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A Hybrid BSC-DEMATEL- FIS Approach for Performance Measurement in Food Industry

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Abstract

Organizational performance is a complex issue given that performance is a multifaceted phenomenon whose components may have distinct managerial priorities and may even be mutually inconsistent. Recently, the balanced scorecard approach (BSC), as an effective multi-criteria evaluation concept received much attention in organizational performance measurement. Although the BSC conceptual framework has been widely accepted in the business community, the proper method of implementing the framework remains an issue. Hence, this study has developed a hybrid expert system composition of BSC, Decision Making Trial and Evaluation Laboratory (DEMATEL) and fuzzy inference system (FIS) to evaluate the food producing companies. To this aim, this paper applied a graph theory based technique (DEMATEL) to determine critical criteria of BSC's perspectives. The results show that "Profit", "Customer satisfaction", "Customer communication", "Innovation management" and "Organizational asset management", are of more importance in performance evaluation. In the next step, these criteria shape a fuzzy rule based inference system with linguistic variables and the membership functions are adjusted by experts. The results of proposed approach in food industry of Guilan province, Iran, show its applicability for evaluating the food companies.

Keywords:
balanced Scorecard (BSC)
DEMATEL
Fuzzy Inference System (FIS)
food Industry
Performance evaluation

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INTRODUCTION

Organizations compete for resources and customers and must somehow assess the results of their decisions and actions (Bentes et al., 2012). The Organizational performance evaluation is a systematic review process carried out to help an organization reach these goals. Performance evaluation is a systematic and periodic process that assesses individuals or organizations performance and productivity in relation to certain pre-established criteria. As a part of the management and control system, it helps an organization to effectively manage its resources and measure its performance in relation to its goals.

Performance is inherently a complex and multidimensional concept. Therefore, a comprehensive and holistic approach to the issue of performance evaluation is not available. Furthermore, individuals may have different preferences about which aspects are of more importance to evaluate performance. Many different approaches are developed for conducting a performance evaluation problem in various organizations for many years (Chang et al., 2011). A strategy should not just exist as a vision among top managers in an organization. It should also be linked to a strategic performance measurement system that helps all employees achieve their strategic objectives in a set time frame. One of the most widely diffused performance measurement systems is the balanced scorecard (BSC) (Lueg, 2015). BSC as a new emerging approach for organizational evaluation is a hybrid performance measurement system with both quantitative and qualitative measures, looking at a business from four perspectives: customer, finance, internal process, and learning and growth (Dessler, 2000). It reflects a balance between short- and long-term objectives, financial and non-financial measures, lagging and leading indicators, and external and internal measures. Because its generality, several methods have been applied in corporation with BSC for better evaluation of various organizations. These approaches include ratio analysis, total production analysis, regression analysis, Delphi analysis, multiple criteria decision making (MCDM), Data Envelopment Analysis (DEA) and others. Each method has its own basic concept, aim, advantages and disadvantages (Gabus & Fontela, 1972). Which one is chosen by management or decision makers for assessing performance depends on the status and type of the organization. Among all, MCDM techniques and fuzzy logic as disciplines have more frequency in supporting organizations faced with numerous and sometimes conflicting evaluations (Green & Keim, 1983).The main objective of the present study is to critically develop an integrated approach that combines three theoretical frameworks - balanced scorecard (BSC), Decision Making trial and evaluation laboratory (DEMATEL) and Fuzzy Inference System (FIS) - in order to comparatively assess the performance of organizations. A subsidiary objective is to extend the external validity of BSC, DEMATEL and FIS by applying those frameworks to a particular industry (Food), which, in literature has rarely examined.Based on the above considerations, the remainder of this paper is organized as follows. First, a brief review of performance evaluation and BSC is presented. Second, The proposed methodology as well as the analytical tools used in this study is introduced. Third, the analysis results of application of the evaluation model through an empirical analysis are presented. Finally, conclusions are presented.

PERFORMANCE EVALUATION

This section briefly reviews the underlying concepts adopted performance evaluation and Balanced Scorecard (BSC) as a newly approach to performance evaluation.

Definitions of performance evaluation

Performance evaluation is referred to as one kind of measurement tools to compare organizations activities with performance targets. Many researchers stated that performance evaluation is an important activity of management control, used to investigate whether resources are allocated efficiently (Huang et al., 2007). Green and Keim (1983) stated that "Performance evaluation is for achieving the entire target. It bases on the quantification standard made in advance or using subjective judgment to assess the result of daily operation; in the meanwhile, performance evaluation also possesses the function of amending responding policies and unifying the target of individuals and organizations." it is applied for the purpose of operational control to achieve a goal adjustment in the short-term and for strategy management and planning in the long run. Kaplan and Norton (1992) described performance evaluation as a way to review the achievements of organizations of both their financial and non-financial objectives.

Performance evaluation and Theoretical foundation of BSC

In the past, the traditional performance methods put much emphasis on quantitative, especially financial criteria such as financial returns, returns on asset (ROA) and returns on earning (ROE). Nevertheless, performance rankings conducted in this way is not an effective measure and offers a narrow and incomplete picture of business performance. To fully utilize the function of performance measurement, it is suggested to set up a series of criteria which properly reflect the performance of an organization. These criteria can be quantifiable, or unquantifiable. For instance, an index such as lead time is viewed as a quantifiable (or financial) measure, whereas the degree of customer satisfaction is unquantifiable (or non-financial) measures.

In recent years, several different theories for performance evaluation have been developed prosperously, which one is chosen for evaluation of performance depends on the status and type of the organization. Among all, the Balanced Scorecard (BSC) as a systemic approach, helps integrating tangible and intangible assets into a comprehensive model and builds a meaningful relationship among different criteria. Kaplan and Norton, who introduced the BSC in 1992, found that existing performance measurement systems that primarily rely on financial accounting measures had become obsolete. In response, they developed the BSC to give organizations a comprehensive view of their business model. The BSC framework would help the organization translate its strategic objectives into a coherent set of performance measures. The purpose was to create a management system where measures of past financial events (lagging indicators) complement operational measures which are the drivers of future financial performances (leading indicators) (Lueg, 2015). The BSC model divides measures into four different groups of perspectives that are constituted by considering short-term and long-term objectives and measures. Measures are a combination of operational and financial indices which are connected to long- and short-term objectives (Rahiminia et al., 2014). These perspectives are:

(1) *Financial perspective* reflects the past operating performance of a company including the achievement of setting up a financial target and the implementation of executing strategies, (2) *Customer perspective* addresses the question of how the firm is viewed by its customers and how well the firm is serving its targeted customers in order to meet the financial objectives, (3) *Internal process perspective* which addresses the internal operating process of organizations that have to follow a plan of operating strategies made by them and also do their best to achieve the expectations of customers and shareholders, and (4) *Learning and growth perspective* refers to employee training and innovation and corporate cultural attitudes result in sustainable development. This is for setting up a complete performance evaluation system and forming a whole set of performance indices to assess strategies so that the strategies and prospect of organizations could be achieved (Kaplan & Norton, 1992).

RESEARCH METHODOLOGY AND ANALYTICAL TOOL

The performance evaluation model proposed by this research is shown as Fig. 1. The analytical process is divided and carried out in four stages: (1) Performance evaluation criteria are collected from the BSC literature and screened by the professional of food industry as a basic evaluation framework of this research, (2) The statistical test is applied to determine more important criteria for each perspective, (3) DEMATEL is used to find the critical criteria of performance perspectives and (4), Fuzzy Inference System (FIS) applied to develop a rule based system for evaluating performance of the food companies.

The analytical methods, DEMATEL and FIS employed by this research, are introduced briefly as follows:

DEMATEL method

DEMATEL is a graph theory based technique, was first put forward by American scientist in

Science and Human Affairs Program (SHAP) between 1972 and 1976 to resolve the complicated and intertwined problem group (Li & Tzeng, 2009). This structural modeling approach adopts the form of a directed graph, a causal-effect diagram, to present the interdependence relationships and the values of influential effect between factors. Through analysis of visual relationship of levels among system factors, all elements are divided into causal group and effected group and this can help researchers better understand the structural relationship between system elements, and find ways to solve complicate system problems (Lin & Wu, 2008). At first, DEMATEL method focused primarily on the fragmented and even contradictory phenomenon to find a reasonable solution. With further research, this method has been widely applied in more and more areas. Currently, DEMATEL method has been applied to many fields, such as Brand marketing (Liou & Chuang, 2010), supplier selection (Liou & Tzeng, 2007), choose KM strategy (Sankar & Prabhu, 2001), improving the advantages of global managers (Sivanandam et al., 2007), to enhance emergency management (Zhou et al., 2011) and etc. Moreover, DEMATEL method is currently applied in many other areas (Solatian et al., 2012), (Toloie & Homayonfar, 2011), (Tsai & Chou, 2009), (Tzeng et al., 2006), (Wang & Tzeng, 2012), (Wu, 2008), (Wu, 2012), (Wu & Lee, 2007). However, this effective structural modeling tool has not yet been used in the field of perfprmance evaluation. This paper will employ DEMATEL method to classify factors influencing perfprmance evaluation, and to identify the most important factors related to perfprmance evaluation. The steps of DEMATEL method based on Gabus and Fontela (1972) (wu et al., 2011) are as follows:

• Find out the factors influencing the under examination system. A large number of literature reviews is required to search and collect relevant information in this phase.

• Generate the initial direct-relation matrix form a committee of experts, and acquire the assessments about direct affect between each pair of elements. Converting the linguistic assessments into crisp values, we obtain the direct-relation matrix A = [a_{ij}], where A is a n×n non-negative matrix, a_{ij} indicates the direct impact of factor i on factor j. When i = j the diagonal elements is zero (a_{ij} = 0).

• Normalize the initial direct-relation matrix (D) through Eq. 1 All elements in matrix D are complying with 0 ≤d_{ij}≤1, and all principal diagonal elements are equal to 0.

$$D = \frac{1}{\max \sum_{j=1}^{n} a_{ij}} \cdot A \quad (1)$$

• Acquire the total-relation matrix T using the Eq. 2 in which I is a n×n identical matrix. The element t_{ij} indicates the indirect effects that factor i have on factor j, so the matrix T can reflect the total relationship between each pair of system factors.

$$T=D(I-D)^{-1} \quad (2)$$

• Calculate the sum of rows and columns in matrix T through Eq .3 and 4. The sum of row i (r_i) represents all direct and indirect influence given by factor i to all other factors, and so r_i can be called the degree of influential impact. Similarly, the sum of column j (c_j) can be called as the degree of influenced impact, since c_j summarizes both direct and indirect impacts received by factor j from all other factors:

$$r_i = \sum_{j=1}^{n} t_{ij} \quad (3)$$

$$c_j = \sum_{i=1}^{n} t_{ij} \quad (4)$$

Naturally, when i = j, the indicator $r_i + c_i$ can represent all effects received by factor i. On the contrary, $r_i - c_i$ shows the net effect that factor i has on the whole system. Specifically, if the value of $r_i - c_i$ is positive, the factor i is a net cause, exposing net causal effect on the system. When $r_i - c_i$ is negative, the factor is a net result clustered into effect group.

• Construct cause-effect relationship diagram based on $r_i + c_j$ and $r_i - c_j$. A cause-effect diagram can be drawn by mapping the dataset of ($r_i + c_j$, r_i + cj).

Fuzzy inference system (FIS)

The FIS is also known as fuzzy rule-based system, fuzzy model and fuzzy expert system. An FIS is a way of formalizing the reasoning process

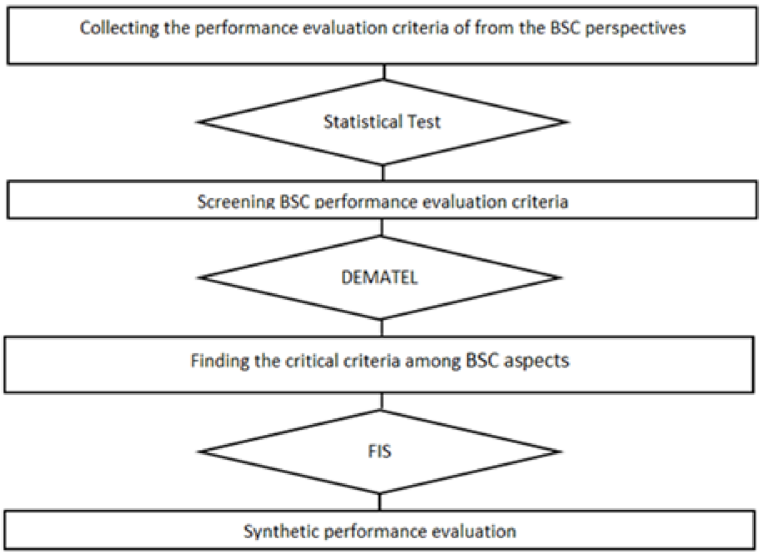

Fig. 1. Framework of the research

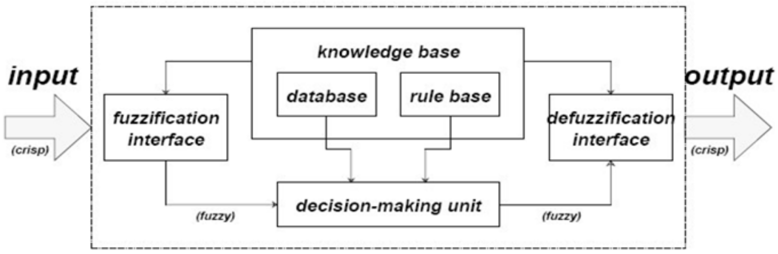

Fig. 2. Fuzzy inference system

of human language using fuzzy logic. The operational mechanism of an FIS is that the system formulates suitable rules, and based upon the rules inference is made using fuzzy IF-THEN rules and fuzzy reasoning (Wu et al., 2009). As shown in Fig. 2. a standard FIS consists of four blocks that include a fuzzification interface, a knowledge-base to define rules and fuzzy sets, a decision-making unit and a defuzzification interface (Yang et al., 2011). Below is a summary of each block:

Fuzzification interface transforms crisp inputs into degrees of belongingness to predefined linguistic expressions (constants) based on membership functions.

Knowledge-base contains a rule base defining a number of fuzzy IF-THEN rules and a database defining fuzzy sets used in the fuzzy rules.

Decision-making unit performs the interface operations of the rules using fuzzy reasoning.

Defuzzification interface transforms the results from fuzzy values into crisp values (Wu et al., 2009).

There are two major fuzzy inference methods:

Table 1: The group relationship matrix

Group Matrix	F1	F2	C1	C2	C3	C4	C5	PI	P2	P3	L1	L2	L3
F1	0	8.12	0	8.23	0	0	7.00	0	0	0	0	0	0
F2	0	0	0	0	0	0	5.77	7.12	6.73	0	6.42	5.69	0
C1	8.58	0	0	8.08	0	0	8.15	0	0	0	0	0	0
C2	8.12	0	0	0	0	0	7.23	0	0	0	0	0	0
C3	0	0	7.85	7.12	0	7.46	7.35	0	0	0	0	0	0
C4	0	0	8.38	6.81	0	0	7.46	0	6.12	0	0	0	0
C5	7.50	0	0	6.73	0	0	0	0	0	0	0	0	0
PI	7.31	7.62	0	0	0	0	6.31	0	0	5.69	0	0	0
P2	7.23	7.27	7.15	7.38	0	0	7.27	0	0	5.92	0	0	0
P3	0	0	6.00	0	0	0	6.62	0	0	0	6.27	0	0
L1	0	0	0	0	0	0	0	7.00	7.12	0	0	0	6.96
L2	7.04	0	0	6.65	6.69	0	0	0	0	0	6.38	0	6.12
L3	0	0	0	0	6.27	0	0	6.96	0	0	6.73	0	0

Mamdani and Sugeno inference method. The main difference between these two methods is that Mamdani uses fuzzy sets as the rule consequent, while Sugeno employs linear functions of input variables as the rule consequent (Zhou et al., 2011).

EMPIRICAL EXAMPLE

Through literature review and experts who have real practical experiences in food industry, 41 performance evaluation criteria for BSC perspectives have been collected. Then applying the statistical tests of collected questionnaires from the 26 experts, 13 more important criteria have been determined and classified into the four BSC dimensions, "Finance (F_1: Sales, F_2: Profit)", "Customer (C_1: Customer satisfaction, C_2: Market share rate, C_3: Customer communication, C_4: Customer complaints, C5: Organization image)", "Internal Process (P_1: Performance of operation management, P_2: Innovation management, P_3: Social/legal management)", and "Learning and Growth (L_1: Human resource management, L_2: Information asset management, L_3: Organizational asset management)".

DEMATEL method

We used the above important factors in a [(m+1)*(m+1)] relationship matrix and asked the experts to determine where, factor cited in each row influences the factors cited in columns. In the next step, experts were asked to score the relation cells according to the influence of raw factor on column factor based on a 1-10 scale. Synthesis of the individual matrixes resulted in a group relationship matrix (Table 1).

Based on the initial direct-relation matrix (Table 1), the total-relation matrix were acquired by using Eq. 1 and 2. In addition, the influential and influenced impacts were determined using Eq. 3 and 4. Table 2 illustrated the results. Finally, the cause-effect relationship diagram (Fig. 3.) is acquired by mapping the dataset of $r_i + c_i$ and $r_i - c_i$.

As shown in Fig. 3. all of the important factors are visually divided into two groups according to whether their value of $r_i - c_i$ is positive or negative (Lin & Wu, 2008). So the cause group with pos-

Table 2: The influential and influenced impacts of criteria

Criteria	Description	r_i	c_i	$r_i + c_i$	$r_i - c_i$
F_1	Sales	1.13	2.81	3.94	1.68
F_2	Profit	1.09	0.53	1.62	0.56
C_1	Customer satisfaction	1.41	0.25	1.66	1.16
C_2	Market share rate	0.68	2.81	3.49	2.13
C_3	Customer communication	1.39	0.43	1.82	0.96
C_4	Customer complaints	1.07	1.05	2.12	0.02
C_5	Organization image	0.64	3.35	3.99	2.71
P_1	Operation management	1.37	1.01	2.38	0.36
P_2	Innovation management	2.05	0.88	2.93	1.17
P_3	Social/legal management	0.88	0.53	1.41	0.35
L_1	Human resource management	1.26	1.04	2.3	0.22
L_2	Information asset management	1.81	1.42	3.23	0.39
L_3	Organizational asset management	1.66	0.33	1.99	1.33

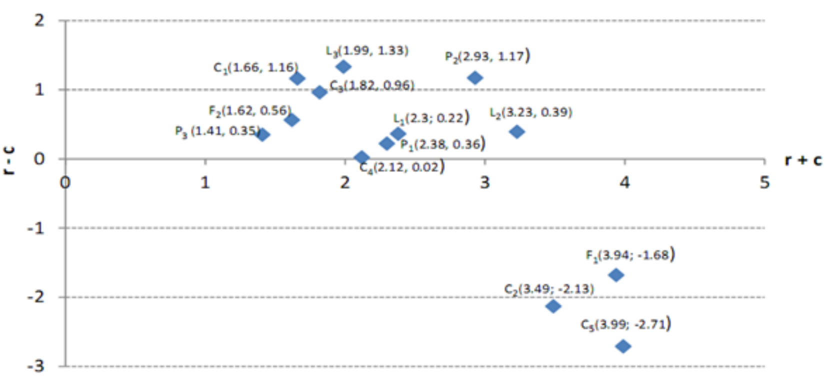

Fig. 3. The cause-effect relationship diagram

Table 3: Membership functions of elements

Variables	Linguistic description					Shape of MF [1]
	VL	L	M	H	VH	
F_2	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular
C_1	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular
C_3	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular
P_2	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular
L_3	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular
Performance	[0 0 2]	[1 2.5 4]	[3 5 7]	[6 7.5 9]	[8 10 10]	Triangular

Table 4: Rule base used in the empirical application

Rule	F2	C1	C3	P2	L3 →	Perf.
1	VH	VH	M	VH	M	VH
2	H	H	H	VH	VH	VH
…	…	…	…	…	…	…
7	L	H	L	M	H	M
8	M	VH	VL	L	M	M
…	…	…	…	…	…	…
13	VL	VL	-	-	L	VL
14	VL	L	H	not H	not VH	VL

Fig. 4. Rules of performance evaluation in food industry

itive r_i - c_i value includes F_2, C_1, C_3, C_4, P_1, P_2, P_3, L_1, L_2 and L_3 and other factors including F_1, C_2, and C_5 situate in the effect group, since their ri - ci value is negative. There are many other valuable clues that can be obtained from Fig. 3. which facilitate making decisions. Based on the Fig. 3. Profit (F_2), Customer satisfaction (C_1), Customer communication (C_3), Innovation management and (P_2) Organizational asset management (L_3) have been known as the critical elements of performance evaluation in food industry in Guilan province, Iran.

Fuzzy Inference System (FIS)

A FIS is a rule-based classification method that uses fuzzy logic to map an input space into an output space. In order to implementing the FIS, first the inputs and outputs of the system should be defined. Among the cause factors affecting on decision problem, the critical elements (outputs of DEMATEL) play the main role in evaluation process. Therefore, based on the consensus of the research experts, five elements with much considerable impact on the system were selected as inputs and performance as output of the FIS. These inputs include: Profit (F_2), Customer satisfaction (C_1), Customer communication (C_3), Innovation management and (P_2) Organizational asset management (L_3).Then fuzzy membership functions of variables must be defined in this stage. Membership functions of the system are verbal variables. . in this study, he linguistic variables are specified by ”Very Good”, “Good’’, “Medium’’, “Poor’’ and “Very Poor”. However,

[1] *Membership Function*

Table 5: comparison of FIS and Conventional appraisal result

Organization	Conventional appraisal	FIS
A	8	9.5
B	7	7.5
C	8	7.5
D	7	5
E	5	5
F	5	2.5

the shapes of membership functions are initially set by experts' experience, for each variable they may vary depending on structure and content of the corresponding elements. To represent the membership functions, first we have summarized the system elements, their linguistic description, their parameters and shape of mf in the following Table (Table 3).

Having defined the membership functions, it's the time to formulate fuzzy rules. Then, inference is made using fuzzy IF-THEN rules and fuzzy reasoning. In this research, experts' consensus leads to setting 14 rules for the under evaluation system. These rules are defined as Table 4 and Fig. 4.

In current study, since there is no linear relationship existing between input and output variables. Mamdani fuzzy method is used. The soft computational operators employed by Mamdani method are listed as follows:"and method: min", "or method: not used", "aggregation: sum" and "defuzzification: centroid".

After defining the membership functions and rules, to better understand the function of the performance appraisal system, consider the following inputs for a given food company. Running the inference system based on the defined rules, performance evaluation is done on the basis of inputs:

Input 1: [5,5,5,5,1.5] performance: 2.5 (Low)
Input 2: [8,3,1,1,1.5] performance: 1.92 (Very Low-Low)
Input 2: [0.5,3,0.5,3,0.5] performance: 0.695 (Very Low)
Input 2: [4,8,8,8,6] Performance: 5 (Medium)
Input 2: [9,9,7,7,7] Performance: 9.25 (Very High)

In order to verify the accuracy, effectiveness and usability of proposed method, 6 food companies in Guilan province, Iran which had precise information about their performance evaluation status, selected among all. Their managers were asked to assess their performance according to the "Profit", "Customer satisfaction", "Customer communication", "Innovation management" and "Organizational asset management", based on a 1 to 10 scale. Then performance score of companies, measured based on the average scores of above five inputs. Table 5 illustrated the comparative study between FIS results and the results of conventional appraisal method.

As can be seen above, conventional performance evaluation based on the range defined in the software shows that except in one case (Company F) the performance scores belong to the same range. FIS as a novel DSS system is proposed to implement the appraisal at the lower levels of the hierarchy and simplify the computations. What needs to be done is just writing new rules instead of rewriting an algorithm in the traditional approach. This advantage allows decision makers to adjust the system based on current situation without any difficulty.

CONCLUSION

The problem of sustainable performance evaluation of food producing companies is a critical because of its unique role in economy, society and environmental of the country. Food industry is faced with increasing market competition. Serve changes in the economical and financial components may lead to an undesirable situation to make a profit. In these conditions, this study Integrates DEMATEL with fuzzy inference system (FIS) in BSC context to form a powerful decision support system. The proposed approach used BSC as a popular approach in performance evaluation to identify evaluation criteria from the financial and non-financial perspectives in evaluating the performance of food industry. In addition, DEMATEL as a powerful method based on graph theory is used to determine the importance and priority of criteria based on the influential and influenced impacts. Based on the critical element of BSC, resulted from DEAMTEL, a fuzzy inference system is designed based upon the experts' consensus to evaluate organizations performance. The proposed approach is an appropriate and effective approach and can easily be coded, to apply inputs of the system in MATLAB. The results of the proposed approach validated based on the results of a real-world case.

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