal table.

Fondue	Production Cost		Sales Price		Profit	
Strawberry	R$	1,10	R$	3,00	R$	1,90
Banana	R$	0,70	R$	3,00	R$	2,30
Grape	R$	0,95	R$	3,00	R$	2,05
Kiwi	R$	1,20	R$	3,00	R$	1,80

Source: Prepared by the author.

During the monthly event known as the "Cultural Fair," an audience of approximately 800 people is expected, and the vendor reported an average sale of 74 fondue units at this event. In this regard, the project seeks to study the variables that most impact the vendor's profitability: increasing production of the best-selling fondue, increasing the initial capital by $200, increasing costs, and removing the most sold fondue from the menu.

3.1 Increased production of strawberry fondue

A vendor reported that 25 units of each flavor were produced, but the strawberry flavor sold out quickly while the others were left in excess. Therefore, it was considered that the production of the strawberry flavor should be increased. The sales percentage can be seen in Table 2.

Table 2: Sales quantity.

Fondue	Quantity produced	Sold amount	Sale
Strawberry	25	25	100%
Banana	25	18	72%
Grape	25	9	36%
Kiwi	25	22	88%

Source: Prepared by the author.

Analyzing this data made it possible to model the problem and define the objective function and constraints. After optimization, it will be determined how many units of each flavor the seller should produce, the amount of raw material needed, and the maximum profit obtained from sales.

Variables: x_1= Strawberry, x_2 = Banana, x_3 = Grape, x_4= Kiwi.

Objective Function: $1,9x_1 + 2,3x_2 + 2,05x_3 + 1,8x_4$

Restrictions:

$x_2 <= 18$, $x_3 <= 9$, $x_4 <= 22$

$1,1P_1 + 0,7 P_2 + 0,75 P_3 + 1,2 P_4 < = 100$

$x_1, x_2, x_3, x_4 = > 0$

The data was inputted into the Linear Optimization Lite software, and the following results were obtained:

Table 3: Result of costs and profits before the application of financial capital

Fondue	Quantity Produced	Sold amount	cost	Profit
Strawberry	25	25	R$ 27,50	R$ 47,50
Banana	25	18	R$ 17,50	R$ 41,40
Grape	25	9	R$ 18,75	R$ 18,45
Kiwi	25	22	R$ 30,00	R$ 39,60
Total			R$ 93,75	R$ 146,95

Source: Prepared by the author.

Table 4: Result of costs and profits after the application of financial capital

Fondue	Quantity Produced	Sold amount	cost	Profit
Strawberry	73	73	R$ 80,30	R$ 138,70
Banana	18	18	R$ 12,60	R$ 41,40
Grape	9	9	R$ 6,75	R$ 18,45
Kiwi	0	0	R$ -	R$ -
Total			R$ 99,65	R$ 198,55

Source: Prepared by the author.

Table 3 shows the results before the additional investment of R$ 100.00 in capital, while Table 4 displays the results after this application. The expected profit increase is R$ 51.60. It is observed that, to produce the same quantity of fondues, the vendor will only need an additional investment of R$ 5.90, which also provides a better utilization of the investment capital.

Considering that strawberry fondue is the customers' favorite, the article aims to investigate the profitability of the confectioner if she cannot find strawberries to produce the sweets. Thus, the article proposes to calculate the profit margin without the strawberry flavor.

3.2 Withdrawal of strawberry fondue

Considering that strawberry fondue is the customers' favorite, the article aims to investigate the profitability of the confectioner if she cannot find strawberries to produce the sweets. Thus, the article proposes to calculate the profit margin without the strawberry flavor.

Table 5: Profitability results without strawberry fondue production

Fondue	Quantity Produced	Sold amount	Profit
Strawberry	0	0	R$ -
Banana	25	18	R$ 48,24
Grape	25	9	R$ 17,32
Kiwi	25	22	R$ 48,60
Total			R$ 114,16

Source: Prepared by the author.

With the removal of the strawberry fondue, the confectioner's profit margin dropped to just $14.71(table 5), indicating that the strawberry flavor is responsible for the confectioner's profitability. However, the price of the raw material, strawberries, fluctuates throughout the year. Thus, the article proposes to study up to what price point of the raw material (strawberries) it is still viable to produce the fondue profitably for the confectioner.

Table 6: Increase in the cost of purchasing strawberries.

Cost	Profit before increase	Profit projection	Difference
110%	R$ 146,95	R$ 196,65	R$ 49,70
121%	R$ 144,20	R$ 181,81	R$ 37,61
132%	R$ 141,45	R$ 166,21	R$ 24,76
143%	R$ 138,70	R$ 161,07	R$ 22,37
154%	R$ 135,90	R$ 149,09	R$ 13,19
165%	R$ 133,20	R$ 142,28	R$ 9,18
176%	R$ 130,45	R$ 136,40	R$ 5,95
187%	R$ 127,70	R$ 133,12	R$ 5,42
198%	R$ 124,95	R$ 126,48	R$ 1,53
220%	R$ 119,45	R$ 118,52	0,93 (negative)

With an increase of up to 80% in strawberry fondue production costs, the seller will still be able to make a profit. However, when the cost exceeds this 80% threshold, producing this flavor will no longer be advantageous as it will result in future losses. Additionally, with a 220% increase in raw material costs (purchase of strawberries), the confectioner begins to incur losses in fondue production.

4. Results

Self-employment in Brazil is a significant reality, especially in the food sector. This article addresses the case of a confectioner who exclusively sells fondue at large festive events throughout the country. In this context, the confectioner's business model presents vulnerabilities that can affect profitability or even make the production of sweets unfeasible. The increase in fruit prices, particularly

the cost of purchasing strawberries, above 220%, makes the production of sweets unfeasible, but any increase in this input significantly affects profitability. Another concern is the high perishability of the fondues, as they have a maximum shelf life of only three days if not sold. Additionally, the confectioner's business model is influenced by the number of potential buyers at these festive events, as it is essential to sell all the fondues to ensure a satisfactory profit margin.

5. Suggested improvement in profitability

5.1 Online sale

Using online platforms like Facebook and Instagram for sales would be an excellent way to increase the confectioner's profit margin, as online sales of chocolates can boost profitability in various ways:

Expanded Market Reach: Online sales allow reaching a much broader audience than in-person sales at festive events. This means that more people will have access to your products, increasing sales opportunities.

Reduced Operational Costs: With online sales, one can reduce the costs associated with operating a physical store, such as rent, personnel expenses, and utility bills. This helps increase the profit margin of the products sold.

Ease of Purchase: Consumers can place orders for chocolates anytime and from anywhere, making it more convenient for them to purchase your products. This can result in increased sales, as customers are more likely to buy when it's convenient for them.

Targeted Marketing: Online sales platforms enable more precise targeting of the target audience through digital marketing campaigns. This can help attract potential customers who are specifically interested in your products, increasing the chances of conversion into sales.

Feedback and Data Analysis: Online sales provide a wealth of data about customer behavior, purchasing preferences, and product performance. This information can be used to adjust sales strategies, develop products better suited to the market, and improve the customer experience, resulting in greater loyalty and return on investment.

5.2 Investment in fondue delivery

Candy delivery can increase the confectioner's profitability in several ways compared to just selling at festive events:

Wide Market Reach: By offering candy delivery, the confectioner can reach a much broader audience than those attending festive events. This expands the geographical reach and allows reaching customers in different locations, increasing sales opportunities.

Flexibility of Schedule: With candy delivery, the confectioner can fulfill orders at more flexible times, not limited only to the days of festive events. This means that customers can place orders at any time, making it more convenient for them to acquire the confectioner's products.

Customer Loyalty: Offering candy delivery can help build stronger relationships with customers as it provides personalized and convenient service. This can lead to customer loyalty, resulting in repeat purchases and recommendations to other potential customers.

Diversification of Sales Channels: In addition to festive events, candy delivery opens up a new sales channel for the confectioner. This diversifies revenue sources and reduces reliance on a single point of sale, making the business more resilient to seasonal fluctuations or unforeseen circumstances.

Marketing Opportunity: Candy delivery can be an opportunity for the confectioner to promote their products through personalized packaging, giveaways, or thank-you cards included in the deliveries. This helps strengthen the brand and create a positive customer experience.

In summary, offering candy delivery expands the business's reach, increases convenience for customers, promotes loyalty, and diversifies revenue sources, thereby contributing to the confectioner's increased profitability.

6. Conclusion

In conclusion, the analysis of the confectioner's case reveals the importance of effective management and operational strategies to ensure business profitability and sustainability. The vulnerability of the confectioner to fluctuations in fruit prices, high product perishability, and dependence on festive events highlights the need for diversification and innovation. The implementation of online sales and delivery services expands market reach, provides greater convenience to customers, and reduces reliance on a single sales channel. Additionally, operational research and data analysis can be applied to optimize production, manage costs, and identify growth opportunities. In summary, by adopting a holistic and strategic approach, the confectioner can increase profitability and ensure competitiveness in the market.

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