Ozer Uygun et al., 2016

Volume 2 Issue 1, pp. 39-58

Year of Publication: 2016

DOI- http://dx.doi.org/10.20319/Mijst.2016.s21.3958

This paper can be cited as: Uygun, Ö, Demir, H. İ, & Erkan, E. F. (2016). Influential Analysis, Prioritization and Mapping of Strategic Goals with Fuzzy Dematel: An Empirical Case Study in a Turkish University. MATTER: International Journal of Science and Technology, 2(1), 39-58.

INFLUENTIAL ANALYSIS, PRIORITIZATION AND MAPPING OF STRATEGIC GOALS WITH FUZZY DEMATEL: AN EMPIRICAL CASE STUDY IN A TURKISH UNIVERSITY

Özer Uygun
Department of Industrial Engineering, Sakarya University, Sakarya, Turkey
ouygun@sakarya.edu.tr

Halil İbrahim Demir
Department of Industrial Engineering, Sakarya University, Sakarya, Turkey
hidemir@sakarya.edu.tr

Enes Furkan Erkan
Department of Industrial Engineering, Sakarya University, Sakarya, Turkey
eneserkan@sakarya.edu.tr

Abstract

The universities are forced to seek the ways to evaluate strategic goals and improve operational performance to obtain a competitive advantage. This is required for attracting more qualified students and reaching to higher quality standards. Thus, an efficient decision making approach should be followed in order to examine strategic goals of a university. Developing a strategy map along this line would be a useful tool which is a diagram that can be used to illustrate cause and effect relationship of the primary strategic goals being pursued by an organization. The aim of the study is to evaluate strategic goals of a university in Turkey to figure out influential relationship among the goals, prioritize them and finally classify the strategic goals into cause *and effect groups. For this purpose, fuzzy DEMATEL approach was implemented and the interrelationships among the strategic goals were illustrated on a strategy map.*

Keywords

Cause-Effect Analysis, Strategy mapping, Fuzzy DEMATEL, CFCS

1. Introduction

The result and advantage of decision-making mostly depend on the ability of the decision-makers to analyze the complex cause and effect relationship between criteria and to take effective actions based on the analysis. Nevertheless, the relationships of cause and effect are often complicated. Thus, employing the cause and effect relationship can be considered as a difficult task. The fuzzy nature of human life makes the cause and effect analysis even more difficult. Hence, a method for inferring the causal relationship in fuzzy environments is of great importance (Lin & Wu, 2008). The proposed approach enables decision-makers of an organization to evaluate its strategic objectives and influence relationship among them in fuzzy environments for improving operational performance of the organization.

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 are 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. The graph theory based strategy mapping outweighs the importance of the DEMATEL method which enables us to project and solve problems visually. A graphical strategy map presenting inter-influence among strategic dimensions can be produced as an output of fuzzy DEMATEL calculations.

A strategy map is a diagram that can be used to illustrate cause and effect relationship of the primary strategic goals being pursued by an organization. Strategy mapping enables managers at each level of an organization to describe the strategic goals as a set of cause-and-effect relationships that helps understand which cluster of sub-objectives are influenced by another cluster of sub-objectives. The illustrative presentation provided by strategy maps gives valuable information to the managers in decision making process so that they can prioritize strategic goals and increase overall success of the organization.

A strategy map is also a component of a balanced scorecard that can be used as a tool for constructing linkages between strategic goals among perspectives of a balanced scorecard system and depicting objectives in multiple perspectives with their corresponding cause-effect relationships (Jassbi, Mohamadnejad & Nasrollahzadeh, 2011).

Strategy maps are useful for all kind of industrial or service organizations, including universities in which operations are based on pre-defined strategic goals. The universities are forced to find ways to evaluate its strategic objectives and to improve operational performance in order to gain a competitive advantage for attracting students with higher grades and reach to higher quality standards. However, current performance evaluation models have been criticized for two reasons (Chen & Chen, 2010). First, the measurement criteria currently used are not completely in accordance with the characteristics of different university types. Second, the models assume independence of measured criteria. Nonetheless, in the real world, such measured criteria are seldom independent.

In this paper, the Fuzzy DEMATEL method is used to build the relative relationship between strategic dimensions for a university in Turkey. This study proposes an approach for evaluating strategic goals of the university by means of addressing their dependence and cause-effect relationships among strategic dimensions and mapping the strategic dimensions in terms of their cause-effect analysis. The study is achieved by using fuzzy DEMATEL method and interpreting its results in a way for developing strategy map. The fuzzy concept is used since decision makers mostly decide in fuzzy nature. The results of the study will give an opportunity for strategy developers and decision makers to give more attention to some specific strategic goals and associated sub-objectives for increasing the overall performance of the organization. It is a new approach to use fuzzy DEMATEL technique for strategy prioritization and cause and effect analysis. The approach can be utilized in any organization for developing action plans according to the cause-effect analysis of strategic goals and the strategy map.

2. The Methodology and Techniques

This section includes two sub-sections which address the methodology and techniques used in this study. The first one explains the fuzzy DEMATEL method and the second one explains the CFCS defuzzification method.

2.1 Fuzzy DEMATEL Method for Group Decision Making

Decision making of the executives and the managers are mostly based on their own knowledge and experience, and they use linguistic assessments such as high, low and very low during their judgments. Therefore an extended DEMATEL method by applying linguistic variables is needed in order to enable DEMATEL method to be suitable for solving group and multi-criteria decision-making problems in fuzzy environments.

Lin & 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 (Lin & Wu, 2004):

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 and their corresponding positive triangular fuzzy numbers are shown in Table 1 and see Figure 1**.**

Table 1 *The correspondence of linguistic terms and linguistic values*

Linguistic terms	Linguistic values
0: No Influence (No)	(0, 0, 0.25)
1: Low Influence (L)	(0, 0.25, 0.50)
2: Medium Influence (M)	(0.25, 0.50, 0.75)
3: High Influence (H)	(0.50, 0.75, 1.00)
4: Very High Influence (VH)	(0.75, 1.00, 1.00)

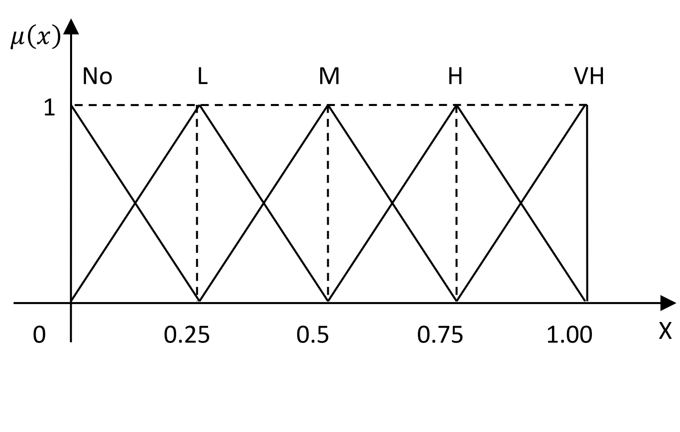

Figure 1: *Triangular Fuzzy Numbers for Linguistic Variables*

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 follows:

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

where $\tilde{z}_{ij} = (\ell_{ij}, m_{ij}, u_{ij})$ are triangular fuzzy numbers. $\tilde{z}_{ii}$ (*i = 1, 2, …, 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 $\tilde{x}_{ij} = \left(\ell'_{ij},\, m'_{ij},\, u'_{ij}\right)$ 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 $\tilde{T} = \lim_{k\to\infty}\left(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^k\right)$ and is shown as:

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

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

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

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

Step 6: Obtaining $(\widetilde{D}_i + \tilde{R}_i)$, $(\widetilde{D}_i - \tilde{R}_i)$, $\left(\widetilde{D}_i + \tilde{R}_i\right)^{def}$ *and* $\left(\widetilde{D}_i - \tilde{R}_i\right)^{def}$ *values*. Lin & Wu (2004; 2008) suggest calculating $(\widetilde{D}_i + \tilde{R}_i)$ *and* $(\widetilde{D}_i - \tilde{R}_i)$ based on $\widetilde{D}_i$ and $\tilde{R}_i$, where $\widetilde{D}_i$ is the sum of rows and $\tilde{R}_i$ is the sum of the columns of $\tilde{T}$. Then a defuzzification algorithm is implemented to get $\left(\widetilde{D}_i + \tilde{R}_i\right)^{def}$ *and* $\left(\widetilde{D}_i - \tilde{R}_i\right)^{def}$ values. The causal diagram and analysis are constructed on those values. Along this line, some of the fuzzy DEMATEL applications in the literature (for example: Jassbi et al., 2011) are based on that method.

In this paper another approach is implemented for calculating defuzzified values ${\widetilde{D}_i}^{def}$, ${\tilde{R}_i}^{def}$, $\left(\widetilde{D}_i + \tilde{R}_i\right)^{def}$ *and* $\left(\widetilde{D}_i - \tilde{R}_i\right)^{def}$ as in Lee, Li, Yen, & Huang (2011). In this study, each $\tilde{t}_{ij} = \left(\ell''_{ij},\, m''_{ij},\, u''_{ij}\right)$ triangular fuzzy numbers of total-relation fuzzy matrix $\tilde{T}$ is defuzzified first and $\tilde{T}^{def}$ matrix is obtained as defined below:

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

Then, CFSC (Converting Fuzzy data into Crisp Scores) defuzzification method proposed by Opricovic & Tzeng (2003) is used for calculating defuzzified total-relation matrix $\tilde{T}^{def}$. Following this way, crisp values for total-relation matrix is obtained like in crisp DEMATEL method, and $\widetilde{D}_i{}^{crisp}$, $\tilde{R}_i{}^{crisp}$, $(\widetilde{D}_i{}^{crisp} + \tilde{R}_i{}^{crisp})$ and $(\widetilde{D}_i{}^{crisp} - \tilde{R}_i{}^{crisp})$ values are calculated as in crisp DEMATEL method.

2.2 CFCS Defuzzification Technique Within a Multi-Criteria Decision Making

CFCS (Converting Fuzzy data into Crisp Scores) method is generated by Opricovic & Tzeng (2003) for multi-criteria decision making which can distinguish two symmetrical triangular fuzzy numbers with the same mean, whereas the Center of Area (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 $\tilde{f}_{ij} = (\ell_{ij}, m_{ij}, u_{ij})$, $j=1, 2, \dots, J$ 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

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

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

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

3. Compute total normalized crisp value:

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

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

$$\widetilde{f_{ij}}^{crisp} = L + x_j^{crisp} \times \Delta \tag{10}$$

3. Empirical Case in a Turkish University

The empirical case study is carried out in Sakarya University (SAU) in Turkey. SAU has a leading role on such activities as strategic planning and total quality management, especially among the universities those that are established recently.

SAU is a role model with also its organizational structure that is constructed in order to manage strategic planning activities. The board for academic evaluation and quality improvement is established in 2003 in SAU. The head of the board is the rector of the university and the members of the board include most of the deans of 12 faculties and directors of 17 vocational schools and academies. The responsibilities of the board are strategic planning, quality improvement, process management, internal and external evaluation and developing strategic management information system.

Under the strategic board, there is an executive committee which puts into practice the decisions taken by the board. The head of the committee is called "Coordinator" who can be considered an inter-mediator between the strategic board and the executive committee. The members of the committee, one of which is the author of this paper, are very experienced and have been on duty since 2003. On the other hand, each academic and administrative unit has a representative of the executive committee, namely "quality envoy" who conveys the decisions taken by the committee to his/her administrator or provides data of his/her unit.

SAU also had inspired the official commission for academic evaluation and quality improvement of higher education (YODEK) for developing a strategic planning and monitoring model for universities. The developed model was published as a guide for the institutions of higher education (YODEK, 2007). SAU has been conducting strategic planning activities in line with YODEK guide and has been following European Foundation for Quality Management (EFQM) Excellence Model as well. As a result SAU received EFQM "3 and 4 Star Competence in Excellence" award in 2006 and 2008 respectively, EFQM National Quality Award in Educational Services Category in 2010, EFQM Sustainability in Excellence National Quality Award in 2013, and EFQM Excellence Prize Winner for Developing Organizational Capabilities in 2015.

The university defined 10 strategic goals as described in Table 2. These goals were established based on 10 strategic dimensions proposed by YODEK, which are illustrated in a model as in Figure 2. Each strategic goal includes many sub-objectives that are measurable and time limited.

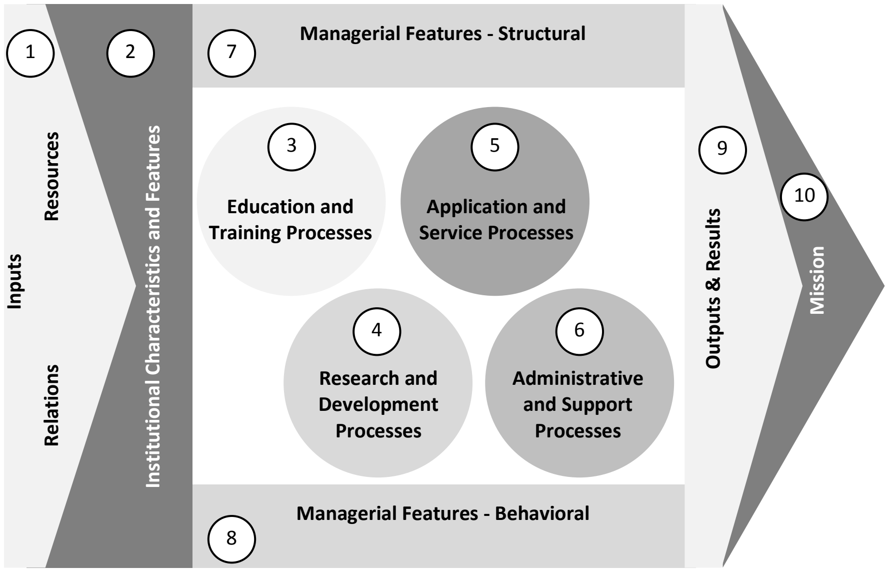

Figure 2: *Dimensions of Strategic Goals*

Table 2 *Strategic Dimensions and Goals of Sakarya University*

Code	**Strategic Dimension**	**Strategic Goal**
SD1	Inputs, relations and resources	Being an efficient and effective university in order to achieve to the mission, strategy and objectives with students, qualifications of staff, relations with stakeholders, opportunities and resources.
SD2	Institutional Characteristics and Features	Being an adequate, effective and manageable university by the number of students and employees, their distributions, and service areas.
SD3	Education and Training Processes	Being an increasingly preferable university in national and international level by education and training quality. Being a university which uses information technologies efficiently in education and training services, and which improves Internet-based teaching continuously and maintains its pioneering role in this area
SD4	Research and Development Processes	Being a university in which universal level knowledge is produced, spread and shared with the quality of research and development activities.
SD5	Application and Service Processes	Being a university which has an active role in dissemination of knowledge, and social, cultural and economic development of the society.
SD6	Administrative and Support Processes	Utilizing the administrative and supportive services effectively and efficiently to achieving strategic objectives of the university.
SD7	Managerial Features -	To create a transparent and sustainable management structure by means of adopting management with strategies and processes and

	Structural	by using the resources efficiently through this line.
SD8	Managerial Features - Behavioural	Being a university which has a management culture that gives priority to student and personnel satisfaction and supports the development of leadership and personal characteristics.
SD9	Outputs and Results	Being a university which uses the resources, institutional attributes and features effectively and efficiently, monitors the results of its services and activities, improves and develops continuously.
SD10	Mission	Being a university which fulfils the mission of higher education in universal, national and regional levels.

The members of the executive committee were interviewed via a questionnaire, to make pair-wise evaluation and comparison on the influence of each strategic dimension (SD) and associated goals. The linguistic terms given in Table 1 were used for pair-wise comparison to evaluate the degree of the influence. As an illustrative example, the linguistic assessment made by the coordinator of the committee is provided in Table 3. The linguistic assessments were converted to corresponding triangular fuzzy numbers using the linguistic values in Table 1. Consequently, p fuzzy matrices $\tilde{Z}^1, \tilde{Z}^2, \dots, \tilde{Z}^p$ were obtained acquiring other assessments from the rest of the committee members. Then the average of the assessments is calculated using Eq. (1) and is called as the initial direct-relation fuzzy matrix $\tilde{Z}$, which is shown in Table 4.

In the next step the normalized initial direct-relation fuzzy matrix $\tilde{X}$ was calculated, using Eqs. (7) and (8). The normalized initial direct-relation fuzzy matrix is shown in Table 5. After retrieving the normalized initial direct-relation fuzzy matrix $\tilde{X}$, the total-relation fuzzy matrix $\tilde{T}$ was produced using formulas (9), (10) and (11). The total-relation fuzzy matrix $\tilde{T}$ is shown in Table 6.

Table 3 *The Linguistic Assessment of the Coordinator*

	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10
SD1	-	H	VH	VH	VH	VH	VH	H	M	H
SD2	H	-	VH	VH	VH	VH	VH	VH	VH	VH
SD3	H	H	-	H	H	L	L	L	M	VH
SD4	H	H	H	-	VH	L	No	No	M	VH
SD5	H	H	L	L	-	No	L	L	M	VH
SD6	H	VH	VH	VH	VH	-	VH	VH	VH	VH
SD7	VH	VH	VH	VH	VH	VH	-	VH	VH	VH
SD8	VH	VH	VH	VH	VH	VH	VH	-	VH	VH
SD9	M	M	M	M	M	M	M	M	-	VH
SD10	H	H	VH	VH	VH	M	M	M	M	-
SD*i*: *i*-th Strategic Dimension given in Table 2										

Table 4 *The Initial Direct-Relation Fuzzy Matrix* $\widetilde{\boldsymbol{Z}}$

	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10
SD1	(.00, .00, .00)	(.40, .65, .90)	(.65, .90, 1.0)	(.65, .90, 1.0)	(.50, .75, .90)	(.50, .75, .95)	(.45, .70, .85)	(.40, .65, .85)	(.60, .85, .95)	(.55, .80, .95)
SD2	(.35, .55, .80)	(.00, .00, .00)	(.55, .80, .95)	(.55, .80, .95)	(.40, .65, .80)	(.50, .75, .85)	(.40, .65, .85)	(.45, .70, .85)	(.60, .85, .95)	(.45, .70, .90)
SD3	(.35, .60, .80)	(.25, .45, .70)	(.00, .00, .00)	(.55, .80, .95)	(.20, .40, .65)	(.15, .35, .60)	(.20, .40, .60)	(.25, .45, .65)	(.55, .80, .90)	(.70, .95, 1.0)
SD4	(.35, .60, .80)	(.25, .45, .70)	(.65, .90, 1.0)	(.00, .00, .00)	(.45, .70, .85)	(.10, .30, .55)	(.20, .35, .60)	(.20, .35, .60)	(.50, .75, .90)	(.70, .95, 1.0)
SD5	(.40, .65, .90)	(.40, .65, .90)	(.30, .55, .80)	(.45, .70, .85)	(.00, .00, .00)	(.20, .40, .65)	(.25, .50, .75)	(.15, .40, .65)	(.55, .80, .95)	(.60, .85, 1.0)
SD6	(.45, .70, .90)	(.55, .80, .90)	(.45, .70, .85)	(.40, .65, .80)	(.50, .75, .90)	(.00, .00, .00)	(.50, .75, .90)	(.45, .70, .90)	(.60, .85, .95)	(.55, .80, .95)
SD7	(.65, .90, 1.0)	(.55, .80, .95)	(.60, .85, 1.0)	(.55, .80, .95)	(.50, .75, .90)	(.65, .90, 1.0)	(.00, .00, .00)	(.55, .80, .95)	(.70, .95, 1.0)	(.65, .90, 1.0)
SD8	(.55, .80, .90)	(.50, .75, .90)	(.60, .85, 1.0)	(.60, .85, 1.0)	(.50, .75, .90)	(.60, .85, .95)	(.65, .90, 1.0)	(.00, .00, .00)	(.75, 1.0, 1.0)	(.65, .90, 1.0)
SD9	(.30, .55, .75)	(.25, .50, .75)	(.35, .60, .85)	(.35, .60, .85)	(.35, .60, .85)	(.35, .60, .85)	(.35, .60, .80)	(.35, .60, .80)	(.00, .00, .00)	(.65, .90, 1.0)
SD10	(.50, .80, .95)	(.45, .70, .90)	(.75, 1.0, 1.0)	(.70, .95, 1.0)	(.70, .95, 1.0)	(.50, .75, .90)	(.50, .75, .90)	(.45, .70, .90)	(.55, .80, .90)	(.00, .00, .00)

Table 5 *The Normalized Initial Direct-Relation Fuzzy Matrix* $\widetilde{\boldsymbol{X}}$

	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10
SD1	(.00, .00, .00)	(.05, .07, .10)	(.07, .10, .11)	(.07, .10, .11)	(.06, .09, .10)	(.06, .09, .11)	(.05, .08, .10)	(.05, .07, .10)	(.07, .10, .11)	(.06, .09, .11)
SD2	(.04, .06, .09)	(.00, .00, .00)	(.06, .09, .11)	(.06, .09, .11)	(.05, .07, .09)	(.06, .09, .10)	(.05, .07, .10)	(.05, .08, .10)	(.07, .10, .11)	(.05, .08, .10)
SD3	(.04, .07, .09)	(.03, .05, .08)	(.00, .00, .00)	(.06, .09, .11)	(.02, .05, .07)	(.02, .04, .07)	(.02, .05, .07)	(.03, .05, .07)	(.06, .09, .10)	(.08, .11, .11)
SD4	(.04, .07, .09)	(.03, .05, .08)	(.07, .10, .11)	(.00, .00, .00)	(.05, .08, .10)	(.01, .03, .06)	(.02, .04, .07)	(.02, .04, .07)	(.06, .09, .10)	(.08, .11, .11)
SD5	(.05, .07, .10)	(.05, .07, .10)	(.03, .06, .09)	(.05, .08, .10)	(.00, .00, .00)	(.02, .05, .07)	(.03, .06, .09)	(.02, .05, .07)	(.06, .09, .11)	(.07, .10, .11)
SD6	(.05, .08, .10)	(.06, .09, .10)	(.05, .08, .10)	(.05, .07, .09)	(.06, .09, .10)	(.00, .00, .00)	(.06, .09, .10)	(.05, .08, .10)	(.07, .10, .11)	(.06, .09, .11)
SD7	(.07, .10, .11)	(.06, .09, .11)	(.07, .10, .11)	(.06, .09, .11)	(.06, .09, .10)	(.07, .10, .11)	(.00, .00, .00)	(.06, .09, .11)	(.08, .11, .11)	(.07, .10, .11)
SD8	(.06, .09, .10)	(.06, .09, .10)	(.07, .10, .11)	(.07, .10, .11)	(.06, .09, .10)	(.07, .10, .11)	(.07, .10, .11)	(.00, .00, .00)	(.09, .11, .11)	(.07, .10, .11)
SD9	(.03, .06,	(.03, .06,	(.04, .07,	(.04, .07,	(.04, .07,	(.04, .07,	(.04, .07,	(.04, .07,	(.00, .00,	(.07, .10,

	.09)	.09)	.10)	.10)	.10)	.10)	.09)	.09)	.00)	.11)
SD10	(.06, .09, .11)	(.05, .08, .10)	(.09, .11, .11)	(.08, .11, .11)	(.08, .11, .11)	(.06, .09, .10)	(.06, .09, .10)	(.05, .08, .10)	(.06, .09, .10)	(.00, .00, .00)

Table 6 *The Total-Relation Fuzzy Matrix* $\tilde{\boldsymbol{T}}$

	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10
SD1	(.05, .21, .85)	(.09, .26, .92)	(.13, .34, 1.02)	(.13, .33, 1.01)	(.10, .29, .94)	(.10, .27, .90)	(.09, .26, .88)	(.08, .25, .87)	(.13, .34, 1.02)	(.13, .35, 1.05)
SD2	(.08, .25, .89)	(.04, .18, .79)	(.11, .31, .97)	(.11, .31, .96)	(.09, .27, .89)	(.09, .26, .85)	(.08, .25, .84)	(.08, .25, .83)	(.12, .33, .97)	(.11, .32, 1.00)
SD3	(.07, .22, .79)	(.06, .20, .76)	(.04, .19, .76)	(.10, .27, .85)	(.06, .21, .78)	(.05, .18, .73)	(.05, .19, .73)	(.06, .19, .72)	(.10, .28, .86)	(.12, .30, .90)
SD4	(.07, .23, .80)	(.06, .20, .78)	(.11, .28, .88)	(.04, .19, .77)	(.09, .24, .81)	(.04, .18, .74)	(.05, .19, .74)	(.05, .18, .73)	(.10, .28, .87)	(.12, .30, .91)
SD5	(.08, .24, .86)	(.07, .23, .84)	(.08, .25, .91)	(.09, .27, .91)	(.04, .17, .76)	(.05, .20, .79)	(.06, .21, .79)	(.05, .19, .78)	(.10, .29, .93)	(.11, .30, .96)
SD6	(.09, .28, .92)	(.10, .27, .90)	(.11, .31, .98)	(.10, .30, .97)	(.10, .29, .92)	(.04, .19, .78)	(.10, .27, .87)	(.09, .25, .86)	(.13, .34, .99)	(.12, .34, 1.02)
SD7	(.12, .32, .99)	(.11, .30, .97)	(.13, .36, 1.06)	(.13, .35, 1.05)	(.11, .32, .98)	(.12, .31, .94)	(.05, .21, .83)	(.11, .29, .92)	(.15, .38, 1.06)	(.15, .38, 1.10)
SD8	(.11, .31, .97)	(.10, .29, .95)	(.13, .36, 1.05)	(.13, .35, 1.04)	(.11, .32, .97)	(.11, .30, .92)	(.12, .30, .92)	(.05, .20, .81)	(.15, .39, 1.05)	(.15, .38, 1.09)
SD9	(.07, .23, .85)	(.06, .22, .83)	(.08, .26, .92)	(.08, .26, .91)	(.08, .24, .86)	(.07, .22, .81)	(.07, .22, .81)	(.07, .22, .80)	(.05, .21, .84)	(.12, .31, .97)
SD10	(.10, .30, .96)	(.10, .28, .93)	(.14, .36, 1.03)	(.14, .35, 1.02)	(.13, .33, .96)	(.10, .28, .90)	(.10, .28, .90)	(.09, .27, .89)	(.13, .35, 1.02)	(.07, .28, .96)

Now, instead of calculating $\tilde{D}_i$, $\tilde{R}_i$ and then $(\tilde{D}_i + \tilde{R}_i)$, and $(\tilde{D}_i - \tilde{R}_i)$ from the total-relation fuzzy matrix $\tilde{T}$; first the fuzzy matrix $\tilde{T}$ is defuzzified using CFCS method which was described in section 2.2, and defuzzified total-relation matrix $\tilde{T}^{def}$ is obtained. The result is shown in Table 7. Since crisp values for total-relation matrix are acquired, (Di + Ri) and (Di - Ri) can easily be calculated, as in crisp DEMATEL method, where Di and Ri are sum of rows and sum of columns of defuzzified total-relation matrix $\tilde{T}^{def}$, respectively. The values are given in Table 8.

This procedure also enables us to determine a threshold value for defuzzified total-relation matrix $\tilde{T}^{def}$ and to identify the degree of influence among strategic goals. The executive committee decided to take threshold value as the third quartile value of all crisp values in defuzzified total-relation matrix. The third quartile value was calculated as 0.41 and the values in the matrix that are above the threshold value are shown in bold in Table 7.

Table 7 *The Total-Relation Matrix* $\widetilde{T}^{def}$ *Defuzzified With CFCS*

	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9	SD10
SD1	0.31	0.37	**0.43**	**0.43**	0.39	0.37	0.36	0.35	**0.44**	**0.44**
SD2	0.36	0.28	**0.41**	0.40	0.37	0.35	0.34	0.34	**0.42**	**0.42**
SD3	0.32	0.29	0.28	0.36	0.30	0.28	0.28	0.28	0.37	0.39
SD4	0.32	0.30	0.38	0.28	0.33	0.27	0.28	0.27	0.37	0.39
SD5	0.34	0.33	0.36	0.37	0.27	0.30	0.30	0.29	0.39	0.40
SD6	0.38	0.37	**0.41**	0.40	0.38	0.29	0.36	0.35	**0.43**	**0.44**
SD7	**0.42**	0.40	**0.45**	**0.45**	**0.41**	0.40	0.31	0.38	**0.47**	**0.48**
SD8	**0.41**	0.39	**0.45**	**0.45**	**0.41**	0.39	0.40	0.30	**0.47**	**0.48**
SD9	0.33	0.32	0.37	0.36	0.34	0.32	0.32	0.31	0.31	**0.41**
SD10	0.40	0.38	**0.45**	**0.45**	**0.42**	0.38	0.37	0.36	**0.45**	0.38
Threshold = 0.41										

Table 8 *The of Di, Ri, (Di + Ri) and (Di - Ri)*

	Di	Ri	(Di + Ri)	(Di - Ri)
SD1	3.90	3.59	7.50	0.31
SD2	3.69	3.43	7.12	0.26
SD3	3.15	3.99	7.14	-0.85
SD4	3.20	3.95	7.15	-0.75
SD5	3.34	3.63	6.98	-0.29
SD6	3.81	3.34	7.15	0.47
SD7	4.18	3.33	7.51	0.85
SD8	4.16	3.24	7.40	0.92
SD9	3.39	4.12	7.51	-0.73
SD10	4.04	4.22	8.26	-0.18

By using the dataset (Di + Ri) and (Di - Ri) given in Table 8, the causal diagram could be plotted as in Figure 3. The strategy maps indicating cause and effect relationship of each strategic dimension can be illustrated as in Figure 4 by using the information given in Table 7, in which the values above the threshold value are shown in bold. Figure 4 and other results are discussed and analyzed in section 4.

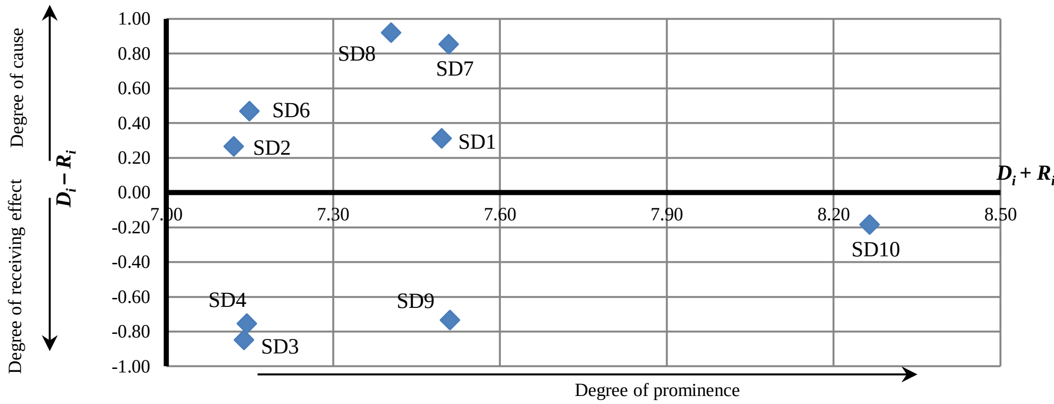

Figure 3: *The Casual Diagram of the Strategic Goals and Dimensions*

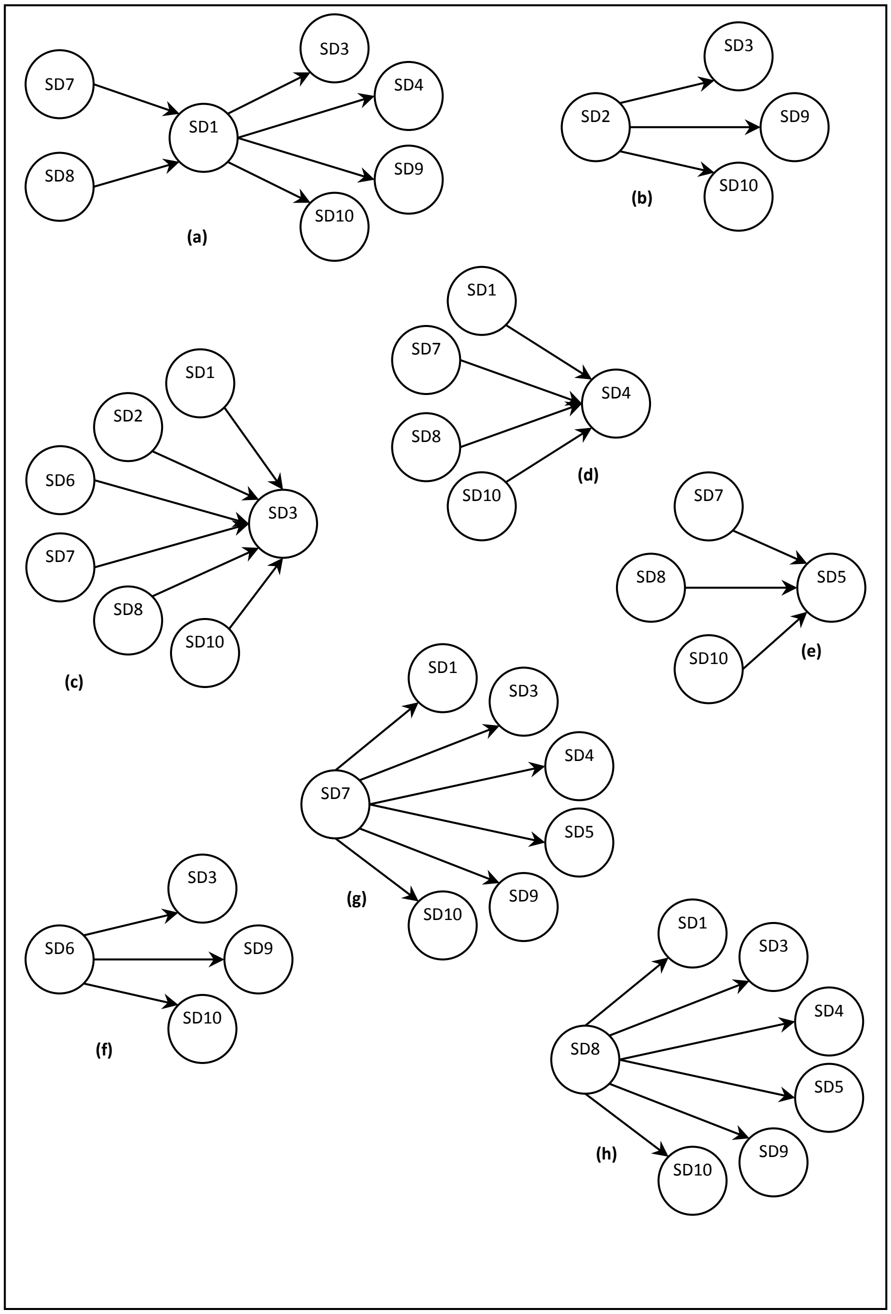

Figure 4: *Strategy Mapping of the Dimensions According to Dispersing and Receiving Influence*

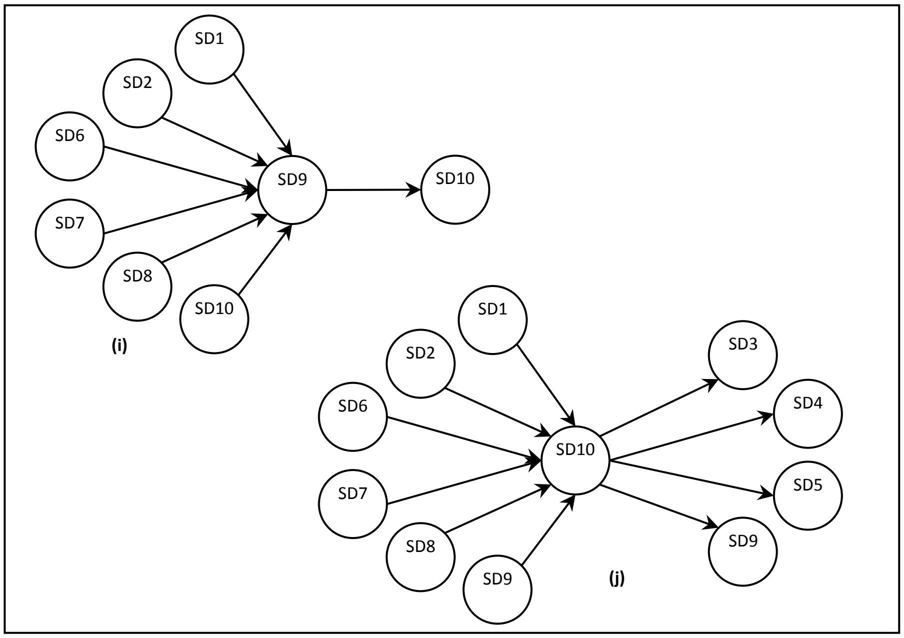

Figure 4 (CONT.): *Strategy Mapping of the Dimensions According to Dispersing and Receiving Influence*

4. Discussions

There are several approaches in calculating crisp values for $(\widetilde{D}_i + \tilde{R}_i)$ and $(\widetilde{D}_i - \tilde{R}_i)$. In some applications in the literature, defuzzification is implemented after calculations of $(\widetilde{D}_i + \tilde{R}_i)$ and $(\widetilde{D}_i - \tilde{R}_i)$ triangular fuzzy numbers (for example: Jassbi et al., 2011). In some other applications, defuzzification is firstly implemented to $\widetilde{D}_i$ and $\tilde{R}_i$ triangular fuzzy numbers, then (*Di* + *Ri*) and (*Di* – *Ri*) crisp values are calculated (for example: Dalalah, Hayajneh, & Batieha, 2011). In both approaches, defuzzification is not implemented to the total-relation fuzzy matrix $\tilde{T}$. Since the crisp values are not available for total-relation matrix, a threshold value cannot be applied.

On the other hand, in some of the fuzzy DEMATEL applications in the literature, defuzzification is implemented to the initial direct-relation fuzzy matrix (Chang, Chang, & Wu, 2011; Lin, 2011; Wu, 2011). Therefore, the rest of the calculations are conducted as in crisp DEMATEL method.

In this study, the total-relation fuzzy matrix $\tilde{T}$ is defuzzified first and then, after obtaining crisp values for the total-relation matrix, *Di*, *Ri*, (*Di* + *Ri*) and (*Di* – *Ri*) values are calculated. It is believed that this way is better in order to use fuzzy calculations and features more effectively.

Several discussions can be made by using the fuzzy DEMATEL results which are shown in Table 7, Table 8, Figure 3 and Figure 4. For a better illustration, Table 9 was produced in which strategic dimensions are ranked according to (*Di* + *Ri*) and (*Di* – *Ri*) values. In DEMATEL method, (*Di* + *Ri*) value indicates the degree of prominence. Table 9 and Figure 4 clearly show that; *Mission* (SD10) is the most important strategic dimension of the university having the highest (*Di* + *Ri*) value. This is followed by *Outputs & Results* (SD9) and *Managerial Features – Structural* (SD7) dimensions which have the same (*Di* + *Ri*) value. The rest of the strategic dimensions are ranked as *Input* (SD1), *Managerial Features – Behavioral* (SD8), *Administrative and Support Processes* (SD6), *Research and Development Processes* (SD4), *Education and Training Processes* (SD3), *Institutional Characteristics* (SD2) and *Application and Service Processes* (SD5) according to the (*Di* + *Ri*) values (see Table 9). There are many sub-objectives for each strategic dimension and goal. Therefore, decision makers of the university should take into account the degree importance of the strategic goals for overall achievement of the university.

Table 9 *The rank of Strategic Dimensions according to* $(D_i + R_i)$ *and* $(D_i - R_i)$

Rank	Strategic Dimension	$(D_i + R_i)$	Rank	Strategic Dimension	$(D_i - R_i)$	Cluster
1	SD10	8.26	1	SD8	0.92	Cause Cluster
2	SD9	7.51	2	SD7	0.85	
3	SD7	7.51	3	SD6	0.47	
4	SD1	7.50	4	SD1	0.31	
5	SD8	7.40	5	SD2	0.26	
6	SD6	7.15	6	SD10	-0.18	Effect Cluster
7	SD4	7.15	7	SD5	-0.29	
8	SD3	7.14	8	SD9	-0.73	
9	SD2	7.12	9	SD4	-0.75	
10	SD5	6.98	10	SD3	-0.85	

As shown in Figure 3 and Table 9, the strategic dimensions were divided into two clusters, namely cause cluster and effect cluster, based on (*Di* – *Ri*) values. The cause cluster includes SD8, SD7, SD6, SD1 and SD2 with positive (*Di* – *Ri*) values, while the effect cluster is composed of SD10, SD5, SD9, SD4 and SD3 with negative (*Di* – *Ri*) values. Classifying strategies based on (*Di* – *Ri*) values provides valuable information for making profound decisions. It is understood that, SD8 which stands for *Managerial Features – Behavioral* strategic dimension has the largest (*Di* – *Ri*) positive value which means that it possesses the strongest effect on the other strategic dimensions.

The second strongest effect found for *Managerial Features – Structural* (SD7) dimension. Therefore, in order to increase the performance of the university, the strategy makers and the managers of the university should pay more attention to the managerial structure and the leadership features of the university compared to the other strategies. In contrast to this example, *Education and Training Processes* (SD3) was found to be the most influenced strategic dimension, which has the most negative value of (*Di* – *Ri*). This is followed by the other influenced strategic dimensions, such as *Research and Development Processes* (SD4) and *Outputs & Results* (SD9) dimensions.

Strategy mapping of each strategic dimension in terms of the direction of the influence, dispersing and receiving, is shown in each section of Figure 4. The strategy mapping gives very valuable tips for making comprehensive decisions. For example, the *Mission* dimension (SD10) is the most important one, which is affected by 6 dimensions and affects 4 strategies. It is worth noting that *Education and Training Processes* (SD3) strategic dimension does not influence any dimension, whilst it is influenced by *Input* (SD1), *Institutional Characteristics* (SD2), *Administrative and Support Processes* (SD6), *Managerial Features – Structural* (SD7), *Managerial Features – Behavioral* (SD8) and *Mission* (SD10) dimensions. *Research and Development Processes* (SD4) is also similar dimension which receives influences from other strategic dimensions but does not disperse any influence. However, it should be remembered that this mapping was illustrated by implementing a threshold value to Table 7. If the threshold value is ignored, it can be seen that the most effected dimension by *Research and Development Processes* (SD4) dimension will be *Mission* (SD10) dimension (0.39) and this is followed by *Education and Training Processes* (SD3) dimension (0.38). Similar inductions can also be made for the rest of the strategic dimensions using related tables and figures.

5. Conclusions

This study uses fuzzy DEMATEL method to analyze cause and effect relationships among strategic dimensions or goals of a university. An illustrative strategy mapping was presented so that the interrelationships between strategic dimensions of a university could be analyzed and interpreted more comprehensively. Also, the strategic dimensions were ranked according to degree of prominence as well as degree of influence (dispersing or receiving). The results indicated that *Mission* (SD10) dimension was found to be the most important strategic dimension with the largest prominence value. In addition, it was found that *Managerial Features – Behavioral* (SD8) dimension influences the other strategic dimensions the most, which means that the leadership features of the university affect the overall success of the institution substantially. On the contrary, *Education and Training Processes* (SD3) dimension was the most influenced strategy by the other dimensions. This implies that results and quality of the education and training depend very much on the performance of the other strategic dimensions.

Within the scope of this study strategy maps were developed using the results of fuzzy DEMATEL approach. The strategy mapping can be seen as a useful tool to illustrate cause and effect relationship of the primary strategic goals being pursued by the university. It helps strategy developers and decision makers of the university to analyze the interrelationships of the strategies easily and to take effective actions accordingly. The approach followed by this study can also be used in any organization or for any multi-criteria decision making problem in order to understand cause-effect relationships among criteria in a comprehensive manner.

REFERENCES

Chen, J. K., & Chen, I. S. (2010). A Pro-performance appraisal system for the university. Expert Systems with Applications 37, 2108–2116. http://dx.doi.org/10.1016/j.eswa.2009.07.063

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

Dalalah, D., Hayajneh, M., & Batieha, F. (2011). A fuzzy multi-criteria decision making model for supplier selection. Expert Systems with Applications 38, 8384–8391. http://dx.doi.org/10.1016/j.eswa.2011.01.031

Jassbi, J., Mohamadnejad, F., & Nasrollahzadeh, H. (2011). A Fuzzy DEMATEL framework for modeling cause and effect relationships of strategy map. Expert Systems with Applications, 38, 5967–5973. http://dx.doi.org/10.1016/j.eswa.2010.11.026

Lee, Y. C., Li, M. L., Yen, T. M., & Huang, T. H., (2011). Analysis of fuzzy Decision Making Trial and Evaluation Laboratory on technology acceptance model. Expert Systems with Applications 38, 14407–14416. http://dx.doi.org/10.1016/j.eswa.2011.04.088

Lin, C. J., & Wu, W. W. (2004). A fuzzy extension of the DEMATEL method for group decision making. European Journal of Operational Research, 156, 445–455.

Lin, C. J., & Wu, W. W. (2008). A causal analytical method for group decision making under fuzzy environment. Expert Systems with Applications, 34, 205–213. http://dx.doi.org/10.1016/j.eswa.2006.08.012

Lin, R. J. (2011). Using fuzzy DEMATEL to evaluate the green supply chain management practices. Journal of Cleaner Production, 1–8.

Opricovic, S., & Tzeng, G.H. (2003). Defuzzification within a multicriteria decision model. Journal of Uncertainty, Fuzziness and Knowledgebased Systems, 11(5), 635–652. http://dx.doi.org/10.1142/S0218488503002387

Wu, W. W. (2011). Segmenting critical factors for successful knowledge management implementation using the fuzzy DEMATEL method. Applied Soft Computing, 12, 527–535. http://dx.doi.org/10.1016/j.asoc.2011.08.008

YODEK, (2007). Guide for academic evaluation and quality improvement in higher education, 2007, www.yodek.org.tr (Accessed on 2011, November 9) www.yodek.org.tr

Zeleny, M. (1982). Multiple Criteria Decision Making. New York: Mc-Graw-Hill.