Conference Paper

# A Fuzzy Logic Model to Enhance Quality Management on R&D Units

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## Abstract

Nowadays, Higher Education Institutions (HEIs), are becoming even more competitive, with the public ones, facing at the same time a greater restriction on public funding. Therefore, HEIs, have to be more effective and more efficient as well, on pursuing their own goals, which includes Research and Development (R&D) units as well. Such demands can be achieved, by enhancing R&D's global performance. Therefore, the use of a framework such as European Foundation for Quality Management (EFQM), can bring value to an organization with the characteristics of a R&D unit. This work presents a new integrated method based on EFQM model, by using Fuzzy Logic, to enhance the organizations' overall performance. The applicability of the proposed approach is demonstrated by a case study in a R&D unit, where an initial performance evaluation takes place, by using RADAR's Logic approach. The proposed method, based on Fuzzy Logic, is then applied, followed by the identification of the strength points as well as the improvement areas, according to the EFQM framework. Then, the improvement actions with high priority are determined, followed by the correspondent action measures.

**Keywords:** Quality management, Fuzzy logic, EFQM

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## 1. Introduction

Nowadays, each organization has to be effective and efficient, in order to gain competitive advantage in a long term. Therefore, and to pursue such purpose, each organization needs to measure its own performance, according to its goals, settled by their correspondent business strategies. This can be done, by using quality management methods, that allows each organization to perform its correspondent self-evaluation.

One of such methods is the European For Quality Management (EFQM). This method arises in 1998, as a Quality Management framework, to attend the purpose referred above. Additionally, to this issue, EFQM also allows the assessment of an organization's overall performance. Therefore, EFQM allows to support organizations, by defining its position in the path of organizational excellence as well as, how far the organization is from its excellence level. This is achieved, through a self-evaluation, performed by the organization, by measuring of its overall performance.

However, and due to the qualitative nature of the EFQM's self-evaluation itself, the assessment framework, don't consider all the issues regarding the problem to be evaluated, which makes it insufficient. One of these issues, is associated with the inaccuracy of information, associated with the decision-agent's preferences, which are somehow subjective, since it is related with each decision-maker. Other related issue points the lack of definition, regarding the decision-agent's own preferences. Furthermore, the Fuzzy nature of the decision phase, allows the decision-agent, to perform its decisions, based on a set of specific values, rather than making its judgements based on interval's values.

Additionally, the results, obtained from the self-evaluation, are partly varied, and also dependent on various perceptions, which makes the score, given by each consultant, sometimes very different from each other. To tackle this problem, Fuzzy Logic is applied, as a useful approach to solve the issues referred above, given the flexibility and robustness achieved through its outputs, which is relevant for a quality manager. Therefore, this study intends to provide a methodology, where Fuzzy Logic is deployed into a self-evaluation process, according to EFQM model.

The contribution of this work is formed by the Fuzzy Logic application into EFQM model, and by the case study itself, given the subject area involved, which is related with the use of Quality Management Models from private organizations (special the industrial ones), in a public Higher Education Institute (HEI). Therefore, this work aims to study the deployment of an EFQM model in the HEI's context, through a R&D unit, and by using Fuzzy Logic. The purpose is to contribute with a practical method, to be deployed into to other performance enhancement situations, and related with the HEI's context. To pursue this purpose, this paper is organized as follows: Section 2 presents the literature review section, while Section 3, describes EFQM model, followed by Fuzzy Logic. On next, Section 4 describes the case study and the problem to solve, which is followed by the proposed method, by starting a performance assessment through the performance of EFQM self-evaluation in two ways; 1$^{st}$ scenario, just only the EFQM self-evaluation approach (i.e., only with RADAR's Logic) and the 2$^{nd}$ scenario, the EFQM model with Fuzzy Logic deployment.

Both results will be compared, and the strength points will be presented, followed by the areas to be enhanced. The necessary actions to improve such areas, will be presented, by showing some examples. The last Section of this work is referred to the conclusions and future work.

## 2. Literature Review

Although the existence of several related works found on literature, most of them are mainly focused on the employment and analysis of EFQM model in several organizations, regarding to different sectors of the economy. One example of EFQM model's employment, is the work from [1], regarding the overall performance in the pharmaceutical firms, where it was identified the strengths, jointly with the areas to improve.

According to the scores obtained, together with the analysis of the strengths and improvement areas, it was prioritized the actions to be carried out. Other works, related to other economic sectors and purposes as well, can be referred here, such as; [2] applied to the tourism sector (hotel industry), where through the EFQM application, it was improved the attendance service, [3] health care organizations, through the improvement of some services, [4] machine industry, [5] components industry, through an EFQM model, integrated to Enterprise Resource Planning (ERP), or even to improve knowledge management ([6]), among others.

The comparison between other quality management systems and the EFQM model, were also carried out. An example is the work of [7], where it's shown an advance demonstrated by using EFQM model over ISO 9000, with regards to the use of innovative work practices ([7]).

Other works combines EFQM model with soft computing approaches in quality management [8], or even hybrid approaches, combining Fuzzy Logic with AHP(Analytic Hierarchy Process) techniques, such as; [9], regarding quality management in certain sectors, [10]regarding applications involving healthcare service quality, [11] regarding the quality of customer service process in insurance. Other works combines EFQM model and Fuzzy logic with other methods, such as the work of [12], which is based on Fuzzy AHP and TOPSIS approaches, the work of [13], which is based in a combination of Fuzzy Logic and AHP to choose ERP systems in textile industry, among others works. There are other fields, where Fuzzy Logic have been employed (e.g. [14-17]). One of such fields is regarding to the EFQM employment in the HEI's [18]. However, this works is normally more focused on the entire HEI's quality management system [18], rather than in just one functional area, such as department, human resources, or even R&D units.Since that each functional unit has different and specific issues to attend (e.g. human resources department), there still exists a lack of some works regarding EFQM employment in some functional areas, which includes R&D units.

# 3. Research Methodology

## 3.1. EFQM framework and RADAR's approach

The EFQM (European Foundation for Quality Management) model, is composed by five criteria, known as “enablers”, and four criteria, known as “results”.

The first 5 criteria are referent to what an organization do, while the second group of four criteria, refers to what an organization gets, through the enabler’s application.

Additionally, the “enablers” criteria, can also be enhanced by using the feedback, obtained from the “results” criteria.

The 1$^{st}$ group (“Enablers”), is formed by “leadership”, “strategy”, “people”, “partnerships and resources”, “processes”, “products & services”, while the second one, (“results”) includes “customer”, “people”, “society”, and “key performance”. In the end, there is a total of 24 sub-criteria, correspondent to “enablers” and 8 sub-criteria, correspondent to “results” [18] (Fig.1).

The purpose of self-evaluation is to find areas to be improved in the organization. It can be chosen to score the result of the self-evaluation, with the scoring method, varying according to the organization preferences. The RADAR expression is resulted from the combination of the words ”Results”, “Approach”, “Deployment”, “Assess” and “Refine” (Fig.2).

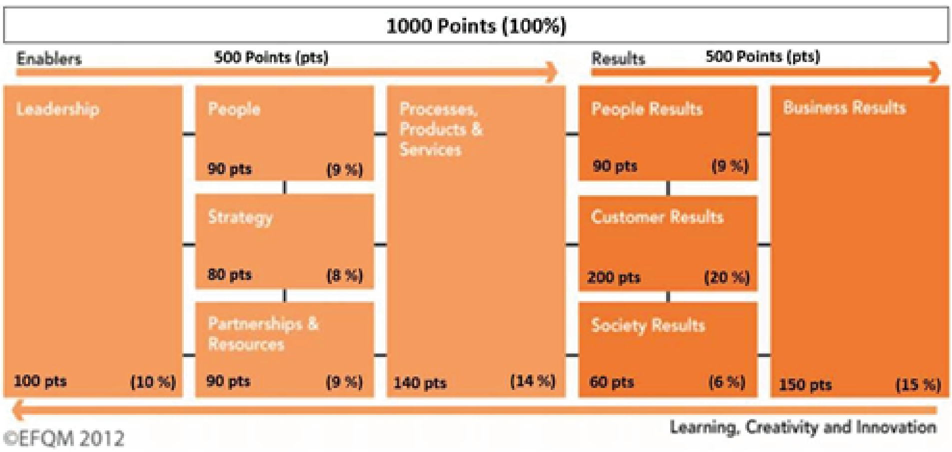


**Figure** 1: EFQM 2013 Model [19]

Based on this assessment matrix, organizations must reach the results that they want to achieve as it being part of their policy and strategy. The achieved results

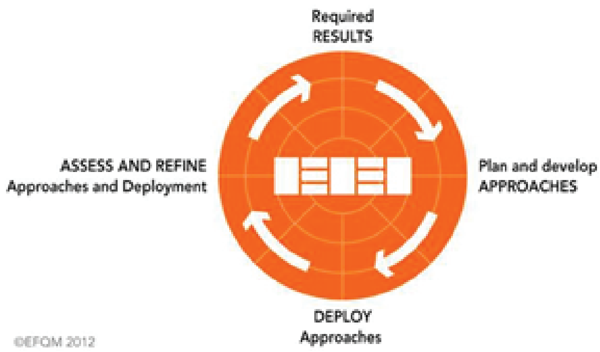


**Figure** 2: The RADAR logic [19]

are related to all dimensions of the model. Organizations are dependent on their own goals to plan systematically the approaches needed to be developed (or deploy) now and in the future. In the end, it is needed to be evaluated and reviewed the implemented approaches, by monitoring the correspondent results. According to these actions, organizations can identify, prioritize, plan and deploy the enhancements where it will be necessary [19-20].

## 3.2. Proposed approach by using Fuzzy Logic

### 3.2.1. Fuzzy Logic

Initially developed by Lotfi Zadeh (1965), it's a theory based on the relative graded membership's concept, being therefore, a theory's set, based on the processes of human perception and cognition [16-18]. The developped theory, allows to deal with information regarding computational perception and cognition. This information is uncertain, imprecise and "half" true [16]. The theory of Fuzzy Logic, allows the inclusion of vague human evaluations in computing problems. Furthermore, its provided an effective way, to solve problems, regarding multiple criteria and better evalution of the different options [18].

A fuzzy set is formed by a group of values, with a continuum of membership grades. Each membership grade, can assume a number between 0 and 1.

Considering a fuzzy subset A, as being part of an universal set X, and defined by a correspondent membership function f(x), which maps each element x in X to a real number [0, 1], when the membership'grade for an element is 1, it means (with certain) that the object belongs to that set. On the other hand, and when the grade of member-ship is 0, it results that the element is not belongging to that set. In cases where exists a certain ambiguity, the correspondent elements, takes values between 0 and 1. Fuzzy Logic also considers mathematical operators in its process. Such operations can include addition, subtraction, multiplication and division, which is applied to the fuzzy groups once it has been formed [17].

### 3.2.2. Proposed approach

The score, presented on EFQM method, can vary from 0% up to 100% (with small steps of 5%) and is deployed regarding each element of sub-criteria, corresponding therefore, to 20 selectable options. It is well-known that all the consultants may not define the same scores, regarding the sub-criteria referred before, which allows the possibility of splitting the obtained scores, into a restricted range.

Based on RADAR's approach, the scoring method was split into 5 different levels, with the number of selectable options, being limited to 5 Fuzzy options, to be chosen by consultants, allowing therefore to reduce the hesitancy, when selecting the suitable score.

Additionally, and considering that the consultant's scores aren't usually definite (although normally closed), by using this approach, their scores, will mainly be similar, making them more realistic. For the definition of the correspondent membership functions, as a first approach it was used triangular functions, since it's widely used on related literature represented by 3 parameters (α, β, γ), according to the relation $\alpha < \beta < \gamma$, with β representing the middle point. The obtained scores can be therefore provided, as a triangular Fuzzy number, whereby consultants, define some scores for the features of sub-criterion elements, by choosing one of 5 Fuzzy sets mentioned (Table 1).

Table 1: Fuzzy sets and membership functions

| Nr. | Cum. Percent. Scoring. | Fuzzy Set | Membership Function [α, β, γ] |
|---|---|---|---|
| 1 | 0 | ("Bad") a small segment of regions/ No evidence | (0,0,25) |
| 2 | 25 | ("Insufficient") limited evidence/≈ ¼ of regions | (0,25,50) |
| 3 | 50 | ("Sufficient") remarkable evidence/ ≈ ½ of regions | (25,50,75) |
| 4 | 75 | ("Good") high evidence/≈ 3⁄4 of regions | (50,75,100) |
| 5 | 100 | ("Very Good") complete evidence/≈ entire region | (75,100,100) |

Based on this table, which is related to the scoring enablers, scores were then assigned as Fuzzy numbers to each feature of RADAR's EFQM logic, i.e., "Results", "Approach", "Deployment", "Assessment" and "Refine". This was made, considering each sub-criterion, criteria and total scores. The obtained scores went through a defuzzification process, by using the centroid method, to produce a quantifiable result into a Crisp value.

The developed model was implemented on MATLAB's software. On Fig.3, can be seen one of the implementations used, related to the Enablers criteria. The same was made for the scoring of "Results" criteria. One of the tables, regarding the scoring of "Enablers" criteria, is presented on Table 2.

The same table was employed to assess each one of the enablers' sub-criteria elements, and it was based on the EFQM's RADAR's approach. All this process was preformed, according to the amount of collected proof, which were identified through the selection one of 5 available options ("Bad", "Insufficient", "Sufficient", "Good" and "Very Good").

The same steps were then preformed, regarding the "Results" criteria. The assessment of each sub-criteria, was preformed, based on the Performance and Relevance & Usability element. This last issue was performed by choosing one of the 5 options, available from the set of presented results ("Bad", "Insufficient", "Sufficient", "Good", and "Very Good").

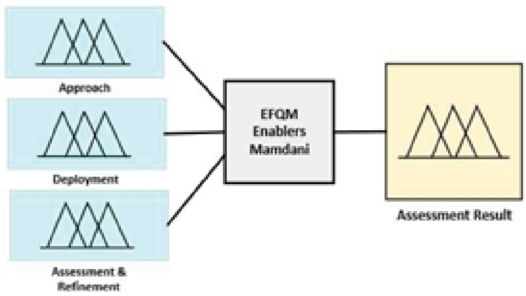


**Figure** 3: Model's deployment on Matlab® software, correspondent to Enablers criteria

# 4. Results & Discussion

## 4.1. Case study & Problem statement

A self-evaluation took place by using EFQM framework, and regarding a Research & Development (R&D) unit, associated to a Portuguese Higher Education Institute (HEI).

This R&D unit has 2 labs, with a total of 16 researchers at the time, where 2 of them were scholars. This unit conducts research in the area of Hydrogen Systems, which brings several needs to be attended by the R&D unit, mainly due to the diversity of

Table 2: One of the proposed scoring, regarding the Enablers criteria

| **Elements** | **Attributes** | **Bad** | **Insuficient** | **Suficient** | **Good** | **Very Good** |
|---|---|---|---|---|---|---|
| Approach | Sound | No evidence | Some evidence | Remarkable evidence | Precise and clear evidence | Complete and compeensive evidence |
| | Integrated | No evidence | Some evidence | Remarkable evidence | Precise and clear evidence | Complete and compeensive evidence |
| Deployment | Implemented | No evidence | Implemented in ¼ of relevant areas | Implemented in ½ of relevant areas | Implemented in ¾ of relevant areas | Implemented in all relevant areas |
| | Systematic | No evidence | Some evidence | Remarkable evidence | Precise and clear evidence | Complete and compeensive evidence |
| Assess and Refine | Measurement | No evidence | Some evidence | Remarkable evidence | Precise and clear evidence | Complete and compeensive evidence |

stakeholders. As a first approach, a 1st self-evaluation was conducted, to assess the organization's performance.

The scores, related to each sub-criterion, criteria and the overall score as well, were calculated according to the scoring table, presented on Table 1.

## 4.2. Unit's performance evaluation

### 4.2.1. Using RADAR's approach method

A self-evaluation was preformed, by using the EFQM award simulation method on the R&D unit, studied in this work. Taken as a first approach, a self-evaluation report was then performed. The achieved scores, related to each sub-criterion and the organization' overall score as well, were then calculated, according to the scoring table, presented on Table 3.

The results expressed before on Table 3, were obtained by an EFQM consultant, who have evaluated the R&D unit' organizational behavior according to the EFQM 9 criteria and (subcriteria as well), whose scoring, were then preformed according to the EFQM RADAR's.

TABLE 3: Self-evaluation for the R&D unit, considering RADAR's approach

| | 1 - Leadership | | 2 - Strategy | | 3 - People | | 4 - Partnerships & Resources | | 5 -Processes, Products & Services | |
|---|---|---|---|---|---|---|---|---|---|---|
| Enablers | 1a | 22 | 2a | 20 | 3a | 20 | 4a | 18 | 5a | 19 |
| | 1b | 22 | 2b | 19 | 3b | 20 | 4b | 20 | 5b | 18 |
| | 1c | 15 | 2c | 15 | 3c | 15 | 4c | 17 | 5c | 17 |
| | 1d | 21 | 2d | 20 | 3d | 20 | 4d | 21 | 5d | 17 |
| | 1e | 19 | | | 3e | 15 | 4e | 19 | 5e | 15 |
| | Total | 99 | Total | 74 | Total | 90 | Total | 95 | Total | 86 |
| | Mean | 19.8 | Mean | 14.8 | Mean | 18 | Mean | 19 | Mean | 17.2 |

| | 6 - Customers | | | | 7 -People | | | | Final Score |
|---|---|---|---|---|---|---|---|---|---|
| Results | 17 | *0.75 | 12.75 | 6a | 18 | *0.75 | 13.5 | 7a | |
| | 16 | *0.25 | 4 | 6b | 19 | *0.25 | 4.75 | 7b | |
| | Total | 16.75 | | | Total | 18.25 | | | |
| | 8 - Society | | | | 9 - Key Results | | | | |
| | 16 | *0.5 | 8 | 8a | 19 | *0.5 | 9.5 | 9a | |
| | 20 | *0.5 | 10 | 8b | 18 | *0.5 | 9 | 9b | |
| | Total | 18 | | | Total | 18.5 | | | 160 |

### 4.2.2. Using Fuzzy approach

In this case, and instead of recurring to an EFQM consultant to evaluate the R&D unit' organizational behavior (as it presented on Table 3), we've decided to ask to a staff member of the R&D unit to, use the Fuzzy approach referred before, to perform the scoring, under EFQM criteria and sub-criteria. The obtained results regarding the criteria, subcriteria and overall score, are presented on Table 4.

TABLE 4: Evaluation for R&D unit by using Fuzzy approach.

| | 1 - Leadership | | 2 - Strategy | | 3 - People | | 4 - Partnerships & Resources | | 5 -Processes, Products & Services | |
|---|---|---|---|---|---|---|---|---|---|---|
| Enablers | 1a | 25 | 2a | 20 | 3a | 20 | 4a | 25 | 5a | 24 |
| | 1b | 13 | 2b | 24 | 3b | 20 | 4b | 23 | 5b | 20 |
| | 1c | 15 | 2c | 22 | 3c | 15 | 4c | 15 | 5c | 14 |
| | 1d | 25 | 2d | 20 | 3d | 20 | 4d | 23 | 5d | 20 |
| | 1e | 19 | | | 3e | 15 | 4e | 19 | 5e | 15 |
| | Total | 97 | Total | 86 | Total | 90 | Total | 105 | Total | 93 |
| | Mean | 19.4 | Mean | 17.2 | Mean | 18 | Mean | 21 | Mean | 18.6 |

| | 6 - Customers | | | | 7 -People | | | | Final Score |
|---|---|---|---|---|---|---|---|---|---|
| Results | 14 | *0.75 | 10.5 | 6a | 18 | *0.75 | 13.5 | 7a | |
| | 16 | *0.25 | 4 | 6b | 19 | *0.25 | 4.75 | 7b | |
| | Total | 14.5 | | | Total | 18.25 | | | |
| | 8 - Society | | | | 9 - Key Results | | | | |
| | 17 | *0.5 | 8.5 | 8a | 23 | *0.5 | 11.5 | 9a | |
| | 21 | *0.5 | 10.5 | 8b | 20 | *0.5 | 10 | 9b | |
| | Total | 19 | | | Total | 21.5 | | | 167 |

They are respectively correspondent to "Enablers" and "Results" EFQM's criteria. On Fig. 4, it's presented the difference obtained between the two scoring methods used. This includes the scores regarding criteria, sub-criteria and overall score. At first glance, and based on the results presented on Fig.4, the difference between both approaches is small. This difference is even clearer, when we compare the total scores from both methods (Tables 3 and 4, respectively). Regarding the obtained scores, correspondent to each sub-criteria, the biggest difference noticed, comes from “Results-Society” (Fig.4), where there is relative difference of about 10 percentual points between both values, correspondent to each approach, which makes the difference between both methods almost neglectable.

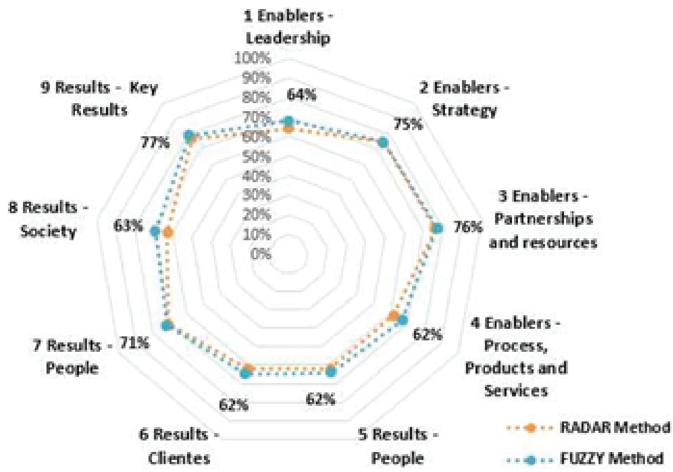


**Figure** 4: Results from the two approachs, used to evaluate the R&D unit, according to EFQM method

## 4.3. Strength points and areas to be improved

### 4.3.1. Definition and planning of the actions, used to improve

From the employment of the EFQM model, has resulted a set of strength points, as well as a set of improvement areas, both, based on the scores, obtained from the EFQM sub-criteria. Furthermore, some forms were distributed to a set of elements involved in the process, to achieve some relevant opinions and also to support the extraction of the strength points, based on the score obtained before. The elements involved on EFQM evaluation, were, the R&D collaborators of the unit and the external consultants, jointly with the Quality Management Office of the HEI where the unit is associated. After some meetings taking place, between these elements, it was identified the strength points, as well as the improvement areas.

### 4.3.2. Improvement actions

Obtained the areas for improvement, it was considered sub-criteria of 1b, 4c, 5c, 6a and 8b to define the correspondent improvement actions, where 5 actions took place (Table 6).

Related to each improvement action, defined through the application of EFQM's self-evaluation method, it was designed an action plan. This document includes issues like, the average time needed to deploy the improvement action, the phases of the implementation to be carried out, and the correspondent method of implementation, regarding each phase to be consider, as well as each improvement action to be consider. An example of such improvement action to be implemented, is presented next:

- Action plan, with regards to the Improvement Action Nr.5 – Goal: Promoting the increase of the efficiency through the reduction of associated costs with the unit (including labs) to respond to the new challenges, i.e.: in the field of knowledge's transmission and in the field of technology transfer.

implementation plan with 4 phases, i.e.; 1$^{st}$ Phase –Team formation, 2$^{nd}$ Phase – Definition of the areas where to reduce the cost associated, 3$^{rd}$ Phase – Results' analysis and the 4$^{th}$ Phase – Final report with conclusions. A period of 4 months was also stablished, as a deadline to implement the improvement action considered above.

Table 5: Improvement actions for each criteria and sub-criteria considered

| Action Nr | Criteria | Sub-criteria | Improvement Actions |
|---|---|---|---|
| **1** | **1** | b | Implementation of self-evaluation model |
| **2** | **4** | c | Implementation of sheets with instructions, regarding the use of the equipment, as well as the correspondent maintenance plan |
| **3** | **5** | c | Development of new channels for the dissemination of activities of the R&D unit (creation of website and Facebook page) |
| **4** | **6** | a | User satisfaction degree, measured by survey |
| **5** | **9** | a | Establishment of an annual goal, regarding the number of equipment that can be simultaneously applied in the research context, as well as on class |

## 5. Conclusions & Future Work

This work has presented an integrated approach, through the deployment of an EFQM model, whose decision-agent decisions, were supported by Fuzzy Logic, in order to improve the overall performance of a Research and Development (R&D) unit, associated to a public Higher Education Institute (HEI).

During the EFQM deployment, self-evaluation was carried out by using two different approaches to score sub-criteria, namely; RADAR's approach (Logic) and Fuzzy Logic approach.

Strength points, jointly with the improvement areas, were then identified, to establish the improvement actions. After the establishment of the improvement actions, correspondent each one, to each area to be improved, a set of correspondent action plans, was designed to be further implemented. The use of EFQM Model, when integrated with Fuzzy Logic to evaluate R&D units, has revealed to be a practical method to carry out a self-evaluation in other R&D units, to enhance their own performance, which can be done, by identifying improvement areas, followed by the correspondent actions of improvement.

One of future developments, that can be carry out, to integrate and improve the proposed approach, is the combination of Fuzzy Logic with multi criteria methodologies, such as ELECTRE, TOPSIS, among others. The aim of this integration would be to improve the method presented in this work, by prioritizing the improvement areas, as well as their actions, according to a set of criteria, previously established.

## References

[1] Dadfar, H., Dahlgaard, J. J., Afazeli, S., & Brege, S. (2015). Quality, export and domesticmarket performance: The case of pharmaceutical firms in Iran. Total QualityManagement & Business Excellence, 26(9–10), 938–957.

[2] A. Bayo-Moriones, J. Merino-Díaz-de-Cerio, S.A. Escamilla-de-León, R. Mary Selvam, The impact of ISO 9000 and EFQM on the use of flexible work practices, Int. J. Prod. Econ. 130 (2011) 33–42.

[3] J.M. Moreno-Rodriguez, F.J. Cabrerizo, I.J. Pérez, M.A. Martı´nez, A consensus support model based on linguistic information for the initial-self assessment of the EFQM in health care organizations, Expert Systems with Applications, Volume 40, Issue 8, 2013, Pages 2792-2798, ISSN 0957-4174, https://doi.org/10.1016/j.eswa.2012.11.011.

[4] J. Nazemi, *A process model for improvement through EFQM*, World Appl. Sci. J. 8 (3) (2010) 279–287.

[5] Abreu, A. & Santos, R., A study on the feasibility of implementing a quality management system, based on the European for Quality Management (EFQM) model

in a School of Engineering. Millenium, 2(9), (2019) 25-38. DOI: https://doi.org/10.29352/mill0209.02.00232

[6] R. Shafaei, N. Dabiri, An EFQM based model to assess an enterprise readiness for ERP implementation, J. Ind. Syst. Eng. 2 (1) (2008) 51–74.

[7] K. Shahroudi, The application of data envelopment analysis methodology to improve the benchmarking process in the EFQM business model – case study: automotive industry of Iran, Iran. J. Optim. 1 (2009) 243–265.

[8] M. Godoy Simoes, M. Friedhofer, *An implementation methodology of a Fuzzy based decision support algorithm*, Int. J. Knowl. Based Intell. Eng. Syst. 1 (4) (1997).

[9] N. Salehi, M. Ghajar Sepanlou, B. Jafari Gorzin, An evaluation of soil fertility using soil organic carbon, potassium, phosphorus and salinity factors for rice cultivation by Fuzzy Logic and AHP techniques, Int. J. Agric. Crop Sci. (IJACS) 5 (19) (2013) 2233–2241.

[10] G. Büyükozkan, G. Cifc¸i, S. Güleryüz, Strategic analysis of healthcare service quality using Fuzzy AHP methodology, Expert Syst. Appl. 38 (2011) 9407–9424.

[11] A. Mohaghar, N. Rajabani, M. Karimi Zarchi, M.R. Fathi, Identifying the best method for using knowledge management in supply chain *using Fuzzy Logic*, Int. J. Business Manag. Econ. 1 (1) (2014) 33–39.

[12] Calvo-Mora, A., Navarro-García, A., & Peria˜nez-Cristobal, R. (2015). Project to improve knowledge management and key business results through the EFQM excellence model. International Journal of Project Management, 33(8), 1638–1651.

[13] J.Hosseini Azabadi, Determining of Improvement Projects Based on EFQM Excellence Model in Yazd Regional Electric Co. B.S. Dissertation in Industrial Engineering, Yazd University, Iran, 2006.

[14] H. Singh, M.M. Gupta, T. Meitzler, Z.-G. Hou, K.K. Garg, A.M.G. Solo, L.A. Zadeh, *Real-life applications of Fuzzy Logic*, Adv. Fuzzy Syst. (2013), Special Issue: Real-Life Applications of Fuzzy Logic.

[15] A. Rabbani, M. Molavi, Y. Beigzadeh, Evaluate and rank the performance of total quality management in manufacturing organizations with approach of Fuzzy ANP, Report Opin. 5 (5) (2013) 67–79.

[16] Abreu, A; Martins, José; Calado, João (2018). *A fuzzy reasoning approach to assess innovation risk in ecosystems*; Open Engineering, Open Engineering, 8 (1), pp. 551–561, ISSN (Online) 2391-5439, doi.org/10.1515/eng-2018-0067.

[17] Abreu, A.; Calado, J. M. F. *A fuzzy logic model to evaluate the lean level of an organization*. International Journal of Artificial Intelligence and Applications (IJAIA), Vol.8, No.5, pp.59-75. DOI: 10.5121/ijaia.2017.8505. (2017)

[18] Abreu, A.; Martins, J. D. M.; e Calado, J. M. F. *Fuzzy logic model to support innovation risk assessment in ecosystems*. Proc. of 3th APCA International Conference on Control and Soft Computing (CONTROLO 2018), Ponta Delgada. Açores, Portugal, 4 a 6 de junho, pp. 104-109 (2018)

[19] Simões Santos, Ricardo & João Pina da Costa Feliciano Abreu, António. (2019). *EFQM model implementation in a Portuguese Higher Education Institution*. Open Engineering. 9. 99-108. 10.1515/eng-2019-0012.

[20] Santos, R., & Abreu, *A. Implementation of an EFQM model in a Higher Education Institution in Portugal*. Revista Produção e Desenvolvimento, 5, doi: https://doi.org/10.32358/rpd.2019.v5.365. (2019)

[21] A. Rabbani, M. Molavi, Y. Beigzadeh, Evaluate and rank the performance of total quality management in manufacturing organizations with approach of Fuzzy ANP, Report Opin. 5 (5) (2013) 67–79.