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Full Length Research Paper

Designing fuzzy multi criteria decision making model for best selection of areas for Improvement in EFQM (European Foundation for Quality Management) model

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In a growingly competitive business environment, numerous organizations adopt the total quality management (TQM) approach, to struggle for business excellence. To monitor the progress towards business excellence, thousands of organizations across the world use self-assessment on a regular basis. There are a few popular business excellence models, that provide standard criteria against which an organization can measure its performances. European Foundation for Quality Management (EFQM) is the most popular ones. The EFQM Excellence Model was introduced at the beginning of 1992, as the framework for assessing organizations for the European Quality Award. It is now the most widely used organizational framework in Europe and across the world and it has become the basis for the majority of international, national and regional Quality Awards. It is a practical tool that can be used as a guide to identify areas for Improvement. However, the current EFQM model has some drawbacks and problems which are not able to identify the priorities in Area for Improvement (AFI). For organizations with limitations of time, budget and resources and that cannot implement all the AFIs, some standards or indexes and limitations should be defined for prioritizing and choosing the AFIs. Using fuzzy multi criteria decision making model, the AFIs' can be identified. Therefore, this work will develop a more comprehensive method of evaluating, assessing and determining the AFIs' in the EFQM model. The results showed that, the new comprehensive developed model is more valid and acceptable and the experts verified the model for selecting of AFIs' in EFQM in practice. The developed model was used in a case study and extracted results from it and were analyzed from different points of view.

Key words: European quality award, EFQM, business excellence model, area for improvement, fuzzy logic, fuzzy multi criteria decision making.

INTRODUCTION

TQM presents a strategic option and an integrated management philosophy for organizations, which allows them to reach their objectives effectively and efficiently, and to achieve sustainable competitive advantage. Their Implementation is based on the European excellence model of the European Foundation for Quality Management (EFQM) which provides a European context (Calvo-Mora et al., 2006). The EFQM Excellence Model was introduced at the beginning of 1992 as the framework for assessing organizations for the European Quality Award. It is now the most widely used organizational framework in Europe and across the world it has

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become the basis for the majority of international, national and regional quality awards. The EFQM Excellence Model is a practical tool that can be used in a number of different ways:

1. As a tool for self-assessment;
2. As a way to benchmark with other organizations;
3. As a guide to identify areas for Improvement;
4. As the basis for a common vocabulary and a way of thinking;
5. As a structure for the organization's management system.

The EFQM Excellence Model is a non-prescriptive framework based on 9 criteria. 5 of these are 'Enablers' (leadership, policy and strategy, people, partnerships and resources and processes describe how things are done in the organization) and 4 are 'Results'(customers, people, society and key performance describe what is achieved by the enablers). The 'Enabler' criteria cover what an organization does. The 'Results' criteria cover what an organization achieves. 'Results' are caused by 'Enablers' and 'Enablers' are improved using feedback from 'Results' (EFQM, 2003a, 2003b). EFQM believes that, the process of self-assessment is a catalyst for driving business improvement. Self-assessment is a comprehensive, systematic and regular review by an organization of its activities and results referenced against the EFQM Excellence Model. The EFQM definition of self-assessment is as follows: The self-assessment process allows the organization to discern clearly its strengths and areas in which improvements can be made and culminates in planned improvement actions that are then monitored for progress. In fact, it is used to identify the organization's strengths and areas for improvement (AFI) (Calvo-Mora et al., 2006).

Self assessment method in EFQM includes; Questionnaire approach, Matrix chart approach, Workshop approach, Pro Forma approach and Award Simulation approach. The EFQM model has one thousand (1000) score that Enablers have 500 points (50%) and Results have 500 points (50%) (Vernero et al., 2007). These approaches assess the organization regularly and simply which is represented by the European Quality Award. However, we have some progressions and successes in areas of introducing and applying of assessment approaches in EFQM, the current assessment methods have problems and weaknesses for determine AFIs and it is necessary to develop models by establishing more researches. As a result of qualitative and ambiguous attributes linked to assessment in EFQM, most measures are described subjectively using linguistic terms, and cannot be effectively described using conventional assessment approaches. According to problems and weaknesses for assessing and identifying AFIs in the current approaches, Fuzzy concepts enable assessors to use linguistic terms to assess indicators in natural language expressions to aid companies in better assessing and recognizing AFIs. Since, the modeling of fuzzy multi-criteria decision making for priority and selecting of AFIs in EFQM is in essence non-existent, this study has several particular contributions comprising:

1. Determining the explicit criteria regarding the enablers and results aspects of EFQM, gap analysis, achieving to strategic plans and objectives of organization.
2. Using Multi Criteria Decision Making (MCDM) approach for selection of Areas for Improvement in EFQM model.
3. Employing Fuzzy MCDM for priority of areas for improvement in EFQM model.

LITERATURE REVIEW

The EFQM is a membership-based, no-profit organization founded in 1988 by 14 representatives of European multinational companies, with the mission of driving sustainable excellence in Europe. The European Commission and the European Organization for Quality supported the initiative. The founding members developed a multi-dimensional quality management representation, known as the EFQM model, and introduced the principles of self-assessment and the European Quality Award Program. The EFQM excellence model (Figure 1) is a non-prescriptive framework with nine dimensions, called criteria, of which five are enablers (leadership, policy and strategy, people, partnerships and resources and processes describe how things are done in the organization) and four results criteria (customers, people, society and key performance describe what is achieved by the enablers). Each criterion is weighted according to its importance; the most important, customer results, has a 20% weighting. The four results and five enabler criteria have a total weight of 50%. The EFQM's underlying assumption is that:

Excellent results with respect to performance, customers, people and society are achieved through leadership driving policy and strategy, people, partnerships and resources and processes (EFQM, 2003a, b; Vernero et al., 2007). The model, which recognizes that there are many approaches to achieving sustainable excellence in all aspects of performance, is based on the premise that:

'Excellent results with respect to performance, customers, people and society are achieved through leadership driving policy and strategy, that is delivered through people, partnerships and resources, and processes'.

The EFQM Model is presented in diagram form (Figure 1). The arrows emphasize the dynamic nature of the model. They show innovation and learning help to

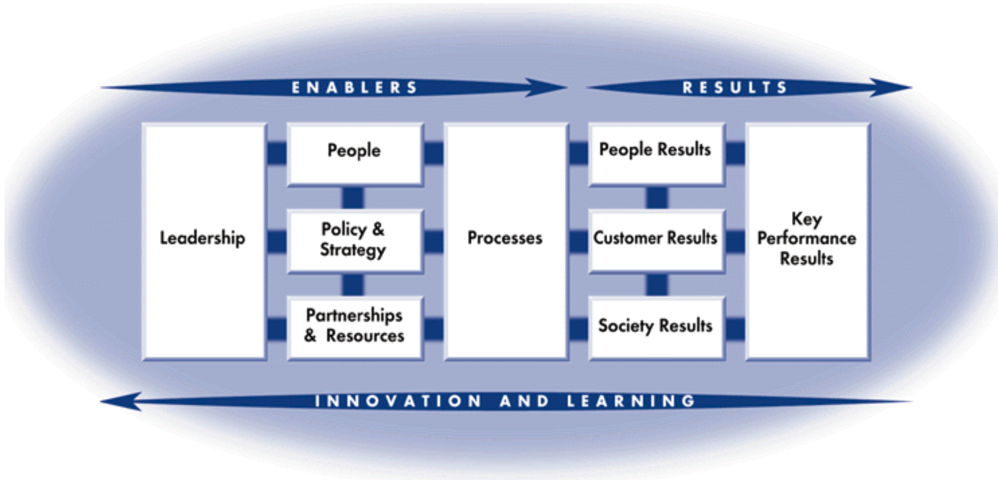

Figure 1. EFQM Model. Source: (EFQM, 2003a, b).

improve enablers that in turn lead to improved results. The model's 9 boxes represent the criteria against which to assess an organization's progress towards excellence. Each of the 9 criteria has a definition, which explains the high level meaning of that criterion. To develop the high level meaning further, each criterion is supported by a number of criterion parts. Criterion parts pose a number of questions that should be considered in the course of an assessment. Finally, below each criterion part are guidance points. Uses of these guidance points is not mandatory nor are the lists exhaustive but are intended to further exemplify the meaning of the criterion part (EFQM, 1999a, b, 2003b).

The EFQM excellence model criteria

The model's 9 boxes represent the criteria against which to assess an organization's progress towards excellence. Each of the 9 criteria has a definition, which explains the high level meaning of that criterion.

Leadership

Excellent leaders develop and facilitate the achievement of the mission and vision. They develop organizational values and systems required for sustainable success and implement these via their actions and behaviors. During periods of change they retain a constancy of purpose. Where required, such leaders are able to change direction of the organization and inspire others to follow.

Policy and strategy

Excellent organizations implement their mission and vision by developing a stakeholder focused strategy that takes account of the market and sector in which it operates. Policies, plans, objectives and processes are developed and deployed to deliver strategy.

People

Excellent organizations manage, develop and release the full potential of their people at an individual, team-based and organizational level. They promote fairness and equality and involve and empower their people. They care for, communicate, reward and recognize, in a way that motivates staff and builds commitment to using their skills and knowledge for the benefit of the organization.

Partnerships and resources

Excellent organizations plan to manage external partnerships, suppliers and internal resources in order to support policy and strategy and the effective operation of processes. During planning and whilst managing partnerships and resources, they balance the current and future needs of the organization, the community, and the environment.

Processes

Excellent organizations design, manage and improve processes in order to fully satisfy, and generate increasing value for customers and other stakeholders.

Customer results

Excellent organizations comprehensively measure and achieve outstanding results with respect to their customers.

People results

Excellent organizations comprehensively measure and achieve outstanding results with respect to their people.

Society results

Excellent organizations comprehensively measure and achieve outstanding results with respect to society.

Key performance results

Excellent organizations comprehensively measure and achieve outstanding results with respect to the key element of their policy and strategy.

Self-assessment

EFQM believes that the process of self-assessment is a catalyst for driving business improvement. The EFQM definition of self-assessment is as follows:

'Self-assessment is a comprehensive, systematic and regular review by an organization of its activities and results referenced against the EFQM excellence model. The self-assessment process allows the organization to discern clearly its strengths and areas in which improvements can be made and culminates in planned improvement actions that are then monitored for progress. In fact you could identify your organization's strengths and areas for improvement (AFI)'

Organizations have enjoyed various benefits as a result of undertaking self-assessment using the EFQM excellence model. Some of these included:

1. Providing a highly structured, fact-based technique to identifying and assessing your organization's strengths and areas for improvement and measuring its progress periodically;
2. Improving the development of your strategy and business plan;
3. Creating a common language and conceptual framework for the way you manage and improve your organization;
4. Educating people in your organization on the Fundamental Concepts of Excellence and how they relate to their responsibilities;
5. Integrating the various improvement initiatives into your normal operations (EFQM, 2003a, b).

In the EFQM model, 9 criteria need to be assessed to generate a final score. Furthermore, there are 32 sub-criteria available under the 9 criteria and many areas to address. Therefore, the EFQM excellence model is structured into 3 levels. The top level with the criteria and the second level with the sub-criteria contain fixed elements that have to be considered when an organization strives for excellence. The third level of the EFQM process is completely open and its content should be defined by the company itself. According to the present scoring system, assessors give a score to each sub-criterion against specific guidelines detailed in the latest version of the model. The score is a decision made by individual assessors through comprehensive analysis of all the information that was provided to them. The assessment represents a judgment of an organization's achievements across a range of areas relating to each sub-criterion in the EFQM excellence model. The self-assessment in an EFQM excellence model is based on RADAR logic. The elements of RADAR are results (used when assessing the results criteria), and approach, deployment, assessment and review (these are used when assessing enabler criteria).

Assessors score each result sub-criterion by consideration of the excellence and scope of the results. With regard to the enabler sub-criterion, scoring of the approach takes account of the soundness of the method or process described and the extent to which the method or process described is integrated. Scoring of deployment takes account of the extent to which the approach has been implemented across different areas and layers of the organization and the extent to which the deployment of the approach is systematic. In scoring the assessment and review, assessors will consider measurements taken, learning activities that follow, and the improvements that have been identified, prioritized, planned and implemented. Taking account of all the mentioned factors, the assessors use the RADAR scoring matrix to give percentage scores to approach, deployment, assessment and review, deriving an overall percentage score to each of the enabler sub-criteria. There are a number of methods for self-assessment suggested by the EFQM model, such as questionnaire, pro forma, matrix, workshop, and award simulation approaches (Rusjan, 2005).

EFQM introduced some self-assessment approach including; Questionnaire approach, Matrix chart approach, Workshop approach, Pro Forma approach and Award Simulation approach. Many authors have highlighted these approach in many organizations for instance, universities, hospitals, industrial organizations and etc (Antunes et al., 2008; Anyamele, 2005, 2007; Bak et al., 2004; Balague, 2007; Bou-Llusar et al., 2009; Calvo-Mora et al., 2005; Calvo-Mora et al., 2006; Conti, 2007; Davies, 2008; EFQM, 1999a, b, 2003a, b; Hennig and Greiner, 2007; McCarthy et al., 2002; Tari, 2008; Tari and De Juana-Espinosa, 2007; Vernero et al., 2007; Weggeman and Groeneveld, 2005).

Fuzzy logic

The origin of the name, fuzzy relates to 2500 years ago when Aristotle revealed the degree of the True-False, particularly in making statement about possible future events (McNeill and Thro, 1994). In 1965, Professor Lotfi Askar Zadeh a lecturer in the University of California Berkley published a paper called “fuzzy sets”. The word of “fuzzy” to indicate “vague” is employed for the first time in his paper. The purpose of the fuzzy logic (FL) is to enhance the connections among humanity and the computer. Recently, the employment of the FL is enhanced and is applied in various aspects of engineering and other areas of study. One of the prominent obvious characteristics of fuzzy sets is capability to demonstrate the extent of uncertainty in human thinking (Terano et al., 1992). Following one decade from the theory of Zadeh, the English professor, Ebrahim Mamdani studied on the steam engine motor that worked with Bayesian decision theory. On that time, he could not achieve logical consequences from Bayesian theory and afterwards concentrated on the FL for solving the problem. Throughout this experience he designed rule-based expert system in fuzzy logic which named fuzzy logic controller (Chevrie and Guely, 1998; McNeill and Thro, 1994).

Fuzzy logic involves fuzzy sets and logical links for designing the human-like reasoning issues of the real world. A fuzzy set, in contrast to conventional sets, covers all components of the universal set of the domain but with different membership values in the interval [0, 1]. It should be considered that a conventional set includes its members with a value of membership equal to one and ignores other components of the universal set, for they have zero membership. The most general operators used to fuzzy sets are AND (minimum), OR (maximum) and negation (complementation), while AND and OR have binary arguments, negation has unary argument. The logic of fuzzy sets was suggested by Zadeh, who presented the concept in systems theory for the first time, and subsequently widened it for approximate reasoning in expert systems (Wah and Li, 2002). Among the pioneering contributors on fuzzy logic, the work of Tanaka in stability analysis of control systems (Tanaka, 2002), Mamdani in cement kiln control (Mamdani, 1977), Kosko (Kosko and Burgess, 1998) and Pedrycz (Pedrycz, 1995) in fuzzy neural nets, Bezdek in pattern classification (Bezdek, 1981) and Zimmerman (Zimmermann, 1996) and Yager (Yager, 1983) in fuzzy tools and techniques requires particular acknowledgement (Konar, 2000).

Fuzzy inference systems

Fuzzy inference systems (FISs) which are also known as fuzzy rule-based systems, fuzzy model, fuzzy expert system, and fuzzy associative memory, form a principal unit of a fuzzy logic system. The decision-making is a prominent part in the whole system. The FIS develops appropriate rules and on the basis of the rules the decision is made. This is principally established on the concepts of the fuzzy set theory, fuzzy IF–THEN rules, and fuzzy reasoning. FIS uses “IF. . . THEN . . .” statements, and the connectors existent in the rule statement are “OR” or “AND” to create the essential decision rules. The basic FIS can accept either fuzzy inputs or crisp inputs, but the outputs it provides are virtually all the time fuzzy sets. When the FIS is employed as a controller, it is needed to have a crisp output. Hence, in this case defuzzification method is matched with best extract a crisp value that best represents a fuzzy set (Konar, 2000).

Fuzzy inference system is perceived in two types: Mamdani-type and Sugeno-type which are two types of inference systems differ to some extent in the way outputs are defined. Mamdani’s type is more well-known than other type. The most important diversities among these two types are related to the representation of the consequents. Mamdani-type fuzzy rules regard linguistic variables on the consequents while Sugeno-type fuzzy rules regard a crisp value or a polynomial function of the inputs as the consequents. Although, in latest Mamdani-type study is applied, because fuzzy consequent in this type is easier to be understood and more useful for obtaining imprecise human expertise (Li and Gatland, 2002; Mathworks, 2010). Several applications of fuzzy inference systems have been employed in production line selection evaluation system in ERP (Bi and Wei, 2008), supply chain (Cheng et al., 2009; Didehkhani et al., 2009), facility location selection (Kahraman et al., 2003), the machine-loading problems of FMS (Kumar et al., 2004) risk in human decision process (Liginlal and Ow, 2006), cognition and decision processes (Zadeh et al., 2007).

MATERIALS AND METHODS

Fuzzy multi criteria decision making

Decision making is a most important scientific, social, and economic endeavor. To be able to make consistent and correct choices is the essence of any decision process imbued with uncertainty (Ross, 2004). Multi-criteria decision making (MCDM) is one of the well-known topics of decision making. Fuzzy logic provides a useful way to approach an MCDM problem. Very often in MCDM problems, data are imprecise and fuzzy. In a real-world decision situation, the application of the classic MCDM method may face serious practical constraints, because of the criteria containing imprecision or vagueness inherent in the information. For these cases, fuzzy multi-criteria decision making (FMCDM) method have been developed (Kahraman, 2008). Application of fuzzy MCDM are used in engineering and management in several studies (Bi and Wei, 2008; Cheng et al., 2009; Grabisch, 1996; Jassbi et al., 2009; Kahraman, 2008; Liginlal and Ow, 2006; Ross, 2004; Sugeno, 1985; Zimmermann, 1996). In general, fuzzy MCDM matrix can be illustrated in Table1.

Algorithm of areas for improvement selection in EFQM

Here, the model inputs, processes and output with selection of areas for improvements (AFIs) are systematically outlined. In the subsequent flowchart (Figure 2), the components of accomplished

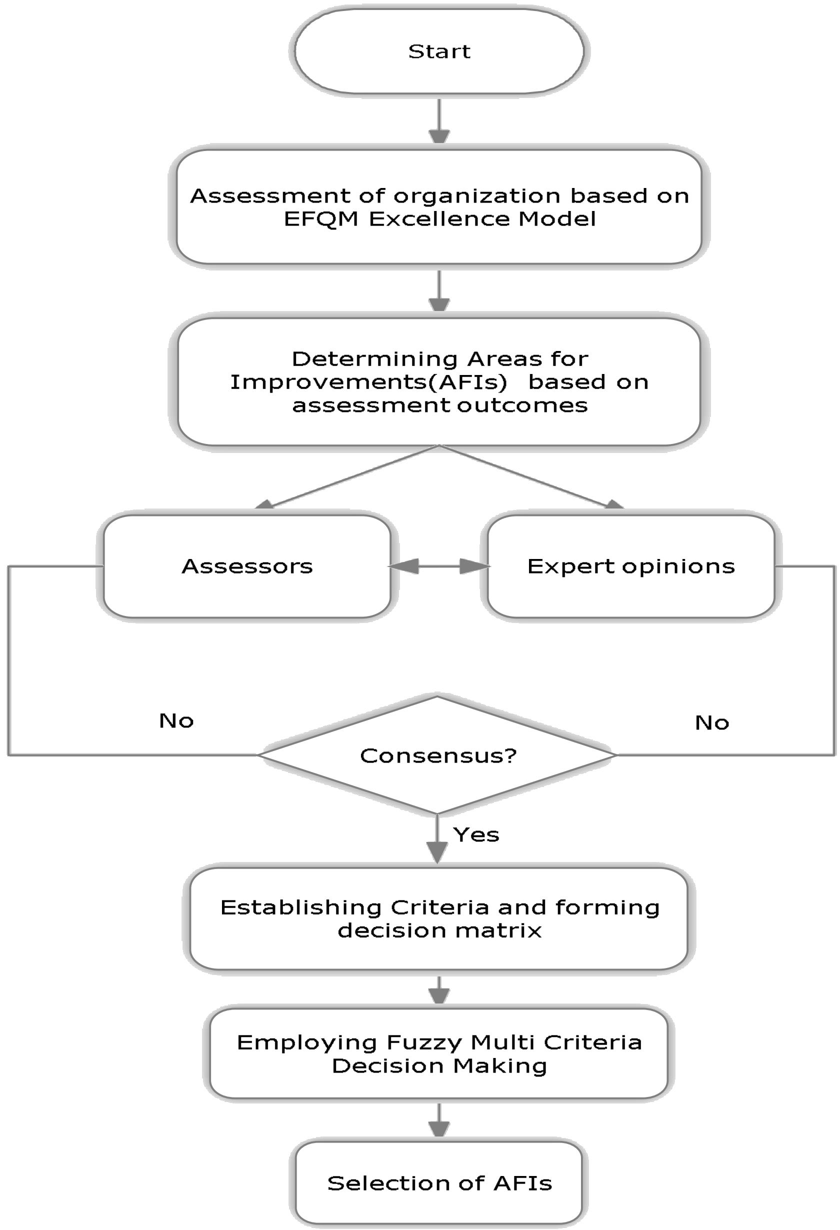

Figure 2. Algorithm of AFIs selections in EFQM business excellence.

algorithm have been depicted. On the basis of algorithm of AFIs selection in EFQM business excellence the implemented steps are:

Step 1: Conducting assessment method based on EFQM business excellence.

Step 2: Consensus for determining AFIs and forming decision matrix based on assessment of assessors and experts experiences with regards to Table 1.

The 4 criteria are defined by 'assessors' and 'experts' knowledge and experience.

1. Importance criterion: Importance criterion is the degree of the weight or importance of each AFIs for the organization and this importance (weight) are defined by EFQM business excellence model and based on 'assessors' and 'experts' knowledge and experience.
2. Gap criterion: The concept of gap is the distance between the present situation and the desirable situation. In this sense, whatever the gap of the present situation be more than the desirable situation in the organization, its importance is more for the organization and it should be performed as soon as possible. Indeed, gap is the distance between assessment score and ideal situation in EFQM model.
3. Cost criterion: Generally, organizations have limitations in budgetary and financial resources; consequently, we are looking for cost of AFIs and whether the organization can perform them with regards to these limitations.
4. Time criterion: Considering that the performance time of each AFI is different from the others and shortness of AFI performance

Table 1. Fuzzy MCDM matrix.

Criteria / Alternatives	C1={fuzzy set}	C2={fuzzy set}	C3={fuzzy set}	Cm={fuzzy set}
A1	A11={fuzzy set}	A12={fuzzy set}	A13={fuzzy set}	A1m={fuzzy set}
A2	A21={fuzzy set}	A21={fuzzy set}	A23={fuzzy set}	A2m={fuzzy set}
…	…	…	…	…
An	An1={fuzzy set}	An2={fuzzy set}	An3={fuzzy set}	Anm={fuzzy set}

Table 2. Definition of verbal values.

Verbal value	Definition	Degree
EL	Extremely low	1
VL	Very low	2
L	Low	3
SL	Slightly low	4
M	Medium	5
SH	Slightly high	6
H	High	7
VH	Very high	8
EH	Extremely high	9

time leads to achievement of the organizational objectives faster and vice versa.

Step 3: Employing fuzzy multi criteria decision making (FMCDM).

1: The first step to construct an FMCDM is defining universe set which is the element of universe U= {1 2 3 4 5 6 7 8 9}.
2: Then select a membership function for each criterion and alternatives (AFIs). A "membership function" is a curve that defines how the value of fuzzy variable is mapped to a degree of membership between 0 to 1. Membership functions are used to calculate the degree of FMCDM in different values expressed by linguistic term. The verbal values defined with regards to Table 2.
3: with considering bell shape membership function, the decision matrix (fuzzy sets of criteria and alternatives) is formed regarding Table 1(Fuzzy MCDM matrix) and Equation 1.

$$\mu_A(x) = \frac{1}{1 + d\ (x - c)^2} \quad (1)$$

Where X€ [0, 1] is the element of universe U= {1 2 3 4 5 6 7 8 9}, c indicates the standard score for determining verbal (linguistic) value of the criteria and AFIs in EFQM and d determines the shape of the membership function (here d = 0.2). In the meanwhile, we determine fuzzy degree of gap from intersection of assessment score and ideal situation in EFQM model, using Equation 2.

$$\mu_{A \cap B}(x) = \min\ (\mu_A(x), \mu_{B(x)}) \qquad x \in U \quad (2)$$

4: with applying subsequent formula the utility of decisions (AFIs) is calculated using Equation 3.

$$Ai = \{(\overline{C1} \cup ai1) \cap (\overline{C2} \cup ai2) \cap \ldots.(\overline{Cm} \cup aim)\}$$
$$Ai = \bigcap_{i=1}^{n} (\overline{Cj} \cup aim) \quad (3)$$

5: with employing centre of gravity method fuzzy outputs of AFIs transform to crisp utility with regards to Equation 4 (Dodangeh, 2006; Dodangeh et al., 2008, 2010).

$$Z^* = \frac{\sum_{j=1}^{n} \mu_A(x_j).\ x_j}{\sum_{j=1}^{n} \mu_A(x_j)} \quad (4)$$

6: Finally, with regards to the last step which determined crisp utility of AFIs subsequently, the AFIs in EFQM are ranked.

RESULTS

A case study was conducted in a mega car manufacturing firm which produces trucks including tractors, construction, distribution and utility trucks and passenger vehicles (minibuses). The assessors' team comprising lead assessor and two assessors was formed and experts panel consist of managing director; marketing and sales director, engineering director, logistic director and production director were made up. The assessors evaluate the organization based on EFQM business excellence model and with regards to experts opinion and the consensus of their opinions, the areas for improvement (AFIs) were determined as Table 3. Based on step 2, the 4 criteria comprising importance, gap, cost and time are defined by assessors' and experts' panel knowledge and experience. Afterwards, the verbal and fuzzy values regarding the steps 1, 2 and 3 and Table 2 and Equation 1 are defined as Table 4.

Table 3. Areas for improvement.

Number of AFIs	Area for improvement
A1	Effective Marketing research
A2	Effective Strategic planning
A3	Cost Reduction(ABC)
A4	After sales service
A5	Balanced Scorecard (BSC)
A6	Knowledge management
A7	Customer relationship Management(CRM)
A8	New product development
A9	ERP
A10	Total preventive maintenance(TPM)
A11	Technology management
A12	TQM
A13	Human resource financial compensation
A14	Strategic human resources planning
A15	Reward system
A16	Implementation of effective MIS

Table 4. Definition of verbal and fuzzy values.

Verbal value	Definition	Fuzzy values
EL	Extremely low	$EL:\left\{\frac{1}{1},\frac{0.83}{2},\frac{0.55}{3},\frac{0.357}{4},\frac{0.238}{5},\frac{0.166}{6},\frac{0.122}{7},\frac{0.092}{8},\frac{0.072}{9}\right\}$
VL	Very low	$VL:\left\{\frac{0.83}{1},\frac{1}{2},\frac{0.83}{3},\frac{0.55}{4},\frac{0.357}{5},\frac{0.238}{6},\frac{0.166}{7},\frac{0.122}{8},\frac{0.092}{9}\right\}$
L	Low	$L:\left\{\frac{0.55}{1},\frac{0.83}{2},\frac{1}{3},\frac{0.83}{4},\frac{0.55}{5},\frac{0.357}{6},\frac{0.238}{7},\frac{0.166}{8},\frac{0.122}{9}\right\}$
SL	Slightly low	$SL:\left\{\frac{0.357}{1},\frac{0.55}{2},\frac{0.83}{3},\frac{1}{4},\frac{0.83}{5},\frac{0.55}{6},\frac{0.357}{7},\frac{0.238}{8},\frac{0.166}{9}\right\}$
M	Medium	$M:\left\{\frac{0.238}{1},\frac{0.357}{2},\frac{0.55}{3},\frac{0.83}{4},\frac{1}{5},\frac{0.83}{6},\frac{0.55}{7},\frac{0.357}{8},\frac{0.238}{9}\right\}$
SH	Slightly high	$SH:\left\{\frac{0.166}{1},\frac{0.238}{2},\frac{0.357}{3},\frac{0.55}{4},\frac{0.83}{5},\frac{1}{6},\frac{0.83}{7},\frac{0.55}{8},\frac{0.357}{9}\right\}$
H	High	$H:\left\{\frac{0.122}{1},\frac{0.166}{2},\frac{0.238}{3},\frac{0.357}{4},\frac{0.55}{5},\frac{0.83}{6},\frac{1}{7},\frac{0.83}{8},\frac{0.55}{9}\right\}$
VH	Very high	$VH:\left\{\frac{0.092}{1},\frac{0.122}{2},\frac{0.166}{3},\frac{0.238}{4},\frac{0.357}{5},\frac{0.55}{6},\frac{0.83}{7},\frac{1}{8},\frac{0.83}{9}\right\}$
EH	Extremely high	$EH:\left\{\frac{0.072}{1},\frac{0.092}{2},\frac{0.122}{3},\frac{0.166}{4},\frac{0.238}{5},\frac{0.357}{6},\frac{0.55}{7},\frac{0.83}{8},\frac{1}{9},\right\}$

In fact, with regards to the consensus of expert panels and assessors of organization taking into consideration Table 1 and step 3 fuzzy weighting of criteria illustrated as Table 5. The membership function of criteria weighting under fuzzy space was depicted as Figure 3. On the basis of Table 1 and step 3, the fuzzy multi criteria decision making was established as Table 6. Indeed, gap is calculated using fuzzy “AND” operation which intersection between fuzzy measuring and fuzzy target of EFQM model. In other words, gap is the distance between assessment score and ideal situation in EFQM model. The fuzzy utility of each AFLs is calculated by steps 3 and 4 and Equations 1, 2 and 3; and after that with employing centre of gravity method fuzzy outputs of AFIs convert to crisp utility with regards to Equation 4 as it exhibited in Table 7. The utility of each AFIs in fuzzy space (outputs) are depicted in Figure 4. Ultimately, with regards to the previous step which determined crisp utility of AFIs subsequently, the AFIs in EFQM are ranked as Table 8.

Table 5. Fuzzy weighting of criteria.

Criteria	Importance	Gap	Cost	Time
Fuzzy weighting	Slightly high	High	Extremely high	Medium

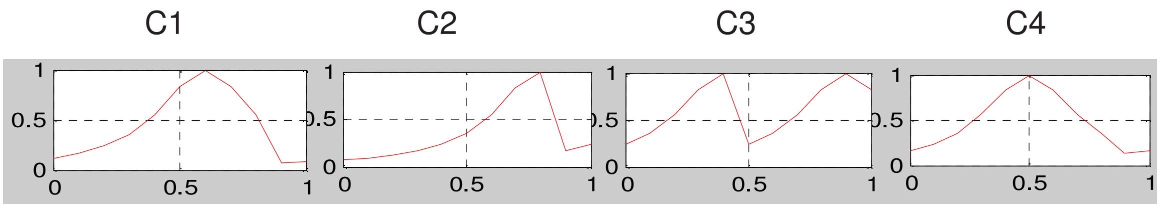

Figure 3. Membership function for weighting of criteria.

Table 6. Fuzzy multi-criteria decision matrix.

AFIs \ Criteria	Importance	Gap Min{M,T}	Cost	Time
A1	EH	(M ∩ SH)	H	SH
A2	SH	(H ∩ VH)	M	H
A3	H	(VH ∩ EH)	SL	L
A4	VH	(L ∩ H)	SH	M
A5	H	(M ∩ VH)	M	SL
A6	EH	(M ∩ VH)	H	VH
A7	SH	(L ∩ M)	L	M
A8	M	(L ∩ VH)	SL	SH
A9	SH	(H ∩ EH)	VL	L
A10	M	(M ∩ H)	SH	SL
A11	SL	(M ∩ VH)	VL	SL
A12	M	(H ∩ EH)	VH	VL
A13	L	(L ∩ H)	M	EL
A14	H	(H ∩ VH)	SL	M
A15	M	(L ∩ M)	L	SL
A16	H	(M ∩ VH)	VH	H

DISCUSSION

In conclusion, the EFQM business excellence model is a most important approach for diagnosis of organization and it is a practical tool that can be used as a guide to identify areas for Improvement. However, the current EFQM model has some drawbacks and problems which are not able to identify the priorities in Area for Improvement (AFI). For organizations with limitations of time, budget and resources, they cannot implement all the AFIs, some standards or indexes and limitations should be defined for prioritizing and choosing the AFIs. Hence, we need the knowledge and experience of expert panels and assessors of organization for determining the criteria and AFIs which often are consistent with vagueness and uncertainty inherent in the information. Since there is no proper method of selecting the AFIs in imprecise and fuzzy space, using fuzzy multi criteria decision making model to solve some of these drawbacks and problems in the EFQM in practice. The presented model has been implemented in a mega car manufacturing firm and revealed more reliable and acceptable results in practice. Moreover, the proposed model in this research has some features, including relations between variables in real life are nonlinear. Abstracting the situation and simplifying the problem to a linear model, will cause the missing of some vital data thereby utilizing the introduced model in the relation between AFIs and criteria can be considered as a nonlinear function.

The model can be extended to be used for any number of inputs, where expanding the classic models to more inputs is not an easy task. This methodology provides

Table 7. Crisp utility of AFLs.

A1	A2	A3	A4	A5	A6	A7	A8
0.5172	0.5040	0.5013	0.5436	0.5243	0.4475	0.5529	0.5387
A9	**A10**	**A11**	**A12**	**A13**	**A14**	**A15**	**A16**
0.4809	0.4977	0.5216	0.4434	0.3796	0.5450	0.5230	0.4938

Table 8. Areas for Improvement ranking.

Number of AFIs	Area for improvement	Utility	Rank
A7	Customer relationship Management(CRM)	0.5529	1
A14	Strategic human resources planning	0.5450	2
A4	After sales service	0.5436	3
A8	New product development	0.5387	4
A5	Balanced Scorecard (BSC)	0.5243	5
A15	Reward system	0.5230	6
A11	Technology management	0.5216	7
A1	Effective Marketing research	0.5172	8
A2	Effective Strategic planning	0.5040	9
A3	Cost Reduction(ABC)	0.5013	10
A10	Total preventive maintenance(TPM)	0.4977	11
A16	Implementation of effective MIS	0.4938	12
A9	ERP	0.4809	13
A6	Knowledge management	0.4475	14
A12	TQM	0.4434	15
A13	Human resource financial compensation	0.3796	16

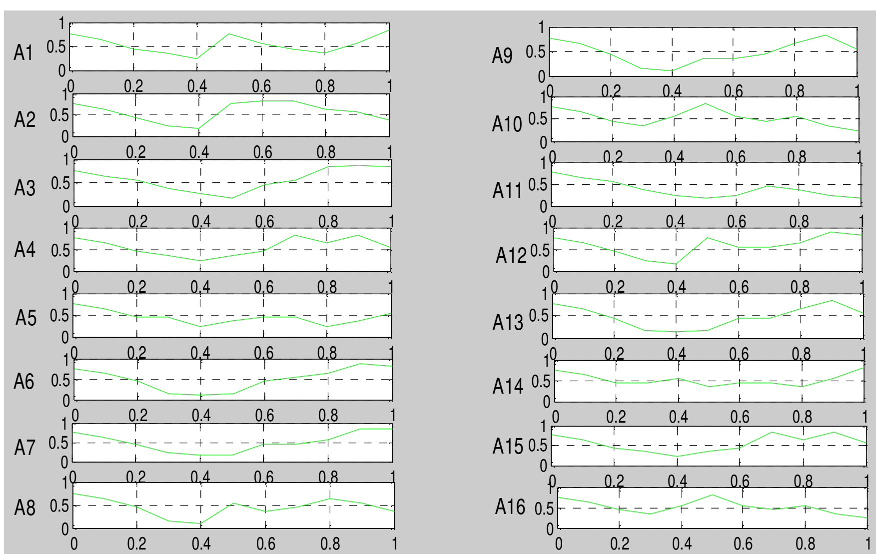

Figure 4. Utility of AFIs.

more informative and reliable analytical results. It also facilitates rapid decision making for managers. The model can facilitate systematic continuous quality improvement; it provides the means for manager to devise an improvement plan. Further research is necessary to develop other models and compare the efficiency of different models for best selection of AFIs in EFQM.

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REFERENCES

Antunes G, Pires A, MacHado V (2008). Ecomomics aspects of quality and organizational performance - A study in Setbal care homes for elderly persons. Total Qual. Manage. Bus. Excel., 19(1-2): 79-88.

Anyamele SC (2005). Implementing quality management in the University: The role of leadership in Finnish Universities. High. Educ. Eur., 30(3-4): 357-369.

Anyamele SC (2007). Applying leadership criterion of the European excellencemodel for achieving quality management in higher education institutions. Acad. Leadersh., 5(2).

Bak P, Bocker B, Muller, WD, Lohstrater A, Smolenski UC (2004). Certification and accreditation systems as an instrument of quality management in the rehabilitation (part 2) - 14(6): 283-290.

Balague N (2007). Quality improvement in university libraries: Evaluations, quality seals, diplomas and certifications. 16(4): 338-342.

Bezdek J (1981). Pattern recognition with fuzzy objective function algorithms: Kluwer Academic Publishers Norwell, MA, USA.

Bi R, Wei J (2008). Application of fuzzy ANP in production line selection evaluation indices system in ERP.

Bou-Llusar JC, Escrig-Tena AB, Roca-Puig V, BeltraÌ n-MartiÌ I (2009). An empirical assessment of the EFQM Excellence Model: Evaluation as a TQM framework relative to the MBNQA Model. J. Oper. Manage., 27(1): 1-22.

Calvo-Mora A, Leal A, Roldan JL (2005). Relationships between the EFQM model Criteria: A study in Spanish universities. Total Qual. Manage. Bus. Excel., 16(6): 741-770.

Calvo-Mora A, Leal A, Roldan JL (2006). Using enablers of the EFQM model to manage institutions of higher education. Qual. Assurance Educ., 14(2): 99-122.

Cheng J, Lee C, Tang C (2009). An application of fuzzy Delphi and fuzzy AHP on evaluating wafer supplier in semiconductor industry. WSEAS Transact. Inform. Sci. Appl., 6(5): 756-767.

Chevrie F, Guely F (1998). Fuzzy Logic: Schneider-Electri Cahier Techniques No. 191.

Conti TA (2007). A history and review of the European Quality Award Model. TQM Mag., 19(2), 112-128.

Davies J (2008). Integration: Is it the key to effective implementation of the EFQM Excellence Model? Int. J. Qual. Reliability Manage., 25(4): 383-399.

Didehkhani H, Jassbi J, Pilevari N (2009). Assessing flexibility in supply chain using adaptive neuro fuzzy inference system. Paper presented at the Industrial Engineering and Engineering Management, IEEE International Conference .

Dodangeh J (2006). Master Thesis: Modeling of Fuzzy Balanced Scorecard. Unpublished Master Thesis, I.A.U, Science and Research Branch, Tehran.

Dodangeh J, Jassbi J, Mousakhani M, Anisseh M, Bt. Mohd YR (2008). Priority of strategic plans in BSC model by using of Group Decision Making Model. Paper presented at the 2008 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM.

Dodangeh J, Mojahed M, Nasehifar V (2010). Ranking of Strategic Plans in Balanced Scorecard by Using Electre Method. Int. J. Innov. Manage. Technol., 1(3): 269-274.

Dodangeh J, Yusuff RBM, Jassbi J (2010). Using Topsis Method with Goal Programming for Best selection of Strategic Plans in BSC Model. J. Am. Sci., 6(3): 136-142.

EFQM (1999a). The EFQM Excellence Model. Brussels: Public and Voluntary Sectors, EFQM.

EFQM (1999b). Assessing for Excellence. A Practical Guide for Self-Assessment. Brussels: The European Foundation for Quality Management.

EFQM (2003a). The Fundamental Concepts of Excellence, from www.efqm.org/uploads

EFQM (2003b). Introducing Excellence, from www.efqm.org/uploads

Grabisch M (1996). The application of fuzzy integrals in multicriteria decision making. Eur. J Oper. Res., 89(3): 445-456.

Hennig S, Greiner W (2007). Quality management systems in ambulatory care - A comparison. 12(4): 235-246.

Jassbi J, Radfar R, Babaali R (2009). Modeling based on multi objective decision making for determining of goals' appropriate selection.

Kahraman C (2008). Fuzzy multi-criteria decision making : theory and applications with recent developments. New York: Springer.

Kahraman C, Ruan D, Doan I (2003). Fuzzy group decision-making for facility location selection. Info. Sci., 157: 135-153.

Konar A (2000). Artificial Intelligence and soft computing: Behavioral and Cognitive modeling of the Human brain: CRC.

Kosko B, Burgess J (1998). Neural networks and fuzzy systems. J. Acoustical Society Am., 103: 3131.

Kumar R, Singh A, Tiwari M (2004). A fuzzy based algorithm to solve the machine-loading problems of a FMS and its neuro fuzzy petri net model. Int. J. Adv. Manufact. Technol., 23(5): 318-341.

Li HX, Gatland HB (2002). A new methodology for designing a fuzzy logic controller. Systems, Man and Cybernetics. IEEE Trans., 25(3): 505-512.

Liginlal D, Ow T (2006). Modeling attitude to risk in human decision processes: an application of fuzzy measures. Fuzzy Sets Syst., 157(23): 3040-3054.

Mamdani E (1977). Application of fuzzy logic to approximate reasoning using linguistic synthesis. IEEE Trans. Comput., pp.1182-1191.

Mathworks (2010). Natick, MA: Mathworks, from http://www.mathworks.com

McCarthy G, Greatbanks R, Yang JB (2002). Guidelines for assessing organisational performance against the EFQM Model of Excellence using the Radar Logic. Working Paper Series, pp. 1-18.

McNeill F, Thro E (1994). Fuzzy logic: a practical approach: Academic Press Professional, Inc. San Diego, CA, USA.

Pedrycz W (1995). Fuzzy sets engineering: CRC.

Ross JT (2004). Fuzzy Logic with Engineering Applications (2 ed.). University of New Mexico, USA: John Wiley and Sons

Rusjan B (2005). Usefulness of the EFQM excellence model: Theoretical explanation of some conceptual and methodological issues. Total Qual. Manage. Bus. Excel., 16(3): 363-380.

Sugeno M (1985). Industrial applications of fuzzy control. Amsterdam; New York; New York, N.Y., U.S.A.: North-Holland ; Sole distributors for the U.S.A. and Canada, Elsevier Science Pub. Co.

Tanaka K (2002). Stability and stabilizability of fuzzy-neural-linear control systems. Fuzzy Systems, IEEE Trans., 3(4): 438-447.

Tari JJ (2008). Self-assessment exercises: A comparison between a private sector organisation and higher education institutions. Int. J. Prod. Econ., 114(1): 105-118.

Tari JJ, De Juana-Espinosa S (2007). EFQM model self-assessment using a questionnaire approach in university administrative services. TQM Mag., 19(6): 604-616.

Terano T, Asai K, Sugeno M (1992). Fuzzy systems theory and its applications: Academic Press Professional, Inc. San Diego, CA, USA.

Vernero S, Nabitz U, Bragonzi G, Rebelli A, Molinari R (2007). A two-level EFQM self-assessment in an Italian hospital. Int. J. Health Care Qual. Assur., 20(3): 215-231.

Wah B, Li G (2002). A survey on the design of multiprocessing systems for artificial intelligence applications. Systems, Man and Cybernetics, IEEE Trans., 19(4): 667-692.

Weggeman MP, Groeneveld, MJ (2005). Applying the business excellence model to a research organization. Res. Technol. Manage., 48(4): 9-13.

Yager R (1983). Some relationships between possibility, truth and

certainty. Fuzzy Sets Syst., 11(1-3): 135-149.
Zadeh L, Fu K, Tanaka K, Shimura M, Negoita C (2007). Fuzzy Sets and Their Applications to Cognition and Decision Processes. Systems, Man and Cybernetics, IEEE Trans., 7(2): 122-123.
Zimmermann HJ (1996). Fuzzy set theory and its applications. Boston [u.a.]: Kluwer.