Transport Cost Optimization in a Beverage Company Using Linear Programming Methods

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Abstract. Organizational transformations are progressively evolving into phenomena characterized by heightened dynamism and complexity. Consequently, the pursuit of competitive differentiators within operational frameworks has become a ubiquitous imperative among contemporary enterprises. Within this paradigm, Operations Research (OR) assumes a pivotal role in facilitating the management of logistical and production systems through the application of mathematical methodologies for problem abstraction and modeling. It is widely acknowledged as a cornerstone in optimizing distribution channels, thereby fostering informed decision-making processes that yield consequential cost efficiencies for organizations. Aligned with this ethos, the present study endeavors to employ linear programming methodologies within a beverage industry setting. Its principal objective is the optimization of logistical distribution processes, achieved through the minimization of associated costs. This entails a meticulous examination of distribution flows, market demands, and pertinent operational constraints. Subsequently, the formulated mathematical model is applied to the transportation problem domain, culminating in the derivation of an optimal solution for the organization's logistical distribution network. This facilitates the identification of the most efficacious means of product conveyance to clientele. The empirical findings of this endeavor attest to a model proficient in effecting a reduction of 42.9% in total transportation costs incurred during the conveyance of goods from the production facility to clientele situated within the Curitiba and Metropolitan regions.

Keywords: Logistics, Operational Research, Transports, Cost Minimization.

1 Introduction

The production process of a company typically involves manufacturing, packaging, and distributing the finished product to consumers. Over time, market demands have become increasingly pronounced, prompting organizations to seek competitive advantages vis-à-vis their counterparts. Consequently, logistics emerges as a tool aimed at securing individualized advantages, ensuring higher quality in the services provided to customers.

Central to logistics management is the understanding of the distribution system structure, intending to economically serve customers geographically distant from the production source while maintaining elevated service levels in terms of delivery times. According to [1], the impact of transportation on customer service is among the most significant, with market demands primarily revolving around service punctuality, the ability to provide personalized service, flexibility, and the transporter's capacity to offer more than just basic transportation services by performing various logistical functions.

Logistics management, as posited by [2], necessitates the integration of all activities connecting the supplier market to the consumer market. In this regard, operations within the company are of utmost importance as they aim to interconnect all functions and activities encompassing logistics, thereby adding value to the final product. Regarding distribution logistics, its responsibility entails the physical distribution of products, aiming to maximize customer service while minimizing unnecessary costs. The efficiency of the distribution logistics chain is contingent upon cooperation between the company and its partner clients.

For the beverage market, where specific and differentiated deliveries are required, errors in management systems and distribution operations result in financial deficits and tarnished corporate image. Hence, the primary role of distribution is to ensure the timely delivery of products to the consumer market at the lowest possible cost. Consequently, transportation represents the most significant portion of an organization's logistics costs and directly influences the dimensions of service levels provided to customers [3].

In the present study, one of the selected company's major challenges lies in the logistics sector, where there is a need to assess the adequacy and efficiency of processes to meet the growing demand in the Curitiba and Metropolitan Region markets.

Through the application of linear programming methods aimed at optimizing the distribution logistics network, it will be possible to increase the capacity to serve more points of sale, achieve better product distribution, reduce transportation time and costs, and enable expansion into new regions and establishments. The consolidation of this delivery process is seen as beneficial as it allows for the identification of bottlenecks and subsequent improvements, thereby enabling the company to establish shorter deadlines and higher quality in meeting its demands.

In summary, the main objective of this study is to optimize the transportation process in a beverage company using linear programming methods to contribute to the reduction of logistics costs and aid in the strategic vision for the efficient use of organizational capacity resources. This will be accomplished by considering the current distribution capacity and average product demand in the regions.

Based on the presented scenario, this study seeks to answer the following question: "Can linear programming methods applied to transportation problems optimize the logistics distribution process in a beverage company?"

To achieve the study's objective, the following steps were taken: a literature review to gather documents on distribution logistics and transportation problem optimization, mapping of the current company's distribution logistics process, data collection and analysis, construction of a linear programming mathematical model, application of the mathematical model, and analysis and validation of the results obtained.

This article is divided into the following sections: Section 01 contextualizes the theme, objectives, problems, and provides a brief explanation of the methodology. Section 02 details the methodological procedures, Section 03 provides a literature review, Section 04 presents the main results obtained, Section 05 discusses the research findings, and Section 06 presents the study's conclusions.

2 Methodological Procedures

To conduct the literature review, the Scopus database was utilized to search for scientific articles on distribution logistics and transportation problem optimization. The research employed combinations of the keywords "Transportation Problem," "Transportation Cost Minimization," "Operations Research," and "Beverage" to identify 44 articles published in the last 20 years. The primary areas of application were Engineering (24%), Decision Science (17%), and Computer Science (16%). Despite the existence of similar studies, this present work distinguishes itself by proposing the simplified application of linear programming methods, aiming to provide a solution of low complexity and simple implementation for beverage sector companies with diverse means of transportation.

For the mapping of the distribution logistics process, Draw.io Software will be used, allowing modeling in BPMN (Business Process Model and Notation). This flowchart method displays the stages of a process from start to finish. The use of BPMN establishes a standard for representing the flow graphically through diagrams and ensures a practical visual display of the process, facilitating understanding by project stakeholders.

Data collection and analysis will be conducted in a tabular manner using Excel software, to systematically collect information, making it more readable and easily interpreted by all project stakeholders. The main data to be collected are related to the construction of the mathematical model, where data on capacity, costs, and demand will be necessary.

For the construction and application of the mathematical model, the Microsoft Office tool Solver, within Excel itself, will be utilized. This tool provides resources to build and solve linear programming mathematical models by defining variables, constraints, and the objective function in specific cells. Thus, due to its familiar interface widely known by all project stakeholders, the program becomes an excellent solution for applying the model and obtaining optimized results.

For the analysis of the results, meetings will be held with stakeholders to present the data and the optimized solution obtained through the application of verification indicators.

3 Literature Review

3.1 Logistics

According to the Council of Supply Chain Management Professionals (CSCMP) [4], logistics can be conceptualized as a process of efficiently planning, implementing, and controlling the flow of product storage, as well as associated services and information, from the point of origin to the point of consumption, with the primary objective of meeting consumer demands.

Logistics encompasses all operations related to production planning and control, material movement, packaging, storage, shipping, physical distribution, transportation, and communication systems that synchronously add value to the services provided by a company to its customers [5].

As per [6], logistics can be divided into two classes of activities: primary activities, involving transportation, inventory maintenance, and order processing, and secondary activities, encompassing warehousing, material handling, packaging, procurement, planning, and information systems. The primary activity of transportation refers to various methods of moving raw materials and products and is considered significant due to its larger representation in logistics cost percentages. Among the activities involving transportation logistics are cited the definition of transportation methods, routes used, and vehicle capacity.

3.2 Distribution Logistics

Distribution logistics, as described in [7], encompasses the physical distribution involving the movement, storage, and order processing of final products. It is often considered the most critical activity in terms of costs for organizations, accounting for approximately two-thirds of logistics costs. Product distribution is a key activity as it establishes the success of customer service processes, ensures customer satisfaction, and creates circumstances for efficiency and reliability throughout the process. Management of physical product distribution occurs at three levels: strategic, tactical, and operational.

At the tactical level, short and medium-term planning is conducted to ensure the efficiency of distribution system operations and the utilization of defined equipment, vehicles, and facilities. The operational level involves the scheduling, execution, and control of activities, ensuring the timely movement of products to consumer markets [8].

According to [9], three different strategic configurations can be applied in distribution. The first involves direct delivery from stocks at the factory. The second refers to direct delivery from salespersons or the production line. Finally, the third involves delivery utilizing a depot system for support.

3.3 Transport

In today's context, transportation can be considered a high-level activity as it is essential for the economic growth of any organization. Consequently, transportation has gained increasing prominence in logistics operations, with its primary goal being the movement of final products to specific sales points of the company, at the lowest possible cost and with a desired level of service established by the customer.

There are two guiding principles in transportation operations and management: economies of scale and economies of distance. Economies of scale are achieved through the reduction of transportation costs per unit weight by using larger or consolidated loads. This is due to the spreading of fixed expenses among the quantity transported, so the larger the cargo volume, the lower the cost incurred. Economies of distance involve reducing transportation costs per unit distance. Therefore, cost dilution occurs when more kilometers are added to the distance traveled, causing the rates per kilometer to decrease.

Transportation problems arise when there are supply points that need to send products to various consumption points. The routes between each origin point (supply) and each destination point (consumption) have costs that are proportional to the quantities of products being shipped. Thus, based on distribution costs, the quantity produced by the company, and customer demands, it is possible to find the optimal quantity of products that should be sent per route, aiming to minimize the costs associated with transportation.

3.4 Linear Programming

The linear programming method is a mathematical technique used to optimize process utilization by minimizing waste through mathematical modeling and optimized solutions related to a linear function and its constraints [12].

According to [11], the core of linear programming problems is to efficiently allocate limited resources to competing activities. The standard way to present such a problem is through mathematical notation, called the standard form of the model. From this formulation, standard terminology is adopted, where the linear function being maximized or minimized is known as the "Objective Function," while the other functions are called constraints, representing the limitations in the model.

The standard form of the model proposed by [11] presents conditions for the development of the mathematical model, aiming to select values for the decision variables x1, x2, ..., xn in such a way as to:

$$Maximize\ Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n \quad (1)$$

subject to:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n &= b_1 \quad (2) \\ a_{21}x_2 + a_{22}x_2 + \ldots + a_{2n}x_n &= b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n &= b_m \end{aligned}$$

and:

$$x_1 \geq 0, x_2 \geq 0, \ldots, x_n \geq 0 \quad (3)$$

According to [13], linear programming problems seek to determine optimal values for decision variables $x_1, x_2, \ldots, x_n$, which must be continuous, to maximize or minimize the linear function. These variables are subject to a set of m linear constraints, which may be either equally or equally constraints.

The objective function is a linear expression from which the generic mathematical formulation of the linear programming problem begins. Its purpose is to maximize or minimize the function $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$ which $c_1, c_2, \ldots, c_n$ represents the contributions to the objective function from the respective variables $x_1, x_2, \ldots, x_n$ [14].

4 Results

4.1 Process Mapping

The beverage company Água da Serra was founded in 1943 in the city of Braço do Norte – SC. Initially, carbonated beverages in raspberry, lemon, and guarana flavors were produced. With over 80 years of experience, the company now specializes in the production, sale, and distribution of non-alcoholic beverages to the state of Santa Catarina and Curitiba and its Metropolitan Region in Paraná. They offer the largest range of flavors in Brazil, with more than 10 soda flavors available in returnable and non-returnable 200ml glass bottles, 250ml PET bottles, 600ml returnable glass bottles, 600ml PET bottles, and 1 and 2-liter PET bottles.

In this project, the focus was on the distribution logistics sector of the company. Therefore, process mapping is limited to the stages between the receipt of customer orders and their proper delivery (See Fig. 1).

The logistical process in the organization was divided into three main areas: the WMW Systems, which consists of the order entry system by the company's representatives and salespeople; the Cargo Preparation area, which takes place on the factory floor, where products are sorted according to orders and directed to the vehicles responsible for delivery; and Distribution, which receives customer demand and, after product sorting, loads the items onto trucks and prepares them for shipment.

The process begins with the entry of an order into the system, which undergoes a series of checks, such as customer conditions, credit limits, date of the last order, and outstanding issues with the factory, to determine if the customer is eligible to receive the requested order. Once the order is entered into the system, a signal is sent to the production area, initiating the process of separating the products in stock, aiming to ensure that after approval in the performed check, the product can continue its flow within the company.

After signaling that the products are in stock and the customer is "OK" in the system, the order proceeds to automatic routing, where the best routes are generated based on the delivery cities' locations, and the need to use a specific type of vehicle for transportation is established. Then, the order is separated on the factory floor, near the loading area, where labels are placed on the products containing the invoice number and the customer's name. Finally, the vehicle is loaded to distribute the demand to the organization's customers according to the stipulated route.

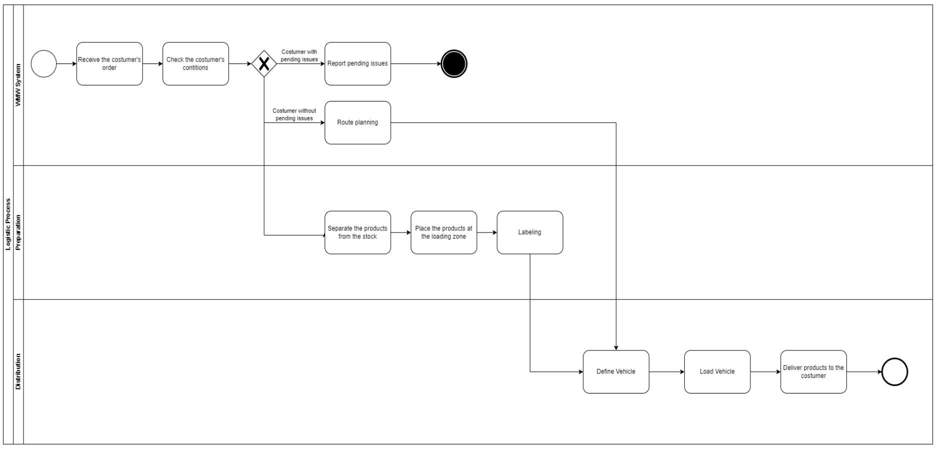

Fig. 1. Logistics process flowchart. Authors, 2023.

4.2 Data Collection

For gathering data for the mathematical model, meetings were held with the responsible departments of the company to provide information.

The company operates in two regions, the state of Santa Catarina and the Curitiba Metropolitan Region, in Paraná. Since it is not possible to address both regions comprehensively in the study due to time constraints, it was chosen to work with the Curitiba Metropolitan Region as it represents a larger share of demands in the company. For this work, we will use the CIF (Cost Insurance and Freight) distribution model. Under this model, the organization bears the responsibility for expenses such as salaries, uniforms, materials, tolls, fuel, and other costs involved in the process. The company provided the quantities of vehicles available in its fleet and an average of their respective costs per delivered pallet, as presented in Table 1. Considering the chosen operating area, only semi-trailers and bi-trucks are directed to Curitiba and the Metropolitan Region.

Table 1. Cost of pallet transportation.

Vehicle	Quantity	Cost / Pallet (average)
Semi-Trailer	2	R$ 239,50
Bi-Truck	4	R$ 257,50

The values presented in Table 1 encompass various factors such as truck maintenance and depreciation, driver salaries, tolls, fuel, driver meals, and distance (mileage). Thus, the involved costs to be used in the model are already known.

The transportation of goods is carried out with the company's trucks, with their capacity defined by pallets. Considering that each vehicle makes an average of two trips per week to the designated region, the dynamic capacity of the vehicles will be used, meaning the capacity of 40 pallets for the semi-trailer and 32 pallets for the bi-truck is considered. Knowing that a year has 52 weeks, this fleet capacity data becomes 2080 pallets for the semi-trailer and 1664 for the bi-truck, as represented in Table 2:

Table 2. Annual capacity of the vehicles.

Vehicle	Capacity (Pallets)	Weekly Capacity (Pallets)	Annual Capacity(Pallets)
Semi-Trailer	20	40	2080
Bi-Truck	16	32	1664

Considering the availability of two semi-trailers and four bi-trucks, the capacity becomes 4160 and 6656 pallets, respectively, resulting in a total capacity of 10816 pallets.

Currently, Curitiba and its Metropolitan Region have a total of over 100 active clients in the portfolio. For gathering demand data, the estimated annual quantity of products purchased was collected individually from each client, considering the following product mix: 200ml returnable and non-returnable glass bottles; Returnable 600ml glass bottles; PET 250ml and 600ml bottles; PET 1 and 2-liter bottles.

As there are a large number of clients, applying the mathematical model individually would be impractical. Therefore, a study was conducted to identify the best solution to serve all clients in the proposed model. Consequently, it was found that there was a need for segmentation into sub-regions based on the geographic location of each client. As a result, eight sub-regions were created, spanning across neighborhoods in Curitiba and adjacent cities in the Metropolitan Region.

This approach enabled the calculation of the total annual pallet demand for each region, as shown in Table 3:

Table 3. Annual demand for each region.

Region	Calculated Demand (Pallets)
R1	293
R2	198
R3	327
R4	365
R5	923
R6	707
R7	1455
R8	456
Total Demand	4724

The mapping of the location of these regions was carried out, followed by the survey of the distance from the Água da Serra factory, located in Braço do Norte/SC, to each of the defined regions.

Table 4. Distance of each region.

Region	Distance (Km)
R1	451
R2	474
R3	470
R4	457
R5	454
R6	453
R7	448
R8	440

From this, all necessary parameters are obtained to begin the modeling and application of the mathematical model of the transportation problem.

4.3 Construction and Application of the Mathematical Model

1. **Model Parameters**

The parameters of a mathematical model are fundamental for defining the behavior of the applied model and how it relates to its input and output data. For the present work, the parameters were presented during the data collection, being: cost, in the unit transportation cost of the pallets presented in Table 1; capacity, in the annual capacity of the vehicles, presented in Table 2; demand, in the calculated demands of the regions, displayed in Table 3; and distance, presented in Table 4 of the distance from the regions.

2. **Decision Variables**

In Table 5 below, it is possible to observe the decision variables, which are 48 in total, originating from 6 sources to 8 destinations.

Table 4. Decision Variables

	Regions								
	R1	R2	R3	R4	R5	R6	R7	R8	Capacity
Semi-Trailer 1	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	2080
Semi-Trailer 2	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	2080
Bi-Truck 1	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	X_{36}	X_{37}	X_{38}	1664
Bi-Truck 2	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}	X_{46}	X_{47}	X_{48}	1664
Bi-Truck 3	X_{51}	X_{52}	X_{53}	X_{54}	X_{55}	X_{56}	X_{57}	X_{58}	1664
Bi-Truck 4	X_{61}	X_{62}	X_{63}	X_{64}	X_{65}	X_{66}	X_{67}	X_{68}	1664
Demand	293	198	327	365	923	707	1455	456	

3. **Construction of the mathematical model**

Based on the data, a graph was constructed to depict the study parameters (See Fig. 2).

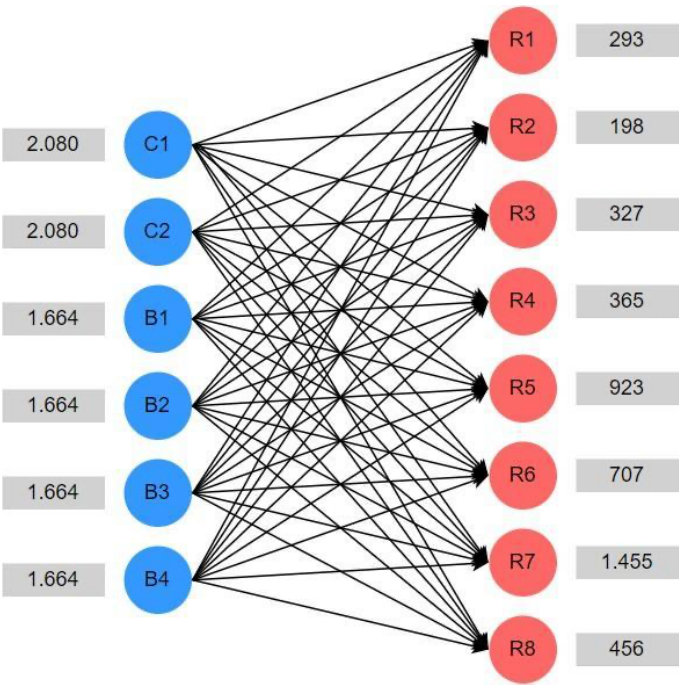

Fig. 2. Graph of the mathematical model network. Authors, 2023

And so the mathematical transportation model for this problem began, consisting of 48 decision variables and 14 constraints, with all variables belonging to the domain of positive real numbers, as it is a linear programming problem. The mathematical model under study is represented as follows:

$$Min. Z = 239{,}50\, x_{11} + 239{,}50\, x_{21} + 257{,}50\, x_{31} + 257{,}50\, x_{41} + 257{,}50\, x_{51} + 257{,}50\, x_{61} + 239{,}50\, x_{12} + 239{,}50\, x_{22} + 257{,}50\, x_{32} + 257{,}50\, x_{42} + 257{,}50\, x_{52} + 257{,}50\, x_{62} + 239{,}50\, x_{13} + 239{,}50\, x_{23} + 257{,}50\, x_{33} + 257{,}50\, x_{43} + 257{,}50\, x_{53} + 257{,}50\, x_{63} + 239{,}50\, x_{14} + 239{,}50\, x_{24} + 257{,}50\, x_{34} + 257{,}50\, x_{44} + 257{,}50\, x_{54} + 257{,}50\, x_{64} + 239{,}50\, x_{15} + 239{,}50\, x_{25} + 257{,}50\, x_{35} + 257{,}50\, x_{45} + 257{,}50\, x_{55} + 257{,}50\, x_{65} + 239{,}50\, x_{16} + 239{,}50\, x_{26} + 257{,}50\, x_{36} + 257{,}50\, x_{46} \quad (1)$$

$$+ 257{,}50\, x_{56} + 257{,}50\, x_{66} + 239{,}50\, x_{17} + 239{,}50\, x_{27} + 257{,}50\, x_{37}$$
$$+257{,}50\, x_{47} + 257{,}50\, x_{57} + 257{,}50\, x_{67} + 239{,}50\, x_{18} + 239{,}50\, x_{28}$$
$$+257{,}50\, x_{38} + 257{,}50\, x_{48} + 257{,}50\, x_{58} + 257{,}50\, x_{68}$$

Subject to:

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} \leq 2080 \quad (2)$$
$$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} \leq 2080$$
$$x_{31} + x_{32} + x_{33} + x_{34} + x_{35} + x_{36} + x_{37} + x_{38} \leq 1664$$
$$x_{41} + x_{42} + x_{43} + x_{44} + x_{45} + x_{46} + x_{47} + x_{48} \leq 1664$$
$$x_{51} + x_{52} + x_{53} + x_{54} + x_{55} + x_{56} + x_{57} + x_{58} \leq 1664$$
$$x_{61} + x_{62} + x_{63} + x_{64} + x_{65} + x_{66} + x_{67} + x_{68} \leq 1664$$

$$x_{11} + x_{21} + x_{31} + x_{41} + x_{51} + x_{61} = 293 \quad (3)$$
$$x_{12} + x_{22} + x_{32} + x_{42} + x_{52} + x_{62} = 198$$
$$x_{13} + x_{23} + x_{33} + x_{43} + x_{53} + x_{63} = 327$$
$$x_{14} + x_{24} + x_{34} + x_{44} + x_{54} + x_{64} = 365$$
$$x_{15} + x_{25} + x_{35} + x_{45} + x_{55} + x_{65} = 923$$
$$x_{16} + x_{26} + x_{36} + x_{46} + x_{56} + x_{66} = 707$$
$$x_{17} + x_{27} + x_{37} + x_{47} + x_{57} + x_{67} = 1455$$
$$x_{18} + x_{28} + x_{38} + x_{48} + x_{58} + x_{68} = 456$$

$$x_{11} \dots x_{64} \geq 0$$

Equation (1) represents the objective function of the model, in which the cost parameter was used as the decision-making criterion. The values presented represent the cost, as shown in Table 1. Inequalities (2) represent the constraints regarding the capacities of each vehicle, where the right-hand side of the constraints can be obtained from Table 2. Equations (3) represent the constraints regarding the demand of each region, where the values can be obtained from Table 3.

4. Mathematical Model Application

The tool used to apply the mathematical model was Microsoft Excel, which is one of the most popular tools in the world, created by Microsoft in 1987 and still used today in countless companies across all industries. It enables the creation of spreadsheets and has an interface with calculation, logic, and charting tools, as well as pivot tables.

Within Excel, Solver was used to apply and solve the model. Solver is an add-in that allows for the resolution of linear programming problems and sensitivity analyses with different variables and parameters in search of optimality. The application of the model began by adding the parameters identified from the problem into Excel, along with their constraints. Additionally, cells were instantiated to receive the results of the decision variables and the objective function.

Next, the parameters were configured in the Solver add-in, where the objective function was defined as a minimization problem, and the supply constraints were set with a less than or equal sign, while the demand constraints were set with an equal sign. The solution method chosen was LP Simplex, indicating that it is a Linear Programming problem using the Simplex method for resolution.

Following the solution applied by Solver, the following results for the decision variables and the objective function were obtained:

Table 5. Results for the minimization of logistics costs.

	Regions								
	R1	R2	R3	R4	R5	R6	R7	R8	Capacity
Semi-Trailer 1	0	0	0	0	923	0	1156	0	2080
Semi-Trailer 2	293	197	326	364	0	706	191	0	2080
Bi-Truck 1	0	0	0	0	0	0	0	0	0
Bi-Truck 2	0	0	0	0	0	0	0	0	0
Bi-Truck 3	0	0	0	0	0	0	0	0	0
Bi-Truck 4	0	0	0	0	0	0	107	456	564
Demand	293	198	327	365	923	707	1455	456	

The results show the ideal quantity of pallets to be transported in each vehicle to deliver the requested demands for each region annually. For example, to meet the demand of R7 of 1455 pallets, capacities of semi-trailer 1 (1156), 2 (191), and bi-truck 4 (107) were consumed, while to supply the demand of R5, with 923 pallets, only semi-trailer 1 was used. For the fulfillment of R8, with 456 pallets demanded, only bi-truck 4 was utilized, and for the other regions, R1, R2, R3, R4, and R6, only semi-trailer 2 was in operation. From this optimal solution, the minimum transportation cost (Min. Z) is R$1,141,473.89.

5 Discussion

Currently, the revenue from the operation in Curitiba and the Metropolitan Region, the subject of this study, is R$12,500,000. Transportation costs represent approximately 16% of this value, which is R$2,000,000. It is observed, then, that the application of the developed model leads to a decrease of approximately 42.9% in the final transportation costs since the minimum cost obtained is R$1,141,473.89, a value considered plausible by the organization and similar to that observed in [15]. Unlike other works with the same approach, this study showed that significant results can be achieved with simple applications of linear programming, using readily available software such as Excel, which is present in the vast majority of companies. It was not necessary to implement complex decision support systems, as presented in [16] and [17], nor was it necessary to use more complex operational research techniques, such as mixed integer programming, or algorithms with more than 2 phases, differentiating from [18].

Given the results, the optimal solution found leads to the use of only 3 vehicles, with both semi-trailers operating at 100% capacity and one bi-truck operating at 33%, while the remaining bi-trucks remain idle. The lack of operation of the three bi-trucks would be coherent since they are used to serve the Santa Catarina region, not included in this study. Despite this, this fact reveals that the application of the model presented can be useful in the initial phases of operation planning, to size the fleet of vehicles to be used. It is also important to emphasize that the allocation of pallets must also take into account traffic regulations, which determine the load limits that vehicles can carry. This aspect signals the importance of not only considering cost optimization but also traffic and load regulations when planning the implementation of logistic solutions.

In addition to the economic benefits found through the minimization of transportation costs, it is imperative to recall that one of the secondary results of route optimization is the reduction of the total distance traveled, leading to lower fuel consumption, resulting in more sustainable practices that align the company's operation with the 2030 agenda and the Sustainable Development Goals.

Finally, the scientific contribution of this study revolves around a successful real-world application of transportation problem using Linear Programming (LP) to minimize transportation costs. The study demonstrates the effectiveness of the LP approach in significantly reducing operational costs, providing valuable insights for companies and researchers interested in optimizing logistic operations. By showcasing a practical and successful application of LP, this work highlights the potential of this technique in solving real-world complex challenges, reinforcing its relevance and applicability in business contexts.

6 Final Considerations

The article aimed at optimizing the transportation process in a beverage company using linear programming methods to contribute to reducing logistic costs and assisting in the strategic vision for the efficient use of organizational capacity resources.

Thus, to comprehend the results, it becomes necessary to segment the study through its steps. Firstly, concerning the process mapping, it was conducted based on the internal processes involved in the organization's logistics, enabling the understanding of the supply chain and the product flow after an order is placed. For data collection and analysis, all input parameters for the model were considered, encompassing unit transportation costs per pallet, annual vehicle capacity, calculated demand from selected regions, and the distances from each region to the company's distribution center. Regarding the construction of the mathematical model, it was modeled in Excel, using the Solver tool to define the optimal solution, based on the structure of a Transportation Problem. Finally, for the analysis and validation of the results obtained, the optimal solution was validated as applicable in reality, meeting the company's needs.

It is understood that cost minimization is a highly relevant topic in the context of logistics and business management. Through this work, it was possible to demonstrate that it is feasible to optimize the distribution logistics process using linear programming methods, besides exploring the complexities of the problem and its applications in the distribution sector of a regional company. Throughout the research, it is evidenced that the Transportation Problem can serve as an opportunity for easy application for operation optimization, resource savings, and, simultaneously, an improvement in the quality of services provided.

During the case execution, limitations influencing the scope and coverage of the proposed model were identified. One of them is the size of the client portfolio involved, making individual analysis of clients unfeasible. In this context, the need arose to create sub-regions for grouping, allowing the extraction of necessary data from representative groups of clients. The second limitation is due to the geographical limitation of the model's application. The model was implemented exclusively in the area of Curitiba and Metropolitan Region, without extending to other locations served by the company, such as the state of Santa Catarina. The solutions adopted to overcome these limitations demonstrate the adaptability of the model to the company's specificities.

This study, while addressing challenges and limitations during the application of the mathematical model and analysis of clients in a specific context, identified opportunities for improvements and future developments. Despite proposing a simplified and easily implementable approach, enhancing the model for all clients on an individual basis and its geographical expansion can be cited as a continuation plan for the project, which may include studying the division of demand among trucks, as done in [18]. Additionally, the production planning stage may be included in the study of the problem in the future, from the perspective of distribution logistics, as explored in [16], which may involve developing machine learning models to create an automatic demand forecasting system. Finally, since this is a study of minimizing logistics costs, it is worth noting the need to monitor variations in the Logistics Service Level to highlight the management of the trade-off between logistics costs and the presented logistics service level [19].

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