A Model for Measuring Institutionalization Level of SMEs

Özer UYGUN[1], Tuba CANVAR KAHVECI[1], Harun TAŞKIN[1], Beytullah PRİŞTİNE[2]

[1]Department of Industrial Engineering,Sakarya University,Esentepe Campus,Serdivan,Turkey
[2]Department of Industrial Engineering,Sakarya University,Esentepe Campus,Serdivan,Turkey
e-mail: ouygun@sakarya.edu.tr

Abstract: Institutionalization help an organization to gain legitimacy, increase resources and maintain survival. In other words, institutionalization is realized by developing appropriate and meaningful behaviors with the environment to gain legitimacy and conformity and transferring them to next generations. It is a crucial issue especially for small and medium sized enterprises (SMEs) to adopt themselves according to the changes in the environment, and sustain competitive. In this study, fuzzy hybrid multi-criteria decision making approach is used in order to measure institutionalization level of SMEs. For achieving this, first of all, criteria that indicate the institutionalization level of SMEs are determined. Then cause and effect interaction among main criteria is determined by fuzzy DEMATEL method. According to the inter influence derived from fuzzy DEMATEL, fuzzy analytic network process (ANP) is implemented in order to obtain the weights of the criteria. Expert opinions and group decision making approach are utilized during both fuzzy DEMATEL and fuzzy ANP methods. After acquiring the weights, several SMEs are evaluated according to the criteria predefined and VIKOR method is implemented for measuring the level of institutionalization of the SMEs.

Keywords: Institutionalization, multi-criteria decision making, Fuzzy DEMATEL, Fuzzy ANP, VIKOR

Introduction

The organizations are not stable; they change with the time in common with their environment. While some of the organizations manage to survive during this period, some of them cannot survive because of not being institutionalized. The main reasons of not being able to survive are the resistance to the change in the organization environment, innovation and improvement, not having strategic thinking and successful knowledge management system. The basic result of the institutionalization is to make the organizations more surviving and consistent. So the institutionalization has come up due to the modern society

Institutionalization is the administration of the enterprise within a set objectives and targets as well as principles and values. These values are comprised of vision, mission, principles and values. The set objectives, principles and values are combining every employee including the managers within a corporation (Kahveci, 2007). Institutionalization is also defined as processes which include creation of a formal structure, emergence of informal norms, development of impersonal/objective procedures, administrative rituals, ideologies, legalization, and focus on legitimization (Alpay et al., 2008).

Institutionalization processes include creation of a formal structure, emergence of informal norms, development of impersonal/objective procedures, administrative rituals, ideologies, legalization, and focus on legitimization. Institutional theory therefore traces the “emergence of distinctive forms, processes, strategies, outlooks, and competences” (Selznick, 1996) from patterns of organizational interaction and adaptation in response to internal and external environments.

Attempts to measure institutionalization at the firm level are rare (Alpay et al, 2008). One of the main objectives of this study is to measure institutionalization level of an organization. The assessment of institutionalization process is based on multiple criteria. Therefore, multi-criteria decision making techniques are used in this study. The process also requires more than one expert opinion. That is why group decision making approach is applied in the measurement model.

Literature Review

Institutionalization

The institutionalization is defined in different ways the literature. The institutional is generally defined by expressing the characteristics of the institutionalized organizations. If the organization is institutionalized, its activities must be performed systematically according to the particular rules. According to these view, the institutionalization is becoming a system. The institutionalized organizations have the common and eligible organizational culture. The professionalism is the other character of the institutionalized organizations (Kahveci, 2007). The organizational culture must be structured based on the strategic management activities and supported by the information systems to gain the expected results of the institutionalization process.

Actually, the institutionalization is an organizational theory which explains the interaction between the organizations and the environment they operate in. It is mainly concerned with the reasons of the changes within the organizations that occur due to pressures by the institutional environment which mainly consists of the governments and some professional organizations. This theory accepts that organizations can not just act rationally to follow their interests. They also have to take the expectations of the institutional environment into consideration. So the decisions maker of the organizations must to consider these expectations and pressures for their decisions.

Institutionalization is the organizational progress in common with the environmental change, and obtaining the standards. In this definition, three following subject are remarkable; (1) The institutionalized organizations changes along with the environmental change; (2) They learn this change; (3) They develop the new standards according to the new circumstance.

The researcher who firstly mentions this theory is Selznick and he notices that organizations adapt and *develop values specific to organization* to adapt to environment thus become legal and reach stability. Zucker considers institutionalization as a tool which provides social stability. According to him, institutionalization is realized by *developing appropriate and meaningful behaviors with the environment* to gain legitimacy and conformity and transferring them to next generations. Meyer and Rowan mentioned that the purpose of institutionalization is to gain legitimacy, increase resources and maintain survival of organizations. They argue that the institutionalization occurs by *developing shared values with the environment.* From another point of view, DiMaggio and Powell posit that institutionalization occurs by *imitating other successful competitors* as a means of adaptation to environment. According to Friedland and Alford, organizations institutionalize in order to affect cognitive and normative pressures *by trying to manipulate the environment* (Apaydın, 2009).

The common idea the researchers mentioned above is that, institutionalization is a process which influences every aspect of organizations, e.g. strategies, structure, decisions, activities, behaviors and performance. As it has a wide and deep impact on organizations, it deserves further researches (Apaydın and Coşkun, 2008).

Ironically, however, the institutional approach has yet to become institutionalized here is very little consensus on the definition of key concepts, measures or methods within this theoretic tradition. Also there has been little attention given to conceptualizing and specifying the processes of institutionalization. In the other words, the process-based approach to institutionalization has not been followed in most organizational analyses. Instead, institutionalization is almost always treated as a qualitative state: structures are institutionalized, or they are not. The institutionalization theory cannot provide the sufficient and concrete suggestions the way of the institutionalization. Consequently, important questions of the determinants of variations in levels of institutionalization, and of how such variation might affect the degree of similarity among sets of organizations, have been largely neglected. There is the need to develop more direct measures and better documentation of claims of the institutionalization of structures, since outcomes associated with a given structure are likely to depend on the stage or level of institutionalization. Also, attempts to measure institutionalization at the firm level are rare (Alpay et al, 2008).

Multi-Criteria Decision Making

Many traditional multi-criteria decision making (MCDM) methods are based on the additive concept along with the independence assumption (Zeleny, 1982). Several previously proposed MCDM methods are very useful but they have generally considered only for independent effects during selection or evaluation of criteria. DEMATEL method and its fuzzy version take into account that any factor of MCDM may affect other factors or may be affected by others.

Wu (2008) stated that knowledge management (KM) strategy selection is a kind of multiple criteria decision-making problem, which requires considering a large number of complex factors as multiple evaluation criteria. He proposed an effective solution based on a combined ANP and DEMATEL approach to help organizations evaluating and selecting KM strategies. Several multi-criteria decision making methods can be implemented in a combined manner. DEMATEL method is very suitable to be combined with ANP as can be seen in Yang and Tzeng (2011), Lee et al (2011) and Wu (2008). Some examples about combination of DEMATEL, ANP and VIKOR techniques can be found in Ho et al. (2011), and Liou and Chuang (2010). DEMATEL, ANP and TOPSIS combinations can be seen in Lin et al. (2010) and combination of three models in fuzzy environment can be seen in Büyüközkan and Çifçi (2012). There are some other combined methods also. In this paper DEMATEL, fuzzy ANP and VIKOR methods are implemented for assessing institutionalization level of organizations.

Readiness Assessment Model for Institutionalization

As there is not common key concepts about the institutionalization process, the components of this process are defined in the different ways too. According to Korkmaz, the basic components of the institutionalization are defined as knowledge, foresight, rationalism, consistency, constancy, reliability, adaptability, flexibility and maintainability. So, the institutionalization is making these components dominant over the organizations to institutionalize the organizations (Korkmaz, 2003). In the other study, the components of the institutionalization are stated as simplicity, diversification, flexibility and autonomy. These components can be used to determine the institutionalization level of the organizations (Karpuzoğlu, 2004). The dimensions of institutionalization are formalization, professionalism, cultural strength, consistency and accountability. Essentially, all of them are either the results of the institutionalization process or the characteristics of the institutionalized organizations. However, the way of institutionalization and measuring the level of institutionalization were not mentioned in the literature.

The simplicity of the job and maintaining it as simplicity cause the Simplicity component of the institutional. The simplicity of the job only can be done by applying the process management approach. On the other hand, when the enterprise handles the competition primarily, focuses on the market and human resources, and concentrates in the main goals, it achieves the Diversification in its structure and operations.

The other component of the institutionalization is the Flexibility which is the adaptability of the enterprise to its environment, can be done by networking, continuous revolution for continuance in the market, monitoring the basic cycles, establishing the systems such as production planning, strategic planning and investment planning.

Finally, the strategic view, the mission union, the managing with the reality and determining the priorities are composing the corporate identity and also provide the Autonomy. The other determinative of the autonomy is certainly capital structure.

When the enterprise is evaluated from the simplicity of their job, the processes should be the focus of this evaluation. The enterprise can gain the diversification on account of its product, human resources and technological resources in the environment. The flexibility is exactly the conformity to the environment. The autonomy of the enterprise is based on the strategy of the enterprise. Consequently, the enterprise should implement strategic management, process management, technology management, human resource management, product management, knowledge management and consider its environment. As a result the evaluation criteria used in institutionalization assessment model are summarized in Table 1.

Table 1. Main and sub-criteria of the institutionalization assessment model

Main Criteria	Sub-criteria
C1: Strategic Management	C11: Strategic Analysis
	C12: Strategy Definition and Planning
	C13: Strategic Performance Evaluation
C2: Process Management	C21: Process Identification and Monitoring
	C22: Process Improvement and Innovation
	C23: Process Implementation
C3: Technology Management	C31: Technology Planning
	C32: Research and Development, Innovation Management
	C33: Marketing and Commercialization of Technology
C4: Product Management	C41: Product Planning& Product Data Management
	C42: Product Specifications
	C43: Product Innovation
C5: Knowledge Management	C51: Enterprise Knowledge Definition and Storage
	C52: Usage of Knowledge and Knowledge Technology
	C53: Knowledge Culture and Performance of Knowledge Management
C6: Human Resource Management	C61: Human Resource Planning, Selection and Orientation
	C62: Personnel Development and Performance Evaluation
	C63: Participation of management, labour relations and organizational structure
C7: Enterprise Environment	C71: Suppliers
	C72: Market and Competitors
	C73: Customers

Technical Background

Fuzzy DEMATEL Method

The DEMATEL method was developed by Gabus and Fontela (1972). It analyzes the influential status and strength between the factors and converts them into an explicit structural mode of a system (Lin and Wu, 2008). Lin and Wu (2004, 2008) developed a fuzzy DEMATEL method to gather group ideas and analyze the cause and effect relationship of complex problems in fuzzy environments. The procedure of the fuzzy DEMATEL method implemented in this study is explained below:

Step 1: Identify the decision goal and set up a committee. During the group decision making process, decision goal is decided first, and subsequently a committee is set up for gathering group knowledge for problem solving.

Step 2: Develop the evaluation criteria and design the fuzzy linguistic scale. For evaluation, sets of criteria are established. Since evaluation criteria have the nature of causal relationship and usually comprise several complicated aspects, and to deal with the ambiguities of human assessments, the fuzzy linguistic scale is used in the group decision making. The different degrees of influence are expressed with five linguistic terms as {No, Low, Medium, High, Very high} and their corresponding positive triangular fuzzy numbers are shown in Table 2 and see Fig. 1.

Table 2. The correspondence of linguistic terms and linguistic values

Linguistic terms	Linguistic values
No Influence (N)	(0, 0, 0.25)
Low Influence (L)	(0, 0.25, 0.50)
Medium Influence (M)	(0.25, 0.50, 0.75)
High Influence (H)	(0.50, 0.75, 1.00)
Very High Influence (VH)	(0.75, 1.00, 1.00)

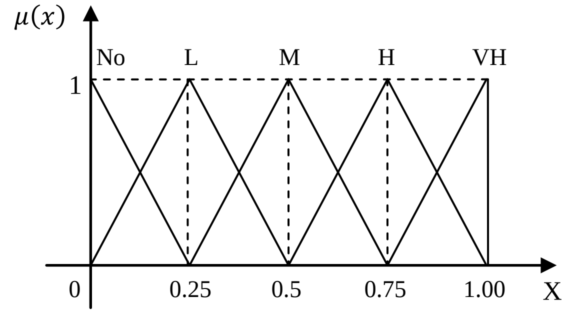

Fig. 1. Triangular fuzzy numbers for linguistic variables.

Step 3: Acquire and average the assessments of decision makers. In this step, a group of *p* expert is asked to acquire sets of pair-wise comparisons of the criteria $C = \{C_i | i = 1,2, \dots, n\}$ by linguistic terms in order to measure the relationship between criteria. So, *p* fuzzy matrices $\tilde{Z}^1, \tilde{Z}^2, \dots, \tilde{Z}^p$ were obtained, each corresponding to an expert. Then, the average fuzzy matrix $\tilde{Z}$ is calculated as below and is called the initial direct-relation fuzzy matrix.

$$\tilde{Z} = \frac{\tilde{Z}^1 \oplus \tilde{Z}^2 \oplus \dots \oplus \tilde{Z}^p}{p} \quad (1)$$

The initial direct-relation fuzzy matrix $\tilde{Z}$ is shown as following

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & 0 \end{bmatrix}$$

where $\tilde{z}_{ij} = (\ell_{ij}, m_{ij}, u_{ij})$ are triangular fuzzy numbers. $\tilde{z}_{ii}$ ($i = 1, 2, \dots, n$) is shown as zero but whenever is necessary it will be regarded as triangular fuzzy number (0, 0, 0).

Step 4: Acquire the normalized direct-relation fuzzy matrix. By normalizing the initial direct-relation fuzzy matrix, normalized direct-relation fuzzy matrix $\tilde{X}$ is obtained by using

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nn} \end{bmatrix}$$

where

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{\ell_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \quad (2)$$

and

$$r = \max_{1 \le i \le n}\left(\sum_{j=1}^{n} u_{ij}\right) \quad (3)$$

It is assumed at least one i such that $\sum_{j=1}^{n} u_{ij} < r$ and this assumption is well satisfied in practical cases.

Step 5: Acquire the total-relation fuzzy matrix. Let $\tilde{x}_{ij} = (\ell'_{ij}, m'_{ij}, u'_{ij})$ and define three crisp matrices, whose elements are extracted from $\tilde{X}$, as follows:

$$X_\ell = \begin{bmatrix} 0 & \ell'_{12} & \cdots & \ell'_{1n} \\ \ell'_{21} & 0 & \cdots & \ell'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \ell'_{n1} & \ell'_{n2} & \cdots & 0 \end{bmatrix} \quad X_m = \begin{bmatrix} 0 & m'_{12} & \cdots & m'_{1n} \\ m'_{21} & 0 & \cdots & m'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m'_{n1} & m'_{n2} & \cdots & 0 \end{bmatrix} \quad X_u = \begin{bmatrix} 0 & u'_{12} & \cdots & u'_{1n} \\ u'_{21} & 0 & \cdots & u'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u'_{n1} & u'_{n2} & \cdots & 0 \end{bmatrix}$$

As in the crisp DEMATEL, total-relation fuzzy matrix $\tilde{T}$ is defined as $\tilde{T} = \lim_{k\to\infty}(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^k)$ and is shown as:

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix} \qquad \text{where } \tilde{t}_{ij} = (\ell''_{ij}, m''_{ij}, u''_{ij}) \qquad \text{and}$$

$$[\ell''_{ij}] = X_\ell \times (I - X_\ell)^{-1} \tag{4}$$

$$[m''_{ij}] = X_m \times (I - X_m)^{-1} \tag{5}$$

$$[u''_{ij}] = X_u \times (I - X_u)^{-1} \tag{6}$$

Step 6: Obtaining $(\tilde{D}_i + \tilde{R}_i)^{def}$ *and* $(\tilde{D}_i - \tilde{R}_i)^{def}$ *values*. Each $\tilde{t}_{ij} = (\ell''_{ij}, m''_{ij}, u''_{ij})$ triangular fuzzy numbers of total-relation fuzzy matrix $\tilde{T}$ is defuzzified and $\tilde{T}^{def}$ matrix is obtained as defined below:

$$\tilde{T}^{def} = \begin{bmatrix} \tilde{t}_{11}{}^{def} & \tilde{t}_{12}{}^{def} & \cdots & \tilde{t}_{1n}{}^{def} \\ \tilde{t}_{21}{}^{def} & \tilde{t}_{22}{}^{def} & \cdots & \tilde{t}_{2n}{}^{def} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1}{}^{def} & \tilde{t}_{n2}{}^{def} & \cdots & \tilde{t}_{nn}{}^{def} \end{bmatrix} \qquad \text{where } \tilde{t}_{ij}{}^{def} = (\ell''_{ij}, m''_{ij}, u''_{ij})^{def}$$

Then, $\tilde{D}_i{}^{def}$, $\tilde{R}_i{}^{def}$, $(\tilde{D}_i{}^{def} + \tilde{R}_i{}^{def})$ and $(\tilde{D}_i{}^{def} - \tilde{R}_i{}^{def})$ values are calculated as in crisp DEMATEL method where $\tilde{D}_i{}^{def}$ and $\tilde{R}_i{}^{def}$ are the sum of rows and columns of matrix $\tilde{T}^{def}$, respectively.

In this study CFSC (Converting Fuzzy data into Crisp Scores) defuzzification method proposed by Opricovic and Tzeng (2003) is used for calculating defuzzified total-relation matrix $\tilde{T}^{def}$.

CFCS Defuzzification Method

There are several defuzzification methods. The most commonly used defuzzification method is the Centroid (Center of gravity) method (Yagler and Filev, 1994), but this does not distinguish between two fuzzy numbers which have the same crisp value in spite of different shapes. Therefore CFCS defuzzification method is used since it can give a better crisp value than the Centroid method.

CFCS method is generated by Opricovic and Tzeng (2003) for multi-criteria decision making which can distinguish two symmetrical triangular fuzzy numbers with the same mean, whereas the Centroid method does not distinguish between two such fuzzy numbers. CFCS method can also be applied when some values are crisp, $\ell = m = u$.

Let $\tilde{f}_{ij} = (\ell_{ij}, m_{ij}, u_{ij})$, j=1, 2,…, J be triangular fuzzy numbers, where J is the number of alternatives. The crisp value of i-th criterion could be determined by the following four step CFCS algorithm:

1. Normalization:

$R = \max_j u_{ij}$, $L = \min_j \ell_{ij}$ and $\Delta = R - L$

Compute for each alternatives

$$x_{\ell j} = (\ell_{ij} - L)/\Delta \, , \, x_{mj} = (m_{ij} - L)/\Delta \, , \, x_{uj} = (\mathrm{u}_{ij} - L)/\Delta \qquad (7)$$

2. Compute left score (ls) and right score (rs) normalized values:

$$x_j^{ls} = x_{mj}/(1 + x_{mj} - x_{\ell j}) \text{ and } x_j^{rs} = x_{uj}/(1 + x_{uj} - x_{mj}) \qquad (8)$$

3. Compute total normalized crisp value:

$$x_j^{crisp} = \left[x_j^{ls} \times \left(1 - x_j^{ls}\right) + x_j^{rs} \times x_j^{rs}\right]/\left[1 - x_j^{ls} + x_j^{rs}\right] \qquad (9)$$

4. Compute crisp values for $\tilde{f}_{ij}$:

$$\tilde{f}_{ij}{}^{crisp} = L + x_j^{crisp} \times \Delta \qquad (10)$$

Fuzzy ANP Method

Analytic network process (ANP) is the general form of analytic hierarchy process (AHP) and was proposed by Saaty (1996) to overcome the problem of interrelation among criteria or factors. Through a supermatrix, whose entries are themselves matrices of column priorities, the ANP synthesizes the outcome of dependence and feedback within and between clusters of elements (Yang and Chang, 2012). The initial supermatrix must be transformed to a matrix in which each of its columns sums to unity. For this reason, this matrix must be normalized by the cluster's weight to get the column sums to unity. Hence, the weighted supermatrix is obtained (Saaty and Vargas, 1998). The supermatrix representation is given in Fig. 2.

$$W = \begin{array}{cc} & \\ & \\ C_1 & \begin{array}{c} e_{11} \\ \vdots \\ e_{1n_1} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ \vdots \\ e_{2n_2} \end{array} \\ \vdots & \vdots \\ C_m & \begin{array}{c} e_{m1} \\ \vdots \\ e_{mn_m} \end{array} \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \\ e_{11} \cdots e_{1n_1} & e_{21} \cdots e_{2n_2} & \cdots & e_{m1} \cdots e_{mn_m} \end{array} \\ \begin{pmatrix} W_{11} & W_{12} & \cdots & W_{1m} \\ W_{21} & W_{22} & \cdots & W_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ W_{m1} & W_{m2} & \cdots & W_{mm} \end{pmatrix} \end{array}$$

Fig. 2. The supermatrix representation

ANP equipped with fuzzy set theory helps in overcoming the impreciseness or vagueness in the preferences. Fuzzy set theory is more advantages than traditional set theory when describing set concepts in human language. The Fuzzy ANP (FANP) method can easily accommodate the interrelationships existing among the functional activities (Mohanty et al., 2005). Table 3 gives the fuzzy linguistic terms and corresponding triangular fuzzy numbers (TFNs) which are used for pairwise comparisons. The pairwise comparisons are implemented according to Fuzzy ANP method within each cluster or main criteria, and according to dependency relationships which are obtained from DEMATEL in order to generate relative importance weights.

Table 3. The Linguistic variables and triangular fuzzy numbers for importance

Linguistic variables	Fuzzy number	Triangular fuzzy number	Triangular fuzzy reciprocal number
Equally Important (EI)	$\tilde{1}$	(1, 1, 1)	(1, 1, 1)
Weekly Important (WI)	$\tilde{3}$	(1, 3, 5)	(1/5, 1/3, 1)
Strongly Important (SI)	$\tilde{5}$	(3, 5, 7)	(1/7, 1/5, 1/3)
Very Important (VI)	$\tilde{7}$	(5, 7, 9)	(1/9, 1/7, 1/5)
Absolutely Important (AI)	$\tilde{9}$	(7, 9, 9)	(1/9, 1/9, 1/7)

There are many fuzzy AHP methods for calculating weights to be used in supermatrix of ANP. These methods were proposed by various authors in the literature (Buckley, 1985; Chang, 1992, 1996; Cheng, 1997; Deng, 1999; Leung & Cao, 2000; Mikhailov, 2004; Van Laarhoven & Pedrycz, 1983). These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis (Yüksel and Dağdeviren, 2010). In this study, Chang's (1996) extent analysis method is employed. The extent analysis method is described below.

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, and $G = \{g_1, g_2, \ldots, g_m\}$ be a goal set. According to the method, each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained with the following signs:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \qquad i = 1, 2, \ldots, n$$

where all the $M_{g_i}^j (j = 1, 2, \ldots, m)$ are triangular fuzzy numbers (TFNs).

The steps of the extent analysis method are given below:

Step 1: The value of fuzzy synthetic extent with respect to the *i*th object is defined as

$$S_i = \sum_j^m M_{g_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} \tag{11}$$

To obtain $\sum_j^m M_{g_i}^j$, perform the fuzzy addition operation of *m* extent analysis values for a particular matrix such that

$$\sum_j^m M_{g_i}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j\right), \tag{12}$$

and to obtain $\left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^j (j = 1, 2, \ldots, m)$values such that

$$\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j = \left(\sum_{i=1}^n l_i, \sum_{i=1}^n m_i, \sum_{i=1}^n u_i\right) \tag{13}$$

and then compute the inverse of the vector in Eq. (9) such that

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^n l_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n u_i}\right) \tag{14}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = sup\left[min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right]$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise,} \end{cases} \qquad (15)$$

where d is the ordinate of the highest intersection point d between μ_{M_1} and μ_{M_2} (see Fig. 3). Both values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are required in order to compare M_1 and M_2.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i = 1, 2, \dots, k)$ can be defined by

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and} \dots \text{and } (M \geq M_k)]$$

$$= \min V(M \geq M_i), \quad i = 1, 2, \dots, k. \qquad (16)$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \quad \text{for } k = 1, 2, \dots, n; k \neq i. \qquad (17)$$

Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), \dots, d'(A_n)\right)^T, \qquad (18)$$

where $A_i(i = 1, 2, \dots, n)$ are n elements.

Step 4: Via the normalization, the normalized weight vectors are

$$W = \left(d(A_1), d(A_2), \dots, d(A_n)\right)^T, \qquad (19)$$

where W is a nonfuzzy number.

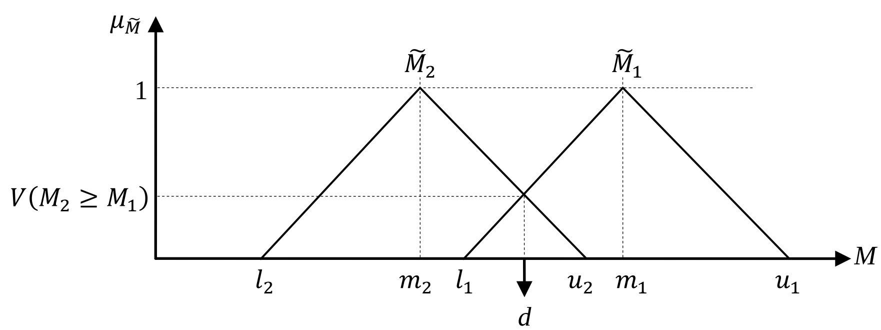

Fig. 3. The intersection between M_1 and M_2

VIKOR Method

VIKOR was developed by Opricovic (1998) and Opricovic and Tzeng (2002) with the Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje, means multi-criteria optimization and compromise solution. The VIKOR method was developed for multicriteria optimization of complex systems and this method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. Development of the VIKOR method started with the following form of Lp-metric:

$$L_i^p = \left\{\left[\sum_{j=1}^{n} w_j \left(\left|f_j^* - f_{ij}\right|\right) / \left(f_j^* - f_j^-\right)\right]^p\right\}^{1/p} \quad (20)$$

where $1 \leq p \leq \infty$; alternatives i = 1, 2, …, m; w_j is derived from fuzzy ANP.

In the VIKOR method $L_i^{p=1}$ (as S_i) and $L_i^{p=\infty}$ (as R_i) are used to formulate ranking measure. The solution obtained by S_i is with a maximum group utility ("majority" rule), and the solution obtained by minR_i is with a minimum individual regret of the "opponent".

The main steps of the algorithm are taken from Sanayei et al.'s (2010) study:

Step 1: Obtain an aspired or tolerable level. Calculate the best f_j^* values (aspired level) and the worst f_j^- values (tolerable value) for all criterion *j = 1, 2, …, n*. Suppose the *jth* function denotes benefits:

$$f_j^* = max_i \, f_{ij}$$

$$f_j^- = min_i \, f_{ij}$$

or these values can be set by decision makers.

Step 2: Calculate mean of group utility and maximal regret. S_i is the synthesized gap for all criteria and R_i is the maximal gap in *i* criterion for prior improvement.

$$S_i = \sum_{j=1}^{n} w_j \left(\left|f_j^* - f_{ij}\right|\right) / \left(f_j^* - f_j^-\right) \quad (21)$$

$$R_i = \max_j \left(\left|f_j^* - f_{ij}\right|\right) / \left(f_j^* - f_j^-\right) \quad (22)$$

Step 3: Calculate the index value.

$$Q_i = v \frac{(S_i - S^*)}{(S^- - S^*)} + (1 - v) \frac{(R_i - R^*)}{(R^- - R^*)} \quad (23)$$

where

$$S^* = min_i \, S_i, \; S^- = max_i \, S_i, \; R^* = min_i \, R_i, \; R^- = max_i \, R_i$$

and *v* is introduced as the weight for the strategy of maximum group utility, whereas (1 – *v*) is the weight of the individual regret.

Step 4: Rank or improve the alternatives for a compromise solution. Order them decreasingly by the value of S_i, R_i and Q_i. Propose the alternative $A^{(1)}$as a compromise solution which is arranged by the measure minQ_i when the two conditions are satisfied:

C1. Acceptable advantage:

$$Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(m-1)$$

where m is the number of alternatives and $A^{(2)}$ is the second position in the alternatives ranked by Q_i.

C2. Acceptable stability in decision making: Alternative $A^{(1)}$ must also be the best ranked by S_i or/and R_i.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consist of:

- Alternatives $A^{(1)}$ and $A^{(2)}$ if only the condition C2 is not satisfied,

or

- Alternatives $A^{(1)}$, $A^{(2)}$, . . ., $A^{(M)}$ if the condition C1 is not satisfied. $A^{(M)}$ is determined by the relation Q($A^{(M)}$) - Q($A^{(M)}$) < DQ for maximum M (the positions of these alternatives are close).

Implementation and Discussion

The case study is implemented in Sakarya, Turkey. First, interactions among the main criteria are derived asking expert opinions and using fuzzy DEMATEL approach. Then fuzzy ANP method is implemented according to the expert opinions in order to calculate the local weights of the sub-criteria. After determining the weights, five SMEs are investigated and graded according to each sub-criterion. As a result, each SME is scored between 0 and 100 implementing TOPSIS method.

The evaluation of one of the experts in terms of the effect between the criteria is given in Table 4. The corresponding triangular fuzzy numbers for the linguistic terms of the expert are given in Tablo 5. The linguistic terms and corresponding fuzzy numbers which were used during fuzzy DEMATEL approach were given in Table 2. Similarly, all of the evaluations from the rest of the experts are obtained and then averages of related triangular fuzzy numbers are calculated using Eq. (1). The average values are given in Table 6. The normalized direct-relation fuzzy matrix is obtained using Eqs. (2 and 3) and the result is shown in Table 7. After calculating the normalized direct-relation fuzzy matrix, the total-relation fuzzy matrix is obtained using Eqs. (4, 5, and 6). The total-relation fuzzy matrix is shown in Table 8.

Table 4. Linguistic evaluation of an expert in terms of effect among the criteria

	C1	C2	C3	C4	C5	C6	C7
C1	N	M	H	H	VH	VH	M
C2	M	N	L	M	M	M	M
C3	H	L	N	H	M	M	M
C4	H	H	M	N	L	L	L
C5	VH	H	H	H	N	M	H
C6	H	L	M	L	M	N	M
C7	VH	L	M	H	M	M	N

Table 5. Corresponding triangular fuzzy number for linguistic evaluation

	C1			C2			C3			C4			C5			C6			C7		
C1	0.00	0.00	0.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.75	1.00	1.00	0.25	0.50	0.75
C2	0.25	0.50	0.75	0.00	0.00	0.00	0.00	0.25	0.50	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75
C3	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00	0.50	0.75	1.00	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75
C4	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.00	0.00	0.00	0.25	0.50	0.00	0.25	0.50	0.00	0.25	0.50
C5	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.00	0.00	0.25	0.50	0.75	0.50	0.75	1.00
C6	0.50	0.75	1.00	0.00	0.25	0.50	0.25	0.50	0.75	0.00	0.25	0.50	0.25	0.50	0.75	0.00	0.00	0.00	0.25	0.50	0.75
C7	0.75	1.00	1.00	0.00	0.25	0.50	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.25	0.50	0.75	0.00	0.00	0.00

Tablo 6. The initial direct-relation fuzzy matrix

	C1			C2			C3			C4			C5			C6			C7		
C1	0.000	0.000	0.000	0.542	0.792	0.917	0.417	0.667	0.875	0.375	0.625	0.833	0.625	0.875	1.000	0.583	0.833	0.958	0.250	0.500	0.750
C2	0.500	0.750	0.917	0.000	0.000	0.000	0.333	0.583	0.833	0.333	0.583	0.833	0.417	0.667	0.875	0.208	0.458	0.708	0.167	0.417	0.667
C3	0.417	0.667	0.917	0.417	0.667	0.875	0.000	0.000	0.000	0.583	0.833	0.958	0.417	0.667	0.875	0.375	0.625	0.833	0.250	0.500	0.750
C4	0.458	0.708	0.875	0.458	0.708	0.917	0.417	0.667	0.875	0.000	0.000	0.000	0.292	0.542	0.792	0.333	0.583	0.792	0.333	0.583	0.792
C5	0.667	0.917	1.000	0.458	0.708	0.917	0.458	0.708	0.917	0.458	0.708	0.958	0.000	0.000	0.000	0.458	0.708	0.917	0.542	0.792	1.000
C6	0.542	0.792	1.000	0.250	0.500	0.750	0.333	0.583	0.792	0.250	0.500	0.708	0.417	0.667	0.875	0.000	0.000	0.000	0.250	0.500	0.750
C7	0.583	0.833	0.958	0.042	0.292	0.542	0.250	0.500	0.750	0.500	0.750	0.958	0.292	0.542	0.792	0.292	0.542	0.792	0.000	0.000	0.000

Tablo 7. The normalized direct-relation fuzzy matrix

	C1			C2			C3			C4			C5			C6			C7		
C1	0.000	0.000	0.000	0.095	0.139	0.161	0.073	0.117	0.153	0.066	0.109	0.146	0.109	0.153	0.175	0.102	0.146	0.168	0.044	0.088	0.131
C2	0.088	0.131	0.161	0.000	0.000	0.000	0.058	0.102	0.146	0.058	0.102	0.146	0.073	0.117	0.153	0.036	0.080	0.124	0.029	0.073	0.117
C3	0.073	0.117	0.161	0.073	0.117	0.153	0.000	0.000	0.000	0.102	0.146	0.168	0.073	0.117	0.153	0.066	0.109	0.146	0.044	0.088	0.131
C4	0.080	0.124	0.153	0.080	0.124	0.161	0.073	0.117	0.153	0.000	0.000	0.000	0.051	0.095	0.139	0.058	0.102	0.139	0.058	0.102	0.139
C5	0.117	0.161	0.175	0.080	0.124	0.161	0.080	0.124	0.161	0.080	0.124	0.168	0.000	0.000	0.000	0.080	0.124	0.161	0.095	0.139	0.175
C6	0.095	0.139	0.175	0.044	0.088	0.131	0.058	0.102	0.139	0.044	0.088	0.124	0.073	0.117	0.153	0.000	0.000	0.000	0.044	0.088	0.131
C7	0.102	0.146	0.168	0.007	0.051	0.095	0.044	0.088	0.131	0.088	0.131	0.168	0.051	0.095	0.139	0.051	0.095	0.139	0.000	0.000	0.000

Tablo 8. The total-relation fuzzy matrix

	C1			C2			C3			C4			C5			C6			C7		
C1	0.071	0.280	1.285	0.139	0.352	1.282	0.120	0.334	1.297	0.117	0.341	1.330	0.157	0.378	1.348	0.146	0.361	1.301	0.084	0.286	1.212
C2	0.132	0.347	1.319	0.040	0.192	1.051	0.093	0.283	1.198	0.096	0.294	1.233	0.111	0.307	1.234	0.075	0.268	1.174	0.060	0.238	1.112
C3	0.130	0.364	1.396	0.115	0.318	1.252	0.046	0.213	1.140	0.143	0.354	1.321	0.118	0.331	1.306	0.108	0.314	1.260	0.079	0.271	1.188
C4	0.132	0.359	1.353	0.117	0.315	1.224	0.110	0.308	1.239	0.047	0.216	1.142	0.096	0.304	1.260	0.098	0.299	1.221	0.089	0.274	1.162
C5	0.182	0.433	1.509	0.130	0.350	1.347	0.129	0.351	1.370	0.135	0.366	1.416	0.062	0.256	1.268	0.132	0.355	1.362	0.132	0.337	1.308
C6	0.140	0.358	1.339	0.082	0.275	1.175	0.094	0.287	1.200	0.085	0.286	1.224	0.112	0.312	1.243	0.041	0.198	1.072	0.074	0.254	1.130
C7	0.144	0.359	1.315	0.048	0.241	1.130	0.080	0.271	1.177	0.122	0.317	1.240	0.090	0.289	1.213	0.089	0.281	1.177	0.031	0.170	0.998

The fuzzy values in total-relation fuzzy matrix is defuzzified by CFCS method using Eqs. (7-10). Then $(\tilde{D}_i^{def} + \tilde{R}_i^{def})$ and $(\tilde{D}_i^{def} - \tilde{R}_i^{def})$ values are calculated and shown in Table 9. The threshold value is determined as 0.48 according to the expert opinions. The values above the threshold are represented in bold in the table which gives the cause and effect relationship among the criteria. By using the dataset $(\tilde{D}_i^{def} + \tilde{R}_i^{def})$ and $(\tilde{D}_i^{def} - \tilde{R}_i^{def})$ given in Table 9, the causal diagram could be plotted as in Fig 3. The impact relation map indicating cause and effect relationship among main criteria can be illustrated as in Fig. 4, based on the information given in Table 9.

Table 9. Defuzzified total-relation matrix

	C1	C2	C3	C4	C5	C6	C7	$\tilde{D}_i^{def}$	$\tilde{D}_i^{def} + \tilde{R}_i^{def}$	$\tilde{D}_i^{def} - \tilde{R}_i^{def}$
C1	0.45	**0.50**	**0.49**	**0.50**	**0.53**	**0.51**	0.44	3.42	7.03	-0.20
C2	0.50	0.34	0.44	0.45	0.46	0.42	0.39	3.00	6.10	-0.11
C3	**0.53**	0.47	0.37	**0.51**	**0.49**	0.47	0.42	3.26	6.40	0.13
C4	**0.52**	0.46	0.46	0.37	0.46	0.45	0.42	3.15	6.43	-0.12
C5	**0.59**	**0.51**	**0.51**	**0.53**	0.43	**0.52**	**0.50**	3.59	6.86	0.31
C6	**0.52**	0.43	0.44	0.44	0.47	0.35	0.40	3.04	6.18	-0.11
C7	**0.51**	0.39	0.42	0.47	0.44	0.43	0.31	2.98	5.86	0.10
$\tilde{R}_i^{def}$	3.61	3.10	3.13	3.28	3.27	3.15	2.88			

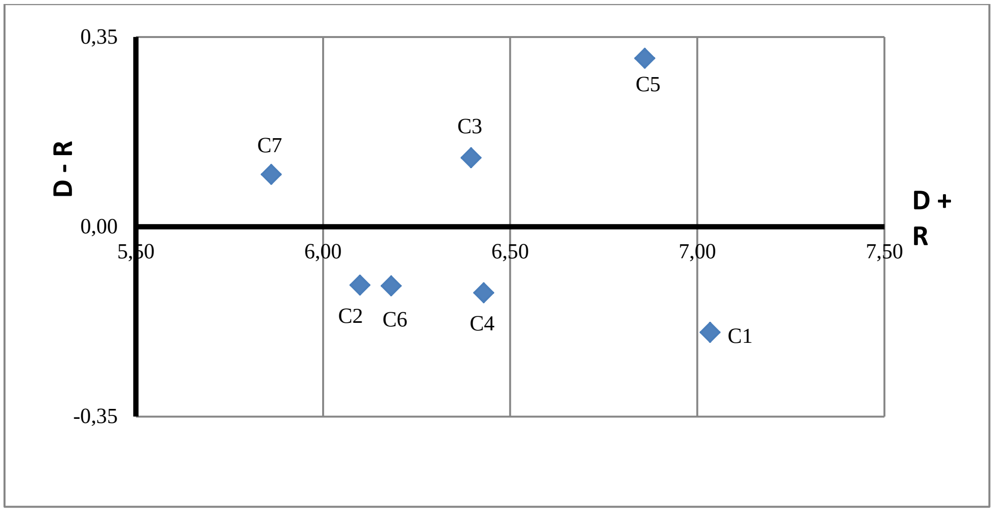

Fig. 3. The influence diagram of the main criteria

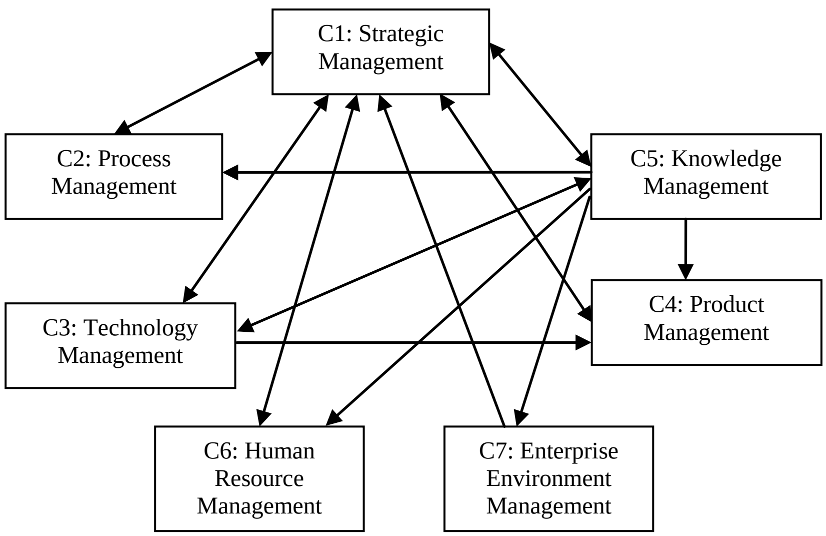

Fig. 4. The impact relation map for main criteria

According to the cause and effect relationship extracted from the fuzzy DEMATEL method, the weights of the sub-criteria are calculated following fuzzy ANP approach in order to form the supermatrix. For example, since “C1: Strategic Management” effects “C2: Process Management”, the fuzzy evaluation of importance of sub-criteria of C2 (C21, C22 and C23) in terms of C11 is given in Table 10. Then geometric average is taken after obtaining evaluations of the rest of the experts in order to calculate the local weights using Eqs. (11-19). The result is shown in Table 11.

The rest of the local weights are calculated in the same way based on the interaction derived from the fuzzy DEMATEL. The supermatrix is formed for the sub-criteria and the local weights calculated are placed into the matrix accordingly. The unweighted supermatrix is presented in Table 12. Then, unweighted supermatrix is normalized to transform it the weighted supermatrix in which each of its columns sums to 1. The power of the weighted supermatrix is taken until the values of each column are stabilized and equal. These calculations are implemented using MATLAB software and the limit supermatrix is obtained which is given in Table 13. Any column of the matrix shows the weights of corresponding sub-criteria.

Tablo 10. Pairwise comparison matrix of an expert terms of C11: Strategic Analysis

Linguistic variables				Fuzzy numbers									
	C21	C22	C23		C21			C22			C23		
C21	EI	SI	VI	C21	1.00	1.00	1.00	3.00	5.00	7.00	5.00	7.00	9.00
C22		EI	WI	C22	0.14	0.20	0.33	1.00	1.00	1.00	1.00	3.00	5.00
C23			EI	C23	0.11	0.14	0.20	0.20	0.33	1.00	1.00	1.00	1.00

Tablo 11. Geometric average of all the expert evaluations, and the weights

	C21			C22			C23			Wi
C21	1.00	1.00	1.00	3.87	5.92	7.94	5.92	7.94	9.00	**0.95**
C22	0.12	0.17	0.26	1.00	1.00	1.00	1.00	3.00	5.00	**0.05**
C23	0.11	0.13	0.17	0.20	0.33	1.00	1.00	1.00	1.00	**0.00**

Tablo 12. Unweighted supermatrix

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52	C53	C61	C62	C63	C71	C72	C73
C11	0	0	0	0.36	0.32	0.23	0.00	0.00	0.25	0.35	0.77	0.37	0.84	0.36	0.05	0.36	0.35	0.36	0.00	0.19	0.08
C12	0	0	0	0.32	0.34	0.00	0.73	0.79	0.48	0.52	0.12	0.44	0.08	0.43	0.45	0.32	0.28	0.32	0.52	0.62	0.45
C13	0	0	0	0.32	0.33	0.77	0.27	0.21	0.26	0.13	0.11	0.20	0.08	0.21	0.50	0.32	0.37	0.32	0.48	0.18	0.47
C21	0.95	0.32	0.00	0	0	0	0	0	0	0	0	0	0.68	0.37	0.02	0	0	0	0	0	0
C22	0.05	0.42	0.60	0	0	0	0	0	0	0	0	0	0.00	0.52	0.49	0	0	0	0	0	0
C23	0.00	0.26	0.40	0	0	0	0	0	0	0	0	0	0.32	0.10	0.49	0	0	0	0	0	0
C31	0.53	0.35	0.28	0	0	0	0	0	0	0	0	0	0.50	0.12	0.53	0	0	0	0	0	0
C32	0.47	0.58	0.23	0	0	0	0	0	0	0	0	0	0.45	0.77	0.31	0	0	0	0	0	0
C33	0.00	0.07	0.49	0	0	0	0	0	0	0	0	0	0.05	0.11	0.16	0	0	0	0	0	0
C41	0.52	0.39	0.38	0	0	0	0.00	0.00	0.03	0	0	0	0.58	0.45	0.33	0	0	0	0	0	0
C42	0.11	0.26	0.05	0	0	0	0.10	0.00	0.36	0	0	0	0.21	0.00	0.33	0	0	0	0	0	0
C43	0.37	0.35	0.57	0	0	0	0.90	1.00	0.62	0	0	0	0.21	0.55	0.33	0	0	0	0	0	0
C51	0.43	0.39	0.43	0	0	0	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
C52	0.20	0.00	0.21	0	0	0	0.95	1.00	0.49	0	0	0	0	0	0	0	0	0	0	0	0
C53	0.38	0.61	0.36	0	0	0	0.05	0.00	0.51	0	0	0	0	0	0	0	0	0	0	0	0
C61	0.63	0.77	0.35	0	0	0	0	0	0	0	0	0	0.46	0.33	0.34	0	0	0	0	0	0
C62	0.00	0.12	0.37	0	0	0	0	0	0	0	0	0	0.09	0.35	0.14	0	0	0	0	0	0
C63	0.37	0.11	0.28	0	0	0	0	0	0	0	0	0	0.45	0.32	0.51	0	0	0	0	0	0
C71	0	0	0	0	0	0	0	0	0	0	0	0	0.61	0.33	0.36	0	0	0	0	0	0
C72	0	0	0	0	0	0	0	0	0	0	0	0	0.39	0.33	0.28	0	0	0	0	0	0
C73	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.33	0.36	0	0	0	0	0	0

Tablo 13. Limit supermatrix

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52	C53	C61	C62	C63	C71	C72	C73
C11	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
C12	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158
C13	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
C21	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
C22	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
C23	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
C31	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
C32	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
C33	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
C41	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045

C42	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
C43	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
C51	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
C52	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
C53	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
C61	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
C62	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
C63	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
C71	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
C72	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
C73	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

After calculating the weights of the criteria, it is time to implement VIKOR method, which is going to score institutionalization level of the SMEs investigated. Five SMEs are investigated in Sakarya region and assigned a score between 0-100 to each SME for each criterion. The scores are given in Table 14. f_j^* is taken as 100 since it is the maximum score of each criterion and f_j^- is take as 0 since it is the minimum score of each criterion.

VIKOR method is implemented by using Eq. (21-23) in order to obtain S_i, R_i and Q_i values. Table 15 shows the results ranked by S_i, R_i and Q_i. It is found out that, firm D is the best institutionalized one among the alternatives. The rest of the SMEs are ranked as A, C, E and B.

Tablo 14. Evaluation of the firms in terms of the sub-criteria

	A	B	C	D	E	f_j^*	f_j^-
C11	75.0	87.5	87.5	87.5	100.0	100	0
C12	81.3	0.0	68.8	75.0	75.0	100	0
C13	75.0	80.0	75.0	90.0	65.0	100	0
C21	63.4	60.3	75.9	65.6	41.5	100	0
C22	56.3	68.8	81.3	68.8	56.3	100	0
C23	100.0	100.0	100.0	75.0	75.0	100	0
C31	75.0	62.5	85.0	80.0	62.5	100	0
C32	81.3	47.5	70.0	92.5	56.3	100	0
C33	50.0	87.5	50.0	100.0	75.0	100	0
C41	82.5	67.5	82.5	85.0	62.5	100	0
C42	87.5	89.3	78.6	87.5	75.0	100	0
C43	75.0	65.0	55.0	95.0	75.0	100	0
C51	88.5	55.8	94.2	65.4	59.6	100	0
C52	81.3	87.5	96.9	68.8	50.0	100	0
C53	75.0	59.4	78.1	68.8	50.0	100	0
C61	81.8	79.5	95.5	63.6	54.5	100	0
C62	75.0	53.9	86.8	57.9	57.9	100	0
C63	75.0	51.6	95.3	68.8	67.2	100	0
C71	75.0	58.3	95.8	66.7	70.8	100	0
C72	100.0	37.5	100.0	68.8	68.8	100	0
C73	90.0	77.5	95.0	85.0	72.5	100	0

Tablo 15. Ranking the SMEs

S_i	Rank by S_i	R_i	Rank by R_i	Q_i	Rank by Q_i
0,205	D	0,034	A	0,021	D
0,206	C	0,039	D	0,059	A
0,227	A	0,042	E	0,062	C
0,312	E	0,049	C	0,319	E
0,391	B	0,158	B	1,000	B

Conclusion

One of the main objectives of this study is to measure institutionalization level of small and medium sized enterprises (SMEs). The assessment of institutionalization process is based on multiple criteria. Therefore, multi-criteria decision making techniques are implemented. The process also requires more than one expert opinion. That is why group decision making approach is applied in the measurement model.

In this study, fuzzy hybrid multi-criteria decision making approach is used in order to measure institutionalization readiness of SMEs. For achieving this, first of all, criteria and sub-criteria that indicate the institutionalization readiness level of SMEs are determined. Then, interactions among main criteria are derived by using fuzzy DEMATEL approach. According to the influence of each criterion over other criteria, the weights of the sub-criteria are calculated obtaining experts' opinion, and by using fuzzy ANP method. Several SMEs are evaluated in terms of the criteria predefined and VIKOR method is implemented for measuring the institutionalization level of the SMEs. The proposed approach can be applied for other multi-criteria decision making problems.

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