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PROPOSAL OF AN EMPIRICAL MODEL FOR SUPPLIERS SELECTION

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, trough the literature review, there were identified five broad suppliers selection criteria: Quality, Financial, Synergies, Cost, and Production System. Within these criteria, it was also included five sub-criteria. Thereafter, a survey was elaborated and companies were contacted in order to answer which factors have more relevance in their decisions to choose the suppliers. 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 Simple Multi-Attribute Rating Technique (SMART). The result of the research undertaken by the authors is a reference model that represents a decision making support for the suppliers/partners selection process.*

Keywords: *Suppliers/partners selection model, hierarchical structure criteria, linear weighting methods, Analytic Hierarchy Process, Multi-Attribute Rating Technique*

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 (Krause *et al.*, 1998).

In order to contribute to the problem resolution, 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

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this process is continuous and it is subjected to new entries and leavings of partners, the process can be classified as dynamic.

Given the inherent complexity, the organizations frequently need tools to support decision-making, in order to identify the most favorable scenarios concerning the "optimal" or the best possible allocation of suppliers/partners (Vayvay *et al.*, 2012).

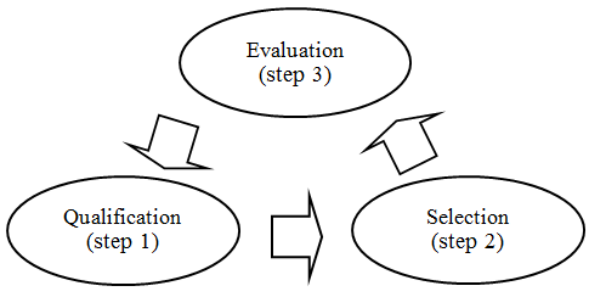

Figure 11. The dynamic process of the Suppliers/Partners selection (Ávila *et al.*, 2012)

Decision making involves many criteria and sub-criteria used to rank the alternatives of a decision, analyzing dependencies between alternatives and implications of these in terms of higher goals (Power and Sharda, 2007; Saaty, 2008).

In literature, the methods of choosing the best supplier begins through the criteria identification for the model. Let's point some of them. Dickson (1966) made a conceptual study where were identified 23 criteria to evaluate the suppliers. This study was based in 170 buyers and management officers. Wind *et al.* (1968) in his comprehensive work presents an overview of the supplier selection methods. Lehmann and O'Shaughnessy (1982) proposed 5 criteria: performance, economy, plenitude, agreements and social norms. Caddick and Dale (1987) referred that quality, production plan, control system validity, historic activity, item category and price must be included on the criteria. Weber *et al.* (1991) based on reading 74 related papers concluded that quality was the most important criterion followed by delivery and cost performance. According to him, in the criteria search there are two different views: conceptual view and the empirical study view. Talluri and Narasimhan (2001) concluded that the cost couldn't be the only criteria in the supplier selection decision. Patton (1996) proposed 7 criteria: price, quality, delivery, sales support, equipment, technology, order process and supplier company financial position. Ellram *et al.* (2002) thought that the compatibility of management or orientation strategy must be added in the usual criteria. Due to differences of each author, the criteria definition, weights and factor evaluations are one of the major difficulties for this type of problems.

Once evaluated and identified the criteria, the analytical methods are used in the supplier selection decision. The analytical methods range from linear weighting methods to mathematical programming methods (Talluri and Narasimhan, 2001). However, the supplier selection problem may consider a large number of criteria. It can be classified as a multi-criteria problem. 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 (de Boer *et al.*, 1998). Some extensions of these methods are the Analytical Network Process (ANP), that includes interaction between supplier selection criteria, and the Fuzzy Sets Theory (FST) method, that deals with

inaccuracy in the supplier selection (Zhao and Xu, 2008). In the mathematical programming, the Multi-Objective Programming (MOP) and Data Envelopment Analysis (DEA) are the most cited in literature.

Despite several papers in the area of selection of suppliers/partners, there isn't still a selection model that is considered as reference for companies when making his decision. Each company follows its method without contrast it with one more standard. For this reason, the final goal of the paper it is to create and supply a new selection reference model for the companies, that can represent an orientation/pattern for a decision making on the suppliers/partners selection process. To get the principal goal, three intermediary objectives will be explored: 1st - through the literature understand what are the relevant criteria and sub-criteria to consider in the selection phase; 2nd - by a questionnaire, submitted to key decision makers in the companies, define the influence of the criteria and sub-criteria in the supplier selection; and 3rd - in order to facilitate the use of the model by the companies, to propose the application of the model using two linear methods, the AHP and the SMART.

The structure of the paper it is aligned with the goals. In the next section it is explained the supplier's selection model construction and in the section 3, its application using the AHP or the SMART methods. Finally, the conclusion section presents some considerations about this work and future approaches.

2. Model Construction

For the model construction it was chosen a hierarchical structure with the capacity to include quantitative and qualitative criteria and prepared to be used by linear weighting methods, namely, by AHP and SMART. For its development were considered two main phases: identification and ranking of selection criteria, and the determination of the criteria weights - sampling procedure and data processing, whose explanation follows.

2.1. Identification and Ranking of the Selection Criteria

This section intends to explain how it was achieved the 1st intermediary objective trough the bibliography revision. To summarize some of the studies conducted to date in the field of supplier selection criteria, was drawn up a table 1 on which are set, in a chronological way, the authors and the criteria they have identified as most important.

Table 11. Synthesis of the literature review for the criteria

Authors / Criteria	Dickson (1966)	Wind et al. (1968)	Perreault and Russ (1976)	Lehmann and O' Shaughnessy (1982)	Abratt (1989)	Billesbach et al. (1991)	Patton (1996)	Mummalaneni et al. (1996)	Choi et al. (1996)	Hirakubo and Kublin (1998)	Verma and Pullman (1998)	Yahya and Kingsman (1999)	Ellram et al. (2002)	Silva et al. (2002)	Bharadwaj (2004)	Haydu and Hodges (2004)	William et al. (2010)
Quality	X		X			X	X	X	X	X	X	X		X	X	X	X
Quality Philosophy									X								
Conditions of the product upon arrival															X		
Maintenance				X	X												
Delivery	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X
Responses to customer needs								X						X		X	
Repair service	X																
After sales service				X	X		X	X									X
Repartee								X									
TQM										X							
History	X	X		X	X			X			X						
Recording of reactions at work	X																
Management and organization	X		X									X	X				X
Professionalism								X				X					
Location	X	X	X														
Confidence in the buyer/order				X													

Communication System	X								X			X	X				
Financial Capacity	X						X					X					
Procedural performance	X												X				
Politics of guarantees and loans	X								X								
Vision for the business	X												X				
Quantity of business achieved	X																
Prior contact with the buyer	X																
Disclosures of financial records									X								
Information and service Market		X											X				
Benefits received by the buyer		X															
Supplier's profit									X								
Financing				X					X								X
Production facilities	X						X										
Operational controls	X																
Technical capacity	X	X		X						X		X		X			X
Technical Innovation		X												X			X
Flexibility				X		X			X		X						X
Materials used											X						
Technical specifications				X													
Ease of use				X	X							X					
Design capacity									X					X			
Reliability				X	X				X								X
Technical service				X	X												
Order size			X				X										
Performance bonuses									X								
Premiums pursuant									X								
Long-term relationship									X				X				X
Conflict resolution									X								
Production										X							
Price	X		X	X		X	X			X			X		X	X	X
Price/quality ratio		X						X									
Unit cost of the components											X			X			
Low starting price									X								
Support training	X			X													
Responsibility												X					
Fulfillment of order															X		
Ability to comply with emergence orders															X		

Resulting from the information presented in Table 1, it is possible to make some observations. The first analysis that can be drawn from this summary is a lack of compliance among authors regarding the criteria that consider. If there are criteria such as price, quality, delivery and reputation that are referred to by most authors, there are others in which only one author refers them. This discrepancy is mainly due to the fact that each one has their vision and perspective of the topic. However, it is not of devalue the criteria that are referred to by an author, but study them and understand its importance in the context of the problem. The second fact to be taken into account in the analysis of Table 1 is that, despite the historical evolution (1966 to 2010), many of the criteria that were important in the early studies, continue to have contemporary relevance, for what, may be inferred from its importance in selection of suppliers.

Based on the analysis of the previous table, were considered five broad 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 2.

Table 2. 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)

2.1. Determination of the Criteria weights - The Sampling Procedure and Data Processing

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 conduct 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.

After the dissemination of the survey, by email, to a broad set of companies registered in the database of our engineering school, unsuccessfully with answers, the collection of survey data was held on the basis of relational knowledge. Through 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 large, small and medium enterprises (SME) 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 (Kothari, 2004). 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 3) and the other five for the sub-criteria associated with them (Table 4, 5 ,6 ,7 and 8). 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 3. 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 3. The statistical values of the survey results for the 5 major criteria

Statistical parameters \ Criteria	Quality S.	Financial S.	Synergies S.	Cost S.	Production S.
Average for: Large enterprise	22,8%	11,1%	9,4%	36,1%	20,6%
Small & Medium enterprise	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%
Standard Deviation	10,3%	8,1%	8,3%	16,2%	11,5%
Sampling Error for 90% of Confidence	3,1%	2,4%	2,5%	4,9%	3,4%

In table 4, 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 4. The statistical values to the quality system

	Quality System Requirements					
Statistical parameters\Sub-criteria	Quality management systems	Guarantees	Service level	Customer focus	Total Quality Management Systems	others
Average for: Large enterprise	26.1%	17.2%	38.3%	10,0%	8.3%	0,0%
Small & Medium enterprise	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%
Standard Deviation	11,9%	10,2%	14,7%	8,1%	6,1%	
Sampling Error for 90% of Confidence	3,6%	3,1%	4,4	2,4%	1,8%	

In Table 5, 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 are distributed by Financial stability, Economic/financial ratios, and Indicators of added value considering the decreasing order of the company size.

Table 5. The statistical values to the financial system

			Financial System Requirements			
Statistical parameters\Sub-criteria	Economic / financial ratios	Indicators of added value	Financial stability	Contractualization	Quoted on financial market / Capitals	others
Average for: Large enterprise	35.6%	15,0%	26.7%	11.1%	11.7%	0,0%
Small & Medium enterprise	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%
Standard Deviation	14,8%	10,5%	10,7%	9,2%	9,0%	
Sampling Error for 90% of Confidence	4,4%	3,1%	3,1%	2,8%	2,1%	

In table 6, 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 6. The statistical values to the Synergies System

	Synergies System Requirements					
Statistical parameters\Sub-criteria	Synergies potential	Location	Strategic aspects	Interorganizational relationships	Cultural aspects	others
Average for: Large enterprise	28,3%	25,0%	14,8%	20,0%	11,9%	0,0%
Small & Medium enterprise	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%	10,1%	0,0%
Standard Deviation	10,4%	11,3%	7,2%	11,0%	6,6%	
Sampling Error for 90% of Confidence	3,1%	3,4%	2,1%	3,3%	2,0%	

In table 7, the Product cost is the most important sub-criteria for all companies'

size. The Logistics cost and Payment flexibility are very relevant too.

Table 7. The statistical values to the Cost System

	Cost System Requirements					
Statistical parameters\Sub-criteria	Product cost	Logistics cost	Payment flexibility	After-sales service costs	Training costs	others
Average for: Large enterprise	40,6%	18,9%	18,3%	13,9%	8,3%	0,0%
Small & Medium enterprise	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%
Standard Deviation	11,0%	7,0%	8,0%	6,8%	5,3%	
Sampling Error for 90% of Confidence	3,3	2,1	2,4	2,0	1,6	

In table 8, 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 8. The statistical values to the Production System

	Production System Requirements					
Statistical parameters\Sub-criteria	Environmental concern	Productive features in production	Innovation	Range of products	Production capacity	others
Average for: Large enterprise	18,9%	21,7%	21,7%	17,2%	20,6%	0,0%
Small & Medium enterprise	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%
Standard Deviation	7,8%	7,4%	7,4%	10,2%	11,5%	
Sampling Error for 90% of Confidence	2,3%	2,2%	2,2%	3,1%	3,4%	

2.3. Proposed Model

The proposed model, as can be seen in Figure 2, is based on a hierarchical structure. The AHP and the SMART 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%).

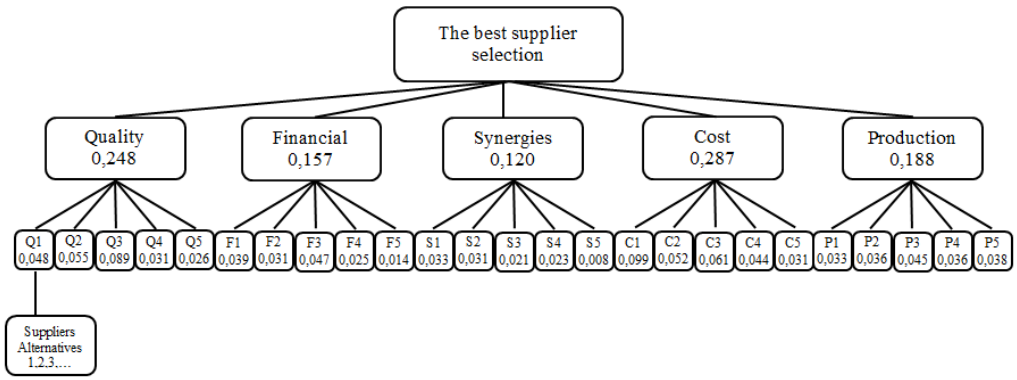

Figure 2. Proposed model

Now, with the model, the AHP and the SMART methods can be applied, as it will be showed in the next chapter.

3. Application of the Model

As was said before, the application of the model could be done by linear weighting methods, in which, the AHP and the SMART will be explained. While the AHP method makes comparisons between all supplier pairs, the SMART 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.

3.1. AHP Method Application

In the seventies Saaty introduced the AHP process (Saaty, 1980), which has been one of the most extensively used methods for Multi Criteria Decision Making (MCDM) and has been extensively studied and refined since then. It provides a comprehensive framework for structuring a decision problem, representing and quantifying its elements, relating these elements to overall goals, and for evaluating alternative solutions. AHP has been used to solve MCDM problems in several different areas such as economic planning, energy policy, project selection, budget allocation (Soh, 2010), software selection (Cruz-Cunha and Varajão, 2011), transportation, resource allocation , human resources selection, and other (Varajão, Cruz-Cunha, 2013). Based on relevant literature, Subramanian and Ramanathan (2012) make a very comprehensive review on the applications of AHP in manufacturing operations and processes, product and process design, supply chain management, including the wide application of AHP to macro and people oriented problems.

In the AHP technique *Analytic* indicates that the problem is broken down into its constitutive elements; *Hierarchy* indicates that a hierarchy of the constitutive elements is listed in relation to the main goal; Process indicates that data and judgments are processed to reach the final result. The basic principle is to decompose the decision problem into a hierarchy of more easily comprehended sub-problems.

It is possible to identify three main moments in the application of this technique:

- The definition of the problem and of the main objective;
- The definition of the tree of criteria (hierarchical structure) with the relative weights of each criteria; and
- The evaluation of the alternative solutions, using the tree defined.

The tree is structured from the top (the main objective under the decision-maker perspective), being necessary to define the

criteria, sub-criteria and successively; the tree can have as many levels as necessary.

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 method is used a 1-9 scale for comparing two factors (see table 9), 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, 2005). Thus it is determined the relative importance (designated by weight) of each criterion.

Table 9. AHP's values scale (Saaty, 2005)

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 *i* 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

After that, the results of the comparison between each pair of criteria are expressed in a normalized matrix and the weight of each criterion is obtained by the arithmetic mean of each row of the matrix. Should be noted that the hierarchical tree for AHP can be more detailed through the inclusion of goal, criteria, sub-criteria and other relevant alternatives (see an example in (Eon-Kyung *et al.*, 2001)).

In our proposed model (figure 2), the determination of the weights of the criteria and sub-criteria were made of different manner of the traditional AHP, as was explained before. However, it is still possible to apply the AHP to the model, as can be seen below.

Application Example:

Starting from the assumption that are available 3 alternatives for the suppliers (A supplier (AS), B supplier (BS) and C supplier (CS)), each supplier will be evaluated for each of the sub-criteria, obtaining the respective supplier's weight. This evaluation is made by the Saaty comparison matrix. As an example, we consider the matrix in Table 10 for the Q1 sub-criterion into the Quality System.

Table 10. 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

Now it is necessary to normalize the comparison matrix. In Table 11, it is presented the normalized matrix with the suppliers weights.

Table 11. Normalized matrix of the A, B and C suppliers for Q1

	AS	BS	CS	Suppliers 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 supplier evaluation result for the Q1 sub-criterion ($S(Q1)$) is obtained multiplying the weights of the supplier (S_{weight_Q1}) by the sub-criterion weight ($Q1_{weight}$) associated from the proposed model (figure 2). So, for Q1 has:

$A(Q1)= A_{weight\_Q1} \times Q1_{weight} = 0,748\times0,048=0,036$

$B(Q1)= B_{weight\_Q1} \times Q1_{weight} = 0,143\times0,048=0,007$

$C(Q1)= C_{weight\_Q1} \times Q1_{weight} = 0,108\times0,048=0,005$

These procedures are repeated for each sub-criterion and after that, the supplier rating is given by the sum of all its values:

$AS_{rating}=A(Q1) + A(Q2) +\ldots+ A(P5) = 0,036+ A_{weight\_Q2} \times0,055+\ldots+ A_{weight\_P5} \times0,038$

$BS_{rating}=B(Q1) + B(Q2) +\ldots+ B(P5) = 0,007+ B_{weight\_Q2} \times0,055+\ldots+ B_{weight\_P5} \times0,038$

$CS_{rating}=C(Q1) + C(Q2) +\ldots+ C(P5) = 0,005+ C_{weight\_Q2} \times0,055+\ldots+ C_{weight\_P5} \times0,038$

At the end, the selected supplier will be the highest classified.

3.2. SMART Method Application

The SMART method was proposed and developed by (Edwards, 1971). In this method the weights of the criteria and the weights of the supplier for each criterion are assigned directly by the decision maker. When the criteria are qualitative, i.e., not quantitative, these weights can be determined mathematically by means of a "Value Function". The simplest choice of a value function is a linear function, and in most cases this is sufficient. However, to better capture human psychology in decision making, it is often advantageous to use non-linear functions. Utility Theory offers a deep and complex literature for choosing value functions (Edwards, 1977).

Application Example:

Considering the same alternatives, AS, BS and CS, analogously each supplier will be evaluated for each of the sub-criteria. However, this evaluation is made differently of the previous method. Indeed this is the unique difference of the SMART for the AHP method. In a simple way, the suppliers may be classified on a scale of 0 to 100 points for each sub-criterion. Let, for example, consider the suppliers weights for Q1 in the table 12:

Table 12. Suppliers' weights for Q1

	Suppliers Weights
AS	30
BS	50
CS	10

The following phases of the method are similar of AHP. So, the result of the suppliers' evaluation for the Q1 is:

$A(Q1)= A_{weight\_Q1} \times Q1_{weight} = 30\times0,048=1,44$
$B(Q1)= B_{weight\_Q1} \times Q1_{weight} = 50\times0,048=2,40$
$C(Q1)= C_{weight\_Q1} \times Q1_{weight} = 10\times0,048=0,48$

These procedures are repeated for each sub-criterion and after that, the supplier rating is given by the sum of all its values:

AS_{rating}=$A(Q1)$ + $AS(Q2)$ +…+ $AS(P5)$ = 1,44+ A_{weight_Q2} ×0,055+…+ A_{weight_P5} ×0,038

BS_{rating}=$B(Q1)$ + $BS(Q2)$ +…+ $BS(P5)$ = 2,40+ B_{weight_Q2} ×0,055+…+ B_{weight_P5} ×0,038

CS_{rating}=$C(Q1)$ + $CS(Q2)$ +…+ $CS(P5)$ = 0,48+ C_{weight_Q2} ×0,055+…+ C_{weight_P5} ×0,038

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

4. Conclusion

As was seen, the supplier selection is a complex process, but very important for operational performance in the companies. Hence, the studies related with the theme already come from the past and will continue. This study it is one more contribution in which was added value to the problem resolution. Concretely: were identified five major criteria, Quality, Financial, Synergies, Cost and Production System, and the respective sub-criteria; determined the weights of criteria and sub-criteria; and presented a selection model to be used, in an easy way, by AHP or SMART method. Because the selection model it was based on the literature analysis and in the survey results, it is the conviction of the research team that the proposed reference model for supplier/partner selection will help companies' managers to select the best supplier/partner for their companies, or, that can represent an orientation/pattern for a decision making on the suppliers/partners selection process.

The proposed reference model allows decision-makers to a supported supplier selection based on a structured set of criteria and following a systematic process, already validated, and used in practically all the domains of decision making for the last years.

As proposal for further work the authors intend to increase the number of survey responses in order to improve the confidence interval to 95% and to propose the selection model divided by company's size. Moreover, it is necessary to validate the model near the companies. In other words, this model should be released to the companies in order to be used and evaluated its corresponding performance.

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