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Full Length Research Paper

Assessment system based on fuzzy scoring in European Foundation for Quality Management (EFQM) business excellence model

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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 one. The organizational self-assessment process is an admissible system in the area of Total Quality Management (TQM). Most specialists concur to the description of self-assessment that is presented by the European Foundation for Quality Management (EFQM). However, the current self-assessment methods in EFQM model have some drawbacks and problems which are scoring in these methods influenced by experts' judgment and thus, are subjective. Furthermore, these methods cannot consider the empirical investigation and expert knowledge in scoring and also they cannot convert uncertain and imprecise data (linguistic variables) to crisp data. Since Artificial Intelligence models such as Fuzzy Logic can solve the uncertainties and complexity in assessment system, a new assessment system for EFQM evaluation will be designed using fuzzy logic. The proposed assessment system can provide an effective and precise scoring, simultaneously considering knowledge and experience of experts and assessors. The results showed that the new comprehensive developed model is more valid and acceptable and the experts verified the model for assessing based on EFQM in practice. The developed model was used in a case study and results drawn out from it were evaluated from distinctive viewpoints.

Key words: European quality award, European Foundation for Quality Management, business excellence model, area for improvement, fuzzy logic, assessment system, self-assessment.

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 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 as a:

1. Tool for Self-Assessment
2. Way to Benchmark with other organizations
3. Guide to identify areas for Improvement
4. Basis for a common Vocabulary and a way of thinking
5. Structure for the organization's management system

The EFQM Excellence Model is a non-prescriptive framework based on some criteria. Five of these are 'Enablers'

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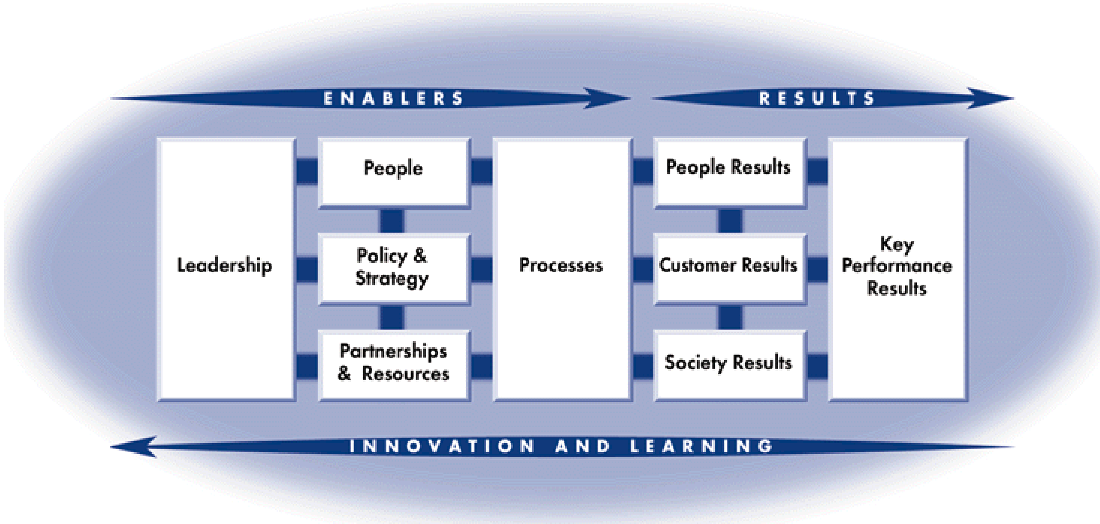

Figure 1. EFQM Model. Source: EFQM (2003a,b).

(leadership, policy and strategy, people, partnerships and resources and processes describe how things are done in the organization) and four 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 has 500 points (50%) and Results has 500 points (50%) (Vernero et al., 2007). These approaches assess the organization regularly and simply which 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 assessing and it is necessary to develop assessment 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 conventional assessment approaches. According to problems and weaknesses for assessing 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. This paper presents a fuzzy rule base system for scoring of sub-criteria and criteria in EFQM model. Its contribution is seen by using the fuzzy rule base system for scoring of the sub-criteria and criteria 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 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 Figure 1. The arrows emphasize the dynamic nature of the Model. They show innovation and learning helping to 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 nine criteria has a definition, which explains the high level meaning of that criterion.

To develop the high level meaning further each a 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, 1999b, 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 nine 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, nine criteria need to be assessed to generate a final score. Furthermore, there are 32 sub-criteria available under the nine criteria and many areas to address. Therefore, the EFQM excellence model is structured into three 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 is 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).

Self-assessment is recognized as an essential incentive for growing performance in a company and is a principal concept of the EFQM Excellence Model. Large numbers of companies that apply the Model employ it as a means of discovering where they are now, regarding where they need to enhance, and subsequently deciding on how to reach there. This is displayed clearly in Figure 2.

Self-assessment is a way of searching across an organization in a particular point in time to ensure where it is in dealing with obtaining its performance outcomes. In the first steps, self-assessment can be employed as a soundness examination which is a commencing point for centering consideration and action.

It is identified that assessment against all nine criteria is both advantageous and recognized as excellent management operation. Companies that are seeking for the European Quality Award has to indicate proof in every criterion part areas. Nevertheless, the fundamental aim of self-assessment is to recognize an organizations strengths and areas for improvement and to progress action plans to enhance organizational performance (EFQM, 1999b), as demonstrated in Figure 3.

EFQM is 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 organization for instance, universities, hospitals, industrial organizations 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, 1999b, 2003a, 2003b; 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

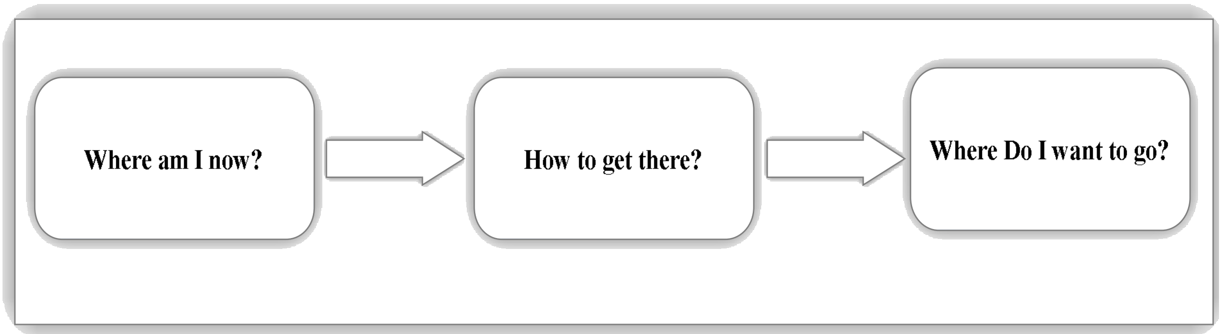

Figure 2. Simple assessment concept (EFQM).

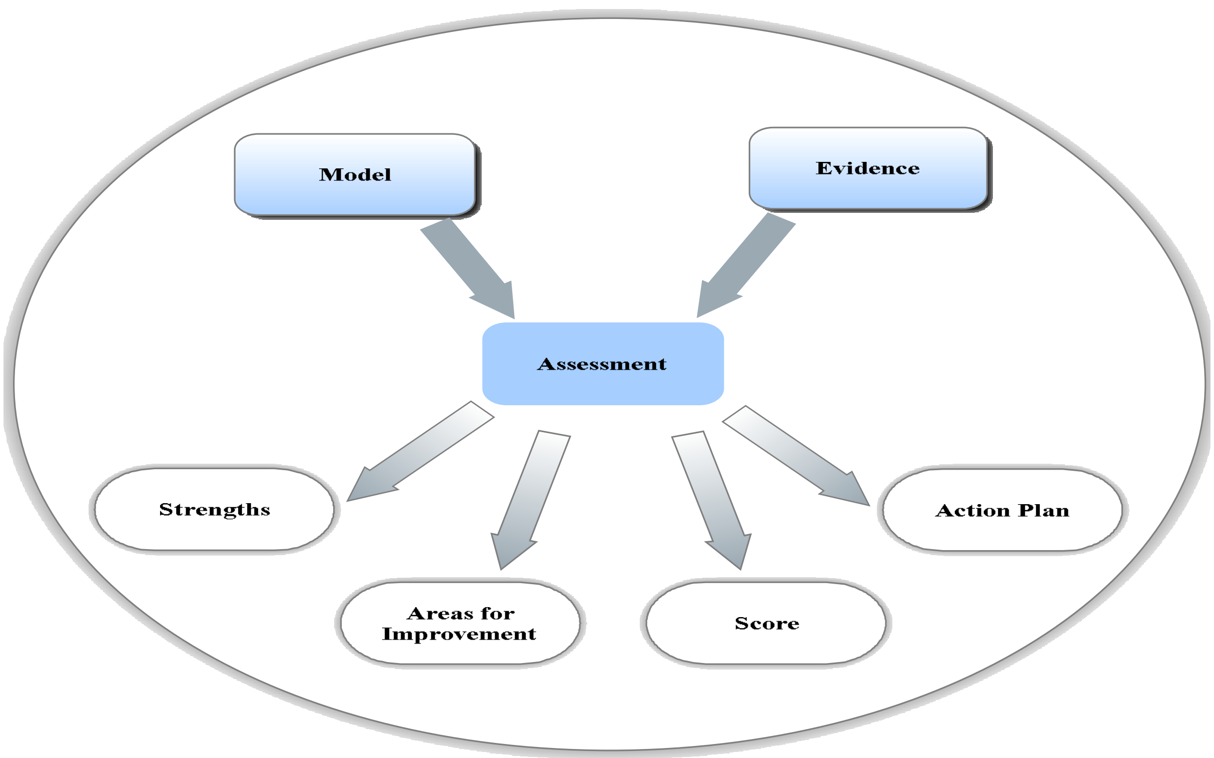

Figure 3. The inputs and outputs of a self-assessment process. Source: EFQM (1999b).

particularly in making statement about possible future events (McNeill and Thro, 1994). In 1965, Professor Lotfi Askar Zadeh the lecturer in 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 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; Pedrycz, 1995) in fuzzy neural nets, Bezdek in pattern classification (Bezdek, 1981) and Zimmerman (1996) 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 a 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

Modeling procedure

Step 1

Firstly, after studying of background and literature review related to topic, the EFQM model is broken down in two levels: 1- EFQM Criteria 2- EFQM sub-criteria which shown as Figure 4 (Li and Yang, 2003).

In this research a fuzzy model based on fuzzy inference system is introduced for assessing EFQM by considering different factors. A fuzzy inference system (FIS) is a rule based system with concepts and operations associated with fuzzy set theory and fuzzy logic. These systems are mapped from an input space to an output space. Therefore, they allow constructing structures to be used to generate responses (outputs) by certain simulations (inputs) based on the stored knowledge of how the responses and simulations related. The knowledge is stored in the form of a rule base, i.e. a set of rules that express the relation between inputs of a system and expected outputs. The first step to construct a fuzzy model is to select a membership function for each variable. A "membership function" is a curve that defines how the value of fuzzy variable is mapped to a degree of membership between 0-1.

Membership functions are used to calculate the degree of fuzzy EFQM assessment in different values expressed by linguistic term such as Extremely Low, Very Low, Low, Slightly Low, Medium, Slightly High, High, Very High, and Extremely High, as Table 1.

Bell shape membership function (medium scale) has been used regarding Figure 5 and Equation 1.

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

Where, XЄ [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 assessing sub-criteria and criteria in EFQM and d determines the shape of the membership function (here d = 0.2).

Step 2

This step is to capture knowledge of decision team (Managers and Assessors). Perhaps the most common way to represent human knowledge is to form it into natural language expressions in the form of IF premise (antecedent), THEN conclusion (consequent) The form in expression is commonly referred to as the IF-THEN rule-based form; this form is generally referred to as deductive form. It typically expresses an inference which says if we know the fact (premise, antecedent), then we can infer or derive another fact (conclusion).This form of knowledge exists entirely in the context of linguistics because it expresses human empirical and heuristic knowledge in of our own language of communication. To do this step, the verbal options of experts regarding the effects of different factors such as sub-criteria 1a, 1b … has been gathered and

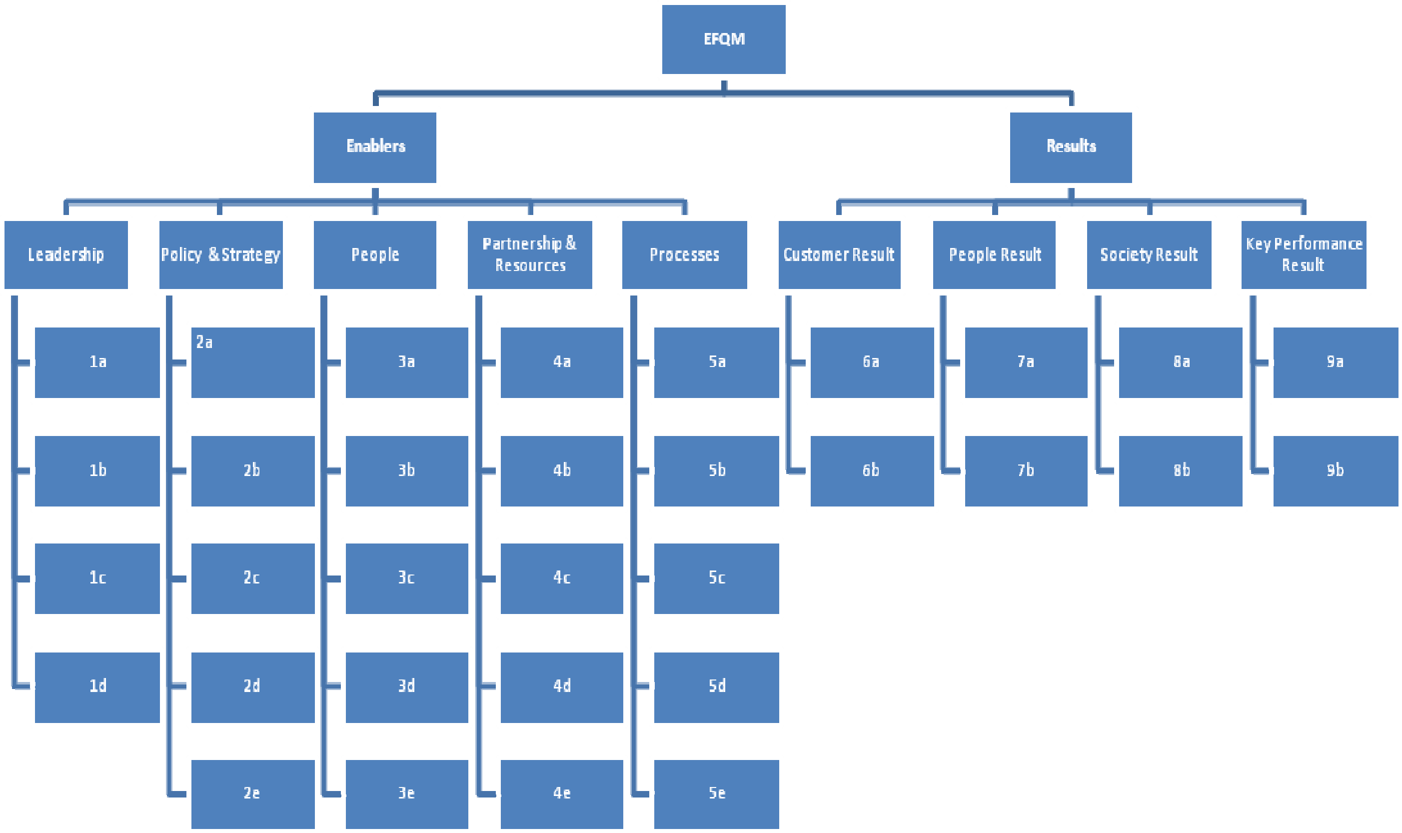

Figure 4. EFQM breakdown model.

Table1. 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

processed for generating a rule base and using them as inputs of the fuzzy inference system and after that aggregated for determining the final score of criteria, for instance, the aggregation of leadership sub-criteria has been shown in Figure 6. For instance, the following set of rules has been used for leadership criteria:

If 1a is Medium and 1b is low and 1c is very high and 1d is high then leadership score is slightly high.

Step 3

In this step, we need an algorithm to aggregate the result of the rules to derive final assessing. The process of deriving overall conclusion from the individual consequents contributed to each rule in the rule base is known as aggregation of the rules. We use Mamdani approach for aggregating rules and it depicted as Figure 7 (Ross, 2004).

Step 4

In the last step, with employing centre of gravity method fuzzy outputs of sub-criteria assessing transform to crisp utility with regards to Equation 2 (Dodangeh 2006; Dodangeh et al., 2008; 2010).

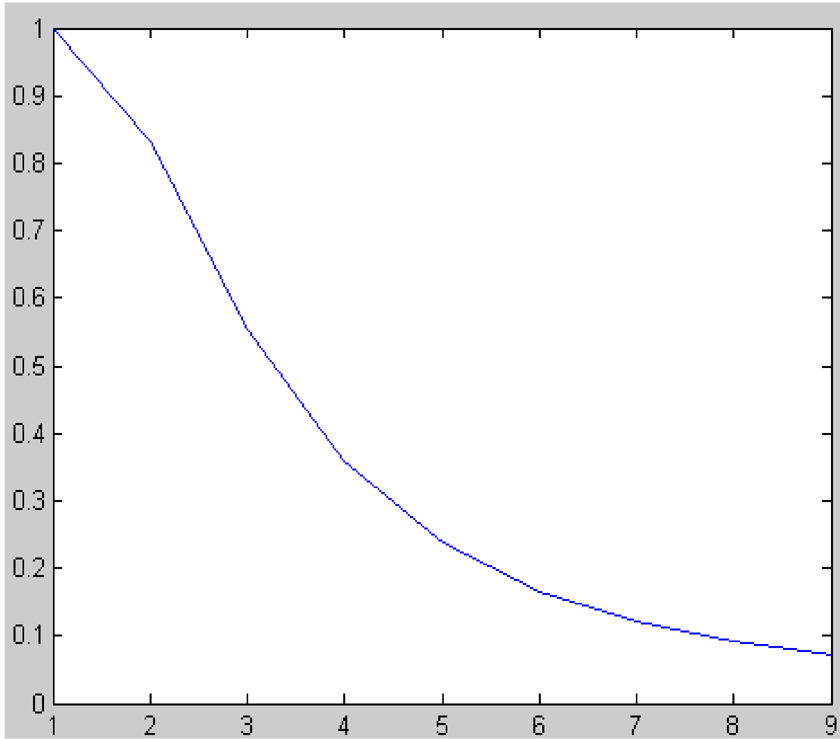

Figure 5. Bell shape membership function (medium scale).

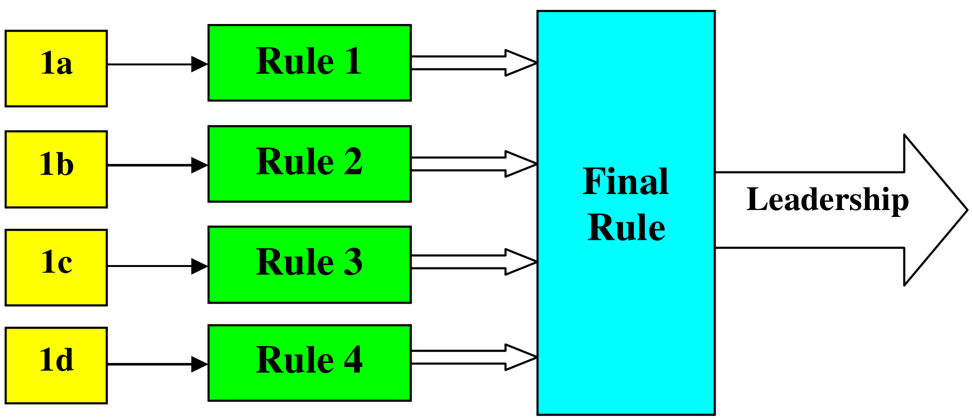

Figure 6. Aggregation of sub-criteria for determining the final score of leadership criteria.

$$Z^{*} = \frac{\sum_{j=1}^{n} \mu_A(x_j).\, x_j}{\sum_{j=1}^{n} \mu_A(x_j)} \quad (2)$$

RESULT

A case study was conducted in a mega car manufacturing which is produce trucks including tractor, construction, distribution and utility trucks and passenger vehicles (Minibuses). The assessors' team comprising lead assessor and two assessors is 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 regarding to experts opinion and the consensus of their opinions, the linguistic assessment based on sub-criteria and criteria of EFQM is determined based on Table 2. And the fuzzy values are calculated by the bell shape function regarding Equation 1.

In this work four sub-criteria of leadership criteria based

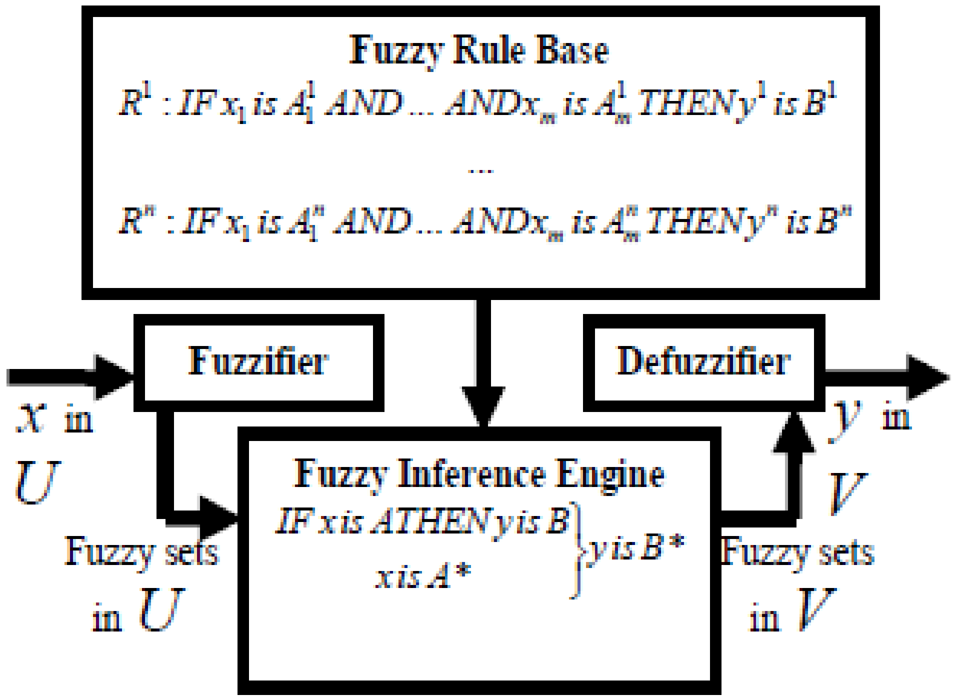

Figure 7. Schematic diagram of Mamdani fuzzy inference system.

Table 2. Definition of verbal and fuzzy values

Verbal value	Definition	Fuzzy value
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	$EH: \left\{\frac{0.072}{1}, \frac{0.092}{2}, \frac{0.122}{3}, \frac{0.166}{4}, \frac{0.238}{5}, \frac{0.357}{6}, \frac{0.55}{7}, \frac{0.83}{8}, \frac{1}{9},\right\}$

on EFQM model will be considered as the input data as shown in Table 3.

So fuzzy rules is determined (Mamdani approach for aggregating rules) with use of experts' knowledge as follows:

If 1a is VL and 1b is SL and 1c is M and 1d is EL then score is L

If 1a is M and 1b is SL and 1c is SH and 1d is M then score is M

If 1a is SH and 1b is M and 1c is H and 1d is H then

Table 3. Sub-criteria of leadership and definition based on EFQM.

Sub-criteria of leadership	Explanation
1a	Leaders develop the mission, vision, and values and are role models of a culture of excellence.
1b	Leaders are personally involved in ensuring the organization's management system is developed, implemented, and continuously improved.
1c	Leaders are involved with customers, partners, and representatives of society.
1d	Leaders motivate, support, and recognize the organization's people.

R1:

$$\begin{pmatrix} 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.1667 & 0.1220 \\ 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.2381 & 0.1667 & 0.1220 \\ 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.3571 & 0.2381 & 0.1667 & 0.1220 \\ 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.2381 & 0.1667 & 0.1220 \\ 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.1667 & 0.1220 \\ 0.1667 & 0.1667 & 0.1667 & 0.1667 & 0.1667 & 0.1667 & 0.1667 & 0.1667 & 0.1220 \\ 0.1220 & 0.1220 & 0.1220 & 0.1220 & 0.1220 & 0.1220 & 0.1220 & 0.1220 & 0.1220 \\ 0.0926 & 0.0926 & 0.0926 & 0.0926 & 0.0926 & 0.0926 & 0.0926 & 0.0926 & 0.0926 \\ 0.0725 & 0.0725 & 0.0725 & 0.0725 & 0.0725 & 0.0725 & 0.0725 & 0.0725 & 0.0725 \end{pmatrix}$$

After calculating the equation in the foregoing, the final rule (R) becomes:

$$\begin{pmatrix} 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.2381 & 0.1667 \\ 0.3571 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.3571 & 0.2381 & 0.2381 \\ 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.3571 & 0.3571 & 0.2381 \\ 0.3571 & 0.3571 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.3571 & 0.3571 \\ 0.2381 & 0.3571 & 0.5556 & 0.8333 & 0.8333 & 0.8333 & 0.5556 & 0.5556 & 0.3571 \\ 0.2381 & 0.3571 & 0.5556 & 0.5556 & 0.8333 & 0.8333 & 0.8333 & 0.5556 & 0.5556 \\ 0.2381 & 0.3571 & 0.3571 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 & 0.5556 \\ 0.2381 & 0.2381 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 & 0.3571 \\ 0.1667 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 & 0.2381 \end{pmatrix}$$

score is SH
If 1a is H and 1b is VH and 1c is SH and 1d is M then score is H
If 1a is VL and 1b is SL and 1c is L and 1d is EL then score is SL

Then with applying the below equation the rules are aggregated (Mamdani approach for aggregating rules).

$$R = \underset{i=1}{\overset{n}{U}} R_i$$

It is noted that the final rule R behaves as the decision support system (Knowledge base system) that gets the verbal values of sub-criteria of leadership as input data and calculates the score of each sub-criteria (Mendel 2001; Ross, 2004).

The obtained score by each assessor from each sub-criterion is given to final rule as input, using the nine verbal values defined from Extremely Low to Extremely High and accordingly a fuzzy output will result for each sub-criterion. The output of the decision support system represents the fuzzy values of the sub-criteria for Leadership criteria. Base on Equation 2, the center of gravity method is used for the diffuzification of output vales based. Finally, the sub-criteria of leadership based on EFQM are assessed on the basis of certain/classic approach and uncertain /new approach by assessors and Figure 4 compare the results obtained by implementing the introduced model.

DISCUSSION

The result of sub-criteria and criteria assessment by using classical and certain approach can be seen in the Table 4. The classical approach efficiency cannot be

Table 4. Comparison of new and classical assessment system.

Sub-criteria of leadership	Explanation	certain/classical approach	uncertain /new approach
1a	Leaders develop the mission, vision, and values and are role models of a culture of excellence.	50	69.14
1b	Leaders are personally involved in ensuring the organization's management system is developed, implemented, and continuously improved.	40	64.81
1c	Leaders are involved with customers, partners, and representatives of society.	60	67.81
1d	Leaders motivate, support, and recognize the organization's people.	25	51.59

improved by considering available data and knowledge of experts. This is why in real world applications the decision Makers and assessors are not generally satisfied (trust the model) by the results obtained by this method. Moreover, we need the knowledge and experience of expert panels and assessors of organization for assessing the sub-criteria and criteria of EFQM which often are consistent with vagueness and uncertainty inherent in the information. Since there is no proper method for assessing the criteria in imprecise and fuzzy space, the introduced fuzzy based method overcomes the mentioned drawbacks in the EFQM. The presented model has been implemented in a mega car manufacturing and revealed more reliable and acceptable results in practice, for instance the difference between scores of 1c and 1d by using classical/certain method is very high whereas introduced method obtains different scores which are more reasonable and applicable. The model presented in this research has some features including, (1) 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 where by utilizing the introduced model the relation between assessment and variables can be considered as a nonlinear function. (2) 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 more informative and reliable analytical results. It also facilitates rapid assessment and decision making for managers, experts and assessors of organizations. 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 advanced models and compare the efficiency of different models for assessing in EFQM.

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