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Total Logistics Costs in Supply Chain Management

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Abstract: The objective of this research is to develop a mathematical model to calculate the total logistics costs of a manufacturing company. To achieve this objective, seven industrial companies in the auto parts sector in the state of São Paulo were analyzed, identifying the main elements of the logistics process and their substantial costs from the perspective of the supply chain and its management. Logistics costs in manufacturing companies can be evaluated not only from an internal point of view, but also in terms of the relationship between all the actors that make up their production and supply chain. This study adopted a qualitative research design, structured around bibliographic, descriptive, and exploratory approaches, with a focus on identifying and analyzing specific data and information on logistics costs. It is considered exploratory because its main purpose is to develop, clarify, and refine concepts and ideas to guide further research. Following these methodological guidelines, a multiple-case study was conducted in the metropolitan region of São Paulo, involving seven manufacturing firms in the auto parts sector. Fifteen semi-structured interviews were conducted with managers and specialists from the seven manufacturing firms between July and September 2019, each lasting approximately 50 minutes. The findings highlight the need to improve logistics cost control systems and, depending on the requirements of the supply chain, decompose logistics resources using Activity-Based Costing (ABC). In conclusion, this study contributes to the understanding of logistics cost management by providing insights into the integration of direct and indirect costs across the supply chain.

Keywords: Total Cost Logistic, Supply Chain Management, Mathematical Model.

INTRODUCTION

In an increasingly competitive environment, firms must be better prepared to succeed in their industries. In recent years, with intensifying competition and growing specialization, many companies have opted to optimize their logistics resources, a trend accelerated by the rapid expansion of e-commerce, which demands faster logistics development.

This study focuses on the manufacturing industry, particularly the auto parts sector, which plays a key role in national economic development. The rapid evolution of logistics not only accelerates the delivery of goods and the flow of capital but also enhances the circulation of products and contributes to socio-economic growth rates.

The general objective of this research is to analyze total logistics costs from a supply chain management perspective, with a focus on strategic cost management. The specific objectives include: (a) providing a brief contextualization of logistics, supply chain management (SCM), and cost components; (b) addressing their general aspects, modes of operation, and cooperation; and (c) conducting an integrated analysis.

Effective cost control requires a broad mastery of supply chain management systems, which several authors identify as a source of competitive advantage Ballou (2004); Pozo (2015). Supply chain integration with suppliers and customers through effective management is essential to generate consistent information for decision-making.

According to Chopra & Meindl (2019) emphasize the need for systematic control of operational costs across the entire supply chain by identifying and analyzing all direct and indirect cost factors affecting its links. Effective cost control is therefore crucial for industries to establish competitive pricing for their products and services.

The expected contribution of this research is to guide companies toward comprehensive cost control across the production and supply chain in which they operate. This study is relevant because, beyond examining internal logistics costs of auto parts firms, it also addresses the costs associated with each link (actor) in the supply chain and their effective management, emphasizing the strict control of activities that influence the final product price.

The objective of this research is to develop a model for controlling total logistics costs. The proposed control model must account for fixed and variable cost categories. To achieve this, it is necessary to identify the structure of companies' logistics systems and define the substantial elements of logistics costs. The theoretical contribution of this study lies in applying a model to highlight logistics costs in a specific context for firms engaged in the processing and commercialization of industrial goods Engblom, Solakivi, Töyli & Ojala (2012).

Based on this analysis, it is essential to identify mathematical relationships that reflect the mutual impact of costs across logistics subsystems. These relationships should be used to design a mathematical model for optimizing total logistics costs in the auto parts manufacturing sector.

LITERATURE REVIEW

Logistics

Logistics is the area of management responsible for providing resources, equipment, and information necessary for the execution of organizational activities. It is the process of planning, implementing, and controlling—efficiently and at market-appropriate costs—the transport, movement, and storage of products both inside and outside the company, ensuring product integrity and timely delivery to customers (Council of Supply Chain Management Professionals CSCMP (2019).

According to Creswell & Poth (2018), logistics is the part of supply chain management that plans, implements, and controls the efficient and cost-effective flow and storage of raw materials, work-in-progress, finished products, and related information from the point of origin to the point of consumption, to meet customer requirements.

According to Bokor (2010) defines logistics as the field of administration concerned with organizing the resources required to deliver products and services when and where consumers desire them. The literature presents multiple definitions of business logistics, reflecting diverse terminologies such as transportation, distribution, physical distribution, procurement, materials management, and operations.

The primary objective of logistics is to make products and services available at the right time and place, thereby facilitating production and marketing activities. As such, cost accounting has evolved to capture the positive effects of logistics on companies. Logistics not only coordinates multiple activities but also aims to reduce costs, accelerate task execution, and enhance customer service.

Logistics System Structure

There is no single correct structure for a logistics system, as it varies depending on the type and scale of business. However, within manufacturing industries, certain subsystems are commonly observed. A typical manufacturing firm engages in purchasing, transportation, planning, and warehousing activities. These activities generate costs related to labor, freight, inputs, and depreciation.

Thus, logistics in manufacturing companies can be structured into cost categories linked to purchasing, storage, transport, and planning, all integrated into supply chain management (SCM). This integration ensures efficient coordination with suppliers and customers, improving overall supply chain performance.

As Ballou (2004) highlights that any business can create four types of value—form, time, place, and possession. Products have value not only when they are available and ready for consumption (form) but also when they are in the right place at the right time (place and time), at a competitive price (possession).

Information sharing is a critical element in this integration. According to Ballou (2004) argue that accurate information improves efficiency, while imprecise data can cause disruptions. As [Marchesini & Alcântara (2016) emphasize the importance of information systems for rapid responses to customer inquiries, while as Bowersox & Closs (2013). stresses the role of information technology (IT) in structuring data processing. However, cultural resistance to sharing knowledge often hinders effective integration (Katunzi, 2011).

Although companies have increasingly sought to improve logistics cost control, many auto parts firms still fail to optimize their resources. One common practice is outsourcing logistics, which often does not enhance technological innovation or cost control (Li, 2012). Many companies prioritize speed, security, and reliability in logistics services but neglect to integrate cost control across the entire supply chain, which results in hidden or underestimated costs.

Obviously, there is no single correct logistics system structure for any type or sector of company. However, due to the specificities of industrial activities, and specifically manufacturing, it is possible to identify subsystems within the logistics activity that are common to most manufacturing companies. Therefore, evaluating the simplified structure of a manufacturing industry, it can be defined as activities involving purchasing, transportation, planning, and warehousing. A typical manufacturing company purchases products from its suppliers, transports, and stores them. These activities involve labor, freight, input, and depreciation costs. Therefore, a logistics activity structure can be established for this type of company, as shown in Figure 1 below, which will integrate supply chain management.

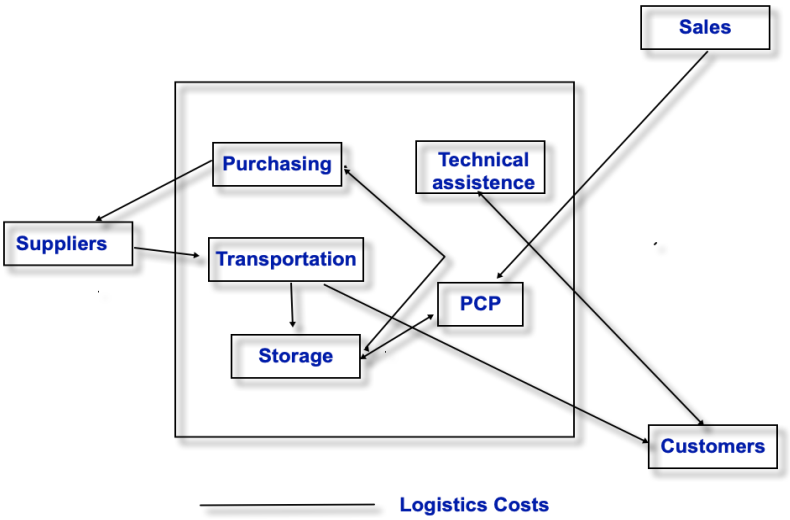

Figure 1: Logisticscost structure

Source: Adaptation of Pozo (2021)

The diagram in Figure 1 makes it clear that supply chain management involves activities that seek optimal integration of the logistics process with suppliers and customers. The flow of information and relationships in the diagram is viewed as a total number of customer orders. There are other information flows and actions that are not shown in the diagram and are not components of the total logistics cost.

According to Ballou (2004) states, any business can generate four types of value in products or services, under the following conditions: form, time, place, and possession (price). The form condition is when the product is available and ready for consumption. For the consumer, in addition to the form condition, the time and place condition is also important, being in the right place and available to purchase (price), which is the possession condition. Thus, the product will only have effective value if the customer can find it where and when they need it.

The goal of information sharing is to improve efficiency Bowersox & Closs (2013)., but inaccurate or distorted information can cause more problems than benefits for an organization. As Lewis Culliton & Steele (1956) add that, for success in the logistics process, it is important to have an information system, resulting in faster responses to consumer inquiries. As Ballou (2004) emphasizes the importance of using IT to store information, m5king procedures related to information processing more structured. However, sharing information and changes among people is still seen as threatening because many fear losing their power (Katunzi, 2011).

Logistics cost control is still inefficient, and companies are accelerating control methods and the use of new tools. Therefore, companies are focusing on technology research, which not only improves technical and control levels but also the overall speed of development, aiming to achieve total logistics cost control.

Obviously, developments in logistics cost control tend to be improved. And, due to a lack of resources, many auto parts companies fail to optimize labor, material, and financial resources in logistics operations. An alternative, employed by some companies, is

outsourcing the logistics sector, which generally has not led to greater use of technology and innovation for cost control (Lambert & Stock, 2013). Currently, most companies only consider the speed, safety, and reliability of services, focusing on what leads to lower logistics costs.

At the same time, these companies also failed to consider the progress and cost of the entire supply chain, resulting in a lack of integrated logistics cost control. However, many problems exist in our country. Many logistics costing methods and their degree of control fail to consider the supply chain as an integrated system, resulting in high costs for the company by failing to account for all the components that impact the reality of logistics costs.

Before developing a model for calculating the logistics cost of a product, including all its functions, it is important to study the relevant literature. The literature review covers production costs, with special attention to subtopics related to logistics. Several case studies have been conducted to determine which product cost models' companies use and which allocation bases are applied to determine the total logistics cost (Alnestig & Segerstedt, 1996). It has been noted that accounting systems are designed primarily to meet accounting demands; therefore, an additional costing model is necessary for adequate logistics costing. For Alnestig & Segerstedt (1996), companies seek to allocate costs in the most logical way possible, within a limited timeframe and with other scarce resources.

Traditional accounting systems, designed for financial reporting rather than logistics, often group costs into overly aggregated categories, preventing detailed analysis. This limitation leads to underestimation of total logistics costs and hinders decision-making (Alnestig & Segerstedt, 1996).

Supply Chain Management (SCM)

The basic objective of SCM is to create synergy among the elements of the production chain, reducing costs while improving customer satisfaction Oke, Prajogo & Jayaram (2013); Pozo (2021). SCM requires cooperation across organizations and emphasizes the control of total costs, service quality, and profit maximization (Pozo, 2015).

As Slack, Brandon-Jones & Burgess (2022) defines SCM as the comprehensive management of supply flows, from raw materials to final distribution to customers. However, Chopra & Meindl (2019) warn that technology alone does not guarantee information quality, as inaccurate or conflicting data can create operational inefficiencies.

Strategic partnerships are central to SCM, as they integrate suppliers, business processes, and customers into a cohesive system (Katunzi, 2011). While internal and external integration is challenging, companies that successfully implement SCM achieve benefits such as market share growth, reduced inventories, lower costs, shorter lead times, flexibility, improved forecasting, and higher customer satisfaction (Lewis Culliton & Steele, 1956).

To remain competitive, companies must deliver high-quality goods and services at lower prices according to Chopra & Meindl (2019). This often requires external partnerships since firms are less vertically integrated today and increasingly depend on supply chain collaboration (Pozo, 2015).

There is a rich literature on the topic of integration that highlights the benefits of internal integration in ensuring that departments are unified toward a single corporate objective, and Fugate & Stank (2010) agree, discussing how a focus on functional excellence should drive corporate goals. Strategic integration combines resources and competencies across business units and companies to support and advance corporate strategy. In this sense, strategic integration may have a stronger relationship with improved performance because the basis for integration is not operational in nature Sergeev & Zinina (2014).

For these reasons, supply chain management needs to control its dynamics, delivery schedules, and product inventory over time. Therefore, a methodology for simultaneously controlling the entire process involving all actors in a supply chain is necessary. The benefits of integration must be maintained within the firm boundaries of the chain. Companies integrate with external supply chain partners to optimize business processes to meet customer demand. External integration has been shown to positively benefit customer service, innovation, and new product development (Marchesini & Alcântara, 2016).

Strategic integration aligns resources and competencies across business units and firms, directly influencing corporate strategy and performance (Wiengarten & Singh, 2019). The external integration positively impacts customer service, innovation, and new product development Oke, Prajogo & Jayaram (2013). Yet, achieving such integration remains a challenge, as companies struggle with resistance to change and coordination complexities according to Fawcett, Hofer & Fawcett (2014).

Logistics Costs

One of the most relevant concepts in logistics is the determination of total logistics cost, which includes all functional areas of logistics and SCM (Chopra & Meindl, 2019); Özbayrak, Akgün & Türker, 2004). Total logistics cost is inherently complex, comprising multiple direct and indirect components that interact with each other (Pozo, Tachizawa & Souza, 2011); (Pudło & Szabo, 2014).

According Bokor (2010) defines total logistics cost as the sum of transportation, inventory, order processing, and customer service costs. From a supply chain perspective, this approach requires consideration not only of internal costs but also of those arising externally, across all supply chain actors.

Many companies, regarding logistics activities, have little or no evidence or detail on how to control and account for all logistics-related costs. This lack of cost information that is useful for decision-making and the control of logistics activities leads to a misinterpretation of costs and, therefore, the need to develop a methodology instrumentalized in the management approach with specific objectives to obtain accurate and more realistic logistics costs. However, a change is observed in companies that have always managed their logistics activities but did not always have a clear idea of how much this cost them, at least until the 1990'S (Ballou, 2004).

According to Bowersox & Closs (2013), the first application of cost to logistics activities was presented by Miguel & Brito (2010) in *The Role of Air Freight in Physical Distribution* (1956), under the thesis that in situations where the speed and dependence on air distribution produced other costs, such as warehouses and inventory. One of the main difficulties many companies face when adopting a logistics cost approach is the lack of

information about the components of these costs. Conventional systems group costs into very narrow, aggregated categories, preventing a more detailed analysis (Miguel & Brito, 2010).

According to Lambert & Stock (2013), who proposed that the supply chain and all its connected components be assessed and controlled at each stage and process, right up to the end consumer, as a cost absorption tool, Fawcett, Hofer & Fawcett (2014) presented the composition of logistics cost theory and the supply chain as consisting of three levels: transaction costs, operating costs, and direct costs.

Many companies have difficulty calculating logistics costs accurately, generating many problems and doubts, according to Song (2014). An analysis and calculation of the total logistics cost involving the processes of each link in the supply chain must be performed. When processing logistics costs, companies only account for transportation and storage data, ignoring other logistics costs such as order processing, purchasing, handling, controls, personnel, technical assistance, etc., which directly impact the company's logistics costs, involving an analysis of the entire supply chain (Pozo, Tachizawa & Souza, 2011).

As already discussed, the cost categories involved in logistics are divided into activities related to transportation and cargo handling; storage and inventory management; planning, purchasing, and indirect activities. This approach, widely used to classify logistics costs and Franco & Gasparetto (2020); Rybakov (2017), suggests a set of performance metrics that encompass various factors and controls within the context of a company's entire supply chain management approach (Pozo, 2021).

As presented by Fawcett, Hofer & Fawcett (2014), total logistics costs include transportation, storage, inventory transportation, logistics administration, packaging, and indirect logistics costs. According to Pudło & Szabo (2014) identify seven categories of logistics costs, namely: transportation costs, inventory holding costs, storage costs for raw materials, materials, semi-finished products, finished product inventory holding costs, logistics administration, and finished product storage. Pudło & Szabo (2014), in their most recent study, introduced an overview of approaches to identifying total logistics costs, also involving tax and logistics administration.

Total absorption costing, that is, the allocation of indirect costs based on direct costs, has been frequently criticized. It used to be an adequate tool, provided the direct cost ratio was high in production systems. Current operations systems, however, are complex, automated systems with a high rate of indirect costs, where ABC costing can be applicable. ABC costing can be a good solution using simulations (Özbayrak, Akgün & Türker, 2004).

Many firms struggle with accurately calculating logistics costs, often focusing solely on transportation and warehousing while ignoring costs associated with procurement, order processing, material handling, technical assistance, and labor (Pudło & Szabo, 2014). This results in incomplete cost assessments and weak managerial decision-making.

Activity-Based Costing (ABC) has been identified as a more effective methodology for logistics costing, especially in complex, automated systems with high indirect costs, according to Özbayrak, Akgün & Türker (2004); Wiengarten & Singh (2019). ABC models, when combined with supply chain-based approaches, enable more accurate allocation of indirect costs such as warehousing, handling, and support services (Ballou, 2004).

Therefore, effective logistics cost management requires detailed analysis of each process and its integration into a holistic total cost model. This approach enhances managerial decision-making and supports competitive advantage through optimized supply chain performance.

METHODOLOGICAL PROCEDURES

This study adopted a qualitative research design, structured around bibliographic, descriptive, and exploratory approaches, with a focus on identifying and analyzing specific data and information on logistics costs. It is considered exploratory because its main purpose is to develop, clarify, and refine concepts and ideas to guide further research. It is also classified as applied research, since its results can be directly implemented to improve managerial practices, and descriptive, as it sought to portray reality as it is, without intervention (Creswell & Poth, 2018).

Following these methodological guidelines, a multiple-case study was conducted in the metropolitan region of São Paulo, involving seven manufacturing firms in the auto parts sector. According to Wiengarten & Singh (2019), case study methodology allows for theoretical analysis to be organized coherently through established frameworks, derived from a review of seminal works in logistics and supply chain management.

The qualitative approach was chosen because the study required intentional sampling, open-ended data collection, and textual analysis of both primary and secondary sources. A defining characteristic of this approach is that the researcher observes, listens to, and interprets real-life phenomena directly.

The central research question guiding this study was: “How can total logistics costs be established from the perspective of supply chain management?”

To address this question, both primary and secondary data were collected. Primary data came from semi-structured interviews, direct observation of processes, and document analysis within the selected firms. Secondary data included articles, reports, and books on logistics costs.

Fifteen semi-structured interviews were conducted with managers and specialists from the seven manufacturing firms between July and September 2019, each lasting approximately 50 minutes. The interviews focused on logistics practices, cost structures, and supply chain integration. Observations of operations complemented these insights, ensuring alignment between reported practices and actual processes.

The data analysis was carried out by grouping responses according to the hierarchical levels of participants. This method ensured alignment of perceptions among groups with similar roles, responsibilities, and organizational profiles, providing a structured view of logistics cost management across the companies studied.

ANALYSIS AND RESULTS

The logistics function must implement a comprehensive cost control system not only within the company but also in connection with external activities across the supply chain. Effective cooperation among supply chain actors is essential to achieve accurate logistics

cost management. As Ibarra-Rojas Giesen & Rios-Solis (2014) argue, logistics cost control should be based on the total logistics cost of the supply chain rather than focusing on minimizing costs in isolated activities. Thus, companies should integrate logistics resources across their operations to ensure that cost management is embedded throughout the entire supply chain.

Proposal of a Costing Model

This research developed a concrete costing model that describes the operation of a logistics operation encompassing all its activities, both internal (direct) and external (indirect). The initial step was to utilize the research results prepared by (Ballou, 2004), Bokor (2010), and Bokor (2011). The general principles developed, but they need to be adapted to the specific needs of logistics costs, with special attention given to the integration of objects and relationships inherent to logistics and their involvement in the supply chain. However, it is necessary to establish a comprehensive and consistent cost absorption model that can cover the entire chain.

In this model, direct costs are classified under essential as primary logistics activities, such as transportation, warehousing, planning, and procurement. and procurement. Unlike Activity-Based Costing (ABC), which uses cost centers, this model incorporates performance intensity coefficients to allocate indirect costs across the supply chain. These coefficients reflect the relative consumption of resources by different supply chain processes. The ABC model uses cost centers/activities instead of cost objectives, the latter focusing on corporate profit objectives.

The relationships in the model reflect performance consumption, and since cost objectives maintain internal and external service relationships involved in the supply chain management process, their total costs also include so-called secondary costs, which can be allocated using a performance-related consumption ratio, called the chain's performance intensity coefficient.

Another important factor is the level of logistics service, and it is known that the higher and better it is, the higher the logistics costs. Several studies have been conducted to identify the optimal logistics service level Guarnieri & Hatakeyama (2010); Ibarra-Rojas Giesen & Rios-Solis (2014). The most significant indicators of logistics service are related to order cycle time and order fulfillment time. The first factor that most influences logistics costs is order fulfillment time, and order cycle time includes the lead time values of all logistics processes.

Objectively, the ABC costing method consists of allocating all production costs to the goods and/or services produced, including direct, indirect, fixed, or variable costs, through direct allocation to each activity. The method considers the expenses inherent to the goods and services—that is, all costs incurred in their production—thus enabling the calculation of all production costs—variable, fixed, direct, and indirect. Therefore, identifying the optimal balance between service quality and logistics cost is a critical decision.

Thus, the level of logistics service affects the costs related to individual processes and, consequently, the value of total logistics costs. It is necessary to identify and classify the most essential logistics costs of all core activities. Special attention should be paid to costs sensitive to process time and order cycle time, as reported by Das & Hanaoka (2014)

as well as those sensitive to inventory turnover. According to Sergeev & Zinina (2014), the structuring and classification of logistics costs, based on their location and function, is a common approach recognized by the scientific community.

The model applies the ABC methodology for allocating both direct and indirect costs. This approach ensures that all logistics activities—whether related to purchasing, storage, transportation, planning, or after-sales services—are fully considered in the calculation of Total Logistics Costs (TLC). Based on this conclusion it is possible to identify the most substantial logistics cost items for a manufacturing company. For reference, the logistics costs reported in Table 1, below.

Table 1: Main elements of a company's total logistics cost

Department	Activity	Direct Cost	Indirect Cost	Cost of SCM
Purchase	Management of purchase	Personal cost	Depreciation and input costs	Part of the personal expenses in the areas of the product, process involved in support and operational activity to keep the SCM operating
Storage	Management of storage	Personal cost	Depreciation and engineering input costs	
Transports	Management of Transports	Personal cost	Depreciation and input costs	
Planning	Management of Planning	Personal cost	Depreciation and input costs Order	
Sales control and technical assistance.	Management of Sales and technical assistance.	Personal cost	Depreciation and input costs	

Source: Research data

According to the table above, purchasing and supply-related costs involve personnel allocated to the department, the depreciation of its assets and inputs, as well as a portion (%) of SCM costs related to purchasing:

- Warehouse maintenance costs (storage) include human resources, the depreciation of its assets and inputs, as well as a portion (%) of SCM costs related to storage,
- Transportation costs include human resources, the depreciation of its assets and inputs, as well as a portion (%) of SCM costs related to transportation and handling,
- Planning costs include human resources, the depreciation of its assets and inputs, as well as a portion (%) of SCM costs related to planning,
- Sales control and technical assistance costs are those related to human resources in the department, the depreciation of its assets and inputs, as well as a portion (%) of SCM costs related to technical assistance and sales support.

Based on the ABC costing model for manufacturing operations, which can be combined with other methods based on similar parameters, and specifically when involving logistics and the supply chain, these combined approaches can be applied primarily in the more accurate costing and execution phases. Therefore, ABC costing can be used as a tool to support the preparation of total logistics costs and opens the possibility of applying procedures to more accurately execute and control logistics costs.

According to Das & Hanaoka (2014, although the principles of ABC costing are applicable to supply chains, practical application has been internally rather than externally oriented. Criticism concerns the lack of development of tools and models for applying ABC

costing to supply chains, leading practitioners to doubt that current tools will be sufficient to accurately detail supply chain management costs. Therefore, the model presented here, in which the logistic cost (LC) has been redesigned to be applicable to supply chain management as well. Cost items should be applied to each department in the logistics sector and all processes related to supply chain management. According to formulas 1, 2 and 3, below, adapted from the model of Bokor (2010) the total logistics cost, which is the object of this cost model, can be calculated as mathematically, the total logistics cost can be expressed according to formula 1 below:

$$\boldsymbol{LC} = \sum_n^1 prm + \sum_n^1 trp + \sum_n^1 srm + \sum_n^1 sfg + \sum_n^1 tfg + \sum_n^1 pcp + \sum_n^1 ass \quad (1)$$

where:

$\sum_n^1$ **prm** = sum purchases of raw materials

$\sum_n^1$ **trp** = sum transportation of raw materials

$\sum_n^1$ **srm** = sum storage of raw materials

$\sum_n^1$ **sfg** = sum storage of finished goods

$\sum_n^1$ **tfg** = sum transportation of finished goods

$\sum_n^1$ **pcp** = sum production planning and control

$\sum_n^1$ **ass** = sum after-sales services

To complement this calculation, the performance intensity coefficient **(k)** was introduced, representing indirect personnel costs related to product engineering, process engineering, finance, quality, and sales. This coefficient is defined according to formula 2 below:

$$k = \frac{IPC}{LC} \quad (2)$$

where:

IPC = indirect personnel costs

LC = logistics costs.

Therefore, to determine the total logistics cost, it is necessary to calculate the sum of the costs of each logistics activity (LC) plus the cost of maintaining management of the entire supply chain (services), involving all suppliers and customers in the chain (intensity coefficient k). Purchasing, planning, sales control and technical assistance, transportation, and warehousing costs are primary, but indirect, as they are already accounted for in the operational costing system. Supply chain management (services) costs are secondary because they are based on supply chain performance intensity data (k) due to the difficulty in obtaining accurate cost values. The Total Logistics Cost (TLC) is calculated according to formula 3 below:

$$\boldsymbol{TLC} = (\sum_n^{1\,1} prm + \sum_n^1 trp + \sum_n^1 srm + \sum_n^1 sfg + \sum_n^1 tfg + \sum_n^1 pcp + \sum_n^1 ass)\,(1 + k) \quad (3)$$

This model highlights that logistics activities (transportation, warehousing, planning, procurement, and customer support) represent direct costs, while supply chain management services represent indirect costs that require proper allocation. The k coefficient was obtained using data provided by the companies surveyed, which are shown in Tables 1 and

2 presented in section 4.2, data analysis. An important element in the discussion is that supply chain performance intensity indicators (k) play a crucial role in the cost allocation process. Therefore, the selection of cost factors and the measurement of their distribution within the performance process must be carried out accurately. In addition to system-specific information, the experience of experts and/or managers responsible for the areas of the activities examined will be useful for their appropriate allocation.

Since logistics activities can be incorporated into the general scheme for calculating the total logistics cost defined above, these activities in the company are primarily factors involving transportation, warehousing, planning, technical assistance, and the procurement process. Services, within the supply chain, are allocated secondary to the main activity—that is, core logistics activities. Therefore, logistics activities should be considered cost targets, representing direct costs, and services as indirect costs, producing final cost performance. Another condition for adding logistics cost objectives is the separate recording of logistics cost items and the separate measurement of performance indicators or intensities Alnestig & Segerstedt (1996).

Cost Data Analysis of Companies

Data were collected from the seven manufacturing firms analyzed (referred to here as Companies A–G). Table 2, presents the logistics costs broken down by activity in each firm.

Table 2: Logistics Costs of the Companies Analyzed (monthly values, in USD)

Activity	Company A	Company B	Company C	Company D	Company E	Company F	Company G
Procurement	16.210	94.750	218.680	164.730	84.730	235.960	110.400
Wareshousing	7.380	38.040	77.750	31.610	31.710	66.750	45.010
Transportation	57.350	377.460	671.950	373.360	373.285	691.010	403.500
Planning	8.705	58.740	73.960	43.560	44.050	85.550	50.530
Sales & technical support	3.880	34.750	61.000	22.880	23.850	57.100	26.910
Logistic cost	93.525	603.740	1.103.340	636.140	557.625	1.136.380	636.350

Source: Research data

To determine the performance coefficient (k), companies provided monthly data on personnel costs in product engineering, process engineering, finance, quality, and sales. Table 3, bellow, is presents these values and the resulting k coefficients.

Table 3: Performance Intensity Coefficient (k) of the Companies (monthly values, in USD)

Activity	Company A	Company B	Company C	Company D	Company E	Company F	Company G
*Total personal costs (product engineering, process, finances, quality & sales)	148.200	946.700	1.770.000	821.140	557.625	1.990.580	790.500
**Partial Costs Support/SCM (PCS)	8.310	53.900	101.510	55.820	45.090	99.770	51.400
Logistics Cost	93.525	603.740	1.103.340	636.140	557.625	1.136.380	636.350
Coefficient K (%) k = PCS / LC	8,89	8,93	9.20	8,81	8,14	8,78	8,08

Source: Research data. Obs.: The value shown in item ** is the corresponding part of item * used to calculate logistics costs.

The results show a very similar **k** coefficient across all companies, with maximum variation between companies are G (8.08%) and C (9.20%), and an overall average of 8.69%. Therefore, an average **k** coefficient of 8.7 was established.

To calculate the Total Logistics Cost, Formula 3, proposed by the authors, was used, with the data obtained in Table 4, which is represented below.

Table 4: Preparation of total logistics costs (monthly values, in USD)

Activity	Company A	Company B	Company C	Company D	Company E	Company F	Company G
Logistics Cost	93.525	603.740	1.103.340	636.140	557.625	1.136.380	636.350
Each company K coefficient	8,89	8,93	9.20	8,81	8,14	8,78	8,08
Total Logistic Cost Each company's *k*	101.840	654.380	1.204.840	685.550	599.050	1.236.080	687.450
Established *k* for ll company	8,7	8,7	8,7	8,7	8,7	8,7	8,7
Total Logistic Cost*	101.660	656.255	1.199.330	689.110	602.150	1.235.170	691.400

Source: Research data, Obs.: *Using the standardized coefficient k of 8.7

Comparing the values obtained with the established coefficient **k** and with the results of each company surveyed, a very small difference in values (percentage and monetary) is observed, justifying the average value of k to 8.7%.

CONCLUSION

Depending on the specific circumstances of each manufacturing company and the different processes within its supply chain, firms adopt distinct costing methods to achieve their strategic objectives. This research was developed from a supply chain perspective, analyzing total logistics costs both globally and locally, with the aim of designing a more precise model for calculating Total Logistics Costs (TLC).

The findings highlight the need to improve logistics cost control systems and, depending on the requirements of the supply chain, decompose logistics resources using Activity-Based Costing (ABC). This approach enables a more focused analysis, generating precise and specific data for managerial decision-making.

As logistics activities are directly linked to corporate strategy, the proposed total logistics cost model represents a valuable managerial tool. It supports managers in controlling real costs that affect logistics performance, identifying and reducing unnecessary expenses, and ultimately enhancing efficiency. The model also assists in evaluating outsourcing decisions, frequently adopted in both internal and external logistics services.

Thus, the proposed theoretical model fulfills the methodological requirements for determining a more accurate and realistic calculation of total logistics costs. The model proved to be quite reliable and becomes a very important tool for determining the total logistics cost involving the entire supply chain of an industry. Nevertheless, some limitations were identified. The study was restricted to seven firms in the auto parts sector in the metropolitan region of São Paulo. Therefore, its findings cannot be generalized to all industries or geographical regions. Future research should replicate this study with firms of

different sizes and in other industrial sectors and regions. Furthermore, employing more rigorous methodological approaches may strengthen the robustness of future analyses.

In conclusion, this study contributes to the understanding of logistics cost management by providing insights into the integration of direct and indirect costs across the supply chain. The model proposed here offers relevant knowledge to logistics managers and establishes a foundation for further research on total logistics costing within supply chain management.

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