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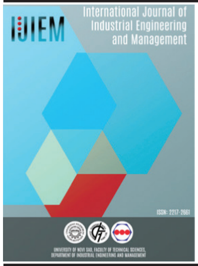

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Original research article

Impacts of Collaborative Logistics: A Brazilian Brewing Sector Case Study

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ABSTRACT

Different organizations and institutions adopt Collaborative Logistics expecting to achieve a sustainable model in which the product serves society and generates profits. This research has the objective of identifying the impacts of collaborative logistics in the Brazilian brewing sector using a mathematical model that considers economic indicators and environmental efficiency. Through a qualitative and exploratory methodology using the case study technique, results show a 100% increase in economic efficiency and a 40% reduction in CO2 emissions. The findings are relevant because they demonstrate that strategies of collaboration are recognized as the most effective approach for costs reduction and for sustainable business performance.

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1. Introduction

The competition currently takes place between supply chains. Different articulations of synchronization of actions started to be implemented in the chains, from free market to collaboration, going through cooperation and coordination in the process [1].

The idea of collaborative logistics should be among the measures to be adopted by an organization in the expectation that it has a performance characterized as sustainable, performing activities so that the product serves society, thus reflecting in profits and mitigation of negative impacts on the environment [2]. This is particularly true for Brazil, a country of continental dimensions in which road transport has become the dominant modal, responsible for 60% of cargo transport in the country [3].

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Considering the three pillars of sustainability (economic, social, and environmental dimensions), the aim of this research is to investigate, from a collaborative logistics point of view, how the economic and the environmental dimensions reduce the cost of transportation and the emission of CO2, respectively, contributing to the efficiency of companies in the beer production chain [4].

In a competitive market, cost reduction due to economies of scale in the short and long term is a fundamental issue for companies. Therefore, this work aimed to identify the impacts of logistical collaboration between two companies of a supply chain in the brewing sector in Brazil through a mathematical model that considers indicators of economic and environmental efficiency related to the cost of transport and CO2 emissions.

A qualitative and exploratory approach is used, with the case study technique relating to the use of Collaborative Logistics. The data collection instruments used were document sources, and semi-structured interviews with the logistics coordinators of the companies studied.

In addition to this introduction, the article is structured in four more sections: (1) theoretical framework; (2) methodological procedures; (3) results and discussion, and (4) conclusions and suggestions for future work.

2. Literature Review

2.1 Collaborative Logistics

Collaborative logistics can be defined as logistical actions aimed at the integration of chain participants through modern information and communication technologies [5]. The objective of this practice is to develop cooperative operational strategies and plans, mainly benefiting the consumer with better products and better-aggregated services, bringing competitive advantages to all participants, and providing the integration of the entire chain. Thus, the exchange of information is increased through the sharing of physical, systemic, and human resources.

The international literature treats collaborative logistics as a strategic way for the company to reduce costs and increase its efficiency. Wang and Kopfer [6] describe collaborative logistics as a functional collaboration that leads to integration economies, coordinating interdependent activities. Likewise, collaboration can simplify and make logistical processes more efficient in terms of time and quality, exploring the knowledge of the people involved in the processes [7].

Coopetition is a business strategy based on a combination of cooperation and competition, derived from the understanding that business competitors can benefit when they work together [8]. Collaborative logistics among key members of the supply chain can be regarded as a form of competition, which aims to bring benefits to the strategic plans of the organizations involved. This practice provides cost reduction, service level increase, inventory reduction, operational flexibility, and business consolidation [9].

For cost reduction to generate a reduction in the final price of the product, it is necessary to share information, knowledge, skills, and technologies between companies to increase their competitiveness against the competition [10]. Partnerships create relevant opportunities mainly for organizations with deficiencies in certain skills and resources, enabling them to acquire competitive advantages that could not be obtained working in isolation. They also allow easier access to new markets and operational synergies, and mutual learning [11].

The expected gains from collaborative logistics are generally more significant than with traditional logistics, in which cost reduction is restricted to individual operations without economies of scale. On the other hand, when the collaborative approach is established early in the project, the benefits are greater as reduced costs, improved service levels, operational flexibility, and overall strengthening of the supply chain, resulting in reduced inventory levels, more accurately in forecasts and increased customer satisfaction [1].

Therefore, the dynamics of collaborative logistics evidence the strengthening of the potential of the participating organizations, configuring improvements in the performance of their actions through the sharing of information, technologies, and resources [9].

2.2 Collaborative Transportation

While transport focuses on moving goods from one place to another, logistics implies a broader spectrum and refers to managing the flow of materials, information, and finance. This includes in addition to the transport and delivery of goods, storage, handling, stocking, packaging, and various other aspects. Transport is a function within logistical operations [12].

Transport occupies a third of the value of logistics costs and influences the performance of the logistics system as a whole [13]. In this context, transport logistics is a strategic aspect, which must consider the optimization of transport in cargo handling, the composition of costs and the added value in the application of each modal, its reliability and consequences in savings and reduction of final values of product [14].

Collaborative transport focuses on cargo consolidation, seeking to concentrate products from different suppliers that use the same route, reducing vehicle movement with idle capacity. The purpose that drives the optimization of space in the vehicle is to achieve more interesting transport rates through better use of the equipment's capacity [15]. As emissions in industries are directly related to energy consumption, an effective way to reduce emissions is to develop an efficient truck loading schedule with the aim of reducing fuel consumption [16].

Chan and Zhang [17] state that the Collaborative Transportation Management (CTM) proposes to increase the efficiency of transport operations (reduce travel and delivery times, improve return freight and reduce transport with idle capacity), increase sales, lower fixed costs, and working capital employed, reduce inventories in the supply chain, maximize customer satisfaction, spend less time carrying out inventories, reduce the rate of errors and waste, improve the exchange of information between partners, increase the level of service, optimize the use of equipment and labor, in addition to the opportunity to obtain lower rates for carrying out contracts. Therefore, the cost involved in adopting a supply chain should be confronted with the benefits generated by reducing taxes and the gains due to increased operational performance [18].

Examples of collaborative transport include contracting the same transporter to distribute products from two companies or even sharing information about transport orders to allow return trips [19]. In this context, [1] highlights, among the potential benefits of collaborative transport, the use of transport resources used in operation. In some situations, collaboration is evidenced only between the shipper and its carriers, with improvements in communication and cargo visibility. However, in other more comprehensive cases, vehicles are shared in matched flows of goods movement, making it possible to reduce the waiting time of carriers at each origin and destination. In this sense, members of the same chain or shippers with complementary loads come together to create high-yield cycles, waking up return loads.

3. Methodology

This research uses a case study methodology carried out with two companies in the same supply chain in the Brazilian beer sector. It should be noted that, due to ethical research purposes, the names of the companies will not be mentioned, using the fictitious names of “Company A” and “Company B” to identify them. The case study is justified because it allows a deep understanding of a real-world phenomenon [20].

Data collection included a) document collection in both companies with the availability of raw data from February 2019 to February 2020; b) remote interview conducted in March 2020 through a semi-structured script, with the logistics coordinators of both companies selected for their direct actions in the companies' operations. The semi-structured script created by the researchers in this study aimed to collect information on the characterization of the profile of the trucks used (t), fuel consumption (km/L), cargo handled (t), transport tariff values (R$/t), and the routes used (km).

In order to carry out the analysis of different scenarios and quantify the savings generated with increased efficiency, as well as measure the improvement in CO2 emissions per ton transported achieved with the collaboration between the companies, this paper is guided by the research already developed by [21], using the method applied there with the necessary changes for the present case, such as distances, type of cargo transported, itinerary, among other operational issues. For this, this paper proposes a mathematical model aimed at collaborative logistics applied to a real scenario between the two companies, with results in terms of transport cost and energy efficiency.

3.1 The scenario of Collaborative Logistics Between Companies

Company A (focus company) is a supplier of Maltose, the main malt component used in the brewing of Company B, which operates in the production and distribution of beer and other beverages. Due to the close commercial relationship between them, there was a growing interest in working together, seeking opportunities for operational synergies that would facilitate collaboration initiatives. Companies are part of the same supply chain and have come together to form a high-productivity cycle, combining return loads by sharing vehicles in “matched streams”.

Company B operates in the management, production and distribution of beer and other beverage products. It operates in over 70 countries, with 165 breweries, over 85,000 employees and over 250 brands. In Brazil, it has 12 breweries, 2 microbreweries, 1 syrup and 29 distribution centers across the country.

Loading and unloading processes are usually the most unproductive activities of the logistic process, as they usually require the assistance of the warehouse staff, such as the driver, who needs to wait for the team's work, in addition to complying with bureaucratic procedures related to the release of the cargo [22]. Thinking about it, in the city of Ponta Grossa/PR, where both have operations, an opportunity for collaboration was identified. Company A serves a client in the city of Ponta Grossa, where Company B has a plant. This, in turn, delivers to cities where Company A has operations. In February 2019, Company A's trucks began to operate with an identification plate to have a preference for loading and unloading at Company B's factories.

This collaboration project aims to make delivery processes more agile and efficient, generating savings in resources and bringing greater visibility to brands. Thus, Company A's Mogi Guaçu (SP) unit sends a shipment of bagged starch (50 kg/big bag) to a customer's factory in Ponta Grossa (PR). After unloading, the vehicle moves to a unit of Company B, which is also located in Ponta Grossa (PR). The vehicle carries the finished products of Company B (beers in cans or bottles – palletized) destined for Sumaré (SP). After unloading at Company B's destination, the vehicle returns to Company A's plant in Mogi Guaçu (SP) for a new shipment of Bagged Starch for the client in Ponta Grossa (PR). The objective is to use possible empty stretches of the companies, where there are no return trips on the networks crossing routes of both companies.

The interviewed managers reported that during the sizing of the fleet that would operate in collaborative transport, the intrinsic characteristics of the activities related to loading, transportation and unloading were discussed, in addition to the structural characteristics of the warehouses and the specifications of all existing resources in the process. The vehicle profile they chose to work with is the 2-axle trailer, which allows the transportation of a total gross weight of 33 tons (25 tons net weight) and is 18 meters long. It was also reported by the interviewees that the consumption of the loaded truck is 2.20 km/L and the empty consumption is 3.40 km/L. These data are consolidated in Table 1 presented in section 3.2.

3.2 Mathematical Model for Collaborative Logistics

The mathematical model proposed for collaborative logistics outlined in Figure 1 considers two issues: the improvement of economic indicators and environmental indicators of the logistics operation.

Regarding the Economic Indicator (Equation 1), the model aims to measure the cost of transport activities with the adoption of the collaborative logistics model. In the Environmental Indicator (Equation 4), the model intends to show that, given the current concerns with sustainability and environmental preservation, the use of collaborative logistics allows for the reduction of the quotient between CO2 emission and cargo transported by the fleet. In order to develop the mathematical modelling for this work, the following considerations were made:

a. Route 1 will be called the route between Company A (Mogi Guaçu/SP) x Client Company A (Ponta Grossa/PR);
b. The internal displacement in the city of Ponta Grossa/PR will be called Route 2 (Client Company A x Company B);
c. Route 3 will be called the route between Company B (Ponta Grossa/PR) x Client Company B (Sumaré/SP);
d. The displacement between the Client Company B (Sumaré/SP) and Company A (Mogi Guaçu/SP) will be called Route 4;
e. The number of trucks that participate in collaborative logistics is a function of the companies' demand;
f. The transportation cost is calculated through the freight value per ton (R$/t). When the truck is empty, its load capacity is used in this calculation.

Based on the above considerations, the collected data presented in Table 1 will be used to calculate the metrics proposed in this work (sections 3.2.1 and 3.2.2).

Table 1. Collected data

Variable	Value
Monthly load (t)	2.194,00
Truck load capacity (t)	25,00
Value of loaded freight (R$/t)	89,00
Empty shipping value (R$/t)	57,85
Average consumption of loaded truck (km/L)	2,20
Average consumption of empty truck (km/L)	3,40

3.2.1 Metrics for Transportation Cost Analysis

The metrics proposed for the analysis of transportation cost aim to measure the return that collaborative logistics provides to the transportation company with the best use of the fleet. As can be seen by [21], as well as in the studies by [6], [23], [24], [25], and [26], essentially collaborative logistics aims to increase the use of the fleet, preventing it from circulating empty. For this, collaborative logistics is based on better integration between commercial partners in order to develop a symbiosis between them, in order to benefit both with the reduction of operating costs. Figure 1 shows each of the analyzed paths and the fraction of the fleet that participates in the collaborative logistics, defined here as fp. In this sense, 1 - fp denotes the fraction of the fleet that does not participate in collaborative logistics and therefore returns empty.

As shown in Figure 1, in Route 1, it is considered that Company A always employs its entire fleet. However, along the other routes, the use of the fleet is subject to the demand of Company B, which will use only a fraction of the fp fleet. In this sense, the portion of the fleet not used by collaborative logistics returns by the same Route 1 in order to be loaded again by Company A. The metrics for analyzing the model's transportation cost are presented in Table 2.

Table 2. Metrics for Transportation Cost Analysis

Metrics	Equation
Revenue from freight	$R_i(f_p) = f_p \cdot CTT \cdot VFC \cdot T_i$
Route i empty shipping value	$C_i(f_p) = (1 - f_p) \cdot CTT \cdot VFV \cdot T_i$
Route i profit	$L_i(f_p) = [R(f_p) - C(f_p)] \cdot T_i$
I-th route	$T_i = 1, \quad i = 1,2,3,4$
Max return	$RMAX = 2 \cdot CTT \cdot VFC$

Where
f_p: Fraction of the fleet that participates in collaborative logistics (-)
CTT: Total Cargo Carried (t)
IE: Economic Indicator (-)
VFC: Value of Freight with Cargo (R$/t)
VFV: Empty Shipping Value (R$/t)
$L_i(f_p)$: Profit (R$)

The calculation of the Economic Indicator - IE (fp) is made considering the metrics in Table 2, being mathematically described by (Equation 1):

$$IE\ (f_p\ ) = \frac{\sum_{i=1,3} R_i(f_p) - \sum_{i=1,2,4} C_i(f_p)}{RMAX} \quad (1)$$

3.2.2 Metrics for Environmental Analysis

The environmental analysis developed in this work considers the amount of CO2 emitted by trucks when traveling through loaded and empty paths, aiming to demonstrate that when they run loaded, the quotient between the amount of CO2 produced and the load transported is reduced.

The GHG Protocol methodology, which is the international accounting tool most used by governments and companies to understand, quantify and manage Greenhouse Gas (GHG) emissions, was used to convert fuel consumption into CO2 emissions. It underpins nearly every global GHG standards and program, from the International Standards Organization (ISO) to The Climate Registry, as well as hundreds of GHG inventories prepared by companies around the world [27]. The methodology adopts the factors converted to kg/L, and the emission factor used was 2.603 kg CO2/L, extracted from the last update of the tool released in February 2021 [28].

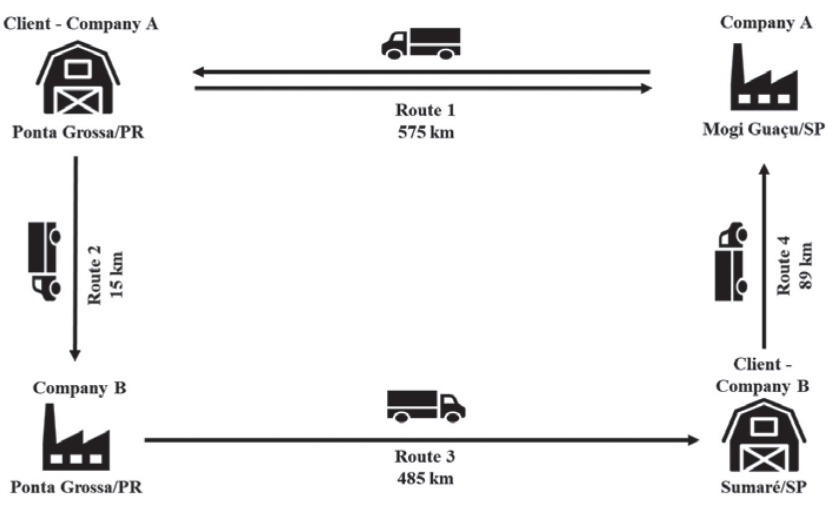

Figure 1. Simplified scheme of the proposed Collaborative Logistics model

In order to calculate the amount of carbon gas produced along the paths shown in Figure 1, the following mathematical relationships were used, respectively Equation 2 and Equation 3, for the loaded and empty paths.

$$QCO2_c = \left(\frac{CTT}{TCC}\right) \cdot \left(\frac{D_i}{CCC}\right) \cdot T_i \cdot f_p \cdot fep, \qquad i = 1,3 \qquad (2)$$

$$QCO2_{empty} = \left(\frac{CTT}{TCC}\right) \cdot \left(\frac{D_i}{CCV}\right) \cdot\cdot T_i \cdot f_p \cdot fep, \qquad i = 1,2,4 \qquad (3)$$

Where
EI: Environmental Indicator (-)
CTT: Total Load Carried (t)
TCC: Truck tonnage (t)
D_i: Route distance i (km)
CCC: Loaded Truck Fuel Consumption (km/L)
f_p: Fraction of the fleet that participates in collaborative logistics (-)
fep: Emission Factor 2,603 kg CO2/L
T_i, i=1,2,3,4: Route analyzed

The Environmental Indicator (EI) is calculated by Equation 4:

$$EI = \frac{f(\overline{x})}{g(\overline{y})} = \frac{kgCO2}{Tonne} \qquad (4)$$

Where

$$f(\bar{x}) = \sum_{i=1,3} f_p \cdot \left(\frac{CTT}{TCC}\right) \cdot \left(\frac{D_i:}{CCC}\right) \cdot fep \cdot T_i + \sum_{i=2,4} f_p \cdot \left(\frac{CTT}{TCC}\right) \cdot \left(\frac{D_i:}{CCV}\right) \cdot fep \cdot T_2 + (1 - f_p) \cdot \left(\frac{CTT}{TCC}\right) \cdot \left(\frac{D_i:}{CCV}\right) \cdot fep \cdot T_1 \qquad (5)$$

$$g(\bar{y}) = CTT \cdot (1 + f_p) \qquad (6)$$

Therefore, the analysis of Equation 4 shows that the better the fleet's cargo-carrying capacity is used, the lower will be the relationship between the amount of CO2 produced and cargo transported.

4. Results and Discussion

For the calculation of the parameters presented in Table 2, the values of participation of the fp fleet vary every 10%. Table 3 shows the revenue values obtained along Routes 1 and 3 (shown in Figure 1), obtained by the equations listed in Table 2. The values obtained in Route 1 are fixed, as it is assumed that Company A always does use of your entire fleet. Thus, revenue is maximum along this route, whereas, on Route 3, revenue is a function of Company B's demand.

Table 3. Revenue obtained from the transportation on Routes 1 and 3

Fraction of the fleet (fp)	Route 1 (R$)	Route 3 (R$)
0%	193.820,78	0
10%	193.820,78	22.820,52
20%	193.820,78	45.641,03
30%	193.820,78	68.461,55
40%	193.820,78	91.282,06
50%	193.820,78	114.102,58
60%	193.820,78	136.923,09
70%	193.820,78	159.743,61
80%	193.820,78	182.564,12
90%	193.820,78	205.384,64
100%	193.820,78	228.205,15

In this context, when the costs of transporting trucks loaded on Route 1 are verified, that is, related to the transport of cargo by Company A, it appears that there is a fixed cost that it will always assume since it makes continuous use of this route due to the need for connection between the companies in Mogi Guaçu/SP and Ponta Grossa/PR. On the other hand, when Company B, on-demand, uses Company A's return fleet, it gains the benefit, as it does not need to assume the cost of transporting the entire fleet, but only the fraction of use. This gain for Company B can be seen as the opportunity cost of not acquiring an entire fleet of its own and starting to use the fleet of the partner company. Likewise, Company A does not assume a large part of the return cost and may even reset it when Company B uses 100% of the trucks in Route 3, reducing its fixed transport cost. Therefore, the "win-win" system is understood.

In order to better explore these results, Table 4 is shown, in which the cost of the fleet running empty is determined, calculated from the equations given in Table 2. For this, the value of empty freight was considered as fixed costs and the same as those of a loaded truck (driver's daily allowance, maintenance, depreciation, tolls, among others), only the variable consumption portion being discounted.

It is inferred, therefore, that, from the moment that there is collaboration between companies A and B, that cost of transporting the fleet running empty, whether on the way to or from any route, which would obviously be assumed by Company A, is now shared with Company B. It is analyzed that, when 100% of the fleet is shared, Company A has its return cost zeroed in Route 1, for example, since its fleet will adopt routes 2 and 3 on return and this cost will be assumed by Company B.

Table 4. Cost of transporting the fleet running empty on Routes 1, 2 and 3

Fraction of the fleet (fp)	Route 1 (R$)	Route 2 (R$)	Routes 3 (R$)
0%	125.413,45	0	0
10%	112.872,10	1.431,19	2.211,83
20%	100.330,76	2.862,37	4.423,67
30%	87.789,41	4.293,56	6.635,50
40%	75.248,07	5.724,75	8.847,34
50%	62.706,72	7.155,94	11.059,17
60%	50.165,38	8.587,12	13.271,01
70%	37.624,03	10.018,31	15.482,84
80%	25.082,69	11.449,50	17.694,68
90%	12.541,34	12.880,68	19.906,51
100%	0	14.311,87	22.118,35

Table 5 calculates the profit as a function of the fraction of the fleet that participates in collaborative logistics considering revenues minus costs in accordance with the equations given in Table 2.

From the analysis of the results obtained by the mathematical model to measure the increase in economic efficiency and, consequently, the increase in profit, it is understood the role that collaborative logistics assumes in reducing the costs of transporting cargo. Initially, the Economic Efficiency (EE) identified was 16%, which resulted in a profit of BRL 68,352.00, whereas, when the entire fleet participates in collaborative logistics, the economic efficiency becomes 91%, increasing the result to R$ 179,508.91.

Table 5. Economic result as a function of the fraction of the fleet (fp) that participates in Collaborative Logistics

Fraction of the fleet (fp)	Profit (R$)	Economic Efficiency (-)
0%	68.407,33	0,16
10%	79.517,49	0,24
20%	90.627,65	0,31
30%	101.737,81	0,39
40%	112.847,97	0,46
50%	123.958,12	0,54
60%	135.068,28	0,61
70%	146.178,44	0,69
80%	157.288,60	0,76
90%	168.398,75	0,84
100%	179.508,91	0,91

In this way, collaborative logistics becomes responsible for doubling the profit obtained in operation. It is emphasized that this gain is distributed between the two companies, consolidating the understanding of the "win-win" perspective.

In order to facilitate the interpretation of the results, Figure 2 graphically presents the relationship between fp and EE (fp), where it is possible to observe that the overall efficiency of the system varies linearly with the fraction of the fleet that participates in collaborative logistics. Furthermore, it is evident that there is a significant increase in overall efficiency when using the entire fleet in collaborative logistics.

Remember that this economic efficiency is directly proportional to the use of collaborative logistics, so that the more developed this business relationship, based on the precept of trust and mutual partnership, the greater the tendency to increase the profit margins of the involved. As the driver does not waste

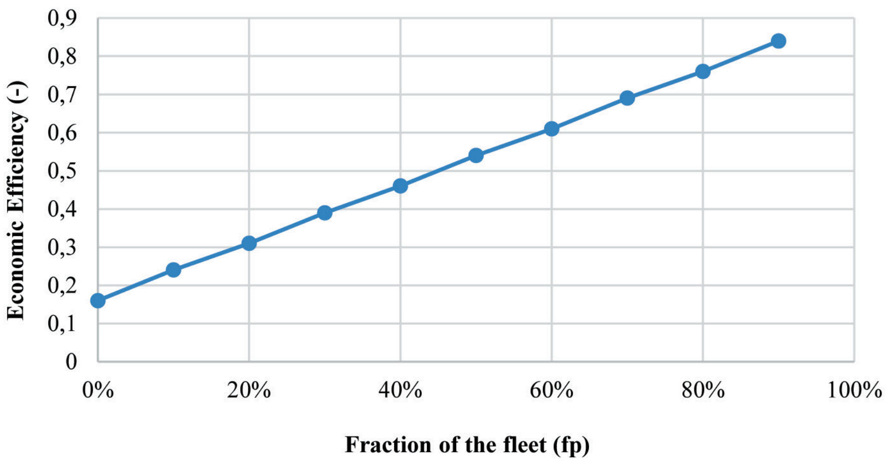

Figure 2. Economic Efficiency as a function of the fraction of the fleet (fp) that participates in Collaborative Logistics

time looking for return cargo, as he is synergistically engaged in a travel cycle, asset productivity grows, causing the total cost of transportation to decrease.

It is worth noting that this can happen even with companies in the same field of activity and that compete in the market for the demand of their products, reinforcing here the concept called coopetition, that is, there is cooperation initially so that both companies will win in this cooperation [9]. In the case in question, it is about the reduction of transport costs, but in the market, they start to compete, whether in the sale of products or in the offer of services.

4.1 CO2 Emission

Table 6 presents the results for the environmental analysis obtained from the discussions and the mathematical model presented in section 3.2.2. As the percentage of the fleet participating in collaborative logistics increases, there is a significant reduction in the quotient between the amount of CO2 produced and the cargo transported. Quantitatively, with 100% of the fleet participating, there is a 40% reduction in the kg CO2 per ton ratio, in addition, to double the amount of cargo being transported.

Table 6. Results of the environmental analysis as a function of the fraction of the fleet (fp) that participates in Collaborative Logistics

Fraction of the fleet (fp)	CO2 Emission (kg CO2/t)	Carried Load (t)	Environmental Efficiency (%)
0%	44,82	2.194,28	0%
10%	41,52	2.413,71	7%
20%	38,77	2.633,14	13%
30%	36,44	2.852,56	19%
40%	34,45	3.071,99	23%
50%	32,72	3.291,42	27%
60%	31,21	3.510,85	30%
70%	29,87	3.730,28	33%
80%	28,69	3.949,71	36%
90%	27,63	4.169,13	38%
100%	26,67	4.388,56	40%

When considering the results obtained by the model regarding environmental efficiency and consequent reduction of damage to the environment, it is observed that, without the use of collaborative logistics, the quotient was 44.82 kg of CO2 per ton transported, while, when the fleet participates in its entirety in collaborative logistics, the quotient is reduced to 26.67 kg of CO2 per ton transported. Therefore, collaborative logistics was responsible for reducing the operation's environmental impact by approximately 40%.

Figure 3 shows the reduction profile of the kg CO2/t ratio, in which for 0% of the fleet participating in collaborative logistics, there is almost 45 kg of CO2 emitted for each ton transported, while for 100% of the fleet participating in the logistics collaborative, 26.67 kg of CO2 is produced, evidencing the role of collaborative logistics in reducing emissions.

Truck-sharing increases the utilization rate of trucks, reducing the number of trips a vehicle would travel empty. With the increase in the fraction of the fleet that participates in collaborative logistics, the percentage of reduction in CO2 emissions would improve. With less equipment in operation, less fuel is consumed and, consequently, GHGs are reduced.

Fundamentally, collaborative logistics aims to reduce the routes that the fleet travels without load. In this sense, the graph in Figure 4 shows the total load transported by trucks as a function of the percentage of vehicles that participate in collaborative logistics. It is possible to observe for 100% of the fleet participating in this dynamic, the total load transported is doubled.

The carrier contemplated to operate in the logistics circuit has the opportunity to work with maximum productivity, reducing empty freights and making the most of return freights between companies A and B. This concept is the central point of collaborative transport, as the increase in this productivity generates attractiveness for the companies involved, which have the opportunity to improve their operational performance and obtain better economic and environmental results.

The results presented so far demonstrate that the constant practice of collaboration in cargo transportation significantly contributes to business synergy, from the development of activities with less use of material resources (such as fuel and fleet maintenance) and the consequent reduction in environmental impacts (from the reduction in mileage and thus, GHG emissions), causing increasingly positive impacts, whether economic or ecological.

In line with the results presented by [1], [7], [17], [23], [24], [25], [29] and [30], [21] assessed in their research an economic efficiency of 38% and an environmental efficiency of 31%, therefore, close to the results presented here. For [32], companies that value economy and sustainability in business are increasingly perceived. This can also be confirmed from the very conceptualization of logistics that di-

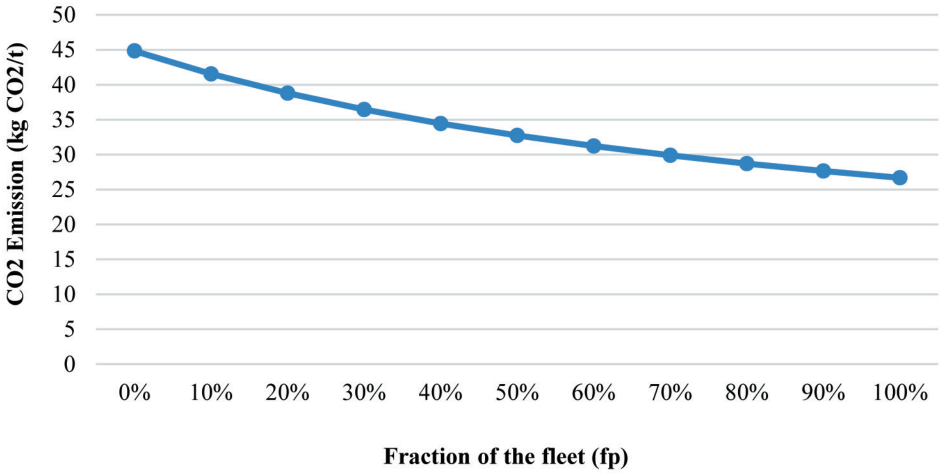

Figure 3. CO2 emissions as a function of fleet fraction (fp) participating in Collaborative Logistics

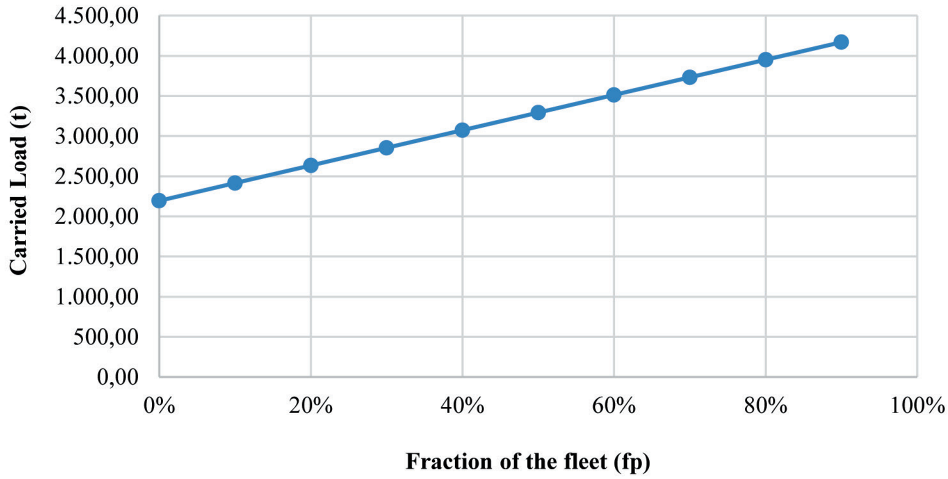

Figure 4. Total cargo transported as a function of fleet fraction (fp) that participates in Collaborative Logistics

rectly points to collaboration, since its main objective is to meet the demands of customers efficiently and effectively [31].

Corroborating the findings of [32], Company A's logistics coordinator states that "in addition to further strengthening ties with our customers, being able to apply dedicated vehicles in these combined operations further reinforces our commitment to implementing differentiated models of logistics contracting, aiming to delight all the stakeholders involved in the process. In a short time of use, we have already had many positive feedbacks regarding the use of these vehicles".

For the Logistics coordinator of Company B, there is a great reinforcement in the brand and engagement of partners and suppliers because "...with dedicated vehicles wrapped with our brand, we have a greater engagement of the carrier and respective drivers, who assimilate even more our values as a company, being in fact an extension of the company and not just a service provider".

According to [33], collaboration makes companies more competitive, and consequently stronger in the market. But for this to happen effectively, in addition to exchanging information, greater bargaining power with suppliers, distribution capillarity and loyalty of transport resources must happen. With these practices, the monetary results are satisfactory in the medium and long term.

Another highlight for collaboration, according to [30], turns to the drivers, as it facilitates their work in the search for return cargo and waiting in loading and unloading operations. Also, according to the study by [30], the relevance of the economic results from the use of collaborative logistics due to the integration of collaboration strategies and tactics is observed, making it possible to build a favorable scenario for the combination of routes and, therefore, savings in freight contracting. In addition to this point, the authors also point to non-economic advantages, such as the reduction of fixed costs of trucks, due to less time in queues for unloading, direct environmental benefits, since there is a reduction in GHG emissions and also benefits for the population, with fewer trucks circulating and, consequently, lower levels of congestion and noise.

5. Final Considerations

The objective of this paper was to analyze the impacts of Collaborative Logistics on the economic and the environmental efficiencies in order to quantify the savings generated with increased efficiency and to measure the reduction in CO2 emissions per ton transported achieved with the collaboration between two companies of a supply chain of the productive brewing sector operating in Brazil. Therefore, a qualitative and quantitative study was conducted in two companies in a supply chain in the brewing sector, which included data collection from documents and semi-structured interviews. For data analysis, a mathematical model was proposed that considers economic efficiency from transport cost analysis metrics and energy efficiency from metrics for environmental analysis.

The efficiency of any transport operation is highly dependent on using its carrying capacity in both directions. In the absence of return cargo, the vehicle must be returned empty, usually at the carrier's expense. This empty trip represents not only a wasted economic resource but also an environmental liability. With the increase in the fraction of the fleet that participates in collaborative logistics in cargo transport, there is an improvement in the percentage of reduction in CO2 emissions from empty trucks. Thus, it is understood that when there is no synergy between the flows on a given route that has large cargo handling, more trucks are needed to carry out the transport and, consequently, higher are the CO2 emission rates.

Both in relation to the analysis of transport costs and the environmental analysis, it is evident that collaborative logistics is of fundamental importance for increasing economic return and environmental sustainability. The results show an increase of approximately 100% in economic efficiency, causing the index to jump from 16% to 91% as shown in Table 5. In the environmental aspect, there was a reduction of approximately 40% in the ratio of kg CO2 emitted per ton transported, that is, the index went from 44.88 kg CO2/t and went to 26.67 kg CO2/t, as shown in Table 6. In this sense, the results obtained encourage the incorporation of the practice of logistical collaboration in management activities since that the increase in efficiency is evidenced by an increase in revenue, cost reduction, and, consequently, greater profitability in operation.

In the academic aspect, this study helps researchers to develop more refined models for this problem, considering the costs per km traveled with an empty and with a loaded truck, the daily demands of each company, and the possible introduction of new partners in the routes where trucks are still running empty. It is understood that, on the one hand, the transportation of goods is a lever for economic growth, but on the other hand, it significantly worsens environmental problems. Thus, it is observed that the most effective and efficient organization of cargo transportation becomes crucial for the success of logistics, as well as for dealing with the current challenges of sustainability.

It was noted, throughout the literature review carried out that, despite being a widely discussed subject in a disintegrated way (cargo transportation, collaborative logistics, transportation cost, and CO2 emission), there are still few works in this area, especially, recent studies that are concerned with the use of collaborative logistics and the possible economic and, especially, environmental impacts combined. It is suggested, therefore, the expansion of investigations in this context mainly studies applied to the Brazilian reality.

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