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Providing a Fuzzy Expert System to Assess the Maturity Level of Companies in Manufacturing Excellence in the Food Industry of Iran

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ABSTRACT

This study seeks to develop a fuzzy expert system to help managers in assessing their effectiveness and position of their business on the manufacturing excellence track. Assessment process is multi-dimensional in nature and there is a relationship between the different variables of the system. In addition, both quantitative and qualitative variables as well as the uncertainty in the statements of experts must be considered in the evaluation process. Fuzzy DEMATEL technique complies with these requirements by respecting the interrelation between the factors and by converting the qualitative judgments into quantitative values for decision. Due to these features, this technique is used in this study as the best technique for developing the decision tool. Evaluation criteria were identified through a literature review and interviews with experts. Multiple pairwise comparisons were performed to determine the weights of these criteria. Then, these weights were used to build If-Then rules of decision system. This reduced the supernumerary rules of the system, and provided a more real If-Then rule base. The decision support tool, presented in this study, enables decision makers to assess manufacturing excellence from different aspects such as External Excellence (EE), Internal Excellence (IE) and Technological Excellence (TE). The results of the implementation of this fuzzy expert system in Zar-Macaron Company (as a case study) were satisfactory.

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1. INTRODUCTION

In an environment with changing demands, complex market and global competition, the ability to achieve or maintain a competitive advantage for manufacturing companies is essential. There is an increasing pressure to produce high quality products with minimal costs. In most of the developing countries, the government's approach is to focus on the development of manufacturing and industrial sector and to remove the barriers of dynamism and a greater mobility for these sectors [1]. In order to survive in the competitive global market, manufacturing companies must review their conventional and traditional activities. There are several strategies and activities to improve sustainable production and growth in the manufacturing industry [2-4]. However, as the literature suggests, WCM strategy is the best option to achieve this popular industrial goal [5, 6]. This strategy enables manufacturing leaders to quickly understand the dynamics of production and take correct steps in manufacturing excellence of their business.

Many industries are moving toward manufacturing excellence (ME) to compete in the global market. To achieve the potential benefits of excellence in manufacturing, practitioners would need to have a practical guide. Unfortunately, despite numerous studies that have been done in this area, organizations are still suffering from the absence of such guidance. Many researchers have identified several factors or performance measures for achieving the dominance in business [7-16]. However, most of these studies have focused on a particular aspect of the performance and they lack in the development of a series of performance variables that cover the whole field of manufacturing excellence. As the organizations apply world-class

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manufacturing, traditional performance variables such as product, cost or profit are not sufficient for their evaluation [17]. There is a need for new performance variables to perform the assessment based on shared goals and business. In order to stay at the top, one must act at the highest level. The basis of manufacturing excellence is continuous improvement. This happens when current performance is monitoring and evaluated continuously. A comprehensive model or framework for assessing the level of manufacturing excellence would be very useful for companies, because such a model would identify the constitutive factors of manufacturing excellence and organize them in a formal structure, and in compliance with the multi-dimensional nature of the assessment process, enable companies to use these factors in order to reach maturity in production with a clear understanding of their place in the road for manufacturing excellence. Some studies have tried to consider various aspects [6, 18-20]; however, the majority of studies are either theoretical or the complexity of their proposed models are not understandable for managers. This has led to the fact that most managers are facing challenges in the application of these models. Therefore, the main aim of this study is to provide a comprehensive tool with an easy application for assessing the level of access for manufacturing excellence. By using literature review and interviews with experts, this study identifies major factors affecting manufacturing excellence (ME) (e.g., Internal Excellence (IE), External Excellence (EE) and Technological Excellence (TE) factors) and categorizes them in a systematic framework and uses them to provide a comprehensive model for assessing the maturity level in manufacturing excellence in food industry of Iran. The existence of qualitative and quantitative variables as well as the relationship between various variables of the system should not be overlooked in a good evaluation model. In order to meet these requirements and to determine the importance and influence of different variables, interrelationships between factors must be observed and qualitative judgments should be transformed into quantitative values for decision analysis. DEMATEL technique copes well with these requirements. Furthermore, the ambiguity and uncertainty in judgments and statements of experts complicates the evaluation process. The systems based on fuzzy rules employ fuzzy methods to solve various types of real-world problems, especially where the system modeling is difficult or there is some ambiguity. Therefore, the application of fuzzy sets theory and expert system which will be very effective in the design of manufacturing excellence assessment tools. The objectives of this study are as follow:

- Identifying and classifying the major factors influencing manufacturing excellence;
- Determining the importance and impact of factors affecting manufacturing excellence in food industry of Iran;
- Submitting a manufacturing excellence to assess the level of corporate maturity in manufacturing excellence in food industry of Iran;
- Studying the applicability of the provided tool in food industry of Iran through case study.

In this paper, a fuzzy expert system to facilitate the assessment of manufacturing excellence in food industry of Iran will be presented after identifying the major criteria of manufacturing excellence through a comprehensive review of the literature and interviews with experts and discovering their importance and effectiveness by using fuzzy DEMATEL method.

2. LITERATURE REVIEW

2. 1. Manufacturing Excellence and its Affecting Factors

The term "manufacturing excellence (ME)" was first used in 1984 [21]. ME is considered as the way to be the best manufacturer or to have the best level of performance in terms of world-class manufacturing capabilities. This concept is a logical development of world class manufacturing (WCM). ME focuses on the competitive priorities of today's industry to remain in the market and steps further than WCM by emphasizing the customer, economy and environment [22]. ME is the stimulus for strict leadership in order to improve the process of creating value from the raw material stage to the built product stage for the customer that will ensure profitable and stable growth [23].

Achieving manufacturing excellence depends on many factors and criteria. Many studies have tried to respond to these questions that what are the critical success factors for achieving the world-class level in an organization? What is the importance of each factor? Which action has a priority? What is the relationship between these factors? And so on. Hayes and Wheelright [24]; Huge and Anderson [25] and Schonberger [26] were among the pioneers in this field. As Moore [27] has proposed, a review of all factors affecting the success of ME is almost impossible. He acknowledges that there is no magic bullet for the excellent performance and all factors are partially effective. However, reviewing the various studies can be useful in providing a list of the variables affecting the ME. A taxonomy of ME/WCM framework has been provided in the study of Sharma and Kodali [22]. A review of manufacturing excellence studies are presented in Table 1.

2. 2. Fuzzy Expert System

The term "fuzzy logic" was first introduced by Zadeh [39] in presenting the fuzzy sets theory.

TABLE 1. A review of manufacturing excellence studies

Related factors	Reference
Workforce skills & capabilities; Management technical competence; Competing through quality; Workforce participation; Rebuilding manufacturing engineering; Incremental improvement approaches.	[24]
Just in Time (JIT); Total Productive Maintenance (TPM); Total Quality Management (TQM); Employee Involvement; Simplicity.	[26]
Automated production: CIM systems; Flexible/human-centered reduction; Manufacturing for customer satisfaction; Resource-saving and environment-preserving (green) production; High added-value production.	[28]
Employee development; Management technical competence; Design for customer needs; Worker participation; Proprietary equipment; Continuous improvement; Process control; Feedback of information; Pull system; JIT supplier relationship.	[29]
Reduction of lead time; Rapid response to market changes; Cut the costs of operation; Excel customer expectations; Managing the global enterprise; Manage processes in outsourcing; Improving the visibility of the performance of your business.	[30]
Advanced manufacturing technology (AMT) ; Integrated information systems (IIS); Advanced management systems (AMS)	[31]
Alignment of operations to business strategy; Focus (Identifying the right operational levers); Building a culture of operational excellence; Mix between global/standardized processes versus local best practices; Realistic time frame to build up capabilities; Performance measures adapted to local market context.	[32]
Manufacturing strategy; Leadership; Knowledge management; Green manufacturing; Change and human resource management; Flexible processes; Supply chain management (SCM); Customer relationship management (CRM); Innovative product planning; Total quality management (TQM); World-class maintenance systems; Lean manufacturing.	[22]
Manufacturing based education; High added-value design; New business models; Advances in industrial engineering; AMT	[33]
Lean manufacturing; TQM; Six-sigma; TPM; customer relationship management; environmentally responsible manufacturing	[34]
TPM, lean and six-sigma	[35]
Quality; Speed; Dependability; Flexibility; Cost; Quantity/capacity; Innovation	[36]
Price; Quality; Conformance; Delivery dependability & speed; Broad line; After-sales service; Innovation; Volume flexibility	[37]
Management/Worker involvement; Competitive advantage; Cost/price; Customer relations/Service; Cycle time; Engineering change; Facility control; Flexibility; Global competitiveness; Green product/process design; Innovation and Technology; Inventory; Measurement and information management; Morale; Plant/Equipment/Tooling reliability; Problem support; Productivity; Quality; Safety; Speed/lead time; Supplier management; Top management commitment; Total involvement of employees; Training.	[38]
Quality; Equipment; Cost; Employee; Technical process; Production systems; Customer-relationship; Supplier-relationship; Lean manufacturing; National policy and other manufacturing related elements.	[23]

This theory has provided a framework for dealing with uncertainty. Several applications for fuzzy theory is offered by researchers. Fuzzy Inference System (FIS) is a popular computational framework based on the concept of fuzzy sets, if-then rules and fuzzy reasoning. These systems have a successful application in the field of automatic control, data classification, decision analysis, expert systems, time series forecasting, robotics, and pattern recognition. Fuzzy expert systems employ fuzzy methods to solve real-world problems, especially when the system modeling is difficult or where ambiguity is common. The major difference of these systems with other software systems is that they process knowledge rather than data or information [40]. Fuzzy expert system is actually an expert system which uses a set of membership functions and fuzzy rules instead of Boolean logic for data reasoning [41].The rules of fuzzy expert system are usually in this way:

If A is *low* and B is *high* then X = *medium*

A and B are input variables and X is the output variable. *Low*, *high* and *medium* are fuzzy sets which are defined on A, B and X, respectively. The antecedent (the rule's premise) describes to what degree the rule employs the inputs, while the conclusion (the rule's consequent) assigns a membership function to each of one or more output variables [41]. Figure 1 shows the basic structure of a fuzzy expert system. The main components of this system are: a fuzzification interface, a rule base (knowledge base), an inference engine (decision logic) and a defuzzification interface (see Figure 1).

Fuzzy expert system is one of the successful branches of artificial intelligence. The advantages of this system has led to its wide application as a decision support system in solving organizational problems as well: analyzing the effectiveness of technology transfer in the

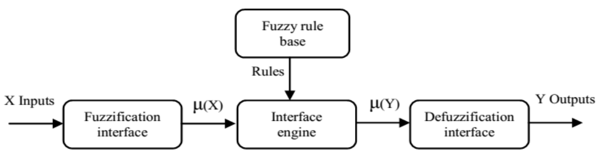

Figure 1. Structure of a fuzzy expert system [41]

machinery industry in Taiwan [42], compiling marketing strategies and related internet strategies [43], the choice of materials handling equipment and loading the materials in it [44], providing guidance on choosing a stock portfolio in Tehran Stock Exchange [45], simulating the behavior of firms to help the management of business [46], assigning the ordering policies of the inventory items in Class B [47], evaluating the performance of closed-loop supply chain in the automotive industry [48], improving the decision-making in portfolio management of new product development (NPD) [49], estimating customer lifetime value (CLV) [50] and breast cancer prognosis to further support the process of breast cancer diagnosis [51].

3. RESEARCH DESIGN

In this study, a group of 10 experts with more than ten years of managerial experience in the food industry was formed. All these people were at a PhD academic level. Then, ME elements were identified and categorized through literature and interviews with these experts. The process of evaluating is multi-dimensional in nature and includes both quantitative and qualitative variables, and there is a relationship between the different elements of the system. In order to have an accurate and practical rule base, it is necessary to identify the importance of system variables by experts in the food industry; since by including the weighting of criteria in the antecedent section of rules, the output of each rule will be unique. Therefore, a more realistic if-then rules will be achieved and redundant rules will be minimized during the creation of the rule base. Given the capabilities of fuzzy DEMATEL method, this method is used to determine the importance and impact of variables. Opinions of the expert group were collected through a pairwise comparison questionnaire especially designed for this method. Then, using the findings of fuzzy DEMATEL method, fuzzy rule bases are designed for assessing the level of ME in food industry companies of Iran. Stages of this research are presented in Figure 2.

4. DESIGNING THE FUZZY EXPERT SYSTEM TO ASSESS THE LEVEL OF MANUFACTURING EXCELLENCE IN FOOD INDUSTRY OF IRAN

4. 1. Identifying the Factors This study has identified the key variables influencing ME after a thorough review of relevant studies and interviews with experts. It was asked from the experts that these variables should be independent (as far as it is possible) and have the least overlap with each other. These variables are classified in three major categories of Internal Excellence (IE), External Excellence (EE) and Technological Excellence (TE) factors. IE factor consists of three categories of Personnel Excellence (PE), Operations Excellence (OE) and Financial Excellence (FE). Table 2 presents a brief description of the variables affecting ME.

4. 2. FDEMATEL Fuzzy DEMATEL technique provided by BaykasogLu et al. [52] has been used in this study to obtain the importance and impact of factors. The results of this method are presented in Table 3.

4. 3. Designing Fuzzy Expert System to Assess the Level of ME The following steps have been taken to create the fuzzy expert system:

Step 1 Determining the input and output variables of each fuzzy expert system.

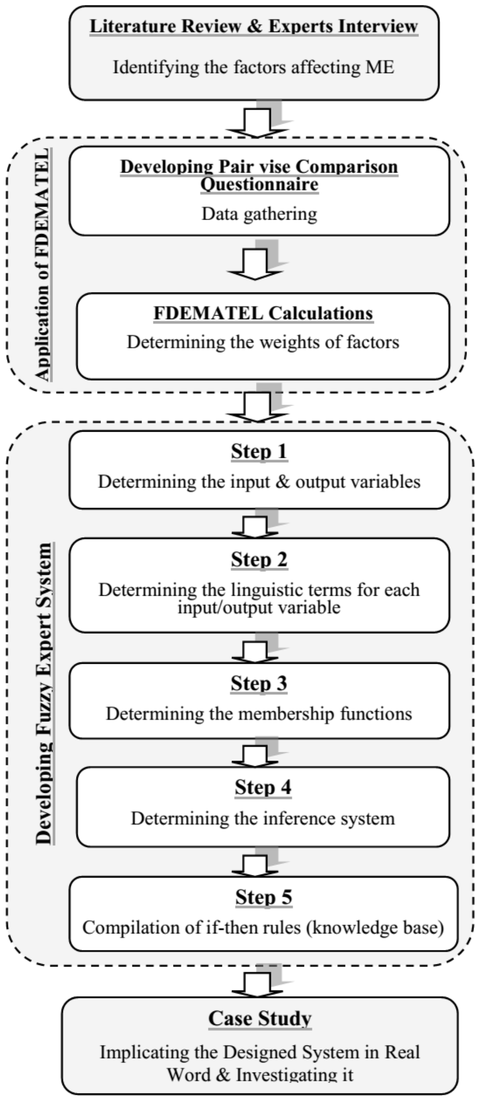

Figure 2. Flowchart of research stages

Elements of the lower level (sub-factors) form the higher level elements and the second level elements (main factors) form the target level, i.e. ME. For each of EE, IE and TE factors we will have an expert system that evaluates the main criterion of each category using their sub-criteria. Thus, the sub-factors of each category will be the input variables for the relevant main factor. So, the main factors which were the output variable for the sub-factors of their relevant expert system will be the input variables for the system which will have ME as its output. In total we will have 7 rule bases in which the output lower levels systems will be considered as the input for higher level systems: fuzzy expert system of ME measurement (final output), EE, IE, TE, PE, OE, FE.

Step 2 Determining the linguistic terms for each input/output variable. This study uses three linguistic variables for input and output variables which are Low (L), Midle (M), and High (H). Fuzzy numbers that have been allocated to the linguistic variables are 1, 2, and 3, respectively.

TABLE 2. List of critical success factors of manufacturing excellence compiled from the literature and interview

Criteria		Sub-Criteria	Description	Related References
External Excellence		Global presence	Growth of export and global production unit facilitating the increase of performance, technology transfer & etc.	[22, 23, 30, 32, 38]
		National regulation framework	A facilitating, simple and effective regulatory framework.	[23]
		Relationships with customers and suppliers	Effective outsourcing, supplier relations, JIT supplier, supplier capabilities along with customer perspective, responding to market changes, after-sales services.	[22, 29, 30, 34, 38, 53]
Technological Excellence		Innovative systems and processes	Differentiation through new products/ features, new materials and applications, value-increasing systems, efficient processes.	[22, 23, 36-38]
		Green production technology	Investment in environment-friendly technology, supporting the preservation of resources, controls the pollution and waste production.	[22, 23, 34, 38]
		The influence of appropriate technology	Delivering the explicit/ implicit customer needs, strengthening innovation and providing technical reliability.	[23, 29, 30]
		Integration of IT in production	Online operational database through MRP and MES, massive data analysis for quick decisions, digital production for improved use of resources.	[22, 23, 31, 33, 34, 38, 54]
Internal Excellence	Financial Excellence	Reducing the cost of operations	Reducing the cost of continuous production through value engineering and so on.	[22, 23, 30, 34, 36-38, 55]
		Reduce the cost of quality	Continuous reduction of quality costs (costs of prevention, assessment and failure)	[23; 24; 25; 27; 35; 36; 37; 38; 39; 56]
	Operational Excellence	Production process capability	Deliver the designed quality compatible with hardware, processes, systems and people.	[22, 23, 35, 37, 38]
		Production flexibility	Respond to changes in variety/ family of segments, versatility in process management and production volume in order to manage high variability in mass customization.	[22, 23, 30, 34, 36-38, 56]
		Customer responsiveness	Absence of delivery failure, responsiveness to new product development/ problem analysis and service quality.	[22, 23, 30, 37, 38]
		Planning, scheduling and control	Synchronization of highs and lows of supply and demand. Meeting a shorter customer delivery times.	[22, 23, 26, 30, 36-38]
		Total productive maintenance	Autonomous maintenance culture with a WCM TPM system.	[22, 23, 26, 34, 35, 38]
	Personnel Excellence	Committed leadership with a shared vision	Production-oriented leadership with the delivery of the strategy, employee involvement and customer relationships.	[22, 23, 34, 38, 57]
		Employee participation	Inclusive employee participation - quality circles, 5s, healthy Industrial conditions, and preferable employer and positive outputs.	[22-24, 26, 29, 38]
		Effective reward system	A systematic performance assessment system, to recognize and celebrate success and a positive atmosphere.	[22, 23, 34]
		Knowledge and training	Consistent growth in knowledge, skills and training together with the effective use of it.	[22-24, 29, 33, 38]

TABLE 3. Prominence, relation and weights of the criteria

Criteria	D + R	D - R	W_i	Normalized weight
External excellence	9.299	0.623	9.320	**0.331**
Internal excellence	9.570	0.455	9.581	**0.340**
Technological excellence	9.205	-1.078	9.267	**0.329**
Personnel excellence	6.494	0.265	6.499	**0.371**
Operational excellence	5.624	0.156	5.626	**0.321**
Financial excellence	5.390	-0.421	5.407	**0.308**
National regulation framework	6.523	0.661	6.557	**0.340**
Global presence	6.275	-0.664	6.310	**0.327**
Relationships with suppliers & customers	6.431	0.003	6.431	**0.333**
Committed leadership with a shared vision	0.865	0.303	0.916	**0.305**
Employee participation	0.579	-0.156	0.599	**0.199**
Effective reward system	0.791	0.068	0.794	**0.264**
Knowledge, training and skills	0.663	-0.214	0.697	**0.232**
Production process capability	4.311	0.062	4.312	**0.182**
Production flexibility	5.016	0.384	5.031	**0.212**
Customer responsiveness	4.072	-0.775	4.145	**0.175**
Planning, scheduling and control	5.040	-0.374	5.054	**0.213**
Total productive maintenance	5.134	0.703	5.182	**0.218**
Reducing the cost of operations	9.292	-0.489	9.305	**0.500**
Reduce the cost of quality	9.291	0.489	9.304	**0.500**
Integration of IT in production	0.803	0.020	0.803	**0.205**
Green production technology	0.937	-0.163	0.951	**0.243**
Innovative systems and processes	1.101	0.255	1.130	**0.288**
The influence of appropriate technology	1.030	-0.112	1.036	**0.264**

The Y output in each rule is unique. It is the product of fuzzy numbers of input variables in the weights of them which is calculated using FDEMATEL method.

Step 3 Determining membership functions: since the bell-shaped membership function creates lower ambiguity than the other functions, this study uses this membership functions for input and output. Figure 3 shows the membership functions of EE input variable as an example. The range of linguistic variables is visible in this figure.

Step 4 Determining the inference system. Since unlike sugeno inference system, mamdani system provides continuous values in output, mamdani system has been used in this study. Figure 4 shows the fuzzy expert system for the main variables affecting ME as an example.

Through fuzzy inference, conclusion of each rule can be transformed into absolute values, this is called defuzzification.

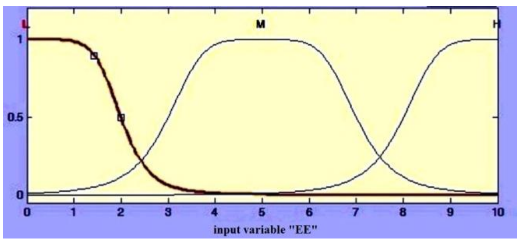

Figure 3. Membership function of EE input variable

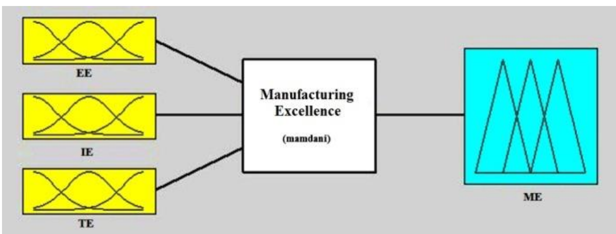

Figure 4. Main variables of fuzzy expert system

Since centroid defuzzification method has continuity and less ambiguity and provides a more accurate output, this method has been used for defuzzification in this study:

$$Z_{COA} = \frac{\int_Z \mu_A(Z)Z\,dZ}{\int_Z \mu_A(Z)\,dZ} \quad (1)$$

Step 5 Compilation of if-then rules (knowledge base): Since there are three linguistic variables defined for each input, in the compilation of the initial rule base, the space of each input is divided into 3 sections and then the operation is applied to each section of it. Each rule has a unique output and its value is defined for every possible categories of inputs. The output spectrum and linguistic terms for each period are presented in Table 4.

Here are the descriptions of fuzzy if-then rules for main factors and then the rules for sub-factors:

- There are 3 input variables (EE, IE, and TE) in the fuzzy expert system for the main factors, each of them can have three values (low, middle, high). At each antecedent, each input variable can take one of these values. Thus we will have $3_\times 3_\times 3$ = 27 possible cases for inputs. The output of each rule is unique. So we will have 27 if-then rule. Calculations based on fuzzy if-then rules of this expert system is presented in Table 5. These rules are defined in the fuzzy expert system rule base in MATLAB^{TM}.
- There are 3 input variables (National regulation framework, Global presence, and Relationships with customers and suppliers) in if-then rules related to EE, each of which can have three values (low, medium, high). Thus we will have $3_\times 3_\times 3$ = 27 rules.
- There are 4 input variables (IT integration in production, Green production technology, innovative processes and systems, and the influence of appropriate technology) in if-then rules related to TE, each of which can have three values (low, medium, high). Thus we will have $3_\times 3_\times 3_\times 3$= 81 rules.
- IE has 3 sub criteria. Therefore we have three input variables (people excellence, operational excellence, financial excellence) in if-then rules related to it, each of which can have three values (low, medium, high). Thus we will have $3_\times 3_\times 3$= 27 rules.
- There are 4 input variables (committed leadership with a shared vision, employee involvement, effective reward system, and knowledge, training and skills) in if-then rules related to people excellence, each of which can have three values (low, medium, high). Thus we will have $3_\times 3_\times 3_\times 3$= 81 rules.
- There are 5 input variables (the production process capability, production flexibility, customer responsiveness, planning, scheduling, and control; and total productive maintenance) in if-then rules related to operational excellence, each of which can have three values (low, medium, high). Thus we will have $3_\times 3_\times 3_\times 3_\times 3$ = 243 rules.
- There are 2 input variables (improving the quality cost and the operation cost) in if-then rules related to financial excellence, each of which can have three values (low, medium, high). Thus we will have 9 = $3_\times 3$ rules.

Figure 5 shows the comprehensive scheme of the final fuzzy expert system and relationship between sub-systems.

TABLE 4. The range of linguistic terms of output variable

linguistic terms	The range of output variable (Y)
High (H)	$2.33 < Y \leq 3$
Middle (M)	$1.67 < Y \leq 2.33$
Low (L)	$1 < Y \leq 1.67$

TABLE 5. Calculations based on fuzzy if-then rules of main variables

ME		EE	IE	TE	Outcome	Linguistic term
Scenario		0.331	0.340	0.329		
1	if	H	H	H	3	H
2	if	H	H	M	2.67	H
3	if	H	H	L	2.34	H
...						
25	if	L	L	MM	1.66	L
26	if	L	L	ML	1.33	L
27	if	L	L	L	1	L

5. CASE STUDY

A case study was used to describe the functionality and the performance of manufacturing excellence assessment intelligent system presented in this paper. As a major food manufacturer in Iran, Zar-Macaron Company is selected for examining and evaluating this system. A panel of experts was formed to evaluate the level of ME in their company. They were asked to state their firm's condition on every single metric from 0 to 10 points. They agreed judgments were considered as input values for the relative variables. For example, in the expert system related to TE (Figure 6) the score of Zar-Macaron Company in IT integration in manufacturing, green technology, innovative processes and systems, and the influence of appropriate technology were: 5, 4, 7 and 7, respectively. The output provided by the system, i.e. the amount of TE is equal to 5.23. This amount will be the TE input for ME fuzzy expert system in total expert system. Similarly, the IE and EE amounts that have been resulted from the relevant expert systems, are 5 and 5.23, respectively. As a result, the amount of Zar-Macaron Company's excellence in manufacturing has been evaluated as Moderate (M) by the expert system. Rule viewer of this system is presented in Figure 7.

The company's moderate situation in EE, TE and IE has led to a moderate level in ME as well. In the case of TE, the low performance of company in green technology is one of the most important reasons that has resulted in a distance between the company and maturity in TE. Improving the investment in environmentally-friendly technologies, and controlling pollution and waste production can be an important step for TE and consequently for ME. Operational excellence expert system shows the excellent performance of company in this case.

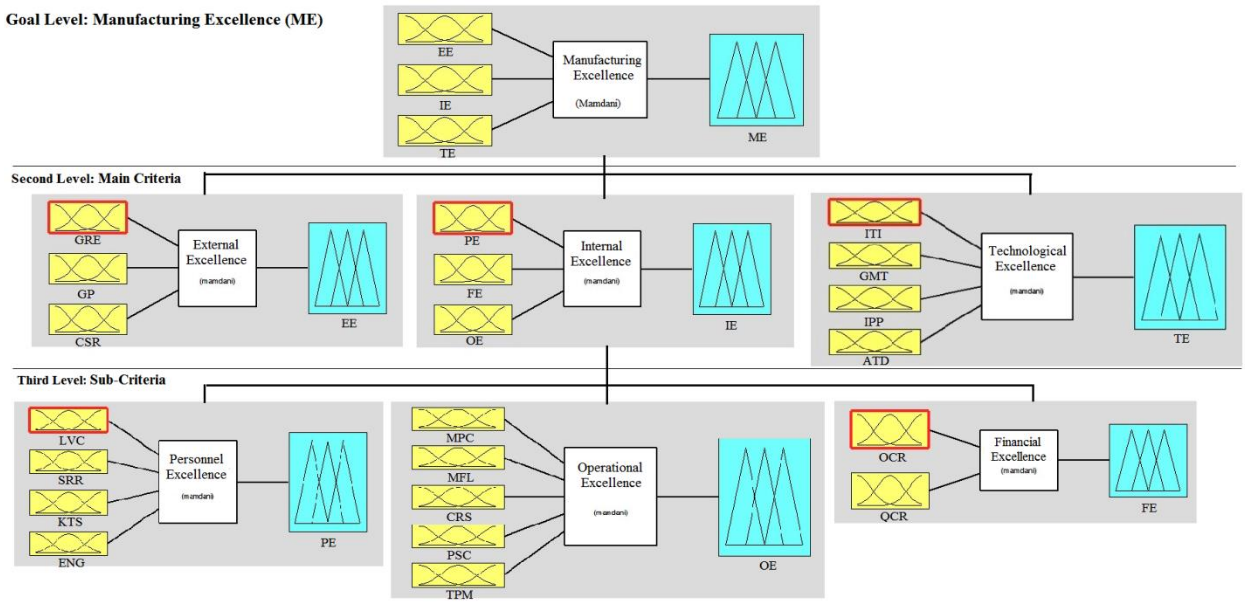

Figure 5. The outline of fuzzy expert system for assessing the maturity level of manufacturing excellence and relationships of sub-systems

Figure 6. Rule viewer of the TE expert system

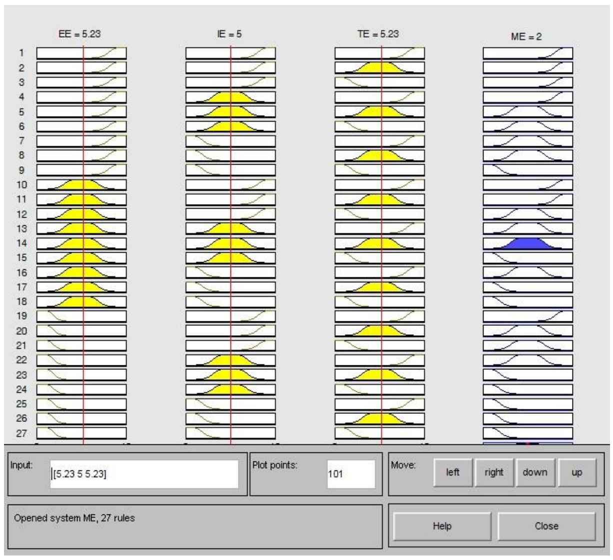

Figure 7. Rule viewer of the ME expert system

The company has acted moderately in financial excellence and weakly in people excellence. Maturity in people excellence should be highly regarded in the company in order to advance on the path to excellence. Given the importance of this factor and its strengthening effect on other internal excellence factors, any improvement in it will result in an improvement in company's situation in ME. Results of the studied system were approved by experts. Also, its performance and ease of use satisfied them. Experts believed that this system could be introduced to the companies in this industry as a useful tool to assess the maturity level of ME.

6. CONCLUSION

Nowadays, manufacturing excellence and continuous improvement for it are being considered as a target for many companies. As organizations employ world-class manufacturing and move towards excellence in manufacturing, traditional variables are not enough to assess the performance of these WCM organizations. They need new performance variables to assess based on common goals and business. The tool designed in this study tries cover the absence of a comprehensive and easy applicable model. The decision support tool, presented in this study, enables decision makers to assess manufacturing excellence from different aspects such as External Excellence (EE), Internal Excellence (IE) and Technological Excellence (TE). The case study shows that this system will be very practical and effective for assessing the maturity level of ME in food industry companies in Iran. Given the comprehensive criteria that form the basis of this expert system, this system can be adjusted for various industries. Therefore, for enhancing the capabilities of this system to measure the level of ME in different companies, it is proposed to study the nature of a multi-industry expert system in future studies.

7. ACKNOWLEDGMENT

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Providing a Fuzzy Expert System to Assess the Maturity Level of Companies in Manufacturing Excellence in the Food Industry of Iran

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چکیده

این مطالعه بدنبال ارائه‌ی یک سیستم خبره فازی است تا به مدیران در ارزیابی میزان اثربخشی و جایگاه سازمانشان در مسیر تعالی تولید کمک نماید. فرآیند ارزیابی ماهیتاً چند بعدی است و بین متغیرهای مختلف سیستم رابطه وجود دارد. بعلاوه، هم متغیرهای کمی و هم کیفی باید در فرآیند ارزیابی مورد توجه قرار گیرند. تکنیک FDEMATEL این الزامات را با رعایت روابط درونی بین فاکتورها و تبدیل قضاوت‌های کیفی به مقادیر کمی برای آنالیز تصمیم برآورده می‌کند. با توجه به این قابلیت‌ها، این تکنیک بعنوان بهترین تکنیک برای ایجاد ابزار تصمیم این مطالعه بکار رفته است. معیارهای ارزیابی از طریق مرور ادبیات و مصاحبه با خبرگان شناسایی شدند. مقایسات زوجی متعدد برای تعیین وزن معیارها انجام شد. سپس، این اوزان در ایجاد قواعد اگر-آنگاه سیستم تصمیم بکار رفتند. این کار قواعد زائد سیستم را کاهش می‌دهد و یک پایگاه قواعد اگر-آنگاه واقع‌گرایانه‌تر فراهم می‌آورد. ابزار پشتیبانی تصمیم ارائه شده در این مطالعه، تصمیم‌گیرندگان را قادر می‌سازد تا تعالی تولید را از جنبه‌های مختلف از قبیل تعالی برون سازمانی، تعالی درون سازمانی و تعالی تکنولوژیک مورد ارزیابی قرار دهند.

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