An Approach to Select Suppliers for Sustainable Collaborative Networks

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Abstract. Supplier selection is an important decision-making process within supply chain management that involves qualitative and quantitative factors. This process is even more complex if different partners that are already collaborating desire to choose a partner for enhancing the sustainability of their collaborative network. Sustainability literature supports the need to consider three main types of sustainability factors: environmental, social, and economic factors. In addition, the management of collaborative networks is better done using a performance management framework/system that allows managing performance under various performance perspectives or dimensions in a structured manner. This paper proposes a novel approach to select suppliers for sustainable collaborative networks using a performance management framework. With this approach, enterprises that are collaborating (or desire to do it) will have a tool to select suppliers aligned with their strategy and the sustainability of their collaborative network, and therefore, improving the supplier selection process and their competitiveness.

Keywords: performance measurement, collaborative networks, sustainability, supplier selection.

1 Introduction

Supplier selection is one of the decision-making processes that organizations perform in order to achieve/maintain a competitive position. This task is even more complex if it involves different partners that are already collaborating and desire to choose a partner for enhancing the sustainability of their collaborative supply chain/ network. Supplier involvement in early and extensive stages has many beneficial results for supply chain management: faster development process, reduced costs, reduced inventory, etc. [1-3]. Thus, selecting suppliers becomes a crucial process for manufacturers.

The academic literature about collaborative relationships points out the importance of considering the performance measurement of the entire supply chain in order to provide products and services that meet the expectations of end customers and promote improvement and innovation of the whole processes [4-6]. For that

reason, it is important to define common performance indicators for all the enterprises that are collaborating as they will aid to focus their efforts towards strategic aspects of their business [7-9]. In fact, in order to provide a general overview of their performance status, those enterprises should define and use a structured performance measurement framework that allows managing performance under various performance perspectives or dimensions. One of the most important performance measurement frameworks is the Balanced ScoreCard (BSC) [10]. The BSC was initially developed for managing performance of individual enterprises and has been extended by different authors for interorganizational performance management such as the frameworks proposed by [11-14].

In addition, there is an increasing interest in improving the sustainability of collaborative supply chains/networks. In [15], the main pressures and incentives for sustainability within these contexts are identified: legal demands/regulations, customer demands, response to stakeholders, competitive advantage, environmental and social pressure groups and reputation loss. Literature supports the need to consider three main types of sustainability factors or criteria: environmental, social, and economic factors [16-17]. Therefore, in order to support the sustainability of the collaborative network, suppliers should be evaluated regarding these three types of criteria and selecting suppliers can be defined as a multi-criteria decision-making (MCDM) problem involving both qualitative and quantitative factors.

Thus, there are two main interrelated inputs that influence the supplier selection problem: performance of the enterprises that are collaborating and sustainability criteria. On the one hand, the enterprises that are collaborating pursue the improvement of the overall system. For that purpose, they should define performance elements (such as performance objectives, performance indicators, etc.) for the whole interorganizational context and select the new supplier that better match those performance elements. On the other hand, enterprises need to identify relevant criteria for sustainability assessment of suppliers regarding a specific collaborative context. In addition, both performance elements and sustainability criteria are interrelated. For example, if one of the sustainability criteria to assess suppliers is "environmental practices", this criterion will influence the outcome of some performance elements such as those related to brand image and process performance of the collaborative network. Similarly, some performance elements may affect the supplier outcome on some criteria. For example, the improvement of waste disposal on the network may improve the environmental practices of the supplier.

Despite the importance of these aspects, the approaches found in the literature for supplier selection do not integrate all these aspects: performance measurement framework of the collaborative enterprises, sustainability criteria and interrelationships among them. The purpose of this paper is to propose an approach that aids to select suppliers that fills this research gap. With this approach, enterprises that are collaborating and have defined a BSC framework (or desire to do it) will have a tool to select suppliers aligned to their common strategy and improving the sustainability of the whole enterprise association.

The structure of this paper is as follows. First, a literature review of MCDM applied for supplier selection is presented focusing attention on the Analytic Network Process (ANP) method. Then, the approach to select suppliers is described and a case study within the automotive industry is presented. Finally, conclusions are exposed.

2 Background

MCDM approaches consists of a set of concepts, methods and techniques that aim to aid individuals or groups to make decisions that imply various criteria or trade-offs and multiple agents. Several methods have been proposed for solving the supplier selection problem such as vendor profile analysis (VPA), multi-objective programming (MOP), data envelopment analysis (DEA), analytic hierarchy process (AHP) and analytic network process (ANP). The ANP method developed by Saaty [18] allows solving problems that involve both quantitative and qualitative criteria as well as considering interdependence and feedback among these criteria. For that reason, ANP is a useful method for modeling and solving the problem of this paper while the other approaches assume the independence among their elements without a clear distinction if they can be generalized to model interdependence without compromising their theoretical foundations.

In addition, ANP has been recently used for supplier selection. In [19], a model to select suppliers depending on different levels of cooperation is defined. In [20], an ANP model to select members for an agile virtual enterprise is presented. In [21], an ANP model to select suppliers to establish strategic alliances is developed. Other models are specifically developed for selecting suppliers within specific industries such as pharmaceutical industry [22]. In addition, in the literature, few ANP models are encountered that consider sustainability factors. In [23], it is presented a strategic decision framework for green supplier management that integrates the economic and environmental dimensions of sustainability. This framework has been lately extended including the social dimension by [24]. However, there is not a specific model developed for selecting suppliers that integrates sustainability factors and the overall system performance. For this reason, the purpose of the remaining of this paper is to present an ANP model for supplier selection that solves this research issue.

3 The supplier selection approach

An approach to select suppliers has been developed in order to integrate under a unique model both types of aspects: performance of collaborating enterprises and supplier sustainability criteria. This approach has been modeled using ANP as it allows considering: qualitative and quantitative criteria as well as interdependences and feedback among the model elements. The approach comprises eight phases and should be developed by a group of experts from all the collaborative enterprises. It is recommended that an internal or external person to the enterprises acts as a consultant to aid in the approach application.

Phase 1: The first phase aims at describing the specific supplier selection problem having as main goal the selection of the best supplier that better match the performance objectives of the collaborative network as well as sustainability criteria.

Phase 2: In this phase, performance elements (objectives and key indicators) are defined for the whole collaborative network according to the four performance perspectives of the BSC [10]: financial, customer, internal business process and innovation & learning perspectives. In addition, it is important that objectives and

indicators are coherently defined from the strategic mission and vision of the collaborative association. For that purpose, it is possible to use benchmarking or standard indicators such as the ones described in the SCOR model. Once established, periodical reviews (normally annual reviews) are to be made by managers of all the collaborative enterprises to verify the relevance of the performance elements and decide if they are to be updated.

Phase 3: Potential suppliers that are to be considered in the decision-making problem are determined.

Phase 4: In this phase, sustainability criteria to assess the different suppliers are defined. These criteria are clustered according to the three sustainability dimensions: business, environmental and social dimensions. It has to be noted that the economic dimension has been renamed to business dimension in order to reflect not only the economical aspect of the suppliers but also other important supplier characteristics such as their product, the relationship with the members of the network given by their trust, commitment, cooperation, conflict management techniques, etc. Environmental criteria comprise two types of sub-criteria. On the one hand, environmental practices such as pollution controls and prevention, and environmental management. On the other hand, environmental performance includes indicators for measuring resource consumption and pollution production. The social dimension involves employment practices, health & safety and stakeholders influence.

Phase 5: The ANP model is built. The ANP model consists of a set of elements (criteria and performance elements) grouped into clusters. A cluster was defined for each type of performance perspective or criteria as clusters are groups of elements with a common characteristic [18]. The different interdependences and feedback between elements of the clusters are defined according to the experience of the group of experts. For modeling and solving the problem, *Superdecisions* software was used.

Phase 6: At this phase, the local priorities among elements are calculated. For that purpose, pairwise comparison matrices among elements are fulfilled by managers of all the collaborative enterprises. In order to fill the pairwise comparison matrices in, the fundamental scale is used which ranges from 1/9 to 9 [25]. In addition, consistency ratio is checked in order to avoid including inconsistent judgments.

Phase 7: This phase comprises obtaining different supermatrices. First, the unweighted supermatrix is composed. This matrix represents the relative influences among all the elements that are formed by introducing the local priorities previously calculated in the columns of the matrix. Then, the eigenvectors of the cluster matrix are calculated in order to prioritize the importance of the different model clusters following a similar procedure to the one explained in phase 6. For that purpose, pairwise comparison matrices among clusters of elements are done and consistency checked. Then, the weighted supermatrix is calculated by multiplying the unweighted supermatrix by the priority weights of the clusters. Thus, the weighted supermatrix gets stochastic which will derive meaningful limiting priorities.

Phase 8: Finally, the limit matrix is calculated raising the weighted supermatrix to powers until all the columns remain with the same values. The values in the columns are the global/limit priorities or influences of each element. The supplier that rates the higher value is selected.

4 Case study

The ANP-based approach to select suppliers has been applied to a collaborative enterprise network belonging to the automotive industry in Spain. The supplier selection problem aims at selecting the best supplier of one high-volume subassembly. Managing directors of purchasing and R&D departments were in charge of the assessment of the suppliers. The three suppliers currently delivering the subassembly have the capability and know-how to manufacture the component and, therefore, are potential candidates for the selection. Thus, the problem is to select the best supplier as single source. Fig. 1 shows the ANP model. The model consists of eight clusters. Four clusters correspond to the four perspectives of the BSC: financial, customer, process and innovation & learning. Specifically, the elements within the clusters are the key performance indicators (KPI) for the collaborative enterprise network. These KPIs have been defined from the specific performance objectives identified for each perspective that were established by consensus by all the members participating in the collaborative enterprise network in order to manage the enterprise network at a global level. Although consensus demands discussion and agreement that takes some time to achieve, the strategic nature of the issues approached justify its application. Reaching consensus may be complicated in some cases. The consultant person should have the role to moderate and organize the meetings in order to develop all the phases successfully.

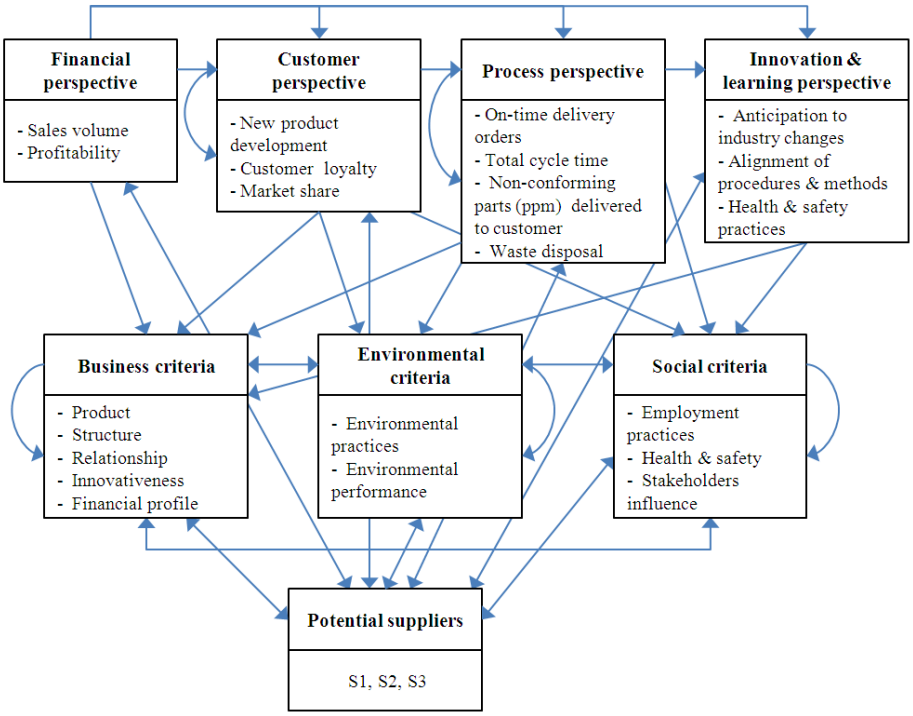

Fig. 1. ANP model for supplier selection

The arrows among the clusters represent the relationships among the elements within the clusters. Thus, interdependences among performance clusters show the relationships among KPIs of the different clusters (outer dependence). Similarly, there are some performance clusters whose elements present inner dependence such as the case of the customer cluster. For example, the success in the development of new products affects the market share and the customer loyalty. This is reflected by an arc on the customer cluster. Regarding sustainability criteria, they were identified from different frameworks [26-30]. All three sustainability clusters present interrelationships among them. In addition, criteria within each cluster also present inner dependences (reflected by an arc). Finally, the cluster of potential suppliers presents interdependence with the rest of clusters, as suppliers will be evaluated regarding the global KPIs and the sustainability criteria.

Once the ANP model is composed, pairwise comparison matrices were fulfilled by using the ANP method [18]. Table 1 shows the pairwise comparison matrix of the KPIs within the customer perspective with respect to the profitability KPI. As can be observed, local priorities are 0.1047 (new product development), 0.2583 (customer loyalty), 0.6370 (market share). Consistency ratio is 0.037 which is acceptable [18].

After all local priorities are calculated, unweighted supermatrix, weighted supermatrix and limit supermatrix are obtained. Limit priorities suggest that supplier 2 is the best. It has to be said that results show that supplier 2 is outstanding for the business and environmental dimensions, which are the two most important dimensions for the group of experts. These results were validated by the decision makers of the collaborative enterprise network so that supplier 2 was selected.

Table 1. Pairwise comparison of customer perspective KPIs with respect to profitability KPI.

	New Prod. Dev.	Cust. loyalty	Market share	Priorities
New Prod. Dev.	1	3	5	0.1047
Cust. loyalty	1/3	1	3	0.2583
Market share	1/5	1/3	1	0.6370
			C.R.	0.037

3 Conclusions and further research

This paper introduces a multi-criteria approach to select suppliers for sustainable collaborative relationships based on two interrelated inputs: supplier sustainability criteria and performance of the collaborating enterprises. The novelty of this approach is that the supplier assessment attributes are the elements within the BSC of the whole collaborative enterprises as well as supplier sustainability criteria. Therefore, the supplier selected is the one that best performs at both aspects while considering interdependence and feedback among them. The main contribution of our approach is the link between supplier sustainability criteria and the common performance indicators defined by all the enterprises that are collaborating. The approach is applicable to all types of inter-enterprise associations taking into account that the performance elements definition will change depending on the specific context analyzed. In addition, some specific collaborative relationships may consider other

factors, e.g. industry specific factors. Modification and adaptations to be performed for these two reasons will enable to use this approach in other collaborative relationships.

Research implications are also noted. We are developing further a BSC for the whole collaborating enterprises that allows integrating sustainability indicators coherently to increase the traceability among the supplier sustainability criteria and the collaborative enterprise performance framework.

Acknowledgments. This work has been developed within the framework of a research project funded by the Polytechnic University of Valencia, titled "Design and Implementation of Performance Measurement Systems within Collaborative Contexts for aiding the Decision-making Process", reference PAID-06-08-3206.

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