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Knowledge and Assessment of Logistics Cost Trade-offs: a Study with Brazilian Professionals*

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ABSTRACT

The balance between costs incurred and the service provided to the customer depends on the identification and exploitation of logistics cost trade-offs. In this sense, the goal of the present study was to identify the extent to which Brazilian logistics professionals understand and assess cost trade-offs. To this end, a questionnaire based on the theoretical framework was administered to a sample of 73 professionals at commercial and industrial companies that were included on the list of the largest Brazilian enterprises in the 'Melhores and Maiores' (Best and Biggest) edition of Exame Magazine. The questionnaire's reliability was ascertained using Cronbach's Alpha (90.8%), and the data thus gathered were quantitatively analyzed through descriptive statistics and the non-parametric Mann-Whitney test. The results showed that most logistics professionals know that there are trade-offs but lack a broad understanding of the concept, especially with respect to the relationship between trade-offs and total cost. Nonetheless, the knowledge that logistics have an impact on economic-financial performance appeared to be widespread for most of the sample, particularly among experienced professionals. The results also revealed that although trade-off assessments are emphasized when designing and redesigning logistics processes and networks, these assessments are still limited in regard to the formulation of specific projects. The non-use of cost simulators and lack of adequate cost information were identified as factors related to the limited assessment of trade-offs. These findings are important because they demonstrate that a company's controllership can help logistics professionals to reverse this situation of non-assessment of trade-offs and to strive for the optimization of economic results.

Keywords: Logistics. Total Cost. Logistics Costs. Logistics cost trade-offs.

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1 INTRODUCTION

A product that is well-conceived, excellently packaged and broadly advertised is worthless if it is unavailable when the customer wants it (LaLonde, 1993). Thus, logistics, which bears the primary responsibility for the right product being at the right place at the right time in the right amount under the right conditions for the right price with the right information, is of the utmost importance (Mentzer, Flint & Hult, 2001).

After initially being restricted to the military realm, logistics began to extend into business operations in the middle of the 20th century. Its dissemination in the corporate environment was characterized by the fragmentation of several logistics activities among multiple organizational areas, which resulted in conflicting goals and high costs (Ballou, 2007).

The fragmentation of logistics activities also showed that the optimal total cost could only be achieved with integrated logistics and with trade-off assessments conducted by logistics professionals (Lambert & Armitage, 1979; Christopher, 1997). Given this context, the present study aimed to (1) investigate the extent to which logistics professionals understand trade-offs; and (2) identify whether professionals assess trade-offs when designing and implementing solutions.

The two questions that guided this study are as follows: "To what extent do logistics professionals understand logistics cost trade-offs?" and "Do logistics professionals assess logistics cost trade-offs?" The answers to these questions were obtained by adopting an empirical-analytical approach involving the administration of a questionnaire to 73 logistics professionals at Brazil's largest industrial and commercial companies as ranked by the 2010 'Melhores e Maiores' (Best and Biggest) edition of Exame Magazine. The data were quantitatively analyzed using descriptive statistics and hypothesis testing.

There are both Brazilian and international studies (Lambert & Armitage, 1979; Christopher, 1997; Bio, Robles & Faria, 2002; Faria, 2003; Fellous, 2009) that acknowledge the existence of trade-offs and discuss the necessity of trade-off assessments. However, these studies explore logistics costs in a broad-brush manner and thus end up treating trade-offs as an accessory topic rather than the primary focus of the study. Therefore, a more in-depth analysis of trade-offs might help to fill the gaps in the literature and provide both theoretical and practical contributions.

This article's main contribution to theory is that it provides a structured means to measure the knowledge and assessment of trade-offs. This structure reduces inconsistencies, improves comparability between studies and encourages the emergence of criticisms on the topic.

From a practical point of view, this article promotes interdisciplinarity by integrating logistics with accounting. This study contributes to logistics by showing that the analysis of trade-offs is necessary to find the balance between resource consumption and service provision (Busher & Tyndall, 1987). In addition, this study contributes to accounting by demonstrating that the assessment of trade-offs is a fundamental step in optimizing total cost and thereby improving the organization's global economic result.

2 THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

Although there is evidence of logistics that dates back at least as far as the construction of the pyramids, logistics were widely perceived until the 1950s as contextually associated with military supply, maintenance and transportation.

A limited expansion of logistics into the business milieu did not start to occur until the second half of the last century. Shortly thereafter (between 1960 and 1970), there were indications that the results achieved by business logistics – which at that time were implemented in a fragmented manner – were not good: there were marked interdepartmental conflicts, costs were high, and the level of customer service was low (Ballou, 2007). These indications made it clear that change would be necessary and drove the emergence of integrated logistics (Lambert & Armitage, 1979).

Integrated logistics aimed to establish a situation that reduces conflicts between business areas and promotes both customer service and profit generation. For that purpose, and knowing that (1) customer satisfaction depends on the level of services provided and (2) profit generation depends on the total cost incurred in the provision of said services, integrated logistics sought to offer solutions that achieved optimal service levels with minimum total cost (Faria & Costa, 2005).

The level of customer service is a measure of productivity in the creation of time and place utilities (Lambert & Lewis, 1983) and is, together with total cost, one of the pillars of integrated logistics. Each level of service determines profit because each level leads to different revenues and different costs.

If no service is provided, then costs are low but no time and place utilities are created and no sales take place. As the level of service is improved, costs rise, but time and place utilities are created and sales are stimulated. In light of this situation, Sabath (1978) maintained that the optimal level of service is the one that retains customers at the lowest possible total cost.

The concept of total cost was introduced in 1956, when Lewis, Culliton and Steele (1956) showed that logistics decisions should not be considered in isolation because logistics activities' costs are interrelated. As an example, the authors emphasized that air freight could replace waterway transportation if airplanes' greater speed and reliability caused the increase in transportation costs to be compensated by lower costs in inventory maintenance, storage and packaging.

The importance of the concept of total cost was later expanded under the rubric that all logistics solutions should aim to optimize total cost rather than to reduce individual

costs (Christopher, 1994) because no cost can be modified without affecting other costs and/or customer service (Gopal & Cypress, 1993).

For example, the centralization of facilities helps to reduce storage costs but makes the planning, coordination and execution of a high level of service more difficult and time-consuming. Conversely, a larger number of facilities broadens market coverage and the level of service but simultaneously increases some logistics costs (for example, costs associated with inventory and storage) as it reduces others (for example, the transportation cost). Moreover, a network with several facilities that are far-removed from customers can offer the same level of service as a network with several facilities located close to customers if the former implements a transportation strategy that reduces response time; however, such a transportation strategy is likely to incur higher costs. All of this occurs because there is a reaction by each logistics component to each plan of action considered when designing solutions (Napolitano, 1997), as exemplified in Table 1:

Table 1 *Examples of actions and reactions in logistics solutions*

Logistics solution (action)	Effect on customer service (reaction)	Effect on transportation (reaction)	Effect on inventory (reaction)	Effect on warehousing (reaction)
Centralization	Products located far from customers	Lowers the inbound transportation cost but increases the outbound transportation cost	Reduces the need for safety stocks	Reduces facilities costs
Decentralization	Products located close to the customers	Increases the inbound transportation cost but lowers the outbound transportation cost	Increases the need for safety stocks	Increases warehouse costs due to the duplication of specialized personnel, equipment and facilities
Use of air mode	Provides timely responses	Higher cost	Reduces inventory due to shorter replenishment cycles and shorter transit times	Increases the number of handlings due to the large number of deliveries
Use of rail mode	Provides less timely responses	Lower cost	Increases inventory due to longer replenishment cycles and transit times	Increases the number of handlings (products are normally not on pallets)

Source: Adapted from Napolitano (1997).

The possible reactions to each proposed action must be analyzed to identify the solution that provides the optimal level of service with the minimum total cost. This requires the identification of substitutions of one cost element with other cost elements, i.e., logistics cost trade-offs (Bio et al., 2002).

Trade-offs are compensatory exchanges between the increase of some logistics costs and the reduction of other logistics costs and/or an increase in the level of customer service. For example, the decision to replace non-waterproof packaging with waterproof packaging increases packaging costs but reduces transportation costs because waterproof packaging allows the use of open-air transportation mode.

Although Lewis et al. (1956) tacitly proposed the notion of trade-offs, it was Lambert and Armitage (1979) who grounded the concept and demonstrated that trade-offs must be assessed. Such an assessment basically involves the identification and measurement of the possible reactions of logistics components to proposed actions. Because logistics professionals are responsible for controlling the resources consumed to achieve a particular level of customer service (Busher & Tyndall, 1987), they are the ones who must identify and assess the trade-offs.

Taking into account that experience has a direct influence on an executive's knowledge and skill (Myers, Griffith, Daugherty, & Lusch, 2004) and considering that an experienced logistics professional can immediately visualize an area's problems and react promptly and aggressively to solve them (Slone, Mentzer, & Dittmann, 2007), hypothesis H_1 is thus formulated: knowledge of logistics cost trade-offs is positively associated with the experience of logistics professionals.

Because formal education broadens professionals' knowledge base, it also helps professionals to identify problems and can minimize logistics errors and the subsequent need to rework solutions. Therefore, based on the argument of Myers, Griffith, Daugherty and Lusch (2004) that formal education is one of the main sources of logistics professionals' astuteness, hypothesis H_2 is proposed: knowledge of logistics cost trade-offs is positively associated with the formal education of logistics professionals.

According to van Hoek, Chatham and Wilding (2002) and Hult, Ketchen Jr., Cavusgil and Calantone (2006), knowledge is only relevant if it is converted into true understanding and applied to problem-solving and decision-making. With this in mind, it must be emphasized that it is not enough to have knowledge of trade-offs per se; rather, one must employ it in the analysis of countless possible solution designs.

The complexity that permeates the design of logistics solutions calls for tools that assist in data processing (LeKashman & Stolle, 1965). Given that the use of information systems and computer technology facilitates the quick and precise identification of cost optimization opportunities (Gustin, Daugherty, & Stank, 1995), hypothesis H_3 is thus constructed: the assessment of logistics cost trade-offs is positively associated with the use of cost simulators.

The availability of adequate cost information is another requirement for assessing trade-offs. This is because calculating trade-offs and analyzing total costs depend on the detailed disaggregation and disclosure of logistics costs (Bio et al., 2002; Fornaciari, Pereira & Zanquetto Filho, 2003; Waller &

Fawcett, 2012). Accordingly, hypothesis H_4 is thus proposed: the assessment of logistics cost trade-offs is positively associated with the adequacy of accounting information.

In sum, this section has presented the theoretical framework that supports the notion that the optimization of total logistics costs depends on the analysis of trade-offs, which in turn depends on logistics professionals' applied knowledge. In the next section, the path that is taken to convert this theory into observable propositions is described. Such propositions allow one to identify the extents of professionals' knowledge and assessment of trade-offs and operationalize the test of the four proposed hypotheses.

3 STUDY DESIGN AND METHODOLOGICAL ASPECTS

This study is characterized as both descriptive and exploratory. It is descriptive because it sought to identify and illustrate the extents of knowledge and assessment of trade-offs; it is exploratory because it sought to determine the factors associated with these extents. Using an empirical-analytical quantitative approach, 73 commercial and industrial companies in Brazil were examined with a survey that involved the administration of a questionnaire.

This section presents the study design and provides details regarding the following elements: constructs and operational definitions of variables; the research instrument; population and sample; and the structure of the analysis of results.

3.1 Constructs and Operational Definitions of Variables

Constructs are created so that reality may be examined through particular, observable and measurable propositions that are supported by a theoretical foundation (Martins & Theóphilo, 2009). In this study, constructs were designed to investigate the extents of knowledge and assessment of trade-offs and, in addition, to identify factors possibly associated with these extents.

3.1.1 Knowledge of logistics cost trade-offs

The variables related to the construct for knowledge of logistics cost trade-offs were established based on the observation by Myers et al. (2004) that rational knowledge stimulates the holistic visualization of problems and improves the decision-making process. Based on the study by Lambert and Armitage (1979), it can be ascertained that a rational knowledge of trade-offs translates to an awareness of the following:

(1) The existence of trade-offs – The knowledge that logistics costs have heterogeneous behaviors and that an increase in the cost of one logistics activity can be compensated by an increase in revenue (due to the improved level of service) or a reduction in the costs of other logistics activities, and vice-versa; and

(2) The relationship between trade-offs and total cost – The knowledge that to achieve optimal total cost, one must not resort to normal cost-cutting techniques because the individual elimination of some costs can lead to the emergence or increase of other costs (2a). In short, it is the knowledge that the total cost is determined by trade-offs (2b).

Later, some authors (Christopher & Ryals, 1999; Presutti & Mawhinney, 2007) warned that it is not enough to be aware of the impact of logistics on total cost but that logistics professionals must also have knowledge of the following:

(3) Economic-financial impacts – The knowledge that logistics solutions design and the consequent trade-offs affect countless economic-financial dimensions. For example, logistics decisions have evident impacts on costs, revenues and the efficient use of fixed and working capital.

These three variables were assessed through four mandatory questions based on a Likert scale in which the respondent indicates how much he/she agrees or disagrees with a given statement (Martins & Theóphilo, 2009). Agreement or disagreement with the statements is rated in a five-point scale, the extremes of which are related to low and high levels of knowledge.

The five-point Likert scale was selected to offer respondents the option of choosing an intermediate position (corresponding to a moderate level of knowledge, i.e., neither weak nor strong). Note that Weijters, Cabooter and Schillewaert (2010) do not recommend the use of scales without an intermediate point because such scales put respondents with neutral postures in an uncomfortable situation in which they feel compelled to choose a polarized position that does not represent their true perception.

Table 2 presents the four questions, describes the extremes of the Likert scale and identifies the main works that support the variables' definitions:

Table 2 *Variables for knowledge of logistics cost trade-offs*

VARIABLE	QUESTION	SCALE EXTREMES	REFERENCES
(1)	Is it a widespread notion in your company that, due to the existence of cost trade-offs, an increase in the cost of one logistics activity may be compensated by increased revenue (originating from a better level of customer service) or by reduced cost in some other logistics activity, and vice-versa?	5= Notion is very widespread 1= Notion is not widespread	Lambert & Armitage (1979)
(2a)	Is it a widespread notion in your company that the reduction of individual costs may increase rather than reduce total logistics costs?		Lambert & Armitage (1979)
(2b)	Is it a widespread notion in your company that the total logistics cost is determined by cost trade-offs?		Lambert & Armitage (1979)
(3)	Is it a widespread notion in your company that logistics have an impact on the company's economic-financial performance?		Christopher & Ryals (1999); Presutti & Mawhinney (2007)

3.1.2 *Assessment of logistics cost trade-offs.*

The variables related to the assessment of logistics cost trade-offs were defined based on the notion that a company's analysis of trade-offs may be incomplete and encompass only a portion of the aspects of logistics cost trade-offs, which are listed below:

(1) Assessment of the trade-off between level of service and total cost – A comparison of the desired logistics results (level of service) and the costs associated with those results (Christopher, 1987), both with respect to solutions for specific projects (1a) and solutions for logistics processes and network design (Gopal & Cypress, 1993) (1b);

(2) Assessment of the relevant cost trade-offs – The identification and measurement of potential trade-offs between reductions (increases) of costs and increases (reductions) of other costs and/or a reduction (increase) in the level of customer service (Lambert & Armitage, 1979). This variable is restricted to the assessment of significant trade-offs because the existence of countless interrelationships between costs precludes the scrutiny of all trade-offs (LeKashman & Stolle, 1965). However, it does not eliminate the need to assess the most material trade-offs, such as those listed by Faria, Bio and Robles (2004);

(3) Assessment of the economic-financial impacts of trade-offs – The simulation and analysis of the economic-financial performance that results from each alternative logistics solutions design. Once implemented, a logistics solution generates long-lasting economic-financial impacts (LeKashman & Stolle, 1965; Mak & Shen, 2010). Simulation and analysis are thus warranted for the trade-off between level of service and total cost (3a) and for other relevant trade-offs (3b);

(4) Systematic assessment of the total costs of the logistics processes and network – Continuous reassessment of the logistics processes and network at regular intervals to ensure that they remain competitive in terms of service level and costs (Chow, 2008). Systematic assessment is necessary because logistics processes and networks must adapt to the constant changes that affect the organization and its external environment (LeKashman & Stolle, 1965); and

(5) The selection of the solution that optimizes total cost – After the aforementioned assessments have been conducted, the company selects the design that best fits the equation between the optimal level of service and minimum total cost (5a) and that supports the operation of the logistics processes and network with optimized total cost (5b) (LeKashman & Stolle, 1965; Faria, 2003; Faria & Costa, 2005).

These variables were assessed through eight mandatory questions that utilized the five-point Likert scale. The questions are listed in Table 3, along with the extremes of the scale used and the main sources consulted for the definition of the variables:

Table 3 *Variables for assessment of logistics cost trade-offs*

Variable	Question	Extremes of scale	References
(1a)	When designing logistics solutions (of various breadths), do you conduct analyses of total logistics costs versus level of customer service, i.e., are total costs simulated relative to the different levels of service that could be offered?	5=They are broadly conducted 1=They are not conducted	Christopher (1987)
(1b)	Have your company's logistics network and/or logistics macroprocesses (inbound logistics, plant logistics, outbound logistics) been the object of studies to improve the level of customer service at the lowest possible cost?	5=They have been broadly studied 1=They have not been studied	Christopher (1987); Gopal & Cypress (1993)
(2)	When designing logistics solutions (of various breadths), are the most relevant cost trade-offs identified and analyzed?	5= They are fully identified 1= They are not identified	Lambert & Armitage (1979); Faria, Bio & Robles (2004)
(3a)	When designing logistics solutions (of various breadths), do you conduct simulations and analyses of the economic-financial impacts that result from different levels of service?	5= They are broadly conducted 1= They are not conducted	LeKashman & Stolle (1965); Mak & Shen (2010)
(3b)	When designing logistics solutions (of various breadths), do you conduct simulations and analyses of the economic-financial impacts of the most relevant cost trade-offs?	5= They are broadly conducted 1= They are not conducted	LeKashman & Stolle (1965); Mak & Shen (2010)
(4)	Are assessments of total costs of the logistics processes and network relative to the level of customer service systematically and routinely conducted?	5= They are broadly conducted 1= They are not conducted	LeKashman & Stolle (1965); Chow (2008)
(5a)	Is the selected logistics solution necessarily the one that optimizes the company's economic-financial performance?	5= It is necessarily so 1= It is not necessarily so	LeKashman & Stolle (1965); Faria (2003); Faria & Costa (2005)
(5b)	Are the costs of the logistics network and/or macroprocesses in your company already optimized, i.e., do you operate at the lowest total cost possible while providing customers the targeted level of service?	5= The costs are optimized 1= The costs are not optimized	LeKashman & Stolle (1965); Faria (2003); Faria & Costa (2005)

3.1.3 *Experience and formal education of logistics professionals*

The variables related to experience and formal education were defined based on the work of Slone, Mentzer, and Dittmann (2007), who argued that logistics executives' functional knowledge is enhanced through experience and education. Similar to the study by Myers et al. (2004), this study measured experience with a mandatory question about time of service in logistics and measured the degree of formal education with a mandatory

question about the highest educational degree obtained by the professional. These questions are given in Table 4, along with the scales used and works consulted for the definition of the variables:

Table 4 *Variables for experience and formal education of logistics professionals*

Variable	Question	Scale		References
Experience of logistics professional	Time working in logistics	1= Up to 2 years 2= 3 to 5 years 3= 6 to 10 years	4= 11 to 15 years 5= More than 16 years	Slone, Mentzer & Dittmann (2007); Myers et al. (2004)
Formal education of logistics professional	Degree of formal education	1= Secondary/vocational education 2= Higher education	3= Specialization/MBA 4= Masters/PhD	

3.1.4 Use of cost simulators and adequacy of accounting information

The variable related to use of cost simulators was established based on the argument by Russell and Cooper (1992) that the assessment of multiple interdependent economic decisions is beyond the human capacity of the decision maker. Simulators allow a decision maker to predicate and measure the possible effects of the various alternatives; this process leads to a more complete understanding of reality than could be achieved using only a professional's own knowledge. In this study, the variable was assessed by means of a mandatory question answered with a binary yes-no scale.

The variable related to the adequacy of accounting information was elaborated based on the notion that appropriate data must be made available to enable an analysis of the extent to which reductions in some costs lead to increases in other costs (Tyndall & Busher, 1985); this in turn makes it possible to analyze trade-offs (Lambert & Quinn, 1981; Faria, 2003). The variable was assessed through two non-mandatory questions about the extent to which logistics professionals believe that the information received from the company's controllership helps to assess trade-offs and to design solutions. These questions were non-mandatory because they applied only to companies that receive accounting information.

Table 5 contains the questions, the extremes of the scale being used and the main studies consulted when defining the variables related to the use of simulators and the adequacy of accounting information:

Table 5 *Variables for use of cost simulators and adequacy of accounting information*

Variable	Question	Extremes of scale	References
Use of cost simulators	When designing logistics solutions, do you use total cost simulators for logistics networks and/or total cost simulators for logistics projects?	1= Yes 2= No	Russell & Cooper (1992)
Adequacy of accounting information	Does the information received from controllership help to assess cost trade-offs as needed to measure total logistics costs?	5= They help very much 1= They do not help	Lambert & Quinn (1981); Tyndall & Busher (1985); Faria (2003)
	Does the information received from controllership help to design logistics solutions?		

3.2 Research Instrument

The questions presented above were aggregated in a questionnaire. To ensure the questionnaire's validity, a professional, a consultant and a professor in the field of logistics evaluated its contents and structure outside the presence of the authors before it was effectively administered. After this evaluation and the incorporation of pertinent modifications, there was an administration of the questionnaire, also outside the presence of the authors, to only one logistics manager with a profile similar to that of potential respondents. There was no indication that the questionnaire needed to be altered further, which allowed the questionnaire to be effectively administered, electronically, in February and March of 2012.

Before using the collected data, Cronbach's alpha was computed to determine whether the research instrument (questionnaire) provided reliable answers. An alpha value above 70% indicates reliability (Martins & Theóphilo, 2009).

In this study, the Cronbach's alpha obtained for the final sample, both for the questionnaire as a whole (covering the twelve mandatory Likert-scale questions) and for each individual construct, was above 70%. The Cronbach's alpha was 90.8% for the entire questionnaire, 81.0% for the construct related to the knowledge of trade-offs, 88.5% for the construct related to the assessment of trade-offs, and 87.4% for the construct related to the adequacy of accounting information.

3.3 Population and Sample

The population of the present study included companies with two specific attributes: (1) they were among Brazil's largest companies, according to the 2010 'Melhores e Maiores' edition of Exame Magazine; and (2) they operated in the industrial and/or commercial sector. The population of this study comprised a total of 659 companies with these two attributes.

The restriction of the sample to larger companies was based on Napolitano's (1997) observation that small organizations do not tend to experience situations in which ro-

bust logistics solutions lead to significant savings.

Restricting the sample to commercial and industrial companies was intended to exclude the services sector because that sector includes industries that do not involve the transfer of physical goods. For example, companies in the businesses of education and religious practices do not transfer goods from supplier to customer; rather, they transfer intellectual teachings and spiritual doctrines, respectively (Ellram, Tate, & Billington, 2004).

Because companies in the service sector do not transfer goods to customers, the variety of logistics activities taking place at these companies is more limited (for example, companies in the service sector do not engage in the maintenance and storage of inventories); likewise, the number of trade-offs experienced by these companies is also limited. Because the scope of trade-offs is limited in some service industries, which is an undesirable operational characteristic for this study, the entire services sector was excluded.

To locate contacts for the companies composing this study's population, the alumni directory of professionals with MBAs in Supply Chain Management & Integrated Logistics from the Institute for Accounting, Actuarial and Financial Studies Foundation (Fundação Instituto de Pesquisas Contábeis, Atuariais e Financeiras - FIPECAFI) and Exame Magazine's database were consulted. Using the alumni directory, it was possible to obtain the email addresses of logistics professionals at 205 different companies, and calling the phone numbers provided in Exame Magazine's database yielded the email addresses/phone numbers of logistics professionals at another 38 companies. The study's goal was explained and the questionnaire was sent to 243 different companies. Ultimately, 73 valid responses were received. These responses comprise the study's sample and correspond to a return rate of 30%.

Because one of the pillars of a study's validity is the segment of the population effectively assessed, the non-response bias was analyzed (Armstrong & Overton, 1977). The 36 participants for whom the invitation to participate had to be resent were considered non-respondents, and their answers were compared to the answers of the 37 participants who responded immediately the study. Using the Mann-Whitney test, no statistically significant difference was detected between the groups, which indicated the absence of non-response bias and confirmed the validity of the study for the contacted population.

3.4 Data Treatment and Analysis

The quantitative analysis of the data used two approaches: descriptive statistics and hypothesis testing.

Descriptive statistics were used to show the distribution of answers regarding the extents of knowledge and assessment of trade-offs. To allow the identification of concentrations, the answers were aggregated in two groups. The first group contained the answers for which the scores according to the Likert scale were weak or average, i.e., 1, 2 or 3, and the second group contained the answers with strong scores on the Likert scale, i.e., 4 or 5.

For the knowledge of trade-offs, weak and average scores (1, 2 and 3) indicate that such knowledge is not or is only partially widespread, whereas strong scores (4 and 5) indicate that the knowledge is broadly widespread. As for the assessment of trade-offs, weak and average scores (1, 2 and 3) reflect the absence or limited nature of trade-off analyses, whereas strong scores (4 and 5) reflect broadly conducted analyses.

The hypothesis testing aimed to identify factors associated with the knowledge and assessment of trade-offs. Their operationalization resulted in the formation of two groups, each one exhibiting the characteristics of the factor being analyzed at opposite extremes, as shown in Table 6. Table 6 also includes (in parentheses) the number of professionals included in each group:

Table 6 *Groups formed for hypotheses testing*

Experience	Degree of formal education	Use of cost simulators	Adequacy of accounting information
Experienced (51): More than 5 years of experience with logistics	Higher degree of formal education(51): Graduate school	Use of cost simulators (42): Simulators are used	Receives adequate accounting information (22): Mean score above 3 for the questions regarding the adequacy of accounting information
Inexperienced (22): Up to 5 years of experience with logistics	Lower degree of formal education (22): Secondary, vocational and higher education	Non-use of cost simulators (31): Cost simulators are not used	Receives inadequate accounting information (20): Mean score below or equal to 3 for the questions regarding the adequacy of accounting information

The normal distribution of the variables was tested with the Kolmogorov-Smirnov and Shapiro-Wilk tests. Considering a significance level of 0.10, none of the variables was normally distributed for the two groups, which indicated the need to resort to non-parametric statistical tests. Because the groups formed for each hypothesis were independent and the variables were ordinal, the non-parametric Mann-Whitney test was selected (Fávero, Belfiore, Chan & Silva, 2009).

4 PRESENTATION OF RESULTS

Before presenting the specific results, the data referring to respondents' profiles are described to demonstrate that most professionals consulted for this study tend to be familiar with logistics, as most professionals in the sample have graduate degrees and more than 10 years of experience in the field, as revealed in Table 7:

Table 7 *Characteristics of respondents*

Experience in logistics	%	Degree of formal education	%
More than 10 years	48%	Graduate degree	70%
From 3 to 10 years	42%	Higher Education	22%
Up to 2 years	10%	Secondary/Vocational Education	8%

4.1 Knowledge and Assessment of Trade-offs

Moving on to the presentation of specific results, Table 8 shows the concentration of scores given in response to questions about the knowledge of trade-offs:

Table 8 *Level of scores assigned to questions about the knowledge of logistics cost trade-offs*

Variable	Assigned scores levels	
	Weak or average (1, 2 or 3)	Strong (4 or 5)
(3) Knowledge of economic-financial impacts	23%	77%
(1) Knowledge of the existence of trade-offs	41%	59%
(2) Knowledge of the relationship between trade-offs and total cost (variable 2b)	52%	48%
(2) Knowledge of the relationship between trade-offs and total cost (variable 2a)	59%	41%

Initially, one notices that the knowledge that is most widespread is that logistics has an impact on the economic-financial dimension, given that 77% of the professionals claimed that they are strongly aware of this. This finding was expected because the notion that effective logistics management helps to leverage economic-financial performance is increasingly well-known (Presutti & Mawhinney, 2007).

Next, the results show that most logistics professionals (59%) gave strong scores to indicate that they know that increasing the cost of one logistics activity may be compensated by reductions in the cost of other logistics activities or by increased revenue (and vice-versa). Given that the existence of trade-offs is defined by the substitutions between cost elements (Bio, Robles & Faria, 2003), these results suggest that professionals know that trade-offs exist.

Finally, one observes that comprehension of the relationship between trade-offs and total cost is the least widespread knowledge among professionals. The concentration of answers to questions on this topic at weak and average levels (52% and 59%) reveals that despite professionals' awareness of possible cost trade-offs, they still struggle with the notion that individual cost cuts are not the best option to optimize total cost (Lambert & Armitage, 1979).

In sum, the results indicate that knowledge of trade-offs is limited; although logistics professionals know that trade-offs exist, they do not have a clear understanding of the trade-off concept or how trade-offs work. To some extent, this finding corroborates the observation by LeKashman and Stolle (1965) that logistics' real impact is much greater than most managers imagine.

Shifting the focus from knowledge of trade-offs to their assessment, Table 9 shows the concentration of scores assigned to the questions on this topic:

Table 9 *Level of scores assigned to questions about the assessment of logistics cost trade-offs*

Variable	Assigned scores levels	
	Weak or average (1, 2 or 3)	Strong (4 or 5)
(1b) Assessment of the trade-off between level of service and total cost when designing logistics processes or networks	40%	60%
(4) Systematic assessment of the total costs of logistics processes or networks	40%	60%
(2) Assessment of relevant cost trade-offs	45%	55%
(3a) Assessment of the economic-financial impacts of the trade-off between level of service and total cost	47%	53%
(1a) Assessment of the trade-off between level of service and total cost in solutions for specific projects	48%	52%
(3b) Assessment of the economic-financial impacts of relevant cost trade-offs	49%	51%
(5b) Optimization of the total cost of logistics processes and/or networks	53%	47%
(5a) Selection of the solution that optimizes total cost	55%	45%

Initially, one observes that the assessment of trade-offs focuses primarily on solutions relating to logistics processes and networks; the questions related to this type of solution obtained the largest proportion (60%) of answers concentrated in strong scores. Two factors may be related to this focus: (1) the large availability of commercial software for network design (Napolitano, 2011); and (2) the significant cost of logistics macroprocesses and networks (Faria, 2003).

Next, one notices that the scores for answers to questions about specific solutions were fairly evenly balanced between strong scores and weak or average scores.

Although more than half of the professionals claimed to broadly identify and analyze the relevant trade-offs (55%), the trade-off between level of service and total cost (52%) and the economic-financial impacts (51 and 53%), the other half indicated that they do not or only partially identify and analyze these aspects.

Finally, the results show clearly that the solution selected by logistics professionals is not necessarily the one that optimizes the total cost, given that the answers of 55% of the respondents were concentrated in weak or average levels. Consequently, it is not surprising that more than half of the companies (53%) consider themselves to be operating far from the optimal total cost.

Therefore, the results indicate that the level of trade-off assessment by Brazilian logistics professionals is still below the desired level. Fellous (2009), who arrived at similar findings when exploring the analysis of total cost, argued that the reality may be even worse, with an effective level of assessment lower than that perceived by respondents.

To identify factors related to the extents of knowledge and assessment of trade-offs hitherto reported, the hypothesis testing is examined next.

4.2 Factors Related to Knowledge and Assessment of Trade-offs

Hypotheses 1 and 2 propose that the extent of knowledge about trade-offs may be influenced by the levels of experience and formal education of logistics professionals. To identify whether these hypotheses were accepted or not, the Mann-Whitney non-parametric test was used. Table 10 presents the results obtained with this test:

Table 10 *Tests for hypotheses 1 and 2*

Variable	Mann-Whitney Test (Experience - H_1)		Mann-Whitney Test (Formal Education - H_2)	
	p-value	Diff.?	p-value	Diff.?
(1) Knowledge of the existence of logistics cost trade-offs	0.467	No	0.548	No
(2) Knowledge of the relationship between trade-offs and total cost (variable 2b)	0.123	No	0.605	No
(2) Knowledge of the relationship between trade-offs and total cost (variable 2a)	0.985	No	0.837	No
(3) Knowledge of the economic-financial impacts	0.031	Yes	0.154	No

Considering a level of significance of 0.10, the Mann-Whitney test shows there is a statistically significant difference for H_1: the extent of knowledge about economic-financial impacts differs between experienced and inexperienced professionals. Table 11 details the scores assigned by each group to the question related to this variable:

Table 11 *Frequency of scores assigned by experienced and inexperienced professionals*

Variable	"Experienced"		"Inexperienced"	
	Weak or average (1, 2 ou 3)	Strong (4 ou 5)	Weak or average (1, 2 ou 3)	Strong (4 ou 5)
Knowledge of the economic-financial impacts	18%	82%	36%	64%

Experienced logistics professionals have more knowledge of economic-financial impacts than inexperienced professionals. These results, together with Christopher's (1997) argument that logistics professionals should be well-informed about finance so that they can effectively control their resources and costs, allow one to infer that experience in the field not only helps to build a base of operational knowledge but also stimulates an interest in understanding economic-financial impacts.

For H_2, at a significance level of 0.10, the Mann-Whitney test did not reject the null hypothesis for any variable. This result indicates that there is no difference in the knowledge of logistics cost trade-offs between professionals with more or less formal education. It is worth noting that the study by Myers et al. (2004) also explored the impact of formal education (and experience) on logistics performance and, similar to this article, did not identify any difference between the variable's different levels.

Additional tests were conducted to assess whether the professionals' field of study (as opposed to the degree of education, as suggested by Myers et al. (2004)) might have an impact on the extent of knowledge about trade-offs. The answers of professionals with a degree in logistics were compared to the answers of professionals with degrees in other fields. Moreover, the answers of professionals with degrees in business (business administration, accounting sciences and economics) were compared with the answers of professionals with degrees in technical fields (mainly engineering and logistics). None of these comparisons resulted in a statistically significant difference according to the Mann-Whitney test.

H_1 and H_2 thus show that knowledge of trade-offs is partially related to experience and unrelated to formal education. Although these results do not conclusively reveal the factors that influence the extent of knowledge about trade-offs, they allow the authors of future studies to start with the observations of this study and to seek evidence of other factors that may affect said knowledge.

With respect to the assessment of trade-offs, hypothesis 3 proposes that the extent of the assessment may depend on the use of cost simulators because processing the vast gamut of data requires computational support (LeKashman & Stolle, 1965). This hypothesis was reinforced by the simultaneous observations that simulators are not used by 42% of the companies in the sample and that trade-off assessments are limited. Table 12 shows the results obtained with the Mann-Whitney test:

Table 12 *Tests for hypothesis 3*

Variable	Mann-Whitney Test (H_3)		Frequency of scores for the groups			
			"Use simulators"		"Does not use simulators"	
	p-value	Diff.?	Weak or average (1, 2 or 3)	Strong (4 or 5)	Weak or average (1, 2 or 3)	Strong (4 or 5)
(1a) Assessment of the trade-off between level of service and total cost in solutions for specific projects	0.000	Yes	24%	76%	81%	19%
(3a) Assessment of the economic-financial impacts of trade-offs between level of service and total cost	0.000	Yes	24%	76%	77%	23%
(5a) Selection of the solution that optimizes total cost	0.000	Yes	19%	81%	68%	32%
(1b) Assessment of the trade-off between level of service and total cost in designing logistics processes and networks	0.001	Yes	21%	79%	65%	35%
(3b) Assessment of the economic-financial impacts of relevant cost trade-offs	0.001	Yes	36%	64%	68%	32%
(4) Systematic assessment of the total cost of logistics processes and networks	0.035	Yes	45%	55%	68%	32%
(5b) Optimization of the total cost of logistics processes and/or networks	0.036	Yes	45%	55%	65%	35%
(2) Assessment of relevant cost trade-offs	0.067	Yes	38%	62%	55%	45%

Considering a level of significance of 0.10, the Mann-Whitney test shows that all variables displayed statistically significant differences between the groups. These differences confirm that using cost simulators, both for specific projects (for example, routing) and for network design, has an impact on the extent of assessment of logistics cost trade-offs.

Moreover, the conclusion reached by Fellous (2009) is confirmed; i.e., the extent of trade-off assessment is greater in companies that use cost simulators. Specifically, the group of companies that uses simulators concentrated all of its answers in strong levels, whereas the group of companies that does not use simulators concentrated all of its answers in weak or average levels.

Hypothesis 4 proposes that the extent of assessment of trade-offs depends on the availability of adequate cost information. This hypothesis was reinforced by the observation that not only do most companies in this study's sample perform a limited assessment of trade-offs, but they also do not receive accounting information that is deemed to be adequate, as shown in Figure 1:

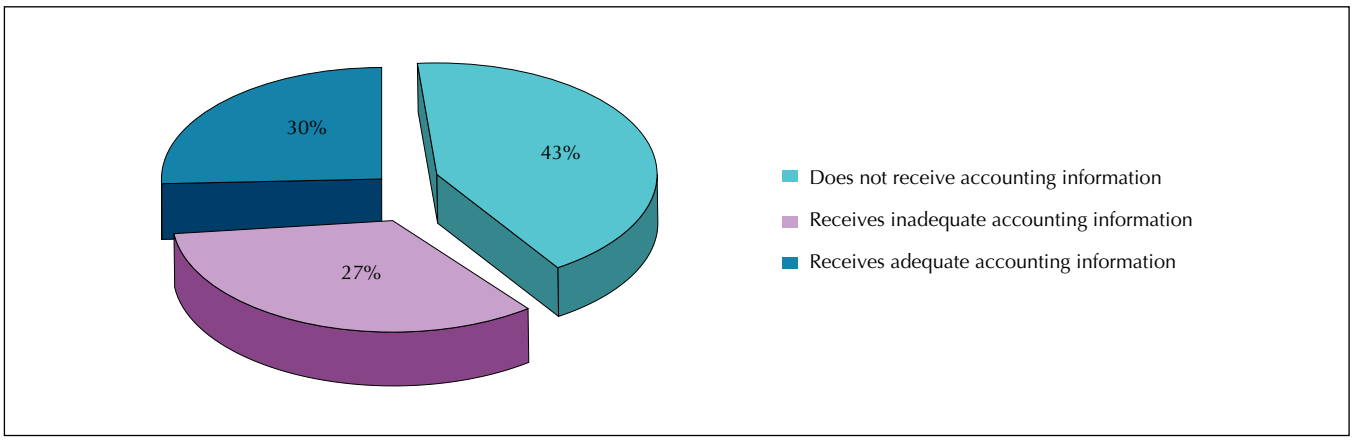

Figure 1 *Availability of accounting information*

The fact that only 30% of the companies in this study are satisfied with the accounting information received shows that a problem that was noted long ago by researchers in the fields of logistics and accounting still exists. For example, in the logistics field, Pohlen and LaLonde observed in 1994 that controllers did not develop information for the analysis of logistics costs, despite the magnitude and relevance of these costs. In the field of accounting, Faria warned in 2003 that the costs of logistics activities were not clearly disclosed and instead were usually included in several other items in accounting statements, particularly stocks, cost of products sold, operational expenditures and deductions from revenue.

Given the considerations mentioned above, one can use the Mann-Whitney test to statistically assess whether the lack of adequate accounting information is significantly related to the limited assessment of trade-offs. Table 13 shows the results:

Table 13 *Tests for hypothesis 4*

Variable	Mann-Whitney Test (H_4)		Frequency of scores for the groups			
			"Adequate information"		"Inadequate information"	
	p-value	Diff.?	Weak or average (1, 2 or 3)	Strong (4 or 5)	Weak or average (1, 2 or 3)	Strong (4 or 5)
(3a) Assessment of the economic-financial impacts of the trade-offs between level of service and total cost	0.029	Yes	23%	77%	55%	45%
(1b) Assessment of the trade-off between level of service and total cost in designing logistics processes and networks	0.030	Yes	18%	82%	40%	60%
(2) Assessment of relevant cost trade-offs	0.039	Yes	23%	77%	50%	50%
(1a) Assessment of the trade-off between level of service and total cost in solutions for specific projects	0.048	Yes	27%	73%	60%	40%
(4) Systematic assessment of the total cost of logistics processes and networks	0.095	Yes	27%	73%	40%	60%
(5a) Selection of the solution that optimizes total cost	0.309	No	-	-	-	-
(3b) Assessment of the economic-financial impacts of relevant cost trade-offs	0.482	No	-	-	-	-
(5b) Optimization of the total cost of logistics processes and/or networks	0.828	No	-	-	-	-

Considering a significance level of 0.10, the Mann-Whitney test shows that all variables except 3b and 5 (a and b) exhibit statistically significant differences between the groups. These differences confirm that the availability of adequate accounting information has an impact on the extent of assessment of logistics cost trade-offs.

Moreover, the hypothesis that the extent of trade-off assessment is greater among companies that receive adequate cost information is confirmed. Specifically, the group of companies that receives adequate information concentrated all of their answers at strong levels, whereas the group of companies that do not receive adequate information assigned weak, average and strong scores. This result was expected because it is known that the lack of accurate accounting information impedes the estimation of the impacts of different levels of service, prevents individuals from becoming aware of the relevance of total cost and hinders logistics integration (Perreault Jr. & Russ, 1976; Christopher, 1997; Faria, 2003).

In summary, the hypothesis testing reveals that both the use of simulators and the availability of adequate cost information affect the extent of trade-off assessment.

5 CONCLUSIONS

The goals of this study were achieved in the sense that, for the sample considered herein, the results allowed one to determine the extent of logistics professionals' knowledge about trade-offs and to identify whether trade-offs are assessed when solutions are designed and implemented; the results also show that survey factors are associated with the knowledge and assessment of trade-offs.

With respect to the extent of knowledge about trade-offs, the revelation that most logistics professionals are aware of the existence of cost trade-offs is particularly noteworthy, as is the finding that they know that an increase in one cost may be compensated by increased revenue or by a reduction in other costs. However, the same majority lacks a full understanding of how trade-offs work, especially with respect to the intrinsic relationship between trade-offs and total cost. Unfortunately, this prevents professionals from recognizing that making individual cost reductions is a mistake.

Another point worth mentioning is that the knowledge that logistics has an impact on economic-financial performance is broadly widespread. This knowledge provides important motivation for logistics professionals to seek a management system that not only meets operational parameters but also meets profitability parameters (Presutti & Mawhinney, 2007).

One must also emphasize the finding that professionals with more experience show a greater extent of knowledge about potential economic-financial impacts than professionals with less experience. This finding suggests that the time spent working in logistics not only broadens functional knowledge but also helps to build economic-financial knowledge. It is worth remembering that Christopher (1997) noted that there is an ever-increasing need for logistics professionals to have financial knowledge so that they know, foremost, how to control the costs arising from their operations.

Regarding the assessment of trade-offs, the focus on logistics processes and network design is notable. The high costs involved (Faria, 2003) and the vast amount of commercial software available for this type of solution (Napolitano, 2011) may be the reasons for this prioritization.

Note also that unlike processes and network design, solutions for specific projects show a limited level of assessment. Nearly half of the companies assess these trade-offs only slightly or moderately, which hinders the success of their logistics integration. It is worth emphasizing that previous studies have shown that the measurement of a company's total costs and the assessment of costs incurred along the entire supply chain are also limited (Faria, 2003; Fellous, 2009).

Also noteworthy is the confirmation that the failure to use cost simulators and the lack of adequate cost information (as perceived by logistics professionals) are factors related to the limited assessment of trade-offs. The association between the lack of simulators and the limited assessment of trade-offs is due to the difficulty (if not impossibility) of processing the data from countless cost interrelations without computational support (LeKashman & Stolle, 1965), and the relationship between the lack of adequate cost information and the limited assessment of trade-offs is derived from the fact that the lack of accurate cost information restricts analyses to the operational dimension and prevents the efficient execution of logistics activities (Faria, 2003).

Thus, the gap filled by this paper relates to the in-depth knowledge that the study provides regarding the topic of logistics cost trade-offs. First, special note is made of the empirical finding that the extents of knowledge and assessment of trade-offs is still limited. Moreover, it is confirmed that the use of cost simulators and access to adequate cost information are important not only for logistics cost management (LeKashman & Stolle, 1965; Faria, 2003) but also for the assessment of trade-offs.

This study's main contributions to the field of accounting knowledge are the revelations that most companies still do not operate under conditions of optimized total cost and that the lack of trade-off assessments is one of the primary causes of this situation. This knowledge can be used to demonstrate to controllers – who are the professionals responsible for ensuring that the organization's global economic result is optimized – how important it is to analyze trade-offs and to disclose the cost information that enables this analysis.

As a recommendation for future works and without any pretense of exhausting the possibilities, some additional explanations for the findings are proposed for consideration:

- The restriction of this study's sample to commercial and industrial sectors sought to select companies that involve the transfer of physical goods and operate with similar broad scopes of logistics processes and activities. Despite the purpose of this restriction, the exclusion of the services sector led to the exclusion of branches that have relevant logistics concerns, e.g., the transportation and energy sectors. Thus, the inclusion of the services sector may expand the issues analyzed here and contribute further to the knowledge on the topic. This would require a new field study;
- The lack of understanding of the term cost trade-offs may be the cause of the lack of a deeper understanding of the relationship between trade-offs and total cost. Regardless of how well logistics professionals understand the trade-off concept, they may not understand the meaning of this term. Based on the constructs elaborated in this article, future studies may propose new survey questions that assess the variables without specifically mentioning the term cost trade-off.
- The results for the assessment of trade-offs reflect respondents' judgments of the extent to which they conduct the steps of the analysis proposed in this study. Therefore, the extents determined here reveal respondents' perceptions, and greater extents of analysis do not necessarily imply a more sophisticated analysis or the use of modeling and software applications. Likewise, perceptions of the relevance of trade-offs touch upon respondents' subjective understanding of trade-offs' materiality. Therefore, it is proposed that later studies use the constructs elaborated in this article to develop new questions or to employ different methods to assess the variables in an alternative manner;
- The five-point Likert scale adopted in the questionnaire allowed respondents to select a neutral position. However, to determine whether the extents of the knowledge and assessment of trade-offs were strong, the weak and average scores had to be aggregated in the presentation of results. Future studies may employ different methods to assess the magnitude of variables;
- The cost simulators available at the companies may be used for some, but not all, logistics solutions. This fact limits the present study in light of the dichotomic answer "yes" or "no" and suggests that future studies develop questions that allow one to identify the intensity of simulator use;
- The provision of adequate cost information facilitates the optimization of total logistics costs but entails additional effort and expense. Because this article only explored the benefit of cost information, it is proposed that subsequent studies focus on the analysis of the cost/benefit ratio.

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