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Determining Strategy Based Supplier Pre-Qualification Criteria With Fuzzy Relational Maps

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ABSTRACT

Supplier Selection is one of the most studied areas in management and decision sciences. However, it is still a highly problematic subject since decision-makers take an educated guess after a certain stage in real life practices. In order to overcome the problems, decision makers should focus their attention on the first stage of the selection process, criteria determination, as the quality of the selection phase heavily depends on the first stage. Additionally, strategic fitness in supplier selection is also not much considered in the literature and real life practices. However, looking for conformity of supplying organizations with corporate strategies of buying organization is crucial for the success and leadership of the buying organization. Therefore, this paper intends to determine the most influential corporate strategy based supplier pre-qualification criteria. Data acquisition phase of the Delphi technique was used for determining criteria and fuzzy relational maps was used for relating criteria with corporate strategies. All data were collected from a global Tier-1 manufacturing company in the automotive industry. The results show that the most important strategy based criteria were mainly about organizational and managerial characteristics of the company. Cost and price, which are considered very important in the literature and in real life practices, were determined as moderately important in strategic context. Companies need to focus their attention on criteria such as technical qualification of employees, continuous improvement systems, and communication abilities when pre-qualifying suppliers

Keywords: Supplier pre-qualification criteria, Criteria determination, Fuzzy cognitive maps, Fuzzy relational maps, Delphi technique

Strateji Tabanlı Tedarikçi Öndeğerlendirme Kriterlerinin Bulanık İlişkisel Haritalar İle Tespiti

ÖZET

Tedarikçi seçimi, yönetim ve karar bilimlerinde en fazla çalışılmış konulardan olmasına rağmen hala en problemli alanlardan bir tanesidir. Çünkü gerçek hayatta karar vericiler, karar verme sürecinin belirli bir aşamasından sonra hisleriyle hareket etmektedir. Seçim sürecinde meydana gelen problemleri bertaraf etmek için karar vericilerin, sürecin ilk aşaması olan kriter tespitine odaklanması gerekmektedir. Çünkü seçimin kalitesi, sürecin ilk aşamasının kalitesine bağlıdır. Gerek akademik camianın, gerek ise gerçek işletmelerin gözden kaçırdığı bir diğer önemli nokta ise örgütler arası stratejik uyumdur. Tedarikçi karakteristiklerinin örgüt stratejileri ile uyumu, işletmenin başarısı için en önemli faktörlerden bir tanesidir. Dolayısıyla bu çalışma, örgüt stratejileri çerçevesinde önemli olan tedarikçi ön değerlendirme kriterlerini tespit etmeyi amaçlamıştır. Kriterlerin tespiti için Delphi tekniğinin veri toplama süreci uygulanmış, kriterlerin örgüt stratejileri ile ilişkilendirilmesi için ise bulanık ilişkisel haritalar kullanılmıştır. Uygulamada kullanılan veriler, otomotiv endüstrisinde faaliyet gösteren Tier-1 nitelikli global bir işletmeden temin edilmiştir. Elde edilen sonuçlar, strateji tabanlı en önemli kriterlerin işletmelerin örgütsel ve yönetsel karakteristiklerini ölçen kriterler olduğunu göstermiştir. Literatürde ve pratikte çok önemli olarak değerlendirilen maliyet ve fiyat, strateji bağlamında orta seviyede önemli olarak tespit edilmiştir. Dolayısıyla işletmelerin aday tedarikçileri ön değerlendirmeye tabi tutarken çalışanların teknik yeterliliği, sürekli iyileştirme sistemleri ve iletişim yetenekleri gibi kriterlere yoğunlaşması gerekmektedir.

Anahtar Kelimeler: Tedarikçi öndeğerlendirme kriterleri, Kriter tespiti, Bulanık bilişsel haritalar, Bulanık ilişkisel haritalar, Delphi tekniği

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1. Introduction

Dickson was undoubtedly the pioneer in the subject of supplier selection, introducing the first set of criteria for supplier selection (SS) in 1966. However, one of the earliest records about procurement and supplier selection belongs to Lewis in 1933, in which he states "There is none more important than the selection of a proper source. Indeed, it is in some respects the most important single factor in purchasing" (Vokurka, Choobineh, & Vadi, 1996). Therefore, one can see that the importance of the selection of a proper source and purchasing was recognized in the early 1900s and its importance today is still rising. As cited in Vonderembse and Tracey (1999), in most manufacturing organizations, the role of purchasing and materials management has gained viability and additional responsibility. According to the authors, in some organizations, such as Honda of America and Daimler-Chrysler, it has gained recognition from top management as a key process (Vonderembse & Tracey, 1999).

Supplier selection is defined as a major element (Raut, Bhasin, & Kamble, 2010), essential activity (Chang, Chang, & Wu, 2011) and most capital decision (Benyoucef, Ding, & Xie, 2003) in the global economy because of following factors: Globalization (De Boer, Labro, & Morlacchi, 2001), increase in costs of outsourced materials (Aissaoui, Haouari, & Hassini, 2007), expanded supply chain networks (Benyoucef et al., 2003), rapid and continuous change (Azadi & Saen, 2012) and eager to gain competitive advantages (Moser & Blome, 2008). All of these factors make supplier selection very complicated because they inherit some paradoxes that require use of conflicting quantitative and qualitative criteria in the selection step of the process (Aissaoui et al., 2007). Moreover, due to vague nature of qualitative criteria, ratings of decision makers about same supplier(s) may differ. This brings more complexity into the process.

In the literature and also real life practices, there is quantum of work has been done in supplier selection. However, many researchers and practitioners still miss a key point. They mainly focus on the selection step which is the last step of the whole process (R. Jain, Singh, Yadav, & Mishra, 2014). However, it is crucial to put an effort on previous steps, criteria determination and pre-qualification because they affect quality of the final decision (De Boer et al., 2001). Another overlooked point in the selection is the strategic interfirm-fit between the subject company and its suppliers. Toulan et al. (2006) state that greater fitness between organizations and their strategies will foster better the performance of relationships between organizations (Toulan, Birkinshaw, & Arnold, 2006). Moreover, strategic congruence between organizations is a key to stay in the competition (Nilsson & Rapp, 2005) so to have sustainable leadership (SL).

Due to all of aforementioned factors, this research aims to introduce a hybrid approach incorporating fuzzy relational maps (FRM), which is a more developed style of fuzzy cognitive maps (FCMs), with Delphi technique to create a set of strategy based criteria that can be used in pre-qualifying suppliers in order to determine strategically misfit companies. Application of the approach was examined in a case of a global Tier 1 manufacturing company operating in automotive industry.

Supplier pre-qualification term is used interchangeably with the terms supplier initial screening, supplier shortlisting, supplier pre-evaluation and supplier pre-selection in the literature.

The remainder of this paper is organized as follows: Section 2 discusses the related literature about today's supplier selection environment, supplier pre-qualification, pre-qualification criteria and strategy based supplier selection/pre-qualification criteria. Section 3 describes a review of Delphi technique and fuzzy relational maps. Section 4 introduces the approach and its application. Finally, section 5 summarizes results and discussion.

2. Literature Review

2.1. Supplier Selection

The problem of supplier selection has been a subject matter both for researchers and practitioners since the seminal research paper of Dickson (1966), and its strategic importance was acknowledged by many researchers (Y. H. Chen & Chao, 2012; R. Jain et al., 2014; Lee, 2009; Micheli, Cagno, & Zorzini, 2008; C. G. Şen, Şen, & Başlıgil, 2010; Yu & Wong, 2014) as well. There are several factors behind its everlasting importance:

- Ever quickening tempo of economic globalization (De Boer, L., Labro, E. e Morlacchi, 2001; Micheli et al., 2008; Moser & Blome, 2008; Pal, Gupta, & Garg, 2013): It serves as a locomotive which prompts companies worldwide to pay closer attention to supply chain management (SCM) and to facilitate more cost effective operations (Lin, 2012). In order to lower costs, organizations tend to do some purchases from foreign suppliers from low cost countries (Cheraghi, Dadashzadeh, & Subramanian, 2011; Pal et al., 2013; D. D. Wu, Zhang, Wu, & Olson, 2010). However, outsourcing from low cost countries poses communication, delivery and quality risks.

- The cost of outsourced materials: It is enormous in today's business due to high outsourcing rates (Aissaoui et al., 2007; Benyoucef et al., 2003; Micheli et al., 2008). For example, several decades ago, the cost of outsourced materials and services comprises up to 80% of the total, especially for high-tech products (Burton, 1988), and for today, it was determined specifically 70% of total operation cost of an automobile (Yu & Wong, 2014).

- Expanded supply chain networks: It is a result of high outsourcing rates (Benyoucef et al., 2003). Expansion is something desired under today's market trends. On the other hand, it may be too dangerous to have numerous suppliers because as the reliance to suppliers grows, performance of the subject company greatly depends on actions of suppliers (Vonderembse & Tracey, 1999). The dependency makes the chain more susceptible to disturbances (Nepal & Yadav, 2015) that may increase total cost and tarnish reputation and position of the company as well (P.-S. Chen & Wu, 2013).

- Rapid and continuous change: It inherits increased uncertainty and risk forcing organizations to focus on their core activities to stay competitive (Azadi & Saen, 2012; Cao, Luo, Kwong, & Tang, 2014; Cheraghi et al., 2011; Farughi, Azar, Sadeghi, Naseri, & Hajebi, 2011; Kasirian & Yusuff, 2013; Lee, 2009; Moller & Torronen, 2003; Ravindran, Bilsel, Wadhwa, & Yang, 2010; Shahroudi & Rouydel, 2012; Tahriri, Osman, Ali, Yusuff, & Esfandiary, 2008). To explain, product lifespan get shorter (Aissaoui et al., 2007;

Micheli et al., 2008), product complexity and quality consciousness get increased due to changing customer demands and preferences (De Boer, L., Labro, E. e Morlacchi, 2001; V. Jain, Wadhwa, & Deshmukh, 2007); also market structure get changed due to suddenly appearing new and specialized competitors that can offer products and services better, faster, cheaper and more efficiently (Gurnani, Gümüş, Ray, & Ray, 2012; Cheraghi, Dadashzadeh & Subramanian, 2011; Hätönen & Ruokonen, 2010). Therefore, organizations start outsourcing their noncore activities to focus on their core activities in order to stay in the competition.

- Competitive advantage: SCM activities have been forced to change its traditional role from a provider of the right products/services at the right time and lowest costs to a generator of competitive advantages (Moser & Blome, 2008; Vonderembse & Tracey, 1999). Activities of suppliers provide value for the subject organization and its customers as well (Siguaw & Simpson, 2004). Therefore, organizations have to work with their supply chain (SC) partners to stay in the competition and improve total performance of the chain (Aissaoui et al., 2007).

All of these factors make supplier selection very hard.

A brief definition of supplier selection is the process by which candidate organizations are reviewed, evaluated and chosen to become a part of supply chain of the company (Aghai, Mollaverdi, & Sabbagh, 2014). The outcomes of the process provides the most suitable suppliers which are able to provide the subject company with the right products/services at the right price, in the right quantities and at the right time (You, You, Liu, & Zhen, 2015). An extensive literature review and detailed information about supplier selection and its methods can be found in (Chai, Liu, & Ngai, 2013; De Boer et al., 2001; Degraeve, Labro, & Roodhooft, 2000; Ho, Xu, & Dey, 2010; Karsak & Dursun, 2016; Pal et al., 2013; Surajit Bag, 2011; Weber, Current, & Benton, 1991). Even though, voluminous work has been published about this subject, there is not much specific paper about the strategic criteria determination and pre-qualification (Aissaoui et al., 2007; Arikan, 2013; De Boer et al., 2001; Ho et al., 2010; Shaw, Shankar, Yadav, & Thakur, 2012).

2.2. Supplier pre-qualification

As cited in Lee (2009) gathering valuable information about resources, capabilities, motives, management and reliability of candidate partners requires a very long time. Otherwise, rushing into a partnership with inadequate preparation often leads to the failure of relationships (Lee, 2009), and the selection of an inadequate supplier can produce disastrous results for the subject company (Wilson, 1994). Therefore, there is a need for a much systematic approach (Aissaoui et al., 2007; Y. H. Chen & Chao, 2012).

An efficient and flexible supply chain enables firms to select right suppliers at the right time for the right purpose, to provide product/services more effectively and efficiently. It is not only significantly reducing purchasing cost but also greatly improving customer satisfaction and corporate competitiveness (Florez-Lopez, 2007; R. Jain et al., 2014; Kotula, Ho, Kumar Dey, & Lee, 2015; Lin, 2012; Paul, 2015). If the selection is done properly, a better quality and long lasting supplier relationship is attainable (Igoulalene, Benyoucef, & Tiwari, 2015; R. Jain et al., 2014). These relationships can be obtained only if the number of suppliers is reduced/shortlisted

to a small number of qualified companies (Aissaoui et al., 2007; Swift, 1995; Wilson, 1994; Yu & Wong, 2014). However, it is a very hard task to achieve. Therefore, a supplier selection model including supplier pre-qualification may be an advantageous approach especially if there are a large number of suppliers (Spekman, 1988; Yu & Wong, 2014).

According to (De Boer, L., Labro, E. e Morlacchi, 2001), supplier pre-qualification is one of the initial steps of classical supplier selection process. It is defined as a process of reducing/shortlisting the number of candidate suppliers to a small set of acceptable suppliers. It is defined as a classifying process rather than a ranking process (De Boer et al., 2001). In other words, while supplier selection is about candidacy of the most possible suppliers, supplier pre-qualification is about nomination candidacy of possible suppliers. It is a step that reduces the number of possible suppliers to a small group of them. However, to the best of our knowledge, pre-qualification is usually omitted both in literature and real life practices (C. G. Şen et al., 2010). To the best of our knowledge, there are just a few research papers about supplier pre-qualification (Cao et al., 2014; Luo, Wu, Rosenberg, & Barnes, 2009; Sarkar & Mohapatra, 2006; C. G. Şen et al., 2010; Yu & Wong, 2014).

2.3. Pre-qualification criteria

The decision process is a time consuming task (Lee, 2009) because all of aforementioned factors bring some paradoxes with. For example, it is hard to decide which one of the following alternatives shall be rational for a company; working with one, some or many supplier, buying from a low cost or high quality supplier (Aissaoui et al., 2007)? Definitely there is no answer that fits all procurement cases. Because of this complicated nature of the selection, types of criteria used in the decision process also get complicated. It is important to use both quantitative and also qualitative criteria to make a proper decision. As a result, some criteria may conflict each other (Aissaoui et al., 2007; Benyoucef et al., 2003; R. Jain et al., 2014). Therefore, working with both quantitative and qualitative criteria at the same time makes decision making process a bit harder. Moreover, experiences and feelings of decision makers are involved in the decision process with the inclusion of qualitative criteria. Consequently, it becomes necessary to make a trade-off between conflicting tangible and intangible criteria (R. Jain et al., 2014). Criteria used in supplier pre-qualification articles mentioned in Section 1.2 are listed in Table 1.

	References				
Criteria	**(Sarkar & Mohapatra, 2006)**	**(Luo et al., 2009)**	**(C. G. Şen et al., 2010)**	**(Cao et al., 2014)**	**(Yu & Wong, 2014)**
Price	X		X		
Quality	X	X			
Delivery lead time	X				
Attitude	X				
Quality systems	X				
Financial capability	X				X
Production capacity	X		X		X
Management	X				X
Technological capacity	X		X		X
Breadth of product line	X				X
Proximity of suppliers	X				
Existence of IT standards	X	X			X
Labor problems	X				

	References				
Criteria	**(Sarkar & Mohapatra, 2006)**	**(Luo et al., 2009)**	**(C. G. Şen et al., 2010)**	**(Cao et al., 2014)**	**(Yu & Wong, 2014)**
Reputation	X	X			
Cost				X	
Localization					
Integration ability		X			
Strategic programming		X			
R&D investment		X			
Manufacture adaptation level		X			
Throughput capacity		X			
Environment adaptation ability		X			X
Production techniques level		X			
Learning organization		X			
Product response time		X			
Compatible corporation culture		X			
Liquidity ratio		X			
Inventory turnover		X			
Net assets value per share		X			
Earnings per share of stock		X			
Net operating margin		X			
Asset/liability ratio		X			
Net profit growth rate		X			
Asset rates of increment		X			
Accounts receivable turnover		X			
Stockholders' equity ratio		X			
Cash flow per share		X			
Debt/equity ratio		X			
Human resource quality-expertise		X	X		X
Fixed assets scope		X			
Information sharing level		X			
Value of trademark		X			
Quality/cost		X			
Service quality		X	X		
Maintenance cost			X		
Quality defects			X		
Quality of packing ability			X		
Service delivery			X		
Performance history			X		
Supply risk				X	
R&D capability					X
Procedural compliance					X
Quality performance history					X
Delivery performance history					X
Service performance history					X

Table 1. Supplier pre-qualification criteria used in previous studies

To the best of our knowledge there is only one article about determination of supplier pre-qualification criteria belongs to (R. Jain et al., 2014). The authors propose to use data mining technique integrated with fuzzy association rules approach. They aim to investigate the influence of suppliers' initial strength on their final work. During the investigation process, they also propose a set of supplier pre-qualification criteria which were actually collected from the literature by the authors. Based on the finding of this paper, organizational strength, performance capabilities and miscellaneous are the most important criteria that affect the final selection.

On the other hand, some articles about supplier pre-qualification have subsections on the criteria determination. Please see Table 2 for the techniques used for it. In addition to these articles, in a literature review article of (De Boer et al., 2001), interpretive structural modelling and expert systems are defined as proper techniques for criteria determination.

	References				
	(Sarkar & Mohapatra, 2006)	(Luo et al., 2009)	(C. G. Şen et al., 2010)	(Cao et al., 2014)	(Yu & Wong, 2014)
A pool of criteria created by	Reviewing the literature	Reviewing the literature	Reviewing the literature	Reviewing the literature	Telephone interviewing.
The final list of criteria created by	Non technique was used. The list kept as it was	Non technique was used. The list kept as it was	Using a two phase optimism algorithm	Non technique was used. The list kept as it was	The authors' evaluation

Table 2. Techniques used for determining supplier pre-qualification criteria in previous researches

2.4. Strategy based supplier selection / pre-qualification

According to Kar & Pani (2014), nowadays senior management of organizations consider procurement as a key factor in strategy formulation. However the literature pertaining to supplier selection model fails to appreciate strategic procurement models (Surajit Bag, 2011) even though dependence between the success of supply chain and its partners has been acknowledged (Lin, 2012).

Operating like an autonomous individual company is no longer accepted. Instead, establishing a sounder strategic alliance with suppliers against competitors is more desirable (Shen & Yu, 2012; You et al., 2015). Therefore, building and maintaining close and long term relationships with a few albeit reliable and high-quality partners (Aissaoui et al., 2007; Y. H. Chen & Chao, 2012; W. Y. Wu, Sukoco, Li, & Chen, 2009; You et al., 2015) is a must to stay in the competition and obtain leadership.

To explain, supply chain activities require coordination, collaboration and cooperation between partners of the chain to maximize the efficiency (Igoulalene et al., 2015; Swift, 1995). This harmony in the chain helps to build and strengthen long standing mutual interactions which are vital for the total value of the chain. It provides synchronization of activities in group members, binding hidden force that unifies actions of the members and mutually decided common goals for the members (Ertay, T., Kahveci, A. & Tabanlı, 2011). However it is not easy to create common goals, synchronization and unification if there is no congruency between the subject company and its vendors.

According to Richards & Jones (2007), there are three types of congruency among organizations, strategic, operational and personal (Richards & Jones, 2007). As cited in Toulan et al. (2006), these types of fitness are actually based on Miles & Snow (1978) seminal work about organizational strategy. According to the authors, greater fitness between organizations and their strategies will result in better performance of the relationship (Toulan et al., 2006). Strategic congruence is a necessary precondition for being competitive (Nilsson & Rapp, 2005). Otherwise conflicting organizational objectives/strategies/values may cause inefficiencies between partners (As cited in Siguaw & Simpson, 2004). In other words, procurement decisions should support the common goals of the partnership and organizational strategies of the subject company (Burton, 1988). Having the best supplier may not guarantee "the best relationship" if the supplier does not consider the business direction of the

subject company. As a result, the evaluation criteria must be in alignment with organizational strategies of the subject company (Shen & Yu, 2012). However, there is not much research paper about strategy based supplier selection or pre-qualification criteria.

Sarkis Talluri (2002), used a set of strategic performance metrics (and also organizational factors) in order to evaluate alternative suppliers strategically (Sarkis & Talluri, 2002). In the study of (S. Şen, Başlıgil, Şen, & H., 2008), supplier selection criteria and their importance weights were determined based on buyer-supplier integration levels. A five level integration model of Ghodsypour & O'Brien (1988) was used for determining importance weights of criteria. In the study of (Chou & Chang, 2008), a supplier selection model that had a criteria, "strategic fit" was proposed. It represented "the fit between firm strategy and supplier strategy". However, the importance weight of this criteria was judged by the decision committee in the buying company. The final selection was made in the light of expected collaboration type with the supplier. Finally, (Shen & Yu, 2012) proposed a set of business process improvement oriented strategic criteria, which were named as process capability indices modified from Garfamy (2005), for supplier selection. Please see Table 3 for the criteria used in these articles.

	References			
	(Sarkis & Talluri, 2002)	(S. Şen et al., 2008)	(Chou & Chang, 2008)	(Shen & Yu, 2012)
Criteria	• Strategic Performance Metrics • Cost (low initial price, compliance with cost analysis system, cost reduction activities, compliance with sectoral price behavior) • Quality (conformance quality, consistent delivery, quality philosophy, prompt response) • Time (delivery speed, product development time, partnership formation time) • Flexibility (product volume changes, short setup time, conflict resolution, service capability)	• Cost (net price, maintenance cost) • Quality (defects, quality of support service, packing ability) • Service (delivery, production facilities and capacities) • Reliability (supplier's expertise, performance history)	• Cost (unit price, cost reduction plan) • Quality (interval rejection rate, customer rejection rate) • Delivery (lead time, flexibility) • Organizational culture and strategy (management capability, strategic fit) • Technical capacity (innovation, technical problem-solving)	• Quality (reliability) • Service (reaction to demand, technical support) • Organization (technological capability) • Relationship (customer base) • Cycle time (development speed)

Table 3. Criteria used in strategic supplier selection and criteria determination articles

3. Preliminaries

3.1. Delphi Technique

As cited in Melenyk et al. (2009), the Delphi technique is a method that is used to obtain reliable consensus opinion of a group of expert by series of questionnaires combined with controlled feedback. It is designed to handle opinions/subjective judgements rather than objective facts. (Melnyk, Lummus, Vokurka, Burns, & Sandor, 2009). It is a traditional approach not requiring large samples of data sets. It helps to

generate a professional consensus for complex topics (C.-M. Wu, Hsieh, & Chang, 2013).

The Delphi technique is designed to overcome interpersonal behavioral problems in group decision making (Azadeh, Keramati, & Jafary Songhori, 2009). A typical consensus process consists of repeated interrogations / Delphi rounds , usually three or four, through questionnaires (Azadeh et al., 2009; C.-M. Wu et al., 2013). However there might be some exceptions. For example, as Fischer stated, there are several variations on the method. In order to reduce the number of rounds, it is possible to prepare the first questionnaire with the director(s) before the first round (Fischer, 1978). Also as group members do not have any face to face meeting during the process, disadvantages of group decision-making, such as groupthink, group polarization and dominant character, are removed from the process (Dalkey & Helmer, 1963). Each interrogation in the process is accompanied by group replies belong to proceeding round. By doing so experts are encouraged to reexamine and (if necessary) change their previous reply in the light of proceeding replies of other group members (W. Y. Wu et al., 2009).

3.2. Fuzzy Cognitive and Relational Maps

As Kosko (2010) stated, fuzzy cognitive maps (FCM) were fuzzy feedback models of causality (Glykas, 2010). They are a modeling methodology for complex decision systems (Yaman & Polat, 2009). They consist of nodes and weighted edges (arcs). Nodes of the maps represent concepts, indicating the main features, nature or attributes of the system (Xiao, Chen, & Li, 2012). Their edge connections represent causality between the nodes (concepts). Figure 1 illustrates a FCM of which each node C_i represents concept variable and each arc w_{ij} represents connection weight (effect of C_i over C_j) in the interval [-1, 1]. Cycled feedback graph structure of FCMs allows what-if inferencing. This structure also allows users creating new maps by combining several maps (Glykas, 2010). Therefore, they are a practical tool for working with a large quantity of data. Moreover, fuzzification enables working with qualitative and quantitative data between which dependencies do not fit in classical logic (Kandasamy & Smarandache, 2003; Zadeh, 2008).

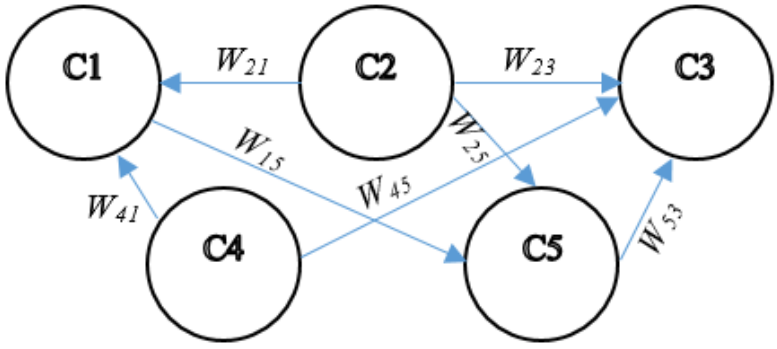

Figure 1. Fuzzy cognitive map

The values of the weights can be showed in a matrix form.

$$W = \begin{bmatrix} w_{11} & \cdots & w_{15} \\ \vdots & \ddots & \vdots \\ w_{51} & \cdots & w_{55} \end{bmatrix}$$

Therefore, it is important to note that matrices of FCMs are always square matrices of which diagonal entries are zero.

Fuzzy relational maps (FRM) are more developed style of FCMs. As (Kandasamy & Smarandache, 2003) stated "In FCMs we promote the correlations between causal associations among concurrently active units. But in FRMs we divide the very causal associations into two disjoint units". In other words while FCMs cannot provide the effect of one group on another group, FRMs can give that effect. Therefore, contrary to the structure of FCMs, there is a need for a disjoint sets in the sense of concepts. These sets are called domain and range space. Number of nodes in the range space do not need to be equal to the number of elements in the domain space. Figure 2 illustrates a typical FRM. Range space is denoted by R_m and domain space is denoted by D_n. Connection weights that show the relationship between domain and range nodes are denoted by w_{ij}, in the interval [-1, 1].

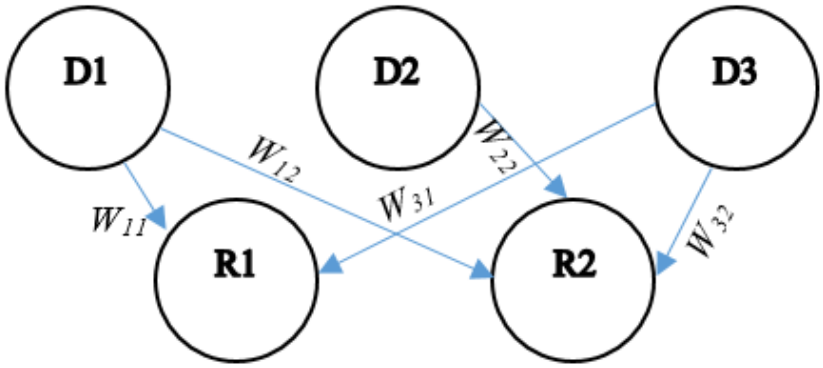

Figure 2. Fuzzy relational map

Relational matrix of the FRM is denoted by W, which is consisted from w_{ij}. Contrary to the relational matrix of FCMs, there is no necessity to become a square matrix for relational matrix of FRMs

$$W = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \\ w_{31} & w_{32} \end{bmatrix}.$$

FRMs also enable to inter-relate two separate systems (Kandasamy & Smarandache, 2003). To explain, suppose there are three spaces, C, D and R. They have m, n and t sets of nodes in the spaces. Directed graphs relating C and D and relating D and R can be inter-related indirectly. In other words FRMs enable users to define and estimate the hidden link between indirectly related spaces. If W_1 is the connection matrix relates C and D, then W_1 is a m x n matrix. The product of the connection matrices belongs to C and D is called the hidden connection matrix, and the map (graph) represent this relation is called the hidden directed graph of the pairwise linked FRMs. If W_2 is the connection matrix relating D and R, then W_2 is an n x t matrix. Therefore, W_1W_2 is an m x t matrix which is the connection matrix relates C and R. Also $W_2^T W_1^T$ matrix relates R and C.

Fuzzy relation between concepts means fuzzy causality that may have various degrees of membership representing strengths of the relationship between the concepts. It may have values in the interval [-1, 1]. The relation may express three different situation; positive causality where $w_{ij}>0$, negative causality where $w_{ij}<0$ and no relationship where $w_{ij}=0$. Please see an algorithm of Groumpos (2010) for

assigning numerical weights to connections of FCMs (Glykas, 2010) which is applicable to FRMs as well.

4. Framework for Defining Strategy Based Criteria and Their Influence On Competitiveness

A systematic procedure consists of Delphi technique and fuzzy relational maps is proposed for this research. The research procedure consists from two main parts, criteria determination and influence estimation. The Delphi technique was used for extracting knowledge about supplier pre-qualification criteria, and fuzzy relational maps for estimating its influence on corporate strategies and the goal of the company which was sustainable leadership. The proposed framework was applied in a Tier-1 company operating in automotive industry in 19 countries over the globe. It develops and manufactures car interiors and also driver and passenger seating systems for off-road vehicles, trucks, buses, and trains. It has an extensive supply network in which 600 suppliers.

- **Step 1. Forming a decision unit:** A list of experts is created initially. At the beginning of the research, there were one procurement director and five procurement executives. However, during the research, two executive left the company; and the research was done with one procurement director and three procurement executives.

- **Step 2. Compiling a list of criteria and preparing the first questionnaire:** After that, a questionnaire explaining nature of the study and asking each person to generate a list of important criteria is sent to the experts. However, in this research as stated in section 3.1., in order to reduce the number of rounds (Fischer, 1978) and to inhibit experts' burnout (Siguaw & Simpson, 2004) the first questionnaire was created with the procurement director of the company. After making a literature review regarding supplier selection and pre-qualification criteria, a meeting was hold with the procurement director, and all possible criteria were determined. However, some criteria were replicated to determine the evaluators' attention level since the number of criteria was very high. Eventually, the list was compiled, the questionnaire was created in MS Excel, and e-mailed to the experts. They were questioned regarding the importance of criteria to purchasing context. All items in the questionnaire were evaluated by using a five point Likert scale where "1" denoted not important and "5" denoted absolutely important. Also they were asked to propose new criteria for the next round if they thought any significant criteria were overlooked.

- **Step 3. Evaluating the results of the first round:** From the first round responses median and interquartile range is calculated. After that results of the first round is returned to the evaluators as a feedback, asking them to consider their responses if they are out of the range or to state reasons for remaining out of the range. In this research, all necessary actions were completed. Additionally, all repeated questions were discarded. Redesigned questionnaire were emailed back to the decision makers.

- **Step 4. Evaluating the results of the second round:** The process of the first round is repeated and respondents are asked for a final revision of their responses. In this research, median and interquartile ranges were calculated again, and final revisions were requested from the experts.

- **Step 5. Preparing the final report:** The outcome of the rounds is a list of possible important criteria with respect to supplier selection context. In this research, the list was finalized and sent to the procurement director for his information.

Additionally, on the request of the procurement director, all criteria grouped under 10 headings in order to ease the evaluations that will be made in the next step.

- **Step 6. Collecting corporate strategies of the subject company:** In this step, existing corporate strategies of the organization was outlined. There were seven of them, using cutting edge technology, satisfying customer needs, making environment friendly production, retaining existing quality certificates and obtaining new ones, keeping supplier ppm level at 10 and if possible decreasing it, increasing logistic performance and the last is obtaining price discounts on purchased goods. All of these strategies were assumed to be the most influential factors that would provide the organization sustainable leadership.

By using results of the Delphi method a pairwise linked FRM was developed for incorporating criteria with corporate strategies and then with sustainable leadership. As it was mentioned in the first step, there were four decision makers in total. Therefore, there would have been four maps each of which were (111x7) matrix, representing relationship between criteria and corporate strategies, and another four maps each of which were (7x1) matrix, representing effects of strategies on SL. Moreover, 9 point scale of fuzzy linguistic variables would be used when evaluating the relationships between, criteria, strategies and competitiveness. Therefore, the size and the complexity of the questionnaire may have caused burnout in evaluators and required long time to be completed if four maps were required from the experts. Therefore, with consideration of reaching a consensus in the prior steps, only one map representing group evaluations was created instead of four maps.

- **Step 7. Preparing the relational maps:** In this step, two evaluation matrix were created in MS Excel as they can be partially seen in Figure 3 and Figure 4.

			CORPORATE STRATEGIES OF YOUR COMPANY						
			Using cutting edge technology	Satisfying customer needs	Make environment friendly production	Retain and obtain more quality certificates	Keep supplier ppm at 10 or lower	Increase logistics performance	Obtain price discounts
YOUR SUPPLIER'S	48	contribution to product development	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	49	contribution to proccess development	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	50	product appropriateness	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	51	number of patents	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	52	having right and enough test equipments	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	53	design verification	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	54	existence of continious improvement systems	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	55	DFMEA	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	56	PFMEA	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	57	existence of prototype workshops	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	58	PSW	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1
	59	existence of project management system	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1	0 1 2 3 4 -1 1

Figure 3. A part of the first relational matrix

		GOAL				
		Sustainable Leadership				
ORGANIZATIONAL STRATEGIES	Using cutting edge technology	0	1	2	3	4
			-1		1	
	Satisfying customer needs	0	1	2	3	4
			-1		1	
	Make environment friendly production	0	1	2	3	4
			-1		1	
	Retain and obtain more quality certificates	0	1	2	3	4
			-1		1	
	Keep supplier ppm at 10 or lower	0	1	2	3	4
			-1		1	
	Increase logistics performance	0	1	2	3	4
			-1		1	
	Obtain price discounts	0	1	2	3	4
			-1		1	

Figure 4. A view of the second relational matrix

The first one was a (111x7 matrix) representing the relationships between criteria and corporate strategies. The criteria were in the rows and corporate strategies were in the columns. The second one was a (7x1) matrix representing the relationships between corporate strategies and SL. The corporate strategies were in the rows and SL was in the column. Each cell was divided into sub cells that represented 9 point scale of fuzzy linguistic variables (Glykas, 2010) as listed in Table 4. The fuzzy membership functions representing fuzzy linguistic variables are given in Figure 5.

Linguistic variable	Membership symbol	Crisp value
Negatively very strong (NVS)	μ_{nvs}	(-4)
Negatively strong (NS)	μ_{ns}	(-3)
Negatively medium (NM)	μ_{nm}	(-2)
Negatively weak (NW)	μ_{nw}	(-1)
Zero (Z)	μ_{z}	(0)
Positively weak (PW)	μ_{pw}	(1)
Positively medium (PM)	μ_{pm}	(2)
Positively strong (PS)	μ_{ps}	(3)
Positively very strong (PVS)	μ_{pws}	(4)

Table 4. Fuzzy linguistic variables

This scale enable decision makers describe the grade of influence with linguistic variables like “strong”, “weak” and etc. After the preparation was done, the spreadsheets was emailed to the experts for the evaluation.

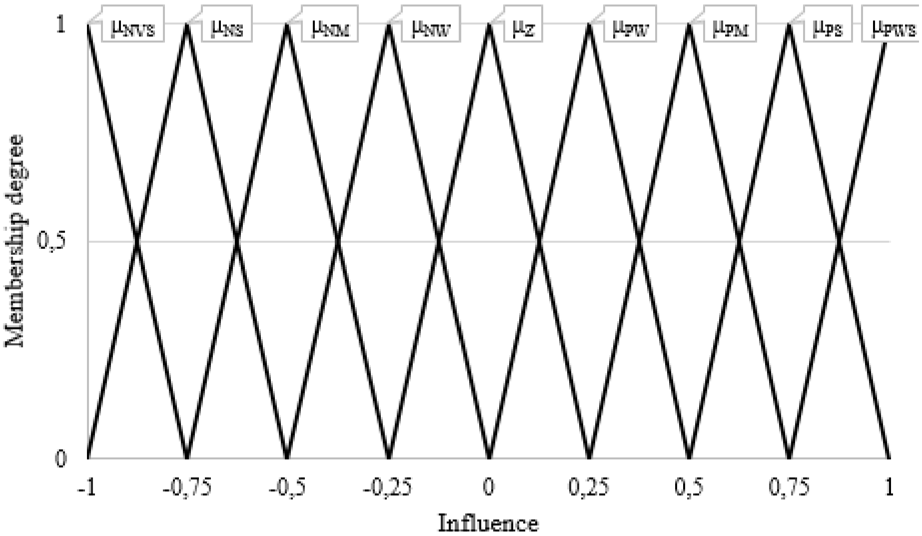

Figure 5. Fuzzy membership function

- **Step 8. Fuzzifying the relations:** After all evaluations were done by the experts, values in the matrix, in other words, influences between nodes, were fuzzified. A sample part of the evaluation and fuzzification of the matrix can be seen in Figure 6 and Figure 7.

YOUR SUPPLIER'S		CORPORATE STRATEGIES OF YOUR COMPANY: Using cutting edge technology	Satisfying customer needs	Make environment friendly production	Retain and obtain more quality certificates	Keep supplier ppm at 10 or lower	Increase logistics performance	Obtain price discounts
48	contribution to product development	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 3 **4**; -1 **1**
49	contribution to proccess development	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 3 **4**; -1 **1**
50	product appropriateness	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
51	number of patents	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	**0**; 1 2 3 4; -1 1	0; **1** 2 3 4; -1 **1**	**0**; 1 2 3 4; -1 1	0; 1 **2** 3 4; -1 **1**
52	having right and enough test equipments	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
53	design verification	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
54	existence of continious improvement systems	0; 1 **2** 3 4; -1 **1**	0; 1 2 3 **4**; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 3 **4**; -1 **1**
55	DFMEA	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; **1** 2 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
56	PFMEA	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; **1** 2 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
57	existence of prototype workshops	0; **1** 2 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	**0**; 1 2 3 4; -1 1	**0**; 1 2 3 4; -1 1	**0**; 1 2 3 4; -1 1	**0**; 1 2 3 4; -1 1	0; 1 2 **3** 4; -1 **1**
58	PSW	**0**; 1 2 3 4; -1 1	0; 1 2 3 **4**; -1 **1**	**0**; 1 2 3 4; -1 1	**0**; 1 2 3 4; -1 1	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**	0; 1 **2** 3 4; -1 **1**
59	existence of project management system	**0**; 1 2 3 4; -1 1	0; 1 **2** 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; **1** 2 3 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 **3** 4; -1 **1**	0; 1 2 **3** 4; -1 **1**

Figure 6. A part of the relational values of the first matrix

	Strategies						
Criteria	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
C48	PM	PS	PM	PM	PS	PM	PVS
C49	PM	PS	PM	PM	PS	PM	PVS
C50	PW	PS	PM	PM	PS	PM	PM
C51	PS	PM	PM	Z	PW	Z	PM
C52	PW	PS	PM	PS	PS	PM	PM
C53	PW	PS	PM	PS	PS	PM	PM
C54	PM	PVS	PS	PM	PS	PS	PVS
C55	PW	PS	PM	PW	PS	PW	PM
C56	PW	PS	PM	PW	PS	PW	PM
C57	PW	PM	Z	Z	Z	Z	PS
C58	Z	PVS	Z	Z	PM	PM	PM
C59	Z	PM	PS	PW	PS	PS	PS

Figure 7. A part of the fuzzified first matrix

If there were one map for each evaluator, there would be one more step between Step 8 and Step 9. That would be aggregation of the maps or relational matrices. Suppose, there are two different answers for one relation, negatively medium and negatively weak. In this case, all fuzzy linguistic values of this relation would be aggregated into a graph as it is seen in Figure 8, and this step would be repeated for each relation that had more than one type of fuzzy linguistic value.

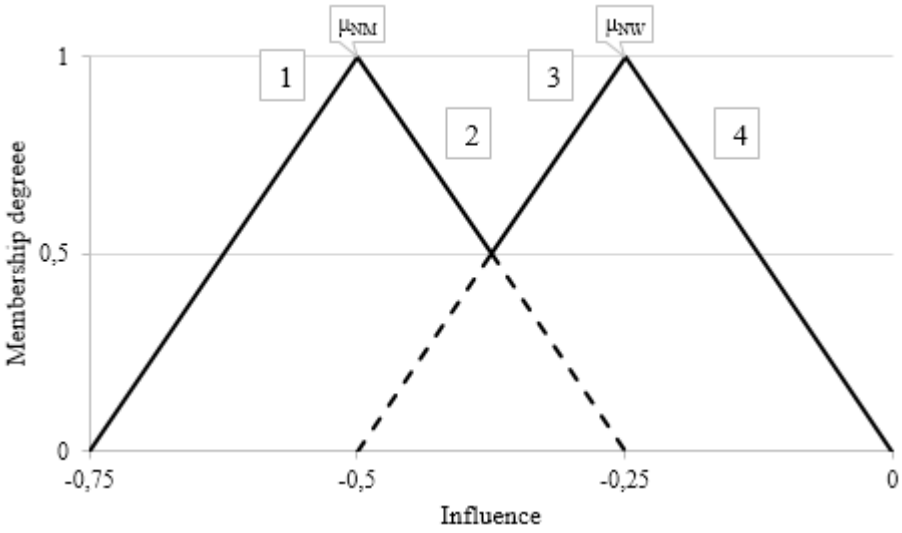

Figure 8. An aggregated graph of NM and NW fuzzy membership functions

- **Step 9. Defuzzifying the relations:** After fuzzification of the relationships, their crisp values were calculated based on the fuzzy membership functions given in Figure 5. Defuzzification is the conversion of a fuzzy quantity to a precise quantity which is called crisp value. The most commonly used method for the conversion is center of gravity (COG). In this method, center of the area below the (aggregated) membership functions is calculated. For the calculation, where crisp value was denoted by z and fuzzy membership function was denoted by $\mu_{\tilde{c}}(z)$, algebraic expression below was used (Alavala, 2008; Ross, 2010).

$$z = \frac{\int \mu_{\tilde{c}}(z).zdz}{\int \mu_{\tilde{c}}(z)dz}$$

Since the membership function given in Figure 6 is a triangular function and a triangle consists from line segments, an equation of a line given two points was used for defuzzifying single and aggregated membership functions.

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$$

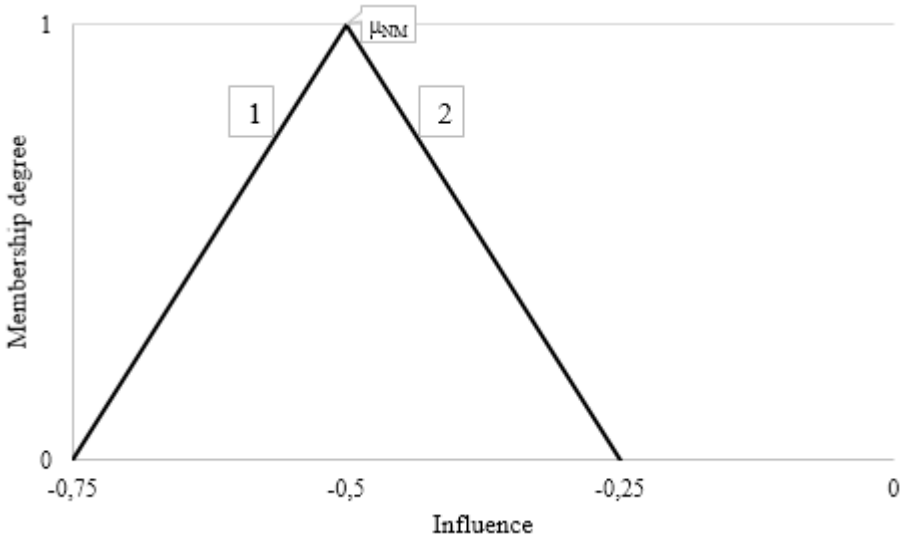

Figure 9. NM membership functions

Given two points of the first line segment of the triangle membership function is (-0.75, 0) and (-0.5, 1), and its equation becomes (z+0.75)/0.25. Given two points of the second line segment of the membership function is (-0.5, 1) and (-0.25, 0), and its equation becomes (-z-0.25)/0.25. Therefore defuzzification of negatively medium membership function is done with this equation below:

$$z = \frac{\int_{-0.75}^{-0.5} \frac{z + 0.75}{0.25} z.dz + \int_{-0.5}^{-0.25} \frac{(-z - 0.25)}{0.25} z.dz}{\int_{-0.75}^{-0.5} \frac{z + 0.75}{o.25} dz + \int_{-0.5}^{-0.25} \frac{(-z - 0.25)}{0.25} dz} = -0.5$$

The rest of defuzzified values of all fuzzy membership functions were calculated with the same method and the results are given in Table 5.

Linguistic variable	Membership symbol	Defuzzified value
Negatively very strong (NVS)	μ_{nvs}	0.92
Negatively strong (NS)	μ_{ns}	0.75
Negatively medium (NM)	μ_{nm}	0.5
Negatively weak (NW)	μ_{nw}	0.25
Zero (Z)	μ_{z}	0
Positively weak (PW)	μ_{pw}	-0.25
Positively medium (PM)	μ_{pm}	-0.5
Positively strong (PS)	μ_{ps}	-0.75
Positively very strong (PVS)	μ_{pws}	-0.92

Table 5. Defuzzified values of fuzzy membership functions

If there were two different answers for a relation as in Figure 8, similar calculations would be done as below.

Line equation of the first line segment between (-0.75, 0) and (-0.5, 1): $\frac{z+0.75}{0.25}$

Line equation of the second line segment between (-0.5, 1) and (-0.25, 0): $\frac{(-z-0.25)}{0.25}$

Line equation of the third line segment between (-0.5, 0) and (-0.25, 1): $\frac{(z+0.5)}{-0.25}$

Line equation of the fourth line segment between (-0.25, 1) and (0, 0): $\frac{(-z)}{0.25}$

$$z = \frac{\int_{-0.75}^{-0.5} \frac{z+0.75}{0.25} z.dz + \int_{-0.5}^{-0.25} \frac{(-z-0.25)}{0.25} z.dz + \int_{-0.5}^{-0.25} \frac{(z+0.5)}{-0.25} z.dz + \int_{-0.25}^{0} \frac{(-z)}{0.25} z.dz}{\int_{-0.75}^{-0.5} \frac{z+0.75}{0.25} dz + \int_{-0.5}^{-0.25} \frac{(-z-0.25)}{0.25} dz + \int_{-0.5}^{-0.25} \frac{(z+0.5)}{-0.25} dz + \int_{-0.25}^{0} \frac{(-z)}{0.25} dz}$$

- **Step 10. Creating crisp matrix:** After defuzzifying fuzzy relations, both fuzzy relational matrix representing the relationships between "Criteria & Corporate strategies" and "Corporate strategies & SL" redesigned with crisp values as it is seen in Figure 10.

	Strategies						
Criteria	S1	S2	S3	S4	S5	S6	S7
C48	0,5	0,75	0,5	0,5	0,75	0,5	0,92
C49	0,5	0,75	0,5	0,5	0,75	0,5	0,92
C50	0,25	0,75	0,5	0,5	0,75	0,5	0,5
C51	0,75	0,5	0,5	0	0,25	0	0,5
C52	0,25	0,75	0,5	0,75	0,75	0,5	0,5
C53	0,25	0,75	0,5	0,75	0,75	0,5	0,5
C54	0,5	0,92	0,75	0,5	0,75	0,75	0,92
C55	0,25	0,75	0,5	0,25	0,75	0,25	0,5
C56	0,25	0,75	0,5	0,25	0,75	0,25	0,5
C57	0,25	0,5	0	0	0	0	0,75
C58	0	0,92	0	0	0,5	0,5	0,5
C59	0	0,5	0,75	0,25	0,75	0,75	0,75

Figure 10. A part of the deffuzified first matrix

- **Step11. Obtaining final results:** Eventually, product of these two matrix was the effect of each corporate strategy based criteria on the SL. MATLAB R2014a was used to obtain the product of two matrix. Based on the results, the criteria of which crisp values were equal and greater than (+3) or equal and smaller than (-3) assumed to be strategic criteria.

5. Results of the Research

5.1. Results of the criteria determination part

Results given in this section cover the first five steps of the process, which are about criteria determination. General findings of this part are as follows:

Delphi rounds were made at the beginning of summer since business was much steady in this time of the year comparing to other seasons. The first and second rounds took 18 and 34 days to be completed and some details about the experts can be seen in Table 6.

Expert	Experience (year)	Number of changed answers between rounds	Number of being out of range before / after feedback
A	6	38	1 / 0
B	14	58	8 / 4
C	6	39	11 / 5
D	1	51	1 / 0

Table 6. Findings about the experts

As it was explained in Step 2, a list of possible criteria regarding the supplier selection context was prepared with the procurement director in order to reduce the number of Delphi rounds and prevent burnout of the experts. In the prepared list, there were 106 criteria. At the end of the Delphi rounds 111 criteria were obtained. Even though, the number of the criteria seemed to be increased after the Delphi rounds, there were not actually any new criteria proposal but propose of using same three criteria under different headings as listed in Table 7. The repeated criteria were flexibility, ability to fulfill unexpected orders and commitment to quality. Flexibility and ability to fulfill unexpected orders were both used in technical capabilities of human resources and also in technical capabilities of production system. Commitment to quality was used both in product quality and system quality. Moreover, organizational structure and length of contract criteria were divided into two complementary criteria. The first one was divided into family owned business and corporate organization criteria. The second one was divided into short term and long term contracts criteria. Therefore, there were 111 criteria in total to be related with the corporate strategies of the company.

Group name	No	Criteria
Technical capabilities of human resources	C1	Technical qualifications of employees(**)
	C2	Ability to use computer technologies
	C3	Continuous employee training
	C4	Ability to solve problems
	C5	Experience of employees
	C6	Flexibility
	C7	Ability to fulfill the unexpected orders
	C8	Ability to speak same language
	C9	Ability to use same jargon (technical language)
	C10	Delegating the authority to operators
Technical capabilities of production system	C11	Production capacity
	C12	Follow up computer technologies
	C13	Goodness of process fit
	C14	Internal communication ability(**)
	C15	External communication ability
	C16	Previous production level
	C17	Flexibility(*)
	C18	Order entry system
	C19	Ability to fulfill the unexpected orders(*)
	C20	Having it department
	C21	Applying cost accounting system
	C22	Amount (%) dedicated to training resources
	C23	Number of stopping production line
	C24	Traceability of performance criteria
	C25	Having proper machineries for production
	C26	Having automated production systems
	C27	Having proper machineries for quality controlling
Product quality	C28	Product quality
	C29	Commitment to quality
	C30	Quality control (**)
	C31	Ppm target
	C32	Scrap level
	C33	Quality costs
	C34	Internal ppm (defects in a million)
	C35	External ppm (defects in a million)
	C36	Supplier's supplier ppm (defects in a million)
	C37	Logistic performance of supplier's supplier
	C38	Product cost of supplier's supplier

Group name	No	Criteria
	C39	Product quality of supplier's supplier
	C40	Production method of supplier's supplier
System quality	C41	ISO 9001
	C42	ISO 14001
	C43	ISO 18001
	C44	ISO 16001
	C45	ISO16949
	C46	EFQM
	C47	Commitment to quality(*)(**)
Project competency	C48	Contribution to product development
	C49	Contribution to process development
	C50	Product appropriateness
	C51	Number of patents
	C52	Having right and enough test equipment
	C53	Design verification
	C54	Existence of continuous improvement systems
	C55	DFMEA (Design Failure Mode Effects Analysis)
	C56	PFMEA (Process Failure Mode Effects Analysis)
	C57	Existence of prototype workshops
	C58	PSW (Part Submission Warrant)
	C59	Existence of project management system
Logistic ability	C60	Delivery terms
	C61	Order quantity
	C62	Packaging
	C63	Geographical location
	C64	Inventory capacity
	C65	Delivery performance
	C66	Able to meet JIT conditions
	C67	Logistic ability in general
	C68	Able to deliver in time
	C69	Comply with SC requirements in general
	C70	Comply with ordering process
	C71	Raw materials safety stock
	C72	Order cycle time
	C73	Finished products safety stock
	C74	Logistics ratings of other customers
Finance	C75	Price
	C76	Cost
	C77	Mistakes in invoice
	C78	Profitability ratio
	C79	Financial stability
	C80	Credibility
	C81	Sales income distribution ratio
Guarantee	C82	After sales support
	C83	Comply with terms of contract
	C84	Recall insurance
	C85	Short term contract
	C86	Long term contract
	C87	Average time of working with customers
Organizational structure	C88	Eagerness for cooperation
	C89	Attitude
	C90	Existence of union
	C91	Rate of occupational accidents
	C92	Environmental awareness
	C93	Social responsibility
	C94	Experience in business
	C95	Waste-scrap management
	C96	Honesty
	C97	Cultural fitness
	C98	Eagerness for sharing confidential information
	C99	Average salary of employees

Group name	No	Criteria
	C100	Relationship with employees
	C101	Collaboration with universities
	C102	Memberships (to other organizations or associations)
Competitiveness	C103	Family owned business
	C104	Corporate organization
	C105	Reputation
	C106	Position in the market
	C107	Business strategy (cost-quality-service sensitive)(**)
	C108	Size of company
	C109	Strategic importance for my company(**)
	C110	The biggest portion(is hold by main customer) in the supplier's budget
	C111	Capability to support my company in having competitive advantage

Table 7. Final criteria list
* Repeated criteria
**Please see the Appendix for the explanation

At the beginning of Delphi rounds, there were six experts in total. However, two of them left the company between the first and second round. One important finding was that, when there were six evaluators, variance of two criteria was zero. They were ISO 9001 and product quality. However, when two of them left the company, number of zero variance criteria increased to twelve. With their rates, they were ability to use computer technologies (3), able to meet JIT conditions (4), number of stopping production line (5), product quality (5), ISO:9001 (5), ISO:16949 (4), existence of continuous improvement systems (4), geographical location (4), recall insurance (4), environmental awareness (3), social responsibility (3) and collaboration with universities (3). Additionally in the first round, variance of three criteria was equal and greater than one. They were continuous employee training (σ= 1), ability to speak same language (σ= 1,09) and supplier's supplier ppm (σ= 1,225).

According to second round evaluations, some other criteria had zero variance. They were previous production level (3), amount (%) dedicated to training resources (3), having proper machineries for quality controlling (4), commitment to quality (4), internal ppm (3), inventory capacity (4), sales income distribution ratio (4), after sales support (4), eagerness for cooperation (5) and capability to support my company in having competitive advantage (4). Criteria of which variance were equal and greater than one in the first round, had variance lower than one in the second round.

5.2. Results of the influence estimation part

Results given in this section cover the last six steps of the process which are about the influence estimation, Fuzzy relational maps technique was used for the estimation. With this technique, effects of each criteria on SL through corporate strategies was obtained as listed in Table 8.

Criteria No	Influence	Criteria No	Influence	Criteria No	Influence
C1	3,7914	C38	1,1500	C75	2,3089
C2	1,3800	C39	1,4400	C76	2,3089
C3	2,9650	C40	1,5250	C77	-0,8150
C4	2,7150	C41	1,7525	C78	2,3089
C5	3,1325	C42	2,2864	C79	1,9964
C6	3,1639	C43	1,6900	C80	1,9964
C7	2,9028	C44	0.9600	C81	1,7550
C8	0,9400	C45	3,6239	C82	2,0564
C9	2,2550	C46	2,8200	C83	3,6328
C10	2,7975	C47	3,6239	C84	0,8775
C11	2,7264	C48	3,3089	C85	-2,1300

Criteria No	Influence	Criteria No	Influence	Criteria No	Influence
C12	1,3800	C49	3,3089	C86	2,5900
C13	1,9625	C50	2,8600	C87	3,0075
C14	3,2775	C51	1,5450	C88	3,4764
C15	3,7914	C52	3,0475	C89	3,4764
C16	2,7264	C53	3,0475	C90	0,6475
C17	3,1639	C54	3,8203	C91	1,0650
C18	0,7100	C55	2,4425	C92	0,8775
C19	2,9028	C56	2,4425	C93	0,6675
C20	1,1075	C57	1,2125	C94	3,6664
C21	1,1500	C58	2,1414	C95	1,3575
C22	1,7639	C59	2,9650	C96	2,3600
C23	-2,0564	C60	1,0650	C97	2,4025
C24	1,5225	C61	1,1500	C98	-1,8064
C25	2,8714	C62	0,9200	C99	-0,4600
C26	2,7975	C63	1,2750	C100	2,1300
C27	2,2150	C64	1,6500	C101	2,2975
C28	3,3739	C65	2,3289	C102	0,5225
C29	3,3739	C66	2,4339	C103	-1,6500
C30	3,0925	C67	2,4339	C104	1,6500
C31	3,3764	C68	2,4339	C105	0,9825
C32	3,2575	C69	2,6414	C106	2,0250
C33	2,2350	C70	2,2039	C107	3,6950
C34	3,0925	C71	2,1414	C108	1,3325
C35	3,3764	C72	2,2575	C109	3,3200
C36	2,9650	C73	1,7550	C110	3,3825
C37	1,3375	C74	0,6900	C111	3,3514

Table 8. Influence of each criterion on sustainable leadership

As it was stated in Step 11, criteria having values equal and greater than (+3) or equal and smaller than (-3) assumed to be strategic criteria. There were 27 criteria assumed to be strategic. However, none of them is negative. Even though, there were six criteria of which values were smaller than zero, value of none of them is equal and smaller than (-3). However, these negative criteria may be considered critical when pre-qualifying candidate suppliers. Also, there were some criteria of which values were in the interval (-1, 1). These criteria may be considered as unimportant in strategic supplier pre-qualification context. A list of strategic, critical and unimportant criteria and criteria-strategy-sustainable leadership map is in Table 9 and Figure 11.

Criteria name	Strategic	Critical	Unimportant
Technical qualifications of employees	3,7914		
Experience of employees	3,1325		
Flexibility of employees	3,1639		
Ability to speak same language(s)			0,9400
Internal communication ability	3,2775		
External communication ability	3,7914		
Flexibility (of the production system)	3,1639		
Order entry system			0,7100
Number of stopping production line		-2,0564	
Product quality	3,3739		
Commitment to quality (product)	3,3739		
Quality control	3,0925		
Ppm target	3,3764		
Scrap level	3,2575		
Internal ppm	3,0925		
External ppm	3,3764		
ISO 16001			0,9600
ISO16949	3,6239		
Commitment to quality (system)	3,6239		

Criteria name	Strategic	Critical	Unimportant
Contribution to product development	3,3089		
Contribution to process development	3,3089		
Having right and enough test equipment	3,0475		
Design verification	3,0475		
Existence of continuous improvement systems	3,8203		
Packaging			0,9200
Logistics ratings of other customers			0,6900
Mistakes in invoice			-0,8150
Comply with terms of contract	3,6328		
Recall insurance			0.8775
Short term contract		-2,1300	
Average time of working with customers	3,0075		
Eagerness for cooperation	3,4764		
Attitude	3,4764		
Existence of union			0,6475
Environmental awareness			0,8775
Social responsibility			0,6675
Experience in business	3,6664		
Eagerness for sharing confidential information		-1,8064	
Average salary of employees			-0,4600
Memberships (to other organizations)			0,5225
Family owned business		-1,6500	
Reputation			0,9825
Business strategy (cost-quality-service sensitive)	3,6950		
Strategic importance for my company	3,3200		
The biggest portion (is hold by main customer) in the supplier's budget	3,3825		
Capability to support my company in having competitive advantage	3,3514		

Table 9. A list of strategic, critical and unimportant criteria

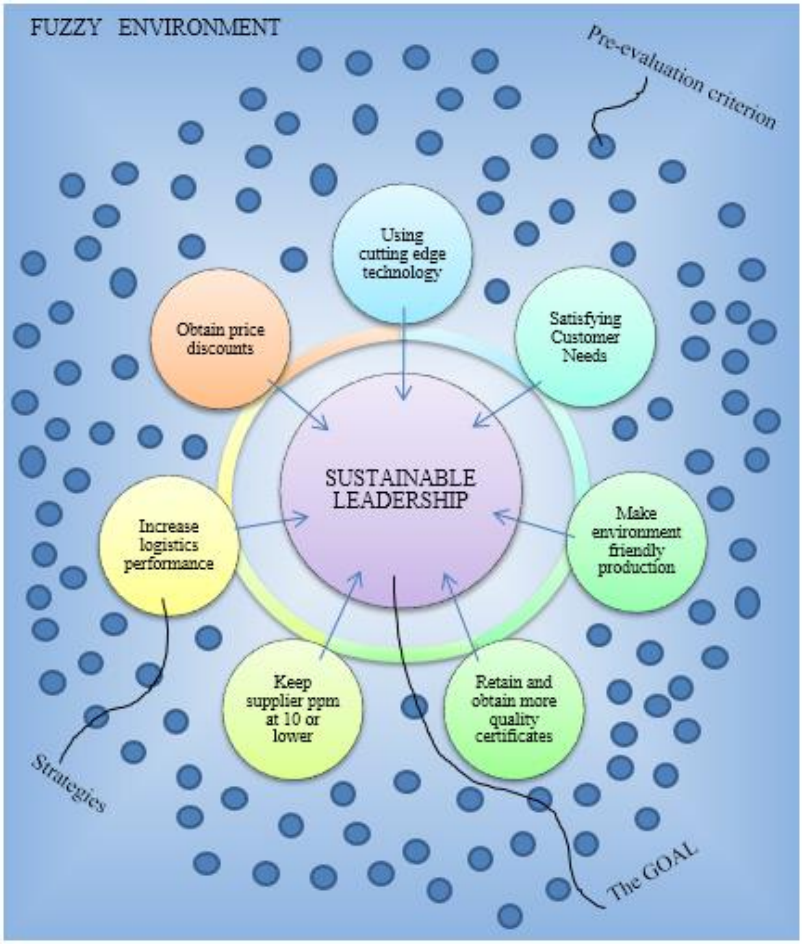

Figure 11. Criteria-Strategy-Leadership map

6. DISCUSSION AND CONCLUSION

In this research study, Delphi method was used for only collecting names of the possible criteria that was considered important regarding supplier selection context. As there were only four evaluators, there was not enough sample data to make some statistical calculations with. Therefore, criteria values obtained in Delphi rounds were not considered to be important to be discussed about in this section. However, there are some interesting findings about the Delphi rounds. The first finding is the length of the rounds. As it is stated in Section 5.1., the second round took two times longer than the first round. The reason might have been that experts were asked to re-examine their first round answers. Also the second Delphi round was hold in the middle of summer, which was vacation time. Therefore, it can be assumed that the time of the year is an important issue for timing of a research project that has Delphi method application.

Another finding is about the experts. As it can be seen in Table 7, there is one one year experience (D) expert and one fourteen year experience (B) expert. Normally, it is expected that the fourteen year experience expert has less variance in his/her answers between rounds as he/she is much more experienced than D. However, expert B did more changes in his/her evaluations than expert D did. Also four of his/her evaluations left out of the range at the end of the rounds while all of the answers of expert B was in range. The situation of expert D may be explained with the person-organization fit theory, which is defined as the congruence between values of employee and values and norms of organizations.

Also, as explained in Step 1 in Section 4, two decision makers resigned between the Delphi rounds. With the resignation, number of zero variance criteria was increased from two to twelve in the first Delphi round. This increase also may be explained with the congruency theory. Values, norms and characteristics of the resigned employees may not be compatible with the organization's. In other words, fitness between employees and organization may be low. Low person-organization fit, especially in procurement department of an organization, may result in disastrous procurement decisions and business partnerships since these employees would make procurement decisions according to their own values not the values of the organization.

As it was stated in Section 5, variance of all criteria was lower than one, and 22 criteria had zero variance at the end of the Delphi rounds. That is more than 20% of all criteria. Therefore, it can be concluded that experts reached a consensus with the Delphi rounds that provide a common point of view about the criteria.

The very most interesting finding about the outcomes of FRM approach was that price and cost were not in the list of strategic criteria. Their influence on SL of the company through corporate strategies were estimated moderate. However, they were two of the most important evaluation factors of the company. Also they are considered important in most of the studies in the literature (Cao et al., 2014; C. G. Şen et al., 2010; Sarkar & Mohapatra, 2006). However, there is a difference in practice of this research. Importance of all criteria were estimated in strategy and leadership context of the company. Having this result actually what was expected. As it was stated previously, this research study aims to define a set of strategy based criteria that help to eliminate strategically misfit companies in the pre-qualification step of

supplier selection process. Cost and price cannot be determined before the final selection because this information can be obtained when quotation request is sent to candidate companies, and usually it is sent just before the final selection. Therefore, these criteria cannot be considered as pre-qualification criteria. As a result, if experts in procurement departments make strategy driven procurement decisions, their final choice may change since the set of considered criteria get changed.

Another interesting finding is about the top five criteria. Existence of continuous improvement systems was the first, technical qualification of the employees and external communication ability were the second, business strategy of the candidate supplier was the third, experience of the company was the fourth and ISO:16949 was the fifth important strategic criteria. As it is clear, organizational and managerial characteristics of the company takes the top five space in the strategic criteria list. Therefore, organizations need to move their attention from monetary / financial criteria to much more managerial criteria when selecting supply chain partners if they want to obtain sustainable leadership in the market. For the supplying company side it is the same. Supplier companies need to invest more in their management systems so their human resources if they want to be a business partner of global companies. Moreover, to the best of our knowledge, this kind of criteria are not usually considered in real life practices. Integrating these criteria into supplier selection and evaluation system of organizations may cause change in procurement decisions of experts.

Number of stopping production line, having short term contract, eagerness of sharing confidential information and being family owned business had negative effects in strategic context on the leadership of the organization. Since their absolute influence was not as high as strategic criteria, they were grouped as critical criteria that may be considered in the final selection of suppliers. Moreover, there is one important point to pay attention on. Having/preferring short term contracts with business partners was considered like a defect by the subject company. In other words, subject company prefers suppliers that have long and most probably strong relationships with its partners. This finding is in accordance with the related literature.

Another interesting finding was about unimportant criteria. For example, influence value of social responsibility and environmental awareness are estimated very low, close to zero. However, these two factors are most popular research and investment area of today's business market. Therefore, a further analysis, for example a more expansive industry based research can be done about this finding.

The list of strategy based supplier pre-qualification criteria determined with this research can be divided into two sets of criteria. While the first set includes criteria about organizational texture of candidate companies, the second set may include technical criteria. This structure enables decision makers apply a stepwise procedure of supplier pre-qualification model. By doing so subject company may eliminate organizationally misfit nominated candidate suppliers with the first set of criteria and then classify the rest with the second set of criteria according to their technical capabilities. As a result, nominated candidate suppliers that pass the organizational evaluation and have high score in technical evaluation become candidate supplier for the final selection.

Regarding the methods used for modelling this framework, Delphi technique was used for only extracting knowledge about important selection criteria and reaching consensus about them. Other techniques like brainstorming was not used since this kind of group decision making techniques inherit some pitfalls. Moreover, only the experts, who had direct relationship with suppliers, involved in this research study. Instead, decision makers, who indirectly affect procurement decisions, from different units of the organization like production or quality departments may also involve in Delphi rounds. Also in this research, a large set of item was determined and evaluated. In a future research, Delphi technique may be used to estimate importance values of only strategy based criteria obtained in this study.

Fuzzy relational maps technique was used in estimating the importance of strategy based supplier pre-qualification criteria for the goal of the company which was sustainable leadership. In classical FRM approach, one map is created for each expert. However, since there was many relationships to be considered, only one map was created for all experts. The small set of strategy based criteria determined in this research can be evaluated by each expert individually in a future research as well. Also in this research, interrelationship among criteria was not investigated. Therefore, fuzzy cognitive map approach can be applied to this kind of investigation in a future research.

To summarize, the supplier selection is one of the most important tasks for organizations since results of the final decision affect profitability, position and market share of the company (Aghai et al., 2014; Cheraghi et al., 2011; Kasirian & Yusuff, 2013; Lee, 2009; Lin, 2012; Xiao et al., 2012). Even though there are voluminous work about this subject in the literature it is still a problematic area as many conflicting subjective criteria and numerous candidates are involved in the selection. This makes the process complicated. To ease the final selection and to find the most suitable supplier, it is essential to define the right criteria and apply a pre-qualification step that shortlists the number of candidate suppliers. Also, strategic fitness is another issue to be considered in supplier selection context. Supply chain systems require a synchronous operations between organizations and it can be achieved only between strategically congruent organizations. Therefore, it becomes important to look for strategic fitness in candidate suppliers. Therefore in this research study a hybrid approach that incorporates Delphi technique with fuzzy relational maps was proposed for determining strategy based supplier pre-qualification criteria and their influence on sustainable leadership.

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References

Aghai, S., Mollaverdi, N., & Sabbagh, M. S. (2014). A fuzzy multi-objective programming model for supplier selection with volume discount and risk criteria. International Journal of Advanced Manufacturing Technology, 71(5-8), 1483–1492. http://doi.org/10.1007/s00170-013-5562-0

Aissaoui, N., Haouari, M., & Hassini, E. (2007). Supplier selection and order lot sizing modeling: A review. Computers and Operations Research, 34(12), 3516–3540. http://doi.org/10.1016/j.cor.2006.01.016

Alavala, C. R. (2008). Fuzzy logic and neural networks basic concepts & applications. India: New Age International Publishers.

Arikan, F. (2013). A fuzzy solution approach for multi objective supplier selection. In Expert Systems with Applications (Vol. 40, pp. 947–952). http://doi.org/10.1016/j.eswa.2012.05.051

Azadeh, A., Keramati, A., & Jafary Songhori, M. (2009). An integrated Delphi/VAHP/DEA framework for evaluation of information technology/information system (IT/IS) investments. International Journal of Advanced Manufacturing Technology, 45(11-12), 1233–1251. http://doi.org/10.1007/s00170-009-2047-2

Azadi, M., & Saen, R. F. (2012). Supplier selection using a new russell model in the presence of undesirable outputs and stochastic data. Journal of Applied Sciences, 12(4), 336–344. http://doi.org/10.3923/jas.2012.336.344

Benyoucef, L., Ding, H., & Xie, X. (2003). Supplier selection problem : selection criteria and methods. Institut National de Recherche En Informatique et En Automatique.

Burton, T. T. (1988). JIT/repetitive sourcing strategies: Tying the knot with your suppliers. Production and Inventory Management Journal, 29(4), 38–41.

Cao, Y., Luo, X., Kwong, C. K., & Tang, J. (2014). Supplier pre-selection for platform-based products: a multi-objective approach. International Journal of Production Research, 52(1), 1–19. http://doi.org/10.1080/00207543.2013.807376

Chai, J., Liu, J. N. K., & Ngai, E. W. T. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. Expert Systems with Applications, 40(10), 3872–3885. http://doi.org/10.1016/j.eswa.2012.12.040

Chang, B., Chang, C. W., & Wu, C. H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. Expert Systems with Applications, 38(3), 1850–1858. http://doi.org/10.1016/j.eswa.2010.07.114

Chen, P.-S., & Wu, M.-T. (2013). A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment: A case study. Computers and Industrial Engineering, 66(4), 634–642. http://doi.org/10.1016/j.cie.2013.09.018

Chen, Y. H., & Chao, R. J. (2012). Supplier selection using consistent fuzzy preference relations. Expert Systems with Applications, 39(3), 3233–3240. http://doi.org/10.1016/j.eswa.2011.09.010

Cheraghi, S. H., Dadashzadeh, M., & Subramanian, M. (2011). Critical success factors for supplier selection : An update. Journal of Applied Business Research, 20(2), 91–108.

Chou, S. Y., & Chang, Y. H. (2008). A decision support system for supplier selection based on a strategy-aligned fuzzy SMART approach. Expert Systems with Applications, 34(4), 2241–2253. http://doi.org/10.1016/j.eswa.2007.03.001

Dalkey, N., & Helmer, O. (1963). An Experimental Application of the DELPHI Method to the Use of Experts. Management Science. http://doi.org/10.1287/mnsc.9.3.458

De Boer, L., Labro, E. e Morlacchi, P. (2001). A review of methods supporting supplier selection, European Journal of Purchasing & Supply Management, 7, 75–89.

De Boer, L., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. European Journal of Purchasing and Supply Management, 7(2), 75–89. http://doi.org/10.1016/S0969-7012(00)00028-9

Degraeve, Z., Labro, E., & Roodhooft, F. (2000). An evaluation of vendor selection models from a total cost of ownership perspective. European Journal of Operational Research. http://doi.org/10.1016/S0377-2217(99)00199-X

Ertay, T., Kahveci, A. & Tabanlı, R. M. (2011). An integrated multi-criteria group decision-making approach to efficient supplier selection and clustering using fuzzy preference relations. International Journal of Computer Integrated Manufacturing, 24(12), 1152–1167. http://doi.org/10.1080/0951192X.2011.615342

Farughi, H., Azar, S. A., Sadeghi, H., Naseri, F., & Hajebi, S. (2011). Using Multi Criteria Decision Making Models to Evaluate Suppliers in Outsourcing Process of Supply Chain Management (Case Study : Potential industrial Clusters of Kurdistan), 5(12), 1999–2009.

Fischer, R. G. (1978). The Delphi Method: A Description, Review, and Criticism. Journal of Academic Librarianship.

Florez-Lopez, R. (2007). Strategic supplier selection in the added-value perspective: A CI approach. Information Sciences, 177(5), 1169–1179. http://doi.org/10.1016/j.ins.2006.08.009

Glykas, M. (2010). Fuzzy Cognitive Maps Advances in Theory, Methodologies, Tools and Applications. (M. Glykas, Ed.). Berlin Heidelberg: Springer. http://doi.org/10.1007/978-3-642-03220-2

GURNANI, H., GÜMÜŞ, M., RAY, S., & RAY, T. (2012). Optimal Procurement Strategy Under Supply Risk. Asia-Pacific Journal of Operational Research, 29(01), 1240006. http://doi.org/10.1142/S0217595912400064

Hätönen, J., & Ruokonen, M. (2010). Revising marketing strategies for supplier selection criteria: small firm approach from the information and communications industry. Journal of Business & Industrial Marketing, 25(2), 159–167. http://doi.org/10.1108/08858621011017778

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research, 202(1), 16–24. http://doi.org/10.1016/j.ejor.2009.05.009

Igoulalene, I., Benyoucef, L., & Tiwari, M. K. (2015). Novel fuzzy hybrid multi-criteria group decision making approaches for the strategic supplier selection problem. Expert Systems with Applications, 42(7), 3342–3346. http://doi.org/10.1016/j.eswa.2014.12.014

Jain, R., Singh, A. R., Yadav, H. C., & Mishra, P. K. (2014). Using data mining synergies for evaluating criteria at pre-qualification stage of supplier selection. Journal of Intelligent Manufacturing, 25(1), 165–175. http://doi.org/10.1007/s10845-012-0684-z

Jain, V., Wadhwa, S., & Deshmukh, S. G. (2007). Supplier selection using fuzzy association rules mining approach. International Journal of Production Research, 45(6), 1323–1353. http://doi.org/10.1080/00207540600665836

Kandasamy, W. B. V., & Smarandache, F. (2003). FUZZY COGNITIVE MAPS AND NEUTROSOPHIC COGNITIVE MAPS and. Ann Arbor: Xiquan.

Karsak, E. E., & Dursun, M. (2016). Taxonomy and review of non-deterministic analytical methods for supplier selection, 3052(January). http://doi.org/10.1080/0951192X.2014.1003410

Kasirian, M. N., & Yusuff, R. M. (2013). An integration of a hybrid modified TOPSIS with a PGP model for the supplier selection with interdependent criteria. International Journal of Production Research, 51(4), 1037–1054. http://doi.org/10.1080/00207543.2012.663107

Kotula, M., Ho, W., Kumar Dey, P., & Lee, C. K. M. (2015). Strategic sourcing supplier selection misalignment with critical success factors: Findings from multiple case studies in Germany and the United Kingdom. International Journal of Production Economics, 166, 238–247. http://doi.org/10.1016/j.ijpe.2014.12.039

Lee, A. H. I. (2009). A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks. Expert Systems with Applications, 36(2 PART 2), 2879–2893. http://doi.org/10.1016/j.eswa.2008.01.045

Lin, R. H. (2012). An integrated model for supplier selection under a fuzzy situation. International Journal of Production Economics, 138(1), 55–61. http://doi.org/10.1016/j.ijpe.2012.02.024

Luo, X., Wu, C., Rosenberg, D., & Barnes, D. (2009). Supplier selection in agile supply chains: An information-processing model and an illustration. Journal of Purchasing and Supply Management, 15(4), 249–262. http://doi.org/10.1016/j.pursup.2009.05.004

Melnyk, S. a., Lummus, R. R., Vokurka, R. J., Burns, L. J., & Sandor, J. (2009). Mapping the future of supply chain management: a Delphi study. International Journal of Production Research, 47(16), 4629–4653. http://doi.org/10.1080/00207540802014700

Micheli, G. J. L., Cagno, E., & Zorzini, M. (2008). Supply risk management vs supplier selection to manage the supply risk in the EPC supply chain. [Em-rs],Management Research News, 31(11), 846–866. http://doi.org/10.1108/01409170810913042

Moller, K. E. K., & Torronen, P. (2003). Business suppliers' value creation potential: A capability-based analysis. Industrial Marketing Management, 32(2), 109–118. http://doi.org/10.1016/S0019-8501(02)00225-0

Moser, R., & Blome, C. (2008). The Influence of Strategic Supplier Selection Criteria on PSM and Company Performance. ICFAI Journal of Supply Chain Management, 5(2), 35–49.

Nepal, B., & Yadav, O. P. (2015). Bayesian belief network-based framework for sourcing risk analysis during supplier selection. International Journal of Production Research, 53(20), 6114–6135. http://doi.org/10.1080/00207543.2015.1027011

Nilsson, F., & Rapp, B. (2005). Understanding Competitive Advantage. Berlin Heidelberg: Springer.

Pal, O., Gupta, A. K., & Garg, R. K. (2013). Supplier Selection Criteria and Methods in Supply Chains : A Review. International Journal of Social, Education, Economics and Management Engineering, 7(10), 27–33.

Paul, S. K. (2015). Supplier selection for managing supply risks in supply chain: a fuzzy approach. International Journal of Advanced Manufacturing Technology, 657–664. http://doi.org/10.1007/s00170-015-6867-y

Raut, R. D., Bhasin, H. V., & Kamble, S. S. (2010). Exploring Critical Criteria for Supplier Selection by CNG/LPG kit Manufacturers in India-Selection of Suppliers for Compressed Natural Gas and Liquefied Petroleum Gas Kit Manufacturers: A Case Study and Proposed Methodology. International Journal of Business Insights & Transformation, 3(2), 35–45.

Ravindran, A. R., Bilsel, R. U., Wadhwa, V., & Yang, T. (2010). Risk adjusted multicriteria supplier selection models with applications. International Journal of Production Research, 48(2), 405–424. http://doi.org/10.1080/00207540903174940

Richards, K., & Jones, E. (2007). Relationship effectiveness and key account performance: Assessing inter-firm fit between buying and selling organizations. AMA Winter Educator's Conference Proceedings, 18, 207–209.

Ross, T. J. (2010). Fuzzy Logic with Engineering Applications (Third). West Sussex, UK: John Wiley & Sons, Ltd.

Sarkar, A., & Mohapatra, P. K. J. (2006). Evaluation of supplier capability and performance: A method for supply base reduction. Journal of Purchasing and Supply Management, 12(3), 148–163. http://doi.org/10.1016/j.pursup.2006.08.003

Sarkis, J., & Talluri, S. (2002). A model for strategic supplier selection. Journal of Supply Chain Management, 38(1), 18–28. http://doi.org/10.1111/j.1745-493X.2002.tb00117.x

Shahroudi, K., & Rouydel, H. (2012). Using a multi-criteria decision making approach (ANP-TOPSIS) to evaluate suppliers in Iran ' s auto industry. International Journal of Applied Operational Research, 2(2), 37–48.

Shaw, K., Shankar, R., Yadav, S. S., & Thakur, L. S. (2012). Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. Expert Systems with Applications, 39(9), 8182–8192. http://doi.org/10.1016/j.eswa.2012.01.149

Shen, C.-Y., & Yu, K.-T. (2012). An integrated fuzzy strategic supplier selection approach for considering the supplier integration spectrum. International Journal of Production Research, 50(3), 817–829. http://doi.org/10.1080/00207543.2010.546586

Siguaw, J. a, & Simpson, P. M. (2004). Toward Assessing Supplier Value: Usage and Importance of Supplier Selection , Retention , and Value-Added Criteria. Journal of Marketing Channels, 11(2/3), 3–31. http://doi.org/10.1300/J049v11n02

Spekman, R. E. (1988). Strategic supplier selection: Understanding lon-term buyer relationships. Business Horizons, 31(4), 75–81. http://doi.org/10.1016/0007-6813(88)90072-9

Surajit Bag. (2011). Review of Supplier Selection Models: Key Success and Growth Factors. International Journal of Supply Chain Mangement Systems, 1, 285–292.

Swift, C. O. (1995). Preferences for single sourcing and supplier selection criteria. Journal of Business Research, 32(2), 105–111. http://doi.org/10.1016/0148-2963(94)00043-E

Şen, C. G., Şen, S., & Başlıgil, H. (2010). Pre-selection of suppliers through an integrated fuzzy analytic hierarchy process and max-min methodology. International Journal of Production Research, 48(6), 1603–1625. http://doi.org/10.1080/00207540802577946

Şen, S., Başlıgil, H., Şen, C. G., & H., B. (2008). A framework for defining both qualitative and quantitative supplier selection criteria considering the buyer – supplier integration strategies. International Journal of Production Research, 46(7), 1825–1845. http://doi.org/10.1080/00207540600988055

Tahriri, F., Osman, M. R., Ali, A., Yusuff, R. M., & Esfandiary, A. (2008). AHP approach for supplier evaluation and selection in a steel manufacturing company. Journal of Industrial Engineering and Management, 1(2), 54–76. http://doi.org/10.3926/jiem..v1n2.p54-76

Toulan, O., Birkinshaw, J., & Arnold, D. (2006). The Role of Interorganizational Fit in Global Account Management. International Studies of Management and Organization, 36(4), 61–81. http://doi.org/10.2753/IMO0020-8825360403

Vokurka, R. J., Choobineh, J., & Vadi, L. (1996). A prototype expert system for the evaluation and selection of potential suppliers. International Journal of Operations & Production Management, 16(12), 106–127. http://doi.org/10.1108/01443579610151788

Vonderembse, M. a, & Tracey, M. (1999). The Impact of Supplier Selection Criteria and Supplier Involvement. The Journal of Supply Chain Management, (Summer), 33–39. http://doi.org/10.1111/j.1745-493X.1999.tb00060.x

Weber, C. a., Current, J. R., & Benton, W. C. (1991). Vendor selection criteria and methods. European Journal of Operational Research, 50(1), 2–18. http://doi.org/10.1016/0377-2217(91)90033-R

Wilson, E. (1994). The relative importance of supplier selection criteria: a review and update. ... Journal of Purchasing and Materials Management.

Wu, C.-M., Hsieh, C.-L., & Chang, K.-L. (2013). A Hybrid Multiple Criteria Decision Making Model for Supplier Selection. Mathematical Problems in Engineering, 2013, 1–8. http://doi.org/10.1155/2013/324283

Wu, D. D., Zhang, Y., Wu, D., & Olson, D. L. (2010). Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach. European Journal of Operational Research, 200(3), 774–787. http://doi.org/10.1016/j.ejor.2009.01.026

Wu, W. Y., Sukoco, B. M., Li, C. Y., & Chen, S. H. (2009). An integrated multi-objective decision-making process for supplier selection with bundling problem. Expert Systems with Applications, 36(2 PART 1), 2327–2337. http://doi.org/10.1016/j.eswa.2007.12.022

Xiao, Z., Chen, W., & Li, L. (2012). An integrated FCM and fuzzy soft set for supplier selection problem based on risk evaluation. Applied Mathematical Modelling, 36(4), 1444–1454. http://doi.org/10.1016/j.apm.2011.09.038

Yaman, D., & Polat, S. (2009). A fuzzy cognitive map approach for effect-based operations: An illustrative case. Information Sciences, 179(4), 382–403. http://doi.org/10.1016/j.ins.2008.10.013

You, X. Y., You, J. X., Liu, H. C., & Zhen, L. (2015). Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information. Expert Systems with Applications, 42(4), 1906–1916. http://doi.org/10.1016/j.eswa.2014.10.004

Yu, C., & Wong, T. N. (2014). A supplier pre-selection model for multiple products with synergy effect. International Journal of Production Research, 52(17), 5206–5222. http://doi.org/10.1080/00207543.2014.900199

Zadeh, L. A. (2008). Is there a need for fuzzy logic? Information Sciences, 178(13), 2751–2779. http://doi.org/10.1016/j.ins.2008.02.012

Appendixes

Explanations of Some Pre-evaluation Criteria

- "Business strategy" represents four types of organizations, follower or reactor, analyzer, defender and prospector or innovator.
- "Internal communication ability" represents effective usage of communication means within the candidate company. For example, usage of e-mail address, phone number, information boards, Andon boards, employee suggestion system, company bulletins or newspapers and social activities, etc.
- "Commitment to quality" represents allocating a budget for corrective & preventive actions, quality trainings and internal audit systems, tracking quality costs, having periodic review meetings and encouraging attendance of employees to these meetings.
- "Eagerness to cooperate" represents that the candidate company is cooperative, communicative and negotiable in case of any problem.
- "Strategic importance for my company" represents that the candidate company is very valuable with respect to its core competencies, technology and patents and therefore it may foster the market position of the buying company if worked with it. It is also strategically important if the candidate company is a monopoly.
- "Technical qualifications of employees" represents that blue and white collar employees of the candidate company are experienced in their fields; their educational background is related to their work; they have comprehensive knowledge about their work.
- "Quality control" represents that the candidate company effectively use statistical process control, poke yoke and quality gate tools.