Supplier's selection model based on an empirical study

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Abstract

The problem of selecting suppliers/partners is a crucial and important part in the process of decision making for companies that intend to perform competitively in their area of activity. The selection of supplier/partner is a time and resource-consuming task that involves data collection and a careful analysis of the factors that can positively or negatively influence the choice. Nevertheless it is a critical process that affects significantly the operational performance of each company. In this work, there were identified five broad selection criteria: Quality, Financial, Synergies, Cost, and Production System. Within these criteria, it was also included five sub-criteria. After the identification criteria, a survey was elaborated and companies were contacted in order to understand which factors have more weight in their decisions to choose the partners. Interpreted the results and processed the data, it was adopted a model of linear weighting to reflect the importance of each factor. The model has a hierarchical structure and can be applied with the Analytic Hierarchy Process (AHP) method or Value Analysis. The goal of the paper it's to supply a selection reference model that can represent an orientation/pattern for a decision making on the suppliers/partners selection process

Keywords

Suppliers/Partners; Selection, Criteria; Weighting; AHP; Value Analysis.

1. Introduction

The supplier selection is a problem that companies face since the beginning of its activity. The choice of supplier/partner is one of the key factors for the operational success of many companies but also a time and resource-consuming complex process. Today, many companies need to constantly strengthen its competitiveness through reliable and efficient supply networks based on suppliers/partners relations in order to increase profit and promote customer value [1]. International competitors, customer requirements, rapid technology changes and short product life cycle influence the competitiveness between supply chains. Companies struggle to counter these forces by minimizing costs, minimizing waste and focusing on their core competencies [1].

This work is focused in the supplier selection phase that in many cases can be presented as a structured and complex algorithm. The supplier selection phase it is normally the second step of the selection process, after the qualification and before the evaluation, as can be seen in the Figure 1. As this process is continuous and it is subjected to new entries and leavings of partners, the process can be classified as dynamic.

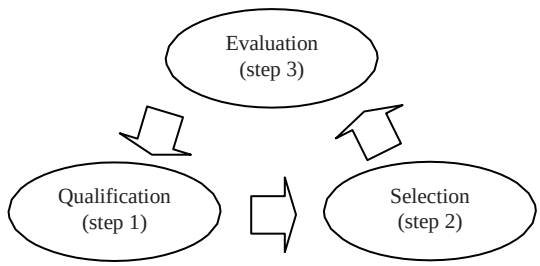

Fig. 1. Suppliers/Partners selection dynamic process

In literature, the methods of choosing the best supplier begin through the criteria identification for the model. Dickson [2] made a conceptual study where were identified 23 criteria to evaluate the suppliers. This study was based in 170 buyers and management officers. Weber [3] based on reading 74 related papers concluded that quality was the most important criterion followed by delivery and cost performance. Quality, capacity, delivery and just-in-time philosophy are also relevant criteria from the literature. Talluri and Narasimhan [4] in his comprehensive work presents an overview of the supplier selection methods. According to him, in the criteria search there is two different views: conceptual view and the empirical study view. Talluri and Narasimhan [5] concluded that the cost couldn't be the only criteria in the supplier selection decision. Lehmann and O'Shaughnessy [6] proposed 5 criteria: performance, economy, plenitude, agreements and social norms. Caddick and Dale [7] referred that quality, production plan, control system validity, historic activity, item category and price must be include on the criteria. Ellram [8] thought that the compatibility of management or orientation strategy must be added in the usual criteria. Patton [9] proposed 7 criteria: price, quality, delivery, sales support, equipment, technology, order process and supplier company financial position.

Once evaluated and identified the criteria, the analytical methods are used in the supplier selection. The analytical methods range from linear weighting methods to mathematical programming methods [5]. However, the supplier selection problem considers a large number of criteria. It can be classified as a multi-criteria problem. The criteria definition, weights and factor evaluations are one of the major difficulties for this type of problems.

In the linear weighting methods, the Analytic Hierarchy Process (AHP) and the Simple Multi-Attribute Rating Technique (SMART) have a hierarchical structure and include quantitative and qualitative criteria [10]. The Analytical Network Process (ANP) includes interaction between supplier selection criteria [11]. The Fuzzy Sets Theory (FST) method deals with inaccuracy in the supplier selection [12].

In the mathematical programming, the Multi-Objective Programming (MOP) and Data Envelopment Analysis (DEA) are the most cited in literature [13].

In the next section, it is presented the AHP method. The section 3 is devoted to the supplier's selection model construction and its application using the AHP or Value Analysis methods. Finally, in the conclusion section presents some considerations about this work and future approaches.

2. The AHP method

The AHP method was proposed and developed by Thomas L. Saaty [14]. This method exploits the qualitative data of a given problem and transforms the data into quantifiable data, which subsequently can be analyzed and interpreted. In the AHP model is used a 1-9 scale for comparing two factors, that in the suppliers selection case are the criteria selection. If the first criterion is of upmost importance than the second, then, it has the value 9. Conversely, the second criterion when compared with the first has score of 1/9, Saaty [15]. Thus it is determined the relative importance (designated by weight) of each criterion. For the rest of the values, Thomas L. Saaty has set a scale, whose explanation can be seen in the Figure 2.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activity contribute equality to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity is has one of the above nonzero numbers assigned to it when compared with *j*, then *j* has the reciprocal values when compared with *i*	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtained *n* numerical values to span the matrix

Fig. 2. AHP's values scale [15]

After that, the results of the comparison between each pair of criteria are expressed in a matrix. Figure 3 illustrates an example where the objective is to estimate the relative consumption of types of drinks in the USA.

Which drink is consumed more in the USA?							
An example of examination using judgments							
Drink consumption in US	Coffee	Wine	Tea	Beer	Soda	Milk	Water
Coffee	1	9	5	2	1	1	1/2
Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	2	1	1/3	1/4	1/3	1/9

Beer	1/2	9	3	1	1/2	1	1/3
Soda	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1

Fig. 3. Example of an AHP weighting matrix [15].

The weight of each criterion is obtained on the normalized matrix. Saaty has recommended that the normalized matrix should be achieved by raising the matrix to its higher power. That can be made by dividing each element of the matrix by the sum of all elements of the column to which it belongs, as can be seen in Figure 4. So, the sum of the elements of each column is one [16]. The weights were obtained by the arithmetic mean of each row in the normalized matrix, as can be seen in the last column of the Figure 4.

	Coffee	Wine	Tea	Bear	Sodas	Milk	Water	Weights
Coffee	0,172	0,188	0,197	0,212	0,187	0,118	0,173	0,178
Wine	0,019	0,021	0,013	0,012	0,021	0,013	0,038	0,020
Tea	0,034	0,042	0,039	0,035	0,047	0,039	0,038	0,039
Bear	0,086	0,188	0,118	0,106	0,093	0,118	0,115	0,118
Sodas	0,172	0,188	0,016	0,212	0,187	0,237	0,173	0,189
Milk	0,172	0,188	0,118	0,106	0,093	0,118	0,115	0,130
Water	0,344	0,188	0,355	0,318	0,373	0,355	0,346	0,326
Total	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Fig. 4. Normalized matrix and estimated weights

The AHP hierarchical tree is built after calculating the weights. In this example, the AHP model has only two levels, the goal and the alternatives to achieve the objective. This is the simplest hierarchical model and the decision is given by the best percentage (see the Figure 5).

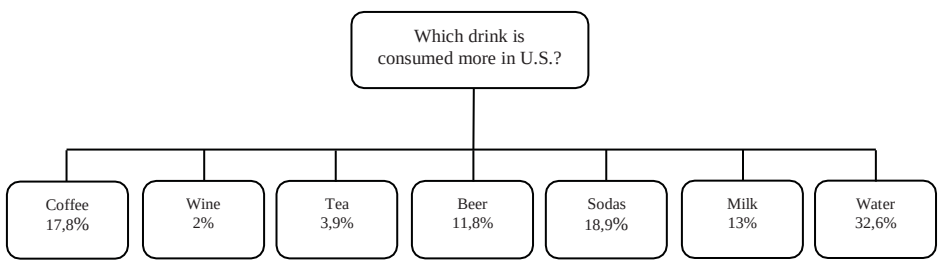

Fig. 5. Hierarchical structure of the Saaty example

However, the hierarchical tree can be more detailed through the inclusion of goal, criteria, sub-criteria and other relevant alternatives (see an example in [17]).

3. Model Construction

This study is based on a quantitative approach. In these types of approaches it is used structured methods in the search for answers. In this work it was chosen to conducted a questionnaire with short and objective answers. The questionnaire consisted in 2 questions. The first one related to the relative importance for the enterprise of the criteria and the other one for the relative importance of the sub-criteria inside each criterion. The answers were given in percentage. The respondent assigned the highest percentage to criteria (or sub-criteria) with the greatest importance and redistributed the remaining percentage by the other criteria (or sub-

criteria) until the total sum of the percentages made up 100%. With this type of structure it is possible understand how important it is a criteria when compared with another.

3.1. Identification and Ranking of Selection Criteria

Based on the analysis of the literature (Dickson [2], William et al. [4], Lehmann and O'Shaughnessy [6], Perreault and Russ [18], Abratt [19], Billesbach et al. [20], Mummalaneni et al. [21], Choi et al. [22], Hirakubo and Kublin [23], Verma and Puliman [24], Yahya and Kingsman [25], Silva et al. [26], Bharadwaj [27], Haydy and Hodges [28]), were considered five generic criteria. For these five criteria, the present work calls them systems. In turn, each system comprises five other criteria directly related, called sub-criteria. The five major criteria are: Quality, Financial, Synergies, Cost, and Production. The Quality system, the criteria more referred in the literature, comprises all the factors that can be important for the quality assessment by consumer. The Financial system, not often referred in the literature, comprises all the issues relating to the financial stability of the supplier/partner. The Synergies system relates all the factors that may potentiate the profit relation between clients and supplier, in all the supply chain. The Cost system, one of the most cited in the literature, aggregates all the items that can contribute for the expenses in commercial transaction. Finally, the Production system includes all the issues relating to technical innovation or processes support. Based on the previous table analysis, it was considered the following sub-criteria inherent to each system, presented in Table 1.

Table 1. Criteria and sub-criteria

Criteria	Sub-criteria
Quality System (Q)	Quality management systems (Q1)
	Guarantees (Q2)
	Service level (Q3)
	Customer focus (Q4)
	Total quality management systems (Q5)
Financial System (F)	Economic/financial ratios (F1)
	Indicators of added value (F2)
	Financial stability (F3)
	Contractualization (F4)
	Quoted price in the financial market/Capitals (F5)
Synergies System (S)	Synergies potential (S1)
	Location (S2)
	Strategic aspects (S3)
	Inter-organizational relationships (S4)
	Cultural aspects (S5)
Cost System (C)	Product cost (C1)
	Logistics cost (C2)
	Payment flexibility (C3)
	After-sales service costs (C4)
	Training costs (C5)
Production System (P)	Environmental concern (P1)
	Productive features in the production (P2)
	Innovation (P3)
	Range of products (P4)
	Production capacity (P5)

3.2. The Sampling Procedure and Data Processing

The collection of survey data was held on the basis of relational knowledge. Trough these contacts it was obtained 30 responses. The sample companies carry a wide range of activities, all of them operating in Portugal. The responses collected came from SME (small, medium and large enterprises) and microenterprises.

Given the large number of companies in Portugal, the size of population was considered infinite. So, the parameters estimation of the population was made on the basis of the sample data and considering a fixed confidence interval. Usually, the samples averages exhibit a normal distribution even if the population does not present a normal distribution. If the sample size is less than or equal to 30 then it is not appropriate to use the normal distribution in the confidence intervals calculation but the t-student table [29]. Data was organized on Microsoft Office Excel spreadsheet for calculation of mean and standard deviations. The values were calculated using 90% confidence interval and obtaining error values between 1,6% and 4,4%.

It was necessary to create six tables for the data input; one table to the criteria (Table 2) and the other five for the sub-criteria associated with them (Table 3,4,5,6 and 7). As already noted, the responses came from different enterprises dimensions and in order to evaluate the information adequately they were evaluated separately. This segmentation was necessary because it was detected from the preliminary analysis of the data, that some responses presented different behavior according to the size of the company.

The mean values of the survey results for the five major criteria can be seen in Table 2. Observing the table, it can be seen that the Cost and Quality systems were given greater prominence for all the size of companies. In spite of this relevance, for each criterion the values differ according to the company's size. Based on the total average, i.e., considering the values of all companies' size, Cost and Quality systems remain the criteria with most relevance, unlike the Synergies system which presents the lowest values.

Table 2. The mean values of the survey results for the 5 major criteria

Size of the Company \ Criteria	Quality S.	Financial S.	Synergies S.	Cost S.	Production S.
Large enterprise	22,8%	11,1%	9,4%	36,1%	20,6%
Small and Medium enterprises	22,9%	18,4%	12,2%	27,5%	19,0%
Microenterprise	29,4%	16,7%	14,4%	22,8%	16,7%
Total Average	24,8%	15,7%	12,0%	28,7%	18,8%

In table 3, for the results associated to Quality system, it can be noted that the Service level have high importance for all companies size. The second sub-criteria with higher importance for large companies is the Quality management, but for the other sizes it is the Guarantees.

Table 3. The means values to the Quality System

	Quality System Requirements					
Size of the company\sub-criteria	Quality management systems	Guarantees	Service level	Customer focus	Total Quality Management Systems	others
Large enterprise	26.1%	17.2%	38.3%	10,0%	8.3%	0,0%
Small and Medium enterprises	18.8%	22,1%	36.3%	12,3%	10,7%	0,0%
Microenterprise	12.8%	26.7%	32.8%	16,1%	11.7%	0,0%
Total Average	19.2%	22,0%	35.8%	12,7%	10,3%	0,0%

In Table 4, the Financial stability has a great importance for Small and Medium, and Micro enterprises, while for Large enterprises it is the criterion Economic/financial ratios. The second more important sub-criteria is distributed by Economic/financial ratios, Financial stability and Indicators of added value considering the decreasing order of the company size.

Table 4. The means values to the Financial System

Size of the company\sub-criteria	Financial System Requirements					
	Economic/ financial ratios	Indicators of added value	Financial stability	Contractua lization	Quoted price in the financial market/Capitals	others
Large enterprise	35.6%	15,0%	26.7%	11.1%	11.7%	0,0%
Small and Medium enterprises	25,4%	21,3%	32,1%	15.4%	5,8%	0,0%
Microenterprise	13,9%	22,8%	30,6%	22,2%	10,0%	0,0%
Total Average	25.0%	19.8%	30.0%	16,2%	9,0%	0.0%

In table 5, the Synergies potential is the most important sub-criteria for Large, and Small and Medium Enterprises, followed by the location. For Micro enterprises the most important is the Location followed by the Synergies potential.

Table 5.The means values to the Synergies System

Size of the company\sub-criteria	Synergies System Requirements					
	Synergies potential	Location	Strategic aspects	Interorganiza tional relationships	Cultural aspects	others
Large enterprise	28,3%	25,0%	14,8%	20,0%	11,9%	0,0%
Small and Medium enterprises	27,9%	24,2%	19,6%	20,8%	7,5%	0,0%
Microenterprise	25,0%	28,3%	18,9%	16,1%	11,7%	0,0%
Total Average	27,2%	25,7%	17,9%	19,2%	6,6%	0,0%

In table 6, the Product cost is the most important sub-criteria for all companies' size. The Logistics cost and Payment flexibility are very relevant too.

Table 6. The means values to the Cost System

Size of the company\sub-criteria	Cost System Requirements					
	Product cost	Logistics cost	Payment flexibility	After-sales service costs	Training costs	others
Large enterprise	40,6%	18,9%	18,3%	13,9%	8,3%	0,0%
Small and Medium enterprises	35,0%	18,3%	19,2%	16,0%	11,5%	0,0%
Microenterprise	27,8%	16,7%	27,2%	15,0%	12,8%	0,0%
Total Average	34,5%	18,0%	21,3%	15,3%	10,9%	0,0%

In table 7, it can be seen that the Innovation sub-criterion is the more important for Small and Medium enterprises, and Micro enterprises. For Large enterprises the Innovation and the Productive features in production appears with equal importance. The total average shows some uniformity between all sub-criteria.

Table 7. The mean values to the Production System

Size of the company\sub-criteria	Production System Requirements					
	Environment al concern	Productive features in production	Innovation	Range of products	Production capacity	others
Large enterprise	18,9%	21,7%	21,7%	17,2%	20,6%	0,0%
Small and Medium enterprises	16.3%	16,7%	25,4%	20,0%	21,7%	0,0%
Microenterprise	17,2%	20,0%	23,9%	20,6%	18,3%	0,0%
Total Average	17.3%	19,2%	23,8%	19.3%	20,3%	0,0%

3.3. Proposed Model

The proposed model, as can be seen in Figure 6, is based on a hierarchical structure. The AHP and the Value Analysis method can be applied in this model. The relative weightings of the criteria and sub-criteria are framed in the linear weighting models.

The weightings were obtained directly from questionnaires and for the criteria correspond to the averages values obtained. The weightings of sub-criteria were calculated by multiplying the percentage of criterion with its sub-criteria. The sum of weightings in each level should be equal to 1 (corresponding at 100%).

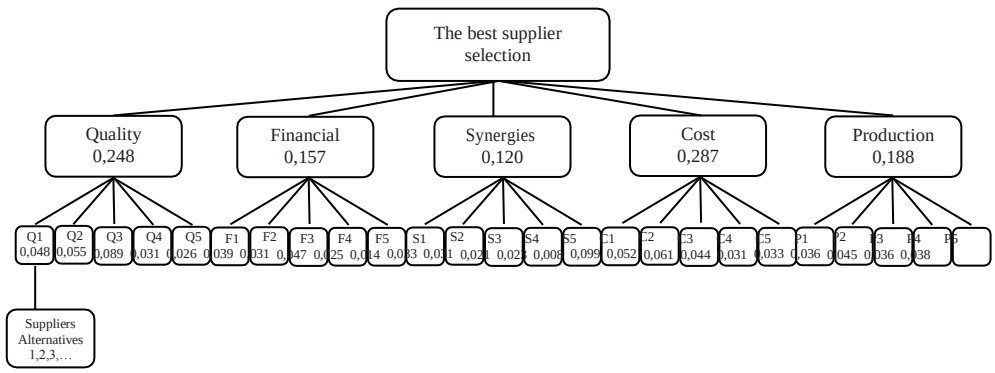

Fig. 6. Proposed model

Now, with the model, the AHP and the Value Analysis methods can be applied, as it will be showed in the next sub-sections.

3.3.1 AHP Method Application

Starting from the assumption that it is available 3 alternatives for the suppliers (A supplier (AS), B supplier (BS) and C supplier (CS)). The A, B and C suppliers will be evaluated for each of the sub-criteria. The evaluation is made by the Saaty comparison matrix. As an example, we consider the matrix in Table 8 for the Quality System (Q1) sub-criterion.

Table 8. Comparison matrix of the A, B and C suppliers for the Q1 sub-criterion

	AS	BS	CS
AS	1	9	5
BS	1/9	1	2
CS	1/5	1/2	1

It is necessary to normalize the comparison matrix. In Table 9, it is presented the normalized matrix with the suppliers weights.

Table 9. Normalized matrix of the A, B and C suppliers to Q1

	AS	BS	CS	Weights
AS	0,763	0,857	0,625	0,748
BS	0,085	0,095	0,250	0,143
CS	0,153	0,048	0,125	0,108
Total	1,000	1,000	1,000	1,000

The evaluation result for the Q1 sub-criterion is obtained multiplying the weights of the supplier by the sub-criterion weight associated. So, for Q1:

$$AS(Ql) = 0{,}048 \text{ x } 0{,}748 = 0{,}036$$
$$BS(Ql) = 0{,}048 \text{ x } 0{,}l43 = 0{,}007$$
$$CS(Ql) = 0{,}048 \text{ x } 0{,}l08 = 0{,}00S$$

These procedures are repeated for each sub-criterion. The supplier rank is given by the sum of all its values. At the end, the selected supplier will be the highest classified. As example, it is showed the formula to calculate the rating of the AS supplier:

$$AS_{rating} = AS(Ql) + AS(Q2) + \cdot + AS(PS)$$

3.3.2 Value Analysis Method Application

Considering the same alternatives, AS, BS and CS, the suppliers are classified on a scale of 0 to 5 points for each sub-criterion. Let, for example, Q1:

AS (Q1) = 3; BS (Q1) = 5, CS (Q1) = 1

This procedure is applied in all sub-criteria and at the end, we will have the following classification:

$$AS_{rating} = AS(Ql) \text{ x } Ql + AS(Q2) \text{ x } Q2 + \cdot + AS(PS) \text{ x } PS$$
$$= 3 \text{ x } 0{,}048 + AS(Q2) \text{ x } 0{,}0SS + \text{ - } + AS(PS) \text{ x } 0{,}038$$

$$BS_{rating} = BS(Ql) \text{ x } Ql + BS(Q2) \text{ x } Q2 + \cdot + BS(PS) \text{ x } PS$$
$$= S \text{ x } 0{,}048 + BS(Q2) \text{ x } 0{,}0SS + \text{ - } + BS(PS) \text{ x } 0{,}038$$

$$CS_{rating} = CS(Ql) \text{ x } Ql + CS(Q2) \text{ x } Q2 + \cdot + CS(PS) \text{ x } PS$$
$$= \mathbf{l} \text{ x } 0{,}048 + CS(Q2) \text{ x } 0{,}0SS + \cdot + CS(PS) \text{ x } 0{,}038$$

Finally, the selected supplier will be the one with the highest classification.

Both models use linear weighting models. While the AHP model makes comparisons between all supplier pairs, the Value Analysis model evaluates individually the supplier on each sub-criterion. The end-user shall take into account the company's needs to determinate the best method to be applied.

4.Conclusion

The supplier selection is a complex and very important process in the companies. Companies' higher operational performance level depends of their suppliers network integration and cooperation. In this work, the objective was to understand which relevant factors to consider when selecting a supplier. In literature studied, it was identified five major criteria: Quality, Financial, Synergies, Cost and Production System. The influence of criteria and sub-criteria in the supplier selection was determined by a questionnaire submitted to key decision makers in the companies. The sample data was based on 30 survey responses ranging from SMEs and micro-companies. T-student distribution was used in the sampling procedure and the maximum error in the confidence interval of 90% was 4,4%.

The proposed reference model for supplier/partner selection presented in this work is based on the Saaty's AHP method. The choice relied on this method due to the linear weighting and hierarchical structure present in this model. In the proposed model, the criteria (and sub-criteria) weights determination was different of the traditional AHP.

Based on literature analysis and the survey results, it is the conviction of the research team that the proposed reference model for supplier/partner selection presents will help company managers to select the best supplier/partner for their companies. The proposed weightings present in the model can be used in the alternative evaluation with the AHP or Value Analysis method given more reliability to the choices made.

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