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A SUPPLIER SELECTION MODEL BASED ON CLASSIFYING ITS STRATEGIC IMPACT FOR A COMPANY'S BUSINESS RESULTS

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ABSTRACT. One of the most important aspects for companies' success is the relationship between companies and their suppliers. Consequently, the way that a supplier is selected is crucial to the outcome of the business. Thus, we propose a multicriteria decision support model with two phases: the analysis of the products/services from suppliers that need to be evaluated, using PROMSORT, and the analysis of the suppliers of such products/services which is considered critical, using PROMETHEE II. The model was applied to a Distribution Center of an important Brazilian retailer which serves stores in the North and Northeast regions of Brazil. Using the proposed model, companies can focus their attention on those products or services that have the greatest impact on their business results. The model predicts that different decision-making processes should be applied, in accordance with the class of importance into which the products or services are classified.

Keywords: supplier selection, Brazilian retail market, Promethee.

1 INTRODUCTION

According to Osman & Demirli (2010), improving the efficiency of supply chain partners has become a major requirement of any supply chain due to the highly competitive nature of the current marketplace. Due to this increase in competitiveness, companies are also adopting strategies to concentrate on their core business by outsourcing other activities related to the business. Therefore, the relationship between companies and their suppliers is gaining increasing importance, as are the characteristics of the partnership necessary for the supply chain. Thus, the way that a company selects its suppliers has an impact on the results of all companies in the chain.

This competitive environment points to the need to seek a closer relationship with suppliers that will improve the results for both parties. Ho, Xu & Dei (2010) show that the management of the supply chain requires the maintenance of long-term partnerships with suppliers, and uses fewer and more efficient suppliers. Punniyamoorthy, Mathiyalagan & Parthiban (2011) explain that

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the selection of suppliers is one of the most important stages of the supply chain and has an important impact on the success of any organization or supply chain.

According to Saen (2007), supplier selection is the process in which suppliers are inspected, evaluated and selected to eventually become part of the supply chain of an organization. The selection and evaluation of suppliers is an area which has attracted the attention of most studies, and there are several approaches to support decision making on this issue.

To Vinodh, Ramiya & Gautham (2011), the supplier selection problem is a multicriteria decision-making problem in the presence of various criteria and sub-criteria, be they quantitative or qualitative. Due to this characteristic, there arises the need to use more robust tools for decision support.

Basnet & Weintraub (2009) assert that, in the current context of globalization, companies are increasing the focus on their core business and outsourcing their other activities. This behavior increases the importance of the process for selecting suppliers. While small firms select partners based on criteria which determine the lowest costs, large companies must select their suppliers more carefully, by considering different criteria that seek a long-term relationship with their suppliers.

This trend shows up in various areas of activity in the market, including in the retail market, which is characterized by a highly competitive and dynamic environment. The fact that there are so many competitors in the market requires retailers to reduce their profit margins so they can offer their products at a competitive price to customers. The environment described requires supplier selection to be effective. All details have an important impact on the results produced by the supply chain.

In most cases, however, companies do not have an overview of the importance of the raw materials and/or services that have been outsourced to their suppliers. In such cases, the company may be focusing its attention on products or services that are not the most critical to its results. Thus, it is important that the company conducts an analysis of the importance of its raw materials and/or third party services, and then reviews the configuration of its suppliers. After having assessed which products or services are most critical to it, the company can direct its efforts towards evaluating the aspects of the critical supply. And thereafter, it can proceed to selecting suppliers for its most critical products or services.

Within this context, this paper aims to propose an integrated model for classifying suppliers in accordance with decision makers' preferences and for supplier selection, in accordance with the class into which the supplier was sorted, taking into account the multiple criteria that should be considered when choosing a business partner. The model was applied in a distribution center of a large retail chain, which sells a wide range of households and personal products, in Brazil.

In order to achieve the proposed goals, a step-by-step approach was undertaken, as follows. The first phase of the study consisted of a bibliographic research. From the results obtained, a supplier selection model was structured that can be applied to companies from different sectors and considers issues related to outsourcing. Then the model was applied to selecting suppliers for a Distribution Center (DC). The model was applied on the Operations Manager of the company who was deemed to be the decision maker (DM). Three interviews were conducted on the spot. In the first interview, data were obtained to characterize the DC. In the second step, the first phase of the model was applied, which involves classifying the outsourced services. In the third step, the second phase of the model was applied. The supplier who was able to provide the transport alternatives in accordance with the DM's needs was selected.

The paper is organized as follows: Section 2 discusses the issue of vendor selection as presented in the literature, and emphasizes the tools used by the authors to deal with the problem. In Section 3, multicriteria approaches to support supplier selection decisions are discussed as is the technique chosen to tackle the problem in this study. In Section 4, a model for supplier selection is proposed that can be used in companies from various sectors. Section 5 gives the results obtained from applying the model in a DC of an important retailer in Brazil. Finally, there are closing remarks in which the contributions and limitations of the study are pointed out as is the need for further research on the topic.

2 SUPPLIER SELECTION PROBLEM

The problem of selecting suppliers has been extensively debated in the literature, as follows.

Several studies were developed using programming models for decision support. Aguezzou & Ladet (2007) propose a non-linear programming model for supplier selection that takes into account the transport of materials in order to select the best supply configuration. Osman & Demirli (2010) proposed a model using bilinear programming goals to achieve a compromise solution that allocates the demands of the company among the suppliers, thus minimizing the distribution cost. Wu et al. (2010) propose a multi-objective programming model for decision making on selecting suppliers, taking into account risk factors. For this purpose, the authors designed a fuzzy multi-objective programming model to deal with this problem. Mansini, Savelsbergh & Tocchella (2012) proposed integer programming based heuristics to solve the problem of selecting a set of suppliers to satisfy product demand at minimal total costs, taking purchasing and transportation costs into account. A computational analysis was developed considering a single purchaser, 29 suppliers and 50 products.

Other researchers used the AHP (Analytic Hierarchy Process) method, on its own or combined with other methods, to support the supplier selection decision. Chan & Chan (2010) used an AHP model to solve the problem of supplier selection in the garment industry, which takes into account the operational performance (flexibility, cost, delivery, etc.) in support of managing the supply chain. Ramanathan (2007), taking a different approach, integrates the approaches of Total Cost of Ownership (TCO) and AHP to select the appropriate supplier for a firm. The objective and subjective information provided by these approaches are then combined by implementing the Data Envelopment Analysis (DEA) method. El-Sawalhi, Eaton & Rustom (2007) proposed a model combining AHP, Neural Networks (NN) and a Genetic Algorithm (GA). The authors hope that the model they propose will overcome the limitations experienced by other methods found in the literature, particularly the accuracy of the results and the forecast performance of suppliers. Ishizaka (2012) proposed the use of clusters and pivots to facilitate the use of AHP use in supplier selection. This advance is useful when the numbers of pairwise comparisons becomes overwhelming. The model was applied in the selection process by twelve suppliers based on three criteria. Ting & Cho (2008) combine the AHP tool with a linear programming model with multiple objectives and a set of system constraints. The programming model is developed to solve the problem and allocate optimal orders quantities of resources to selected suppliers.

Gomes, Rangel & Leal Junior (2011) dealt with the supply selection problem, considering uncertainty, by using the MAUT method, combined with the Interval Smart/Swing Weighting Method. The second method was used in the weights definition process, when making judgments by intervals. The model was applied in the selection of a printing service supplier.

Schramm & Morais (2012) proposed a multi-criteria decision model for supplier selection in the Brazilian construction industry. The model was based on the Simple Multi-Attribute Rating Technique Exploiting Ranking method (SMARTER).

The ANP (Analytic Network Process) was the tool selected by other scholars to deal with the problem. Gurpinar & Gencer (2007) used an ANP tool in order to evaluate the relationship between the criteria for selecting suppliers in a company in the electronics field. Kirytopoulos, Leopoulos & Voulgaridou (2008) also used an ANP to support the selection of the best compromise solution in the environment of the pharmaceutical industry. Verdecho et al. (2012) present an approach based on an ANP to manage collaborative relationships by considering not only the elements of inter-enterprise performance, but also the factors that influence collaboration. The approach was applied in a network of collaborating enterprises from the renewable energy sector in Spain.

Basnet & Weintraub (2009) dealt with the problem of supplier selection where there are several suppliers with limited capabilities. To solve the problem, the authors propose a genetic algorithm be used in the search for Pareto optimal solutions.

Alencar & Almeida (2010) used PROMETHEE VI method in order to select suppliers (project team members) based on group decision, considering the preference structure of each member. The model was applied in a construction environment.

A large number of other studies on this area have been published including those by: Kahraman, Cebeci & Ulukan (2003), Narasimhan, Talluri & Mahapatra (2006), Bansal, Karimi & Srinivasan (2007); Chen & Huang (2007); Yang et al. (2008); Ordoobadi (2009), Golmohammadi et al. (2009); Sawik (2010); Barker & Zabinsky (2011); Bai & Sarkis (2012), and Qin et al. (2012).

These studies include the following industries and markets: White good manufacturers, electronic firm, widget manufacturer, computer industries, and civil construction. The models proposed range from those that use multi-objective programming to a neural network and genetic algorithms and they also include the use of various members of the MCDA family. Note that no studies were found in our review of the literature that rank suppliers according to the class to which the product/service was allocated.

In the next section, the importance of using a multicriteria decision method as a tool to aid companies in finding a solution to the problem is discussed.

3 MULTICRITERIA DECISION METHODS

In the field of decision support tools, multicriteria approaches are gaining attention because of their robustness and to facilitate the analysis of more complex cases in a very effective way. Vincke (1992) says that multicriteria decision analysis aims to give a decision maker (DM) the tools to solve decision problems where different, often contradictory points of view must be taken into consideration.

Vincke (1992) points out there are three families of multicriteria methods:

- The first is characterized by aggregating different viewpoints into a single function. The most important methods are MAUT, SMART, SMARTS and AHP.
- The second aims to start building what is deemed an outranking relationship and to explore these relationships to assist the DM. The most widely known methods are ELECTRE and PROMETHEE.
- The third family, known as interactive methods, alternates calculation and dialogue steps.

The PROMETHEE method is the one used in the model proposed in this article. According to Brans et al. (1998), the PROMETHEE method is important because it involves concepts and parameters that have some physical or economical interpretation that is easy for most DMs to understand.

Brans & Vincke (1985) point out that assigned weights p_j representing the degree of importance of each criteria, the degree of outranking $\pi(a, b)$ are computed in accordance with the equation below:

$$\pi(a, b) = \frac{1}{P} \sum_{j=1}^{n} p_j F_j(a, b), \quad \text{where} \quad P = \sum_{j=1}^{n} p_j.$$

Where the function $F_j(a, b)$ is a number between 0 and 1 that increases when the values of $g_j(a) - g_j(b)$ increases and is equal to zero if $g_j(a) = g_j(b)$, where $g_j(a)$ is the evaluation of the alternative a in the criterion j. In order to find the value of the function $F_j(a, b)$, the DM can choose, for each criterion, one of six types of function as follows (Brans and Vincke, 1985):

- Usual criteria: No threshold needs to be defined;
- U-shape criteria: the q threshold should be defined;
- V-shape criteria: the p threshold should be defined;
- Level criteria: the q and p thresholds should be defined;
- Linear criteria: the q and p thresholds should be defined;
- Gaussian criteria: the standard deviation should be set.

Where q is the indifference threshold, a value at which a valuation gap between the alternatives makes the DM indifferent, and p is the preference threshold, a value from which the DM expresses a preference between two alternatives.

To Brans & Vincke (1985), $F_j(a, b)$ is a type of "intensity of preference". After having obtained the values of $\pi(a, b)$, two complete preorders can be obtained, as per the equations shown below:

$$\varphi^+(a) = \frac{1}{n-1} \sum_{b \in A} \pi(a, b).$$

$$\varphi^-(a) = \frac{1}{n-1} \sum_{b \in A} \pi(b, a).$$

The intersection of these two streams produces a partial preorder, resulting from the application of the PROMETHEE I method. The PROMETHEE II method, in turn, ranks the alternatives based on the flow $\varphi(a)$ such that:

$$\varphi(a) = \varphi^+(a) - \varphi^-(a).$$

Thus, the complete preorder of the alternatives is obtained.

Araz & Ozkarahan (2007) proposed PROMSORT (a PROMETHEE Sorting method) which consists of a multicriteria method based on PROMETHEE, which ranks alternatives in predefined categories. In order to classify the alternative, PROMSORT follows the steps shown below:

According to Araz & Ozkarahan (2007), in order to determine the reference alternatives, all the alternatives are compared with the limit profiles by using the outranking relation obtained from using PROMETHEE. Thus, the comparison of a particular alternative a with the profile defined limit b_h is defined as per the relations determined below:

– a is preferred to b_h:

$$(aPb_h) \text{ if } \begin{cases} \phi^+(a) > \phi^+(b_h) \ e \ \phi^-(a) < \phi^-(b_h) & \text{or} \\ \phi^+(a) = \phi^+(b_h) \ e \ \phi^-(a) < \phi^-(b_h) & \text{or} \\ \phi^+(a) > \phi^+(b_h) \ e \ \phi^-(a) = \phi^-(b_h). \end{cases}$$

– a is indifferent to b_h:

$$(aIb_h) \quad \text{if} \phi^+(a) = \phi^+(b_h) \ e \ \phi^-(a) = \phi^-(b_h).$$

– a is incomparable to b_h:

$$(aRb_h) \text{ if } \begin{cases} \phi^+(a) > \phi^+(b_h) \ e \ \phi^-(a) > \phi^-(b_h) & \text{or} \\ \phi^+(a) < \phi^+(b_h) \ e \ \phi^-(a) < \phi^-(b_h). \end{cases}$$

The classification of the alternatives into certain categories is obtained by the direct use of outranking relations obtained in the previous step. The following steps should be followed to allocate the alternatives to the respective categories:

After this phase, some alternatives may not yet have been allocated to a category. In the third stage, the process of allocation uses the alternatives that have been allocated to a class as the reference point of the classes, in order to allocate the alternatives which have not yet been put into some class. For an alternative a that has not been allocated to a class, the procedure for doing so is as follows:

- Determine the distance from the cut-off point. The cutoff value of b can be set with the values 0 or 1 for optimism and pessimism, respectively. If the value of b is zero, the alternatives that were not allocated will be placed in categories according to their distance function. If $b = 1$, these unallocated alternatives will be placed in the lower classes.

$$d_k = \frac{1}{n_t} d_k^+ - \frac{1}{n_{t+1}} d_k^- .$$

  where:
  d_k^+ measures the outranking character of a on all the alternatives allocated to category C_t, and:

$$d_k^+ = \sum_{x \in X_t} (\Phi(a) - \Phi(x)).$$

  d_k^- measures the outranking character of a on all the alternatives allocated to category C_{t+1}, and:

$$d_k^- = \sum_{x \in X_t} (\Phi(x) - \Phi(a)).$$

  n_t is the number of reference alternatives in category C_t.

- Allocate the cutoff point b. If the distance is greater than the cutoff point b, the alternative a is allocated to category C_{t+1}; otherwise, it is allocated to category C_t. The cutoff point b can be specified by the DM and reflects his/her point of view, whether this is pessimistic or optimistic.

In the next section, the model for supplier selection is proposed.

4 SUPPLIER SELECTION MODEL

The model for supplier selection proposed is divided into two phases: in the first, the products or services being focused on and used by the agent are placed into classes; in the second, having selected the most critical product or service, the best supplier can be chosen. The model is shown in Figure 1.

In the first phase, the alternatives (products supplied or outsourced services) are placed into classes as per the requirements and criteria set by the DM. The objective of this phase is to

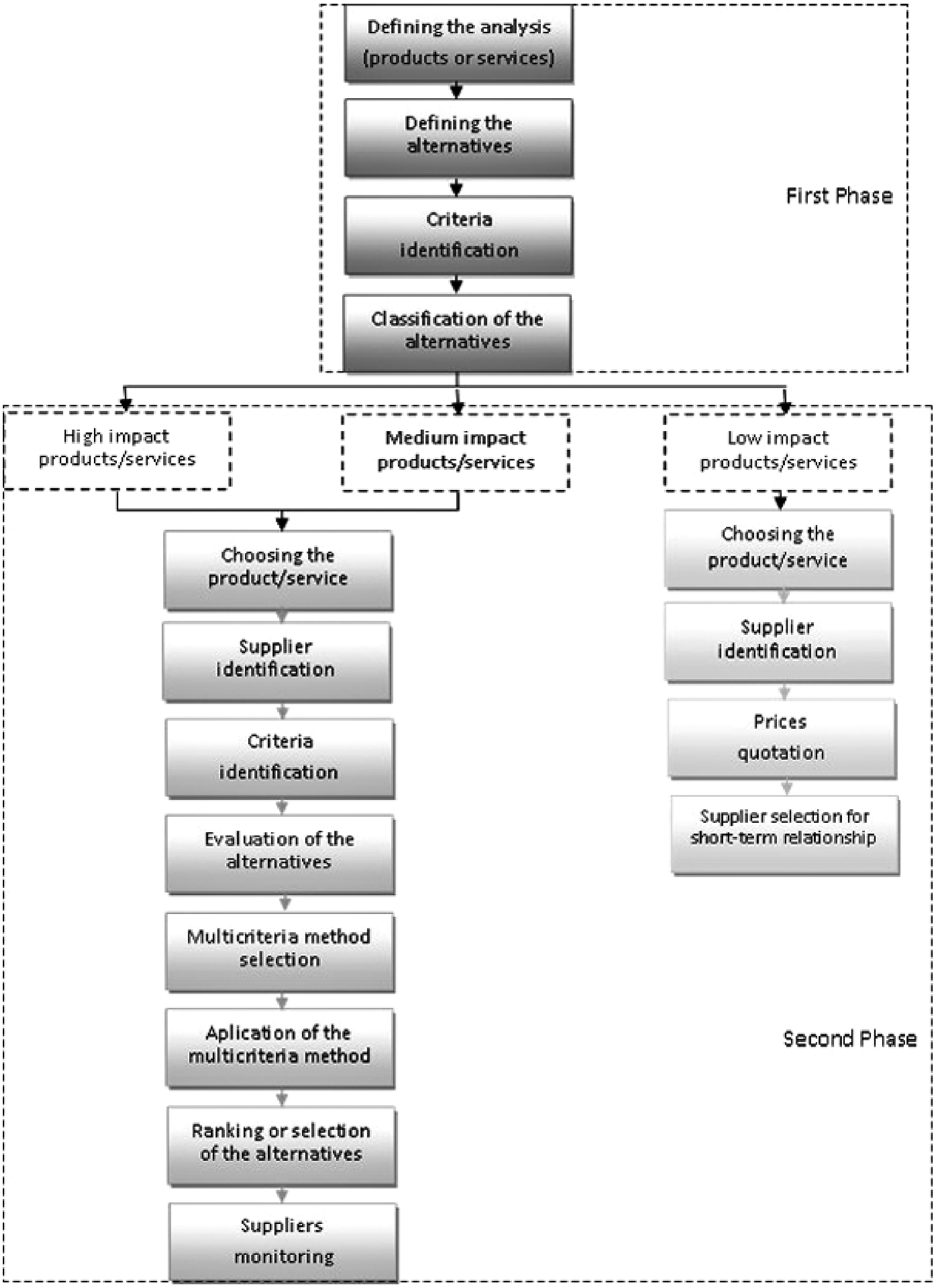

Figure 1 – Supplier selection model.

classify the goods or services supplied in accordance with the level of their strategic impact on the company's business.

First of all, the focus of the analysis is defined, whether for products or services, given the company's needs. After making this definition, the alternatives should be selected, i.e., the products or services to be considered in the analysis. The next step involves applying a multicriteria method so as to classify the alternatives according to the DM's preferences. Then, the alternatives have to be classified into one of the three pre-defined classes: a high, medium or low impact on the company's strategic objectives.

In the second phase, one of three approaches is chosen which is suited to the respective class of products or services determined in the first phase.

Depending on the class, the approach to follow is different. For products or services of lesser strategic impact, the selection can be performed more simply, by means of considering the cost criteria. For the products or services that are most important for the business results, a multicriteria analysis for ranking suppliers is proposed.

The first class discussed is that of products or services that have a high impact. The products or services that are arranged in this class have a direct impact on the company's results and more attention should be given to aspects of their supply. Initially, among the alternatives classified as high-impact, the product or service for which the analysis will be performed must be selected. Then the alternatives (suppliers) must be defined. The next step involves determining the criteria to be considered in the analysis. It is important to take into account the need for a partnership between the company and the suppliers of the service or product considered. Then, as per business needs, the analyst has to determine the most appropriate issue to be considered: selection, sorting or classifying suppliers. In accordance with the nature of the problem, the characteristics of the scenario, the profile of the issue and the DM's views, the multicriteria decision support method needs to be selected. The method chosen shall be applied, considering the various alternatives with respect to the criteria selected.

The products or services of medium impact on business results will be allocated into the second class. Their level of importance is lower than those that were allocated to the high impact class, but they should also be considered carefully. The subsequent steps are similar to those for analyzing high-impact products, i.e.: all of the following must be done – selecting the product or service that will be evaluated and defining who the potential suppliers will be, considering which criteria will be the most appropriate for the problematic, defining the multicriteria method and, finally, applying the method, and selecting, sorting or ranking such suppliers.

The third class allocates the products or services that have low impact on the business results, i.e., problems that arise in providing this type of service but which do not have a high impact on results. So, maintaining a long or medium term relationship with these suppliers is not necessarily required. Thus, in accordance with the model, costs may be the only criteria that have to be considered when selecting such suppliers. Thus, the DM has to: select the product or service that will be considered; define the alternatives (suppliers) to be evaluated; obtain a price quotation from the suppliers who meet the minimum requirements, and finally the DM has to select the supplier.

5 APPLYING THE MODEL

The company studied is one of the most traditional retailers in Brazil. It was founded in the 1930s, and it currently has over 600 stores in almost every state in the country and three distribution centers: two in the Southeast and one in the region Northeast.

The company sells over 60,000 SKUs (Stock Keeping Units) from 4,000 different suppliers; this demonstrates the wide variety of products that are distributed by the company and the importance of its maintaining good relationships with all of its suppliers.

Currently, the company has adopted a very aggressive expansion strategy and opened new stores, usually small ones, in line with the tendency to decentralize its outlets. This strategy, in turn, demands investing more in logistics and, at this point, the company's distribution centers are the key elements of its strategy for maintaining a good overall performance. It therefore needs to pay greater attention to critical points related to the performance of its distribution centers, which includes its relationships with the various service providers it contracts.

Over the years, many methods have been proposed to address the problem of classifying alternatives, amongst which are: ELECTRE TRI; the THESEUS method, proposed by Fernandez & Navarro (2011); and the PROMSORT method, proposed by Araz & Ozkarahan (2007). We selected PROMSORT as the tool for the first phase of the application. This uses the concepts of both "limit profiles" and a "reference alternative" to deal with the DM's judgment, thus giving the DM the flexibility to define his/her (optimistic or pessimistic) point of view, and guarantees ordered categories, as per Araz & Ozkarahan (2007). Thus, when there is some hesitation in allocating a certain alternative to a class, the method compares it to a reference alternative, which has been allocated in a class based on comparison with the limit profiles. This process also considers whether the DM is being optimistic or pessimistic. Moreover, the PROMSORT method uses the PROMETHEE structure to address the DM's preferences with the support of the preference functions. Therefore, the DM choose the function that best suits his/her preference structure, thereby facilitating the definition of the parameters for modeling the problem. These technical features facilitated the contact with the DM and the results proposed being achieved. Furthermore, by having used the PROMSORT Method in the first step of the application, it became easier for the DM to understand the meaning of the method's parameters in the second phase.

For this second phase of the application, the PROMETHEE method was selected because it is an outranking method and due to the flexibility it offers to the DM in choosing the weights of the criteria and the generalized criteria for each weight. In other words, just the evaluation criteria completed by his/her preference function – is important complementary information to have. A set of six types of preference functions is proposed to the DM and the choice is made taking into account his/her degree of preference on the basis of observed differences. In each case it is necessary to set a maximum of two parameters, indifference and preference thresholds, to deal with the DM's hesitation (Mareschal & Brans, 1992). Besides, there is the possibility of considering both qualitative and quantitative data.

5.1 First Phase of the Application

First of all, the decision maker (DM) chooses to analyze the services outsourced by the distribution center (DC). Thus, in the first phase, the classification of the services is obtained.

5.1.1 Defining alternatives

Several subcontractors carry out activities to support operations in the DC. The DM therefore listed the services that are currently outsourced by the DC. So, the eight services that have been outsourced were considered and are shown in Table 1.

Table 1 – Characterization of the outsourced services in the company's distribution center.

Service	Attributions	Number of suppliers
Cleaning (A1)	Responsible for cleaning and maintenance of internal and external areas of the Distribution Center.	2
Armed security (A2)	Responsible for protecting the DC from the actions of external agents. Work in the guardhouse and do the rounds in external areas.	1
Property security (A3)	Responsible for internal security on the premises of the DC. Perform rounds and oversee the receipt and shipment of goods of high value.	2
Loading and unloading (A4)	Responsible for loading and unloading of vehicles both in receiving and in dispatch	1
Separation of goods. (A5)	Separation of the goods to be shipped to the stores.	2
Maintenance (A6)	Responsible for maintenance of the machinery used in the DC.	1
Maintenance of the monitoring system (A7)	Responsible for maintenance of the cameras monitoring the DC.	1
Transport (A8)	Responsible for the transportation of goods from the DC to each store.	7
Refectory (A9)	Responsible for providing food for the employees.	1

5.1.2 Defining criteria

The DM defined a set of criteria in order to consider how critical the outsourced services are to the outcomes of the distribution center. Thus, five criteria were defined, which are given in Table 2.

For most of the criteria, a 9-point qualitative scale was adopted, since the DM was more comfortable using this scale. This verbal scale was then translated into an ordinal scale. It should

Table 2 – Characterization of the criteria.

Criteria	Description	Scale	Min/Max
Impact on sales	This takes into account the DM's evaluation of the direct importance of that service to the company's financial results, specifically in the performance of stores.	Qualitative (9 points)	Max
Cost	This takes into account the monthly cost of the service.	Monetary	Max
Alternative suppliers	This takes into account the DM's evaluation of the ease of finding alternative suppliers in the market.	Qualitative (9 points)	Min
Availability of resources	This takes into account the DM's evaluation of the ease with which suppliers can supply inputs (people, vehicles, equipment, etc.).	Qualitative (9 points)	Min
Quality	This takes into account the quality of services provided by subcontractors.	Qualitative (9 points)	Min

be noted also that the goal of analysis is to evaluate the impact that services have on business results. The DM directly assigned a weight to each criterion and was advised that a weight of $2x$ attributed to certain criteria means that these criteria are twice as important as any criteria which are given a weight of x. Thus, the weight represents the DM's preference for any given criterion.

In order to classify the outsourced services into categories that represent their importance to the business, according to the DM's needs, the PROMSORT method was chosen. The steps to obtain the configuration of these classes are as follows.

5.1.3 Apply PROMSORT

Having determined the criteria and their weights, a table was drawn up and the DM evaluated the alternatives considered, based on the chosen scales. Table 3 gives the matrix of the evaluations obtained and the weights assigned to each criterion.

The next steps involved defining the other parameters needed to perform the analysis. Thus, the DM selects the functions based on the usual criteria for the alternatives evaluated by using a qualitative scale. For the cost criteria, represented by the Brazilian unit of currency, the real (R$), the DM used a pseudocriterion function, for which the DM has adopted an indifference threshold of R$ 3,000 and a preference threshold of R$ 10,000.

In accordance with the model proposed, however, the alternatives needed to be allocated into classes in line with the critical role that they have for the company. PROMSORT was, therefore, used to allocate the alternatives into classes, based on the DM's preferences.

The DM stipulated the parameters that characterize the classes mentioned in the model. Thus, the limits of the profiles b_1 and b_2 were defined, by setting the frontiers of the classes. These

Table 3 – Evaluation matrix of the alternatives.

Criteria	Impact	Cost	Alt. Suppliers	Resources	Quality
Weights	6	4	2	2	4
A1	1	R$ 5,000	9	9	7
A2	2	R$ 20,000	7	5	5
A3	3	R$ 30,000	9	7	7
A4	4	R$ 30,000	9	6	5
A5	9	R$ 40,000	6	6	5
A6	6	R$ 5,000	3	3	8
A7	7	R$ 120,000	5	3	7
A8	2	R$ 2,000	1	1	1
A9	3	R$ 18,000	6	5	2

limits may be regarded as fictitious alternative profiles used to determine the boundaries of the classes.

It should be noted that the DM showed sufficient understanding of the meaning of the concepts that underpin the model. He questioned the analyst during the elicitation process whenever he had any doubts.

Table 4 gives the evaluation matrix in which the parameters determined for the PROMSORT application are included:

Table 4 – Matrix of the limit profiles.

Criteria	Impact	Cost	Alt. suppliers	Resources	Quality
Limit Profile 1	3	R$ 10,000	7	7	7
Limit Profile 2	6	R$ 40,000	4	4	5

PROMETHEE I was applied and the values shown in Table 5 were obtained.

Following the application of the PROMSORT method, comparisons were made between the alternatives and the limit profiles of the classes. Thus, at the end of this stage, there is the following configuration of the classes of critical services that the company outsourced:

After this step, hesitation in allocating the transport alternative was detected. This alternative provided further input streams and output streams that were greater than the threshold profile b_2. Thus, doubt arises as to whether the service should be allocated to the high impact or medium impact class.

To achieve this allocation, the second stage of PROMSORT is conducted. This involves using the alternative reference to allocate the alternatives that could not be sorted. In this case, the reference alternative is alternative A5, which is allocated to the class of high impact services. Thereafter, the distance function between alternatives is calculated.

Table 5 – Matrix of the values for φ, φ^+ and φ^-.

	φ^+	φ^-	φ
A1	0.7111	0.1778	0.5333
A2	0.7111	0.2111	0.5000
A3	0.4889	0.3889	0.1000
A4	0.4778	0.4000	0.0778
A5	0.4778	0.4333	0.0044
A6	0.4222	0.4778	-0.0556
A7	0.3222	0.5333	-0.2111
A8	0.2667	0.5444	-0.2778
A9	0.0222	0.8333	-0.8081
Limit Profile 1	0.2000	0.6000	-0.4000
Limit Profile 2	0.6889	0.1889	0.5000

Table 6 – Partial results of the classification process.

High impact services	Medium impact services	Low impact services	Incomparabilities
[A5]	[A9]	[A1]	[A8]
	[A4]		
	[A7]		
	[A6]		
	[A2]		
	[A3]		

The calculations resulted in $d_k^+ = 3{,}3623$ and $d_k^- = 0{,}0333$. Thus, we have the distance function $d_k = 0{,}527$. The DM has identified his view as being optimistic. Therefore, the alternative was allocated in accordance with the distance function. If $d_k > b = 0$, the alternative of transport is allocated to the class of services most critical to the company's results, in line with the DM's preferences. The final allocation is shown in Table 7.

Table 7 – Final results of the classification process.

High impact services	Medium impact services	Low impact services
[A5]	[A9]	[A1]
[A8]	[A4]	
	[A7]	
	[A6]	
	[A2]	
	[A3]	

5.1.4 Sensitivity analysis

A sensitivity analysis was conducted in order to assess the robustness of the results when small variations in the values of the parameters are considered.

For the sensitivity analysis, the authors adjusted the weights assigned to each criterion. Therefore, the analysis took into account an increase of 15% in the weight of each of the criteria, and a proportionate reduction in the others. The results are shown in Figure 2. The color key shows which alternative classes were allocated to each of the scenarios tested.

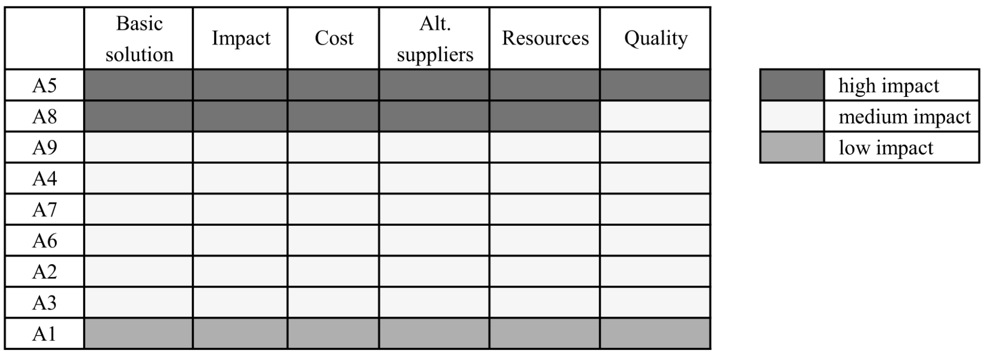

Figure 2 – Results of the Sensitivity analysis.

The sensitivity analysis was used to evaluate the robustness of the results arising from applying the method. For C1, C2, C3 and C4, increasing the values of the weight did not change the configuration of the classes and the services remained in the positions observed in the optimal solution. For criteria C5, however, the Freight service ended up being classified as a medium strategic impact, due to varying the values of the weights.

5.2 Applying the Second Phase

The results obtained from implementing the first phase of the model were shown to the DM and he suggested that the second phase be applied to the service of transporting goods. Note that is the manager interviewed who acts directly on the DC's relationship with hauliers.

As previously assessed, transport is one of the most critical services to the performance of the DC, as per the DM' preferences. Thus, it became necessary to perform an analysis taking into account important criteria with regard to selecting and improving the hauliers' performance.

5.2.1 Defining alternatives

The DC works with seven haulage companies, each with its own characteristics and constraints, to deliver goods to the stores. All of them were pre-selected and can be included in the day-to-day planning of the company's shipments. Table 8 provides relevant information on the alternatives considered.

Table 8 – Characterization of the transport alternatives.

Supplier	Type	Description
CMT	Private	Large haulier with nationwide operations. Specializes in medium-sized and large vehicles.
FLG	Private	Medium haulier with regional operations. Specializes in medium-sized vehicles
CTVL	Cooperative	Large cooperative with nationwide operations. Specializes in medium-sized and large vehicles
VTR	Private	Large haulier with nationwide operations. Specializes in medium-sized and large vehicles
DNM	Private	Medium haulier with regional operations. Specializes in medium-sized and small vehicles
NLG	Private	Small haulier with regional operations. Specializes in medium-sized and small vehicles
OLG	Private	Small haulier with regional operations. Specializes in medium-sized and small vehicles

5.2.2 Defining criteria

The DM then defined a set of criteria in order to obtain the ranking of the hauliers. These are shown in Table 9.

The DM, unlike in the first phase, selected a five-point scale to evaluate the alternatives according to the criteria. This change happened because the DM felt more comfortable about using that scale. Similarly to the first stage, the verbal scale is translated into a 5-point ordinal scale.

The DM highlighted the difficulty in measuring an average value for the service cost of each haulier. Thus, the DM used his experience and his day-to-day contact with the setting of freight rates to conduct a subjective assessment of costs related to each of the hauliers.

5.2.3 Applying PROMETHEE II

Table 10 shows the evaluation matrix evaluated by the DM and the values of the weights assigned to criteria.

The DM then defined his preference function for each criterion, in accordance with his assessment profile and considering his hesitation regarding his preference and indifference between the alternatives. Table 11 summarizes the parameters defined for applying the PROMETHEE method.

Then, PROMETHEE II was used to rank the transport alternatives, as per the preference of the manager of the area.

By applying PROMETHEE II, the following values for φ, φ^{+} and φ^{-} were obtained, as shown in Table 12.

Table 9 – Characterization of the criteria considered by the decision maker.

Criteria	Description	Scale	Min/Max
Variety of areas (C1)	Considers the states (stores) that can be served by the hauliers.	Qualitative (5 points)	Max
Variety of vehicles (C2)	Considers the types of vehicles that can be offered to the DC for the transport of goods.	Qualitative (5 points)	Max
Rate of service (C3)	Considers the frequency with which the hauliers meet the DC's requests for supplies.	Qualitative (5 points)	Max
Speed in attendance (C4)	Considers how quickly the haulier meets a request for a vehicle.	Qualitative (5 points)	Max
Capacity for Reverse Logistics (C5)	Considers the conditions set by the haulier for bringing materials back to the DC.	Qualitative (5 points)	Max
Quality of personal service (C6)	Evaluates the personal service provided by hauliers to the contacts made by the DC.	Qualitative (5 points)	Max
Quality of vehicles (C7)	Considers the physical condition of the vehicles that are sent by the hauliers.	Qualitative (5 points)	Max
Supply of raw materials (C8)	Evaluates the provision for materials that have to be sent with the vehicle, such as tarpaulins and other protective equipment.	Qualitative (5 points)	Max
Cost of freight (C9)	Assesses the profile of the freight rates charged by hauliers to transport goods to many different areas.	Qualitative (5 points)	Max

Table 10 – Evaluation matrix of the alternatives.

Service/Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Weight	20	10	15	10	5	5	10	5	30
CMT	5	5	4	4	3	5	3	4	2
FLG	4	4	5	4	4	3		3	3
CTVL	5	5	4	4	3	3		3	5
VTR	1	2	3	3	3	3		2	3
DNM	3	4	3	2	3	2		3	3
NLG	2	2	5	5	4	4		4	2
OLG	2	3	5	5	5	4		4	3

Table 11 – PROMETHEE II parameters.

Function	Criteria
Usual (any difference in valuation is considered a preference)	C1, C2, C3, C4, C7 and C9
Pseudo-criteria (with indifference thresholds $q = 1$ and preference thresholds $p = 2$)	C5, C6 and C8

Table 12 – Matrix of the values for φ, φ^+ and φ^-.

	φ^+	φ^-	φ
CMT	0.3409	0.3939	-0.0530
FLG	0.3788	0.2348	0.1439
CTVL	0.6212	0.1136	0.5076
VTR	0.1515	0.5303	-0.3788
DNM	0.2273	0.4621	-0.2348
NLG	0.2576	0.4242	-0.1667
OLG	0.4091	0.2273	0.1818

The results were expressed in Figure 3. On analyzing the results obtained, it is observed that haulier CTVL had the best performance in comparison with the other hauliers, followed by OLG and FLG. Then in descending order, come the suppliers CMT, NLG, DNM, and finally the haulier VTR.

With these results, the DM has information regarding the performance of hauliers that work with the Distribution Center and can take actions to intensify the relationship with the best hauliers, while looking for new suppliers of transport for the areas served by hauliers with the worst performance and, more importantly, can take measures to improve their performance.

The DM found the results very satisfactory. He was surprised, however, with the performance of haulier CMT, which meets most of the demand for vehicles and has an important history with the company. But it is pointed out that there are problems in that supplier's performance, which justifies the result.

5.2.4 Sensitivity analysis

In order to assess the consistency of results achieved, the sensitivity analysis was conducted using the walking weights methods. The weight of each criterion, in turn, was increased by 15% and thus the overall importance of the others was reduced.

6 DISCUSSION

The model proposed can be applied to the problem of selecting suppliers of products (raw materials) or selecting providers of services that companies require. The model is divided into two

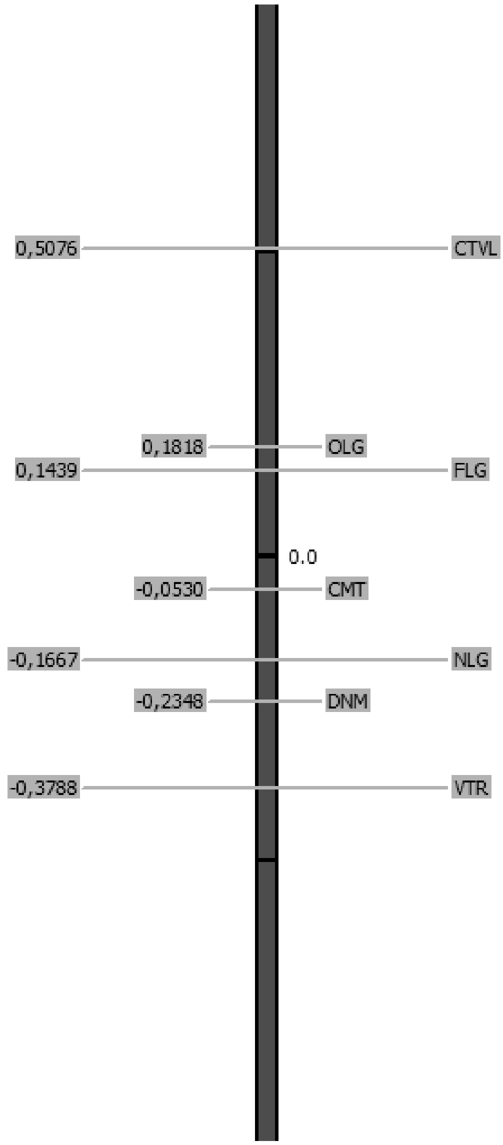

Figure 3 – Representation of the PROMETHEE II results.

phases. In the first phase, an important analysis of the critical aspects of the various products or services is conducted. Thus, companies can obtain an overview of the impact that these have on their business results and this can be used when designing the company's strategy. Therefore, the classification of products or services was proposed so that the company would then pay greater attention to those products/services that are the most critical ones for their results.

In order to determine what the best results might be, PROMSORT and PROMETHEE were used. These are outranking methods that have parameters which have a more tangible meaning for the

DM. Other methods can be used in the model, but the problem analysis demands a lot of information and the method to be used should facilitate the analysis. During the process of assigning weights, the DM understood the importance of weights for the results and sought to determine them in the most faithful way as to his preference structure At this point, the information that a certain alternative, which was assigned a weight $2x$, is twice as important as another alternative, with weight x, facilitated the assignment process. There was no great difficulty with the other parameters of the methods used. The DM, in turn, always requested examples to understand the meaning of each parameter for both PROMSORT, and for PROMETHEE.

For the case described in this study, the DM proved to be very interested in the benefits that the application could yield with regard to results. Furthermore, it was pointed out that the DM understood the concepts involved in applying the methods.

The results somewhat surprised the manager as to the performance of some suppliers. These partners had an inferior performance when compared to the size of the share in outsourced services that they have. Thus, the DM stated that the results obtained will be used to draw up the company's strategy, by increasing partnerships with those vendors with the best performance, while seeking while seeking to negotiate improvements from those whose performance was lower than expected and to seek new suppliers to fill the gaps detected in this study.

In particular, the situation of the carrier CMT was the most critical one for the DM. This was the only carrier when the distribution center began operations but, over the years, it had been losing share to other carriers that were emerging. In the past, CMT alone had transport for some regions, but the retailer is seeking to diversify the delivery destinations of the other hauliers to ensure its stores are supplied, especially in periods of high demand.

7 CONCLUSIONS AND FURTHER RESEARCH

The retail market is characterized by the strong competition between the various entities. Therefore, companies are increasingly reducing their profit margins, thus offering products at a lower price to their customers. This trend requires the efficiency of the retailer's supply chain to be increased which requires a better relationship between the various agents in the supply chain.

Thus, it is important to consider how retailers select their suppliers. This paper proposed a model to address the problem of supplier selection, taking into account the DM's preferences. It considers the strategic role that the product or service offered plays in the success of a supply chain.

The proposed model can be adapted to companies from different sectors and is applicable to both products and services. The model was applied to the distribution center of one of the largest retailers in Brazil.

With regard to the specific results of the selection of suppliers, the company should intensify its relationship with the supplier ranked first by the analysis and seek improvements in performance by the other suppliers. Thus, this tool can lead to guidelines for the relationship between companies and their suppliers being produced.

In this paper, a model for supplier selection in a real situation was applied. In this context, the proposed model has been shown to be well suited to this case, providing an interesting tool for decision support in that environment. It was also observed that the methods used can be applied in real situations without the need for more resources, but rather all that is required is greater interaction with the decision maker. The application of the PROMETHEE method is given by software. Otherwise, the application of PROMSORT was undertaken without any software support, but was nevertheless conducted quite satisfactorily.

As to suggestions for future studies, investigations should be made of how the distribution centre could apply the proposed model to selecting suppliers of products and evaluating other service providers it uses, ranging from those assessed as most critical to those with less impact, where relevant. Furthermore, how the model could be extended to the stores should be examined as it is the stores which are the points of interface between the company and the customer, and they should seek partnerships with various service providers.

More generally, further studies should explore how the model proposed can be applied to companies in other sectors, not only the retail one, thus leading to the same benefits that were observed to arise from compiling the model proposed in this study.

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