ENGLISH VERSION

An approach fuzzy for self-assessing in micro and small building companies

Un enfoque fuzzy para la autoevaluación en micro y pequeñas empresas de construcción

Welton De França Magalhães [*], Fagner José Coutinho de Melo [**] [1] https://orcid.org/0000-0002-0550-5177,
Denise Dumke de Medeiros [*] http://orcid.org/0000-0001-7927-9021

[*] Universidade Federal de Pernambuco, Pernambuco, Brazil
[**] Universidade de Pernambuco, Pernambuco, Brazil

Fecha de Recepción: 11/08/2020
Fecha de Aceptación: 26/11/2021
PAG 322-341

Abstract

Due to increased competition enterprises have sought alternatives to improve their processes and increase the quality of their products and services. The enterprises of construction sector are related to the buildings construction. They have adopted Quality Management System (QMS) to improve their processes and to fill the demands of the market. Among the existing QMS, the Brazilian Program of Habitat Quality and Productivity (PBQP-H/Siac) has distinguished itself by offering benefits that are favorable to the enterprises in this segment. However, unlike medium and large enterprises, the Micro and Small enterprises (MSEs) have limited financial resources, lack on quality management, and others obstacles. MSEs have fitted their quality implementation to match with the larger construction enterprises, to better competition and to get opportunities in the market. Because of this, the present paper proposes an approach to self-evaluation requirements of PBQP-H/Siac, using fuzzy logic as a measurement tool. The fuzzy logic will formalized the assessed requirement, providing better definition on decision making. The approach exposed as a simulation based on real case to demonstrate their applicability. As a result the approach determines the degree of formalization of the desired level.

Keywords: QMS; PBQP-H/SiAC; Brazilian MSEs; Fuzzy Logic.

Resumen

Debido al aumento de la competencia, las empresas han buscado alternativas para mejorar sus procesos y aumentar la calidad de sus productos y servicios. Las empresas del sector de la construcción están relacionadas con la construcción de edificios. Han adoptado el Sistema de Gestión de Calidad (SGC) para mejorar sus procesos y satisfacer las demandas del mercado. Entre los SGC existentes, el Programa Brasileño de Calidad y Productividad del Hábitat (PBQP-H/Siac) se ha distinguido por ofrecer beneficios que son favorables para las empresas de este segmento. Sin embargo, a diferencia de las medianas y grandes empresas, las micro y pequeñas empresas (MYPE) tienen recursos financieros limitados, falta de gestión de calidad y otros obstáculos. Las PyMEs han ajustado su implementación de calidad para que coincida con las empresas de construcción más grandes, para una mejor competencia y para obtener oportunidades en el mercado. Debido a esto, el presente documento propone un enfoque para los requisitos de autoevaluación de PBQP-H/Siac, utilizando la lógica difusa como herramienta de medición. La lógica difusa formalizará el requisito evaluado, proporcionando una mejor definición en la toma de decisiones. El enfoque expuesto como una simulación basada en un caso real para demostrar su aplicabilidad. Como resultado, el enfoque determina el grado de formalización del nivel deseado.

Palabras clave: SGC; PBQP-H / SIAC; MYPE brasileños; Lógica Fuzzy

1. Introduction

Globalisation and market opening have helped the power of choice and purchase of the population in recent decades. Due to these changes in marketing environments, enterprises of all economic sectors have to be more competitive, especially regarding the quality on their products and services, it must meet the requirements and customer demands in order to survive (Park et al., 2020).

In this context construction enterprises, especially the buildings' construction enterprises have been encouraged to plan, develop and/or implement Quality Management System (QMS), to meet both domestic needs ensuring their business competition (Kahraman and Kaya, 2012); (Silva et al., 2014); (Batista and Medeiros, 2014); (Tokuori, 2014); (Cui, 2015); (Yu et al., 2015); (Marasini et al., 2016); (Akhmetova et al., 2019); (Chen et al., 2020).

Have two ways to implement QMS by the construction enterprises, first was prepared by academics, for example, models of (Willar et al., 2015), (Seth et al., 2015) and (Park et al., 2013); second, by the adoption of professional programs, like the Brazilian Program of Habitat Quality and Productivity Project Evaluation System Services Companies in Compliance and Construction Works in specialty Execution of Works Technique (PBQP-H/SiAC), or Brazilian standard of International Organization for Standardization ISO 9001:2008, or with other sectoral programs.

[1] ***Corresponding author:***
Universidade de Pernambuco, Pernambuco, Brazil
E-mail: Fagnercoutinhomelo@gmail.com

In this sense both systems have been highlighted in the adoption by buildings construction companies, both for allowing recognized certification of the requirements service warranty and customer requirements, which is not recognized by academia: the ISO 9001:2008 and PBQP-H / SiAC (García et al., 2014); (Finger et al., 2015); (Orozco et al., 2018).

Among QMS and PBQP-H/SiAC, presents way some advantages initially be implemented, for example, to allow improving the company QMS with the progress in the program, balancing the demands required with available corporate resources for the flexibility of requirements to be applied in the company and its regulatory framework be evolving character by meeting the requirements levels (Santos and Powell, 2001); (Genaro Chiroli et al., 2015); (Hossain and Ng, 2019).

Another advantage, of PBQP-H/SiAC is the similarity with characteristics of ISO 9001:2008, the enterprises only small additional adjustments to get the certification (Lordsleem and Melhado, 2014); (Díaz et al., 2019). So, it is advantageous to know the level of formalized (documented and implemented), even before the certification itself, that is, conduct a preliminary diagnosis of MSE QMS building front construction to the level of requirements that intends to seek in the program.

In order to know the degree of formalization of the requirements, we use fuzzy logic (Zadeh, 1965), to acess the subjective human answers on their decision making process. Fuzzy sets will become favorable as a measurement tool, because it will allow working satisfactorily aspects of vagueness and imprecision present in human communication and enable a better position the level of formalized requirements by the relevance of the element.

In this way, we search for improvement and development of Micro and Small Enterprises of buildings construction with regard to the requirements of the levels of PBQP-H/SiAC technical expertise. This paper proposes an approach for evaluating the level of requirements intended in PBQP-H/SiAC, using the Fuzzy Logic as a measuring tool.

2. Literature review

In this section, the pertinent issues to be addressed will be addressed, they are the Brazilian Program of Habitat Quality and Productivity (PBQP-H) and the Fuzzy Logic.

2.1 Brazilian Program of Habitat Quality and Productivity (PBQP-H)

PBQP-H project is the System Assessment Services Companies Compliance and Works (SiAC), which according to (Santos and Powell, 2001), (Genaro et al., 2015), and (Hossain and Ng, 2019) is the cornerstone of the program, since it applies the requirements to be met for the QMS certification of the construction company. The purpose of SiAC resides in the conformity of the QMS corporate services and works considering the specific characteristics of the area of operation, aiming at the improvement and evolution of their quality (Ministry of Cities, 2011). It is expected that it will contribute in raising the quality scores through their technical expertise.

The PBQP-H/SiAC is divided into four certification progressive levels (D, C, B and A), where this evolutionary character favors construction enterprises in the improvement of its quality management system on the floor of the program levels greetings, unlike standard ISO 9001: 2008 which is necessary to meet the fulfillment of all requirements at once. The Reference Regulatory of the Brazilian Quality and Productivity Program of Habitat (PBQP-H) in Specialty Execution of Works technique was based on the ISO 9001:2008, so both standards have requirements or eight major sections, of which only five are applicable (the fourth to eighth).

Importantly, the sections 1, 2 and 3 of both standards have general and introductory aspects (Lordsleem and Melhado, 2014), while the other. The fourth until to eighth are the requirements of the Management System. Another important factor to mention is that the PBQP-H/SiAC is modulated into four evolutionary skill levels (D, C, B and A), and the scope of the greetings of the D level requirements, with lower rates of scope, up to level A, covering all requirements.

2.2 The Fuzzy Logic

Classical Logic, also called Western Logic, has been used to classify a statement as 'false' or 'true', and not admitting and/or assuming a possible coexistence of both responses, for example, 'partially true'. That is, it has assumed a binary character in saying whether a statement is totally 'false' or 'true', which has since been represented in the mathematical language by the digits 0 (zero) and 1 (one), respectively (Megahed and Mohammed, 2020).

However, the treatment of these statements in characterizing them in just two extreme responses, contradicts, in a way, with the reality experienced by the human being. Not unlike, human communication is expressed through a non-numerical language, that is, adopting qualitative verbal expressions presenting imprecise, vague, uncertain and ambiguous aspects, which are not satisfactorily translated through the Classical Logic that adopts the concept of bivalence (Aquino et al., 2019).

This form of qualitative communication, (Zadeh, 1975), characterized them as 'linguistic terms', since the values are not expressed in the form of numbers, but rather a set of words associated with responding to a certain qualitative word. Thus, because human reasoning and communication present this state of multivalence, Western Logic becomes unfavorable when trying to translate aspects of human characteristics through a binary system, since it would present gaps, imperfections and interpretation errors when trying handle these qualitative, subjective and vague aspects.

Thus, since its introduction, Fuzzy Logic has been used in several areas of science (exact, human and health) around the world, mainly in the development of analyzes, evaluations, diagnoses, decision making, among others, where it is possible to verify several publications about it (Markiewicz and Muślewski, 2020); (Ahmad et al., 2020).

The applicability of Fuzzy Logic in the areas of engineering is quite common today, especially those focused on the fields of robotics, in the development of Artificial Intelligence, where the use of the diffuse concept has become quite effective in emulating human behavior and reasoning, known in this branch as neural network systems, or neurofuzzy (Awais et al., 2020); (Adedeji et al., 2020). In order to better present the use of the diffuse concept in the various engineering segments, some academic articles covering both words will be exposed below.

(Nguyen et al., 2008) carried out a work whose objective was to present an evaluation method in order to determine the capacity of an Architectural Engineering team to choose the best team to be able to execute a given construction project. The evaluation system consisted of a multi-criterion environment containing subjective and imprecise variables, where the concept of the theory of fuzzy sets was used to work with these data. They obtained as a result that the use of the fuzzy set theory made it possible to work with inaccurate, vague and incomplete information and data, thus providing a better decision making by the contractors in choosing the best company with the risk of failure minimized.

(Rheingantz, 2003) presents a model for evaluating the performance of office buildings using the hierarchical analysis model with Fuzzy Logic. In his analysis, the results of the use of both concepts through a simulation, confirm the applicability and flexibility of the model, allowing, for example, better decision making and a better index of operational systematization of the processes for the evaluation of office buildings.

(Tan et al., 2011) present a fuzzy model to assess the competitiveness of civil construction contractors. They used the Key Competitiveness Indicators with the fuzzy approach to present a Fuzzy Competitiveness Classification applied to a Hong Kong construction industry. As a result, they obtained good indications of applicability, which are valuable to contractors, as it will help them in their strengths and weaknesses in competitiveness and in addition provide contractors with strategies to improve their competitiveness.

Since its introduction, fuzzy logic has been widely used in academic works in several areas besides engineering, such as in the quality area, for example, in the works (Medeiros, 2009); (Ramasamy and Selladurai, 2004) and (Aquino et al., 2019); (Fofan et al., 2019) and in assisting investment decision makers, for example, in the works of (Eraslan and Iç, 2011); (Zandi and Tavana, 2011); (Zou et al., 2020), (Díaz and Nojima, 2020) and (Suh and Kim, 2020).

3. Proposed approach for self-assessment of building construction mses the requirements pbqp-h / siac

In this section, it will present the five phases of the proposed approach for evaluating the MSEs construction of buildings to PBQP-H/SiAC requirements.

3.1 Approach Construction

The approach proposed in this paper for evaluating the company's QMS construction of buildings to the desired level requirements of PBQP-H/SiAC. (Figure 1) discriminated five levels composing the approach and their main actions.

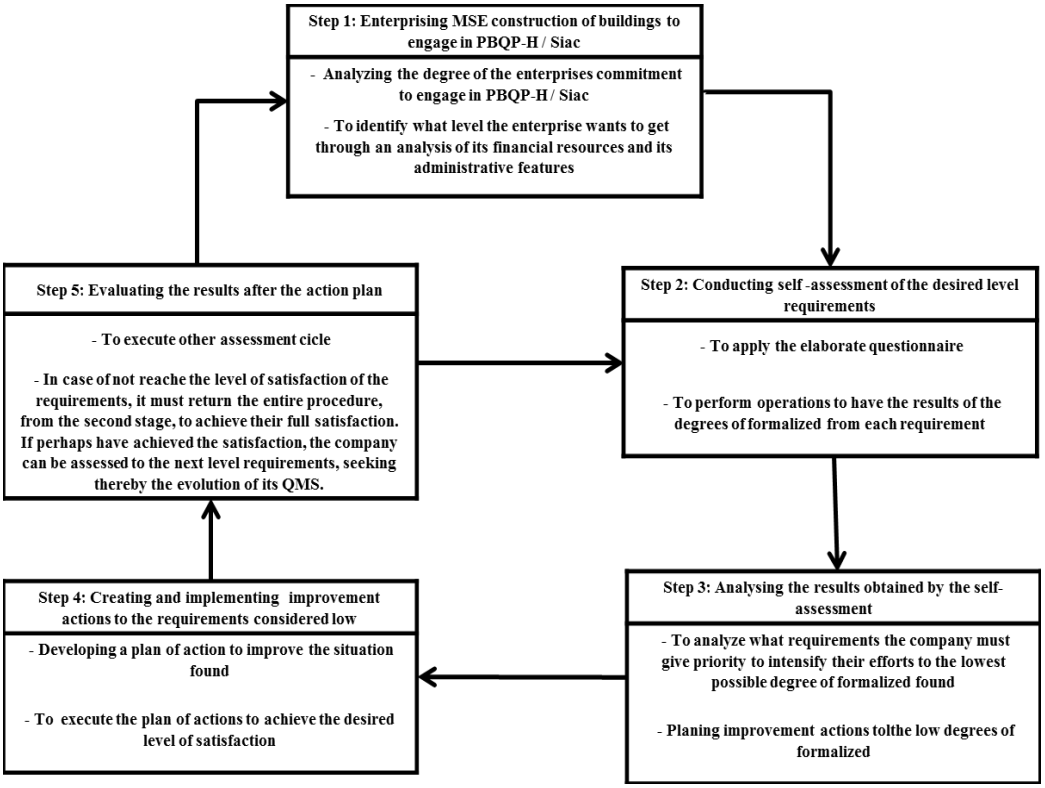

Figure 1. Approach of the proposed framework for evaluating the PBQP-H/SiAC

3.1.1 1ª Step: Enterprising MSE construction of buildings to engage in PBQP-H/Siac

At the initial step, the company construction of buildings must conduct an internal analysis in the search for the level of commitment of its employees in all sectors, from the productive to the administration, to rise to the intention to engage in PBQP-H/SiAC.

After this impairment analysis, we are going to examine what level the manager want to achieve. We need the support of analyzing their financial resources due to the implementation and maintenance of quality management system, and its administrative features, because of the management direction have the necessary specifications for the program of care and the number of workers to be classified as MSE.

3.1.2 2ª Step: Conducting self-assessment of the desired level requirements

At the second step, the company must apply the questionnaire developed in wich each item evaluated their requirement, the manager will respond by marking an 'X' on a scale that ranges from '0' and '10', represented, respectively by 'nothing' and 'totally' two analysis variables that are documented and implemented. For this study is as close to reality, it is essential that the participant who will answer the questions of the items be one company that is better equipped for the productive and administrative activities to review, upon answering the questions, relevance of the items.

After defining the respondent and the questionnaire, then goes to the operations to be achieved the only representative value of the requirement of care, that is, the degree of formalized. The functions pertinence of effort is intended to help the difficulty of meeting certain item. The choice of a particular function that will represent each documented and/or implemented the item. The analysis of each pre-defined concept of each function, when the participant will choose one that considers more representative, this analysis exposes the reality of the company to meet certain variable of the analyzed item.

Operations to achieve only a value that will represent the level requirement must be analyzed and chosen by adjusting to the organizational profile. It is suggested the use of fuzzy aggregation operators since they work with inaccurate or vague aspects of human communication, and after that it makes data closer their reality. So are two

operations to be performed: the first to agglomerate the results of documented and implemented for each item of the requirement, and the second to aggregate the results generated from the first operation, that is, for each item of the requirement in just a single value that will represent.

The construction of the questionnaire came from the fundamental point of this work, namely the level of formalized (documented and implemented) of PBQP-H/SiAC requirements that the company had during his self-assessment to the desired level. The questionnaire was structured in a single piece divided into two items:

- *The first item is the introductory part on the level, and the Fill method to be answered in the self-assessment;*
- *The second item refers to meeting the desired level program requirements, where the participant was asked to express themselves by degrees (zero to ten) the situation in which the construction company was at that moment in meeting requirements on the issue of documentation and implementation.*

With respect to the methodology employed to answer the questions of level requirements, we used the structure of eleven point scale ranging from zero (0) and ten (10), in which only the ends were set their language concepts, adopting 0 (zero) as "nothing", while the ten (10) as 'fully' documented and/or implemented. The participant's office the names of the remaining numbers on the scales.

In order to evaluate the items in each of the desired level requirement, were created in this work calls functions pertinence of effort, aiming at closer, more realistically, the difficulty to meet particular item that is being evaluated. This is because the program is structured in qualification levels, which depending on the level, there may be additions requests in some of the requirement items, leaving their care more difficult, causing thereby a greater effort to run to get your attention. In addition, the intensity of the effort applied to meet a particular item during its initial phase of the implementation is much higher when compared, for example, to meet the same item during its stage of conclusion.

The functions pertinence of effort was created in this work to represent the effort or the difficulty of completing the requested item, totaling in the seven functions. This set of functions presents a gradual process of difficulty, in wich the lower function (F1) will be applied when the effort to perform and complete such item is in a mild character. The highest function (F7) will be applied when it is noted that the effort to meet the requirement of item present more difficulties to be, for example, increases in requests.

Regarding the pertinence of the effort functions, they were developed by the authors of this research together with a specialist in the evaluation of the Quality Management System, where we sought to differentiate them with curves, as they would better represent the application development of the item over time and with the research objectives. Regarding the choice of the effort pertinence function to represent the evaluated item, your choice will depend only on the participant's opinion when analyzing the questioned item with the predetermined application application definitions.

Thus, for the choice of the function that will represent that item in its evaluation, namely, its degree of relevance of the evaluation response in what is documented and / or implemented, it will be up to the individual decision analysis of the participant due, for example, to their future experiences of other companies, their knowledge, etc.

The functions pertinence of effort was structured on three levels and four intensities. The levels, the functions are subject to early efforts during the intermediate process and in the end to complete it, or outlining item developmental stages. As regards intensity, the functions are the subject forms, Little, Moderate, much consideration and in order to delineate under stress, where the former is characterized as the smallest and the latter as the highest intensity, respectively.

The default settings to aid the participant 'which function to use the item' were exposed as well as their ways of effecting it can be seen from (Table 1). After defining each functions pertinence of effort representing a particular issue of an item of the level requirement to be evaluated, it follows to review itself, which through an "X" value will express their agreement of documented and implemented the construction company's QMS is meeting that item. It then passes to the choice of calculations that will add the various sets so that this amount represents only one answer.

Table 1. Function od pertinence, uses and equations

Function of pertinence	Uses	Equation
Function pertinence of effort 1 (F1)	It will be used when the documentation and implementation of the evaluated item requirement need little effort to complete, from its beginning to the end.	$\mu_{F1}(x) = \begin{cases} \frac{3{,}165 * \sqrt{x}}{10}, & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 2 (F2)	It will be used when the documentation and implementation of the evaluated item requirement need moderate effort to complete, from its beginning to the end.	$\mu_{F2}(x) = \begin{cases} (-0{,}0034 * x^2) + (0{,}134 * x), & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 3 (F3)	It will be used when the documentation and implementation of the evaluated item present in its early stages an effort considered, in the intermediate little effort and in the end a considered effort.	$\mu_{F3}(x) = \begin{cases} \frac{3{,}51 * (x-5)^{\frac{1}{3}}}{12}, & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 4 (F4)	It will be used when the documentation and implementation of the evaluated item present in its early stages an effort considered, a moderate effort in the intermediate and end little effort.	$\mu_{F4}(x) = \begin{cases} \left(e^{\left(\frac{-(x-10)^2}{20}\right)}\right), & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 5 (F5)	It will be used when the documentation and implementation of the item evaluated present at an early stage an effort considered, an effort considered in intermediate and in the end a considerate effort.	$\mu_{F5}(x) = \begin{cases} \frac{0{,}1 * (x)^2}{10}, & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 6 (F6)	It will be used when the documentation and implementation of the item evaluated present at an early stage much effort, in the middle a considerate effort and in the end a moderate effort.	$\mu_{F6}(x) = \begin{cases} \left(\frac{1{,}0145}{\left(1 + e^{\left(\frac{x-7}{0{,}7}\right)}\right)}\right), & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$
Function pertinence of effort 7 (F7)	It will be used when the documentation and implementation of the evaluated item present in its early stages at the end be characterized as much effort.	$\mu_{F7}(x) = \begin{cases} \left(\frac{1}{2000} * x^{\left(\frac{5{,}733}{2}\right)} * e^1\right), & \text{if } 0 \le x \le 10 \\ 0, & \text{if } x < 0 \text{ or } x > 10 \end{cases}$

In this step, the fuzzy operators are presented, which were used to affect the aggregation of data obtained in the self-assessment of the QMS for the degree of formalized in the program via a single value of the condition to be studied later. Operators chosen are working on aggregation of data were the aggregations between the degrees of relevance ($\mu.(x)$) documented and implemented and aggregations between items of requirement.

To approximate the actual value without camouflage the difference between the transferred data followed for the use of other fuzzy aggregation operators. So in view of those who would have a better proximity to the value of the degree of QMS formality of the construction company to program requirements, that is, those who could portray with better accuracy the formal status of the company, employment of the two aggregate operators fuzzy, "and" and "compensatory and" have become satisfactory ever employed in this work after a simulation of random data with both types of operators.

However, both operators "and" and "compensatory and" suffered transformations to adapt the study of this work, as described below:

- *The fuzzy aggregation operator of intersection (and or min) will be used to aggregate the degree of relevance of documented and implemented from the functions pertinence of effort. Its transformation into the study environment is described in (Equation 1).*

$$\boldsymbol{\mu_{A\cap B}(x) = \min[\mu_A(x), \mu_B(x)] \rightarrow \mu_{Doc\cap Imp} = \min[\mu_{Doc}(x), \mu_{Imp}(x)]} \quad \textbf{(1)}$$

This operator is considered easy to understand and effective in their calculations, because it will result in the smallest of its intersection relevance assemblies in question.

- *The fuzzy operator "compensatory and" aggregation is used to add the outputs of the intersections of aggregations of items of requirements to obtain the level of formalized requirement. Its transformation into the study environment is described in (Equation 2).*

$$\mu_{A_i.comp}(x) = (\prod_{i=1}^{m} \mu_i(x))^{(1-\gamma)} \left(1 - \prod_{i=1}^{m}(1 - \mu_i(x))\right)^{\gamma} \rightarrow$$

$$\mu_{Formal\ i} = \left(\prod_{i=1}^{m} \mu_{Doc \cap Imp\ i}(x)\right)^{(1-\gamma)} \left(1 - \prod_{i=1}^{m}\left(1 - \mu_{Doc \cap Imp\ i}(x)\right)\right)^{\gamma} \quad (2)$$

The gamma (γ) used in this study was obtained through a simulation of seven random data between the degrees of relevance of 0,600 to 0,900 as a result the value that would be closest to the arithmetic average, this average being the point of reference for the analysis of the range between 0,10 to 0,90.

The results indicated that by adopting the γ=0,85 showed a result that came closest to the reality of the result. Then was established, this value, as the range for this job. The execution of this operator, the aggregate fuzzy "compensatory and", unfolds in the product operator (Π.). Among the membership degrees of the items provided the requirement of intersection between documented and implemented. For this reason, their implementation is also easy to carry out, contributing in this way to people who do not have such an affinity with advanced mathematical calculations and with so much knowledge over cloudy environment.

After the fuzzy operations using the aggregation operators, one passes to step analysis of these results. On the basis of these results, the decision maker, or if the direction of the construction company will have reliable subsidies formalized progress of the state of its QMS to program the desired level requirements to make the necessary improvement actions in time before the external audit certification. To better outline the development of the proposed approach, following the construction enterprises will be presented.

3.1.3 3ª Step: Analyzing the results obtained by the self-assessment

At the third step takes place analysis and interpretation of the values of the desired level requirements with regard to their degree of care. After a brief preview of each the level of formalized requirements, their interpretations are necessary to measure efforts in meeting the requirements that had low attendance rates. Thus, the interpretation of the results of the level of formalized in this work as follows discrimination below:

- *The level of formalized will be considered unsatisfactory that are between 0,000 and 0,799, with the primordial urge to serve them, that is, the company will have to take immediate action to win their satisfaction;*
- *The degrees of formalized between 0.800 and 0.950 will be considered partially satisfactory, with only a few adjustments and/or improvements to achieve the full requirements requirements;*
- *Finally, shall be considered satisfactory degrees of formalized that present between 0,951 and 1,000.*

With possession of interpretations, the company goes to the prioritization of requirements that had the grades considered unsatisfactory and partially satisfactory ordering them from the lowest level to the highest of them. They are also analyzed in the prioritization step, the requirements that are considered essential and important for advisors and/or auditors working with the program. Thus, the company must order prioritizing all requirements analyzing both aspects, the results obtained by calculations and the importance assigned by the consultants and/or program auditors.

3.1.4 4ª Step: Creating and implementing improvement actions to the requirements considered low

In the fourth step, the construction company will develop an action plan to seek the care of the requirements that had low levels of satisfaction, if necessary. The way to do this will depend on the organizational planning of the company profile, choosing the structure that will facilitate their improvements that will increase the attendance rate requirements.

3.1.5 5ª Step: Evaluating the results after the action plan

At that last step, the company should examine carefully the results of the action plan. To this end, after the application of the necessary improvements, the company reassesses up by running another evaluation cycle following the second phase to further analysis of the data again.

The number of times the cycle execution will depend on the need that the requirements are fully satisfactory, that is, if it has not achieved the satisfaction level of the requirements, you should return the entire procedure, from the 2nd level, to get satisfaction. In this moment the company will be more confident of possible certification and can evaluate up to the next level requirements, seeking thereby the evolution of its QMS.

4. Results and discussion

To test the applicability of the approach, one application has been done in company, wich will be ideitified only as KYW Construction company, founded in 02/02/07, with a staff of 56 (fifty-six) employees. The company is considered small with the main activity the construction of buildings for the lower and middle classes. The current level of certification in PBQP/H-SiAC is Level D, technical expertise subsector of works execution of works of buildings linked to the execution scope of building works.

We did the approach in two cycles. In the first, the development of formalized was presented (documented and implemented) of the desired level during the first months; while in the second, it is a relationship to the last months of meeting requirements after the implementation of the action plan and its review.

Assuming that the construction company has obtained the attendance of all items ordered from the D level requirements as it declares itself as the requirements in the membership application of the act to the program, and being the company motivated and committed to stay and seek next program level, the C level, in improving its QMS, followed by self-assessment of the level of requirements to be obtained states of the degrees of formalized.

The questionnaire prepared predefined effort functions (F1 to F7) and fuzzy aggregation operators chosen. We used effort functions to assess these levels of service that the company. Before the data analysis to be started, it is necessary to familiarize the structure of created tables, which are created in order to summarize the data and facilitate their understanding, as described below:

- *The result of the interview is as summarized in the "Questionnaire answers - documented and implemented";*
- *The functions chosen to determine the degree of pertinence of questions or items of each requirement is contained in the "Function of effort chosen";*
- *The completion of the self assessment values and effort membership functions to represent the items assessed requirement of documented and implemented are described in the "Responses of functions";*
- *Fuzzy aggregation operations between the degrees of relevance of documented and implemented for each item of the requirements in order to determine a single value that represents the "aggregation of the degrees of relevance Doc. And Imp. the functions";*
- *The fuzzy aggregation operations between the degrees of membership of all items of each requirement, arising from aggregation operations of the previous task. The degree of each requirement is formalized as the "Aggregation between the pertinence of requirement of questions" (Table 2).*

Table 2. Table structure for summarizing data

Requirements	**Requirements / Items/ questions**	**Questionnaire answers**		**Function of effort chosen**	**Responses of functions**		**Aggregation of the degrees of pertinence Doc. And Imp. functions**	**Aggregation between the pertinence of the requirement of questions**
		Documented	Implemented	Is the output of the degree of pertinence about the answer data with the effort to conclusion the question	Is the output of the degree of pertinence about answer data with the effort to conclusion the question		Operator *and*: $\mu_{DocNImp}(x) = \min[\mu_{Doc}(x), \mu_{Imp}(x)]$	Operator *compensatory and*: $\mu_{Formalizado_i}(x) = \left(\prod_{i=1}^{m} \mu_{DocNImp_i}(x)\right)^{(1-\gamma)} \left(1 - \prod_{i=1}^{m} \left(1 - \mu_{DocNImp_i}(x)\right)\right)^{\gamma}$ Onde, $\gamma = 0{,}85$
					Documented $\mu_{Doc}(x)$	Implemented $\mu_{Imp}(x)$		

4.1 Simulation: Formalization Degrees of Level C Requirements During the 1st Cycle

After the impairment analysis of employees, available resources and the definition of the level you want to achieve, it follows the questionnaire application phase and the implementation of projects, thus, the beginning of self-assessment.

In the analysis of Level C requirement 4.1 the company has obtained as a result of the degree of formalized 0.928, reaching thus a partial satisfaction of state requirements. The requirement for the company obtained 0.433 points. It is classified as unsatisfactory. It is noted that the item 4.2.4-iii) obtained the lowest grade of service, causing thus the sharp reduction of cases, compared to those other levels of items. Among the requirements presented the one who achieved the satisfaction was the requirement 5.3, while the others showed partial satisfaction (5.1 and 5.5 requirements) and dissatisfaction (5.2, 5.4 and 5.6), the most aggravating item 5.6 grade of 0.041 formalized.

Requirement 6.1 meet the requirements, followed by partial satisfaction of requirement 7.2 and the dissatisfaction of the requirements 6.2, 7.1 and 7.4. Requirement 7.5 is what deserves more prominence, as presented between all levels of requirements the worst degree of care. Since the others did not lag behind, with dissatisfaction also in the degree of formalized. Requirements 8.2 and 8.3 do not have a good application development your requests, as noted in the results after the assessment calculations and is thus in a state of dissatisfaction. Requirements 8.4 and 8.5 were evaluated as unsatisfactory level of formalized, with 0.153 and 0.014 of the items respectively. All requirements can be seen in (Appendix 1) regarding the Results of calculations related to Level C requirements a the 1st Cycle.

From the Results of calculations related to Level C requirements a the 1st Cycle, it was possible to verify, through descriptive statistics, that only 5% of the requirements (item 5.3) presented a state of satisfaction, 20% of the requirements (items 4.1, 5.1, 5.5 and 7.2) showed a partial satisfaction status and 75% of the requirements (items 4.2, 5.2, 5.4, 5.6, 6.1, 6.2, 7.1, 7.4, 7.5, 7.6, 8.1, 8.2, 8.3, 8.4 and 8.5) were classified as unsatisfactory.

The development of effective calculations of fuzzy aggregation operators, followed a sequence of tasks, that are discriminated at requirement 8.1. This requirement are being evaluated three items (8.1-i, 8.1-ii; 8.1-iii), which, through the answers given by the participant along with the equations defined in each item, the degrees of relevance were calculated as to its documented and implemented.The first item (8.1-i) and the second item (8.1-ii) have the values of "x" equals 4 and 4 / 5 and 5 documented and implemented in the same item as well as the same function pertinence of effort (F4). There were only one effecting on each item to be represented in both linguistic variables with up to three decimal places (Equation 3).

$$\mu_{F4_{8.1-i)_{Doc\ e\ Imp}}}(\mathbf{4}) = \left\{\left(\mathbf{e}^{\left(\frac{-(4-10)^2}{20}\right)}\right) \quad \rightarrow \quad \mu_{F4_{8.1-i_{Doc\ e\ Imp}}}(\mathbf{4}) = \mathbf{0,165}\right.$$

$$\mu_{F4_{8.1-ii)_{Doc\ e\ Imp}}}(\mathbf{5}) = \left\{\left(\mathbf{e}^{\left(\frac{-(5-10)^2}{20}\right)}\right) \quad \rightarrow \quad \mu_{F4_{8.1-i_{Doc\ e\ Imp}}}(\mathbf{5}) = \mathbf{0,286}\right. \qquad (3)$$

Continuing the evaluations, we used the intersection of operator "and" the equation 1 to be obtained representative value of the two variables, according fallowing (Equation 4).

$$\mu_{Doc\cap Imp_{8.1-i)}} = \mathbf{min}\left[\mu_{Doc}(\mathbf{4}), \mu_{Imp}(\mathbf{4})\right] \rightarrow \mu_{Doc\cap Imp_{8.1-i)}} = \mathbf{min}[\mathbf{0,165}, \mathbf{0,165}] \rightarrow$$

$$\mu_{Doc\cap Imp_{8.1-i)}} = \mathbf{0,165}$$

$$\mu_{Doc\cap Imp_{8.1-ii)}} = \mathbf{min}\left[\mu_{Doc}(\mathbf{5}), \mu_{Imp}(\mathbf{5})\right] \rightarrow \mu_{Doc\cap Imp_{8.1-ii)}} = \mathbf{min}[\mathbf{0,286}, \mathbf{0,286}] \rightarrow$$

$$\mu_{Doc\cap Imp_{8.1-ii)}} = \mathbf{0,286} \qquad (4)$$

The values of "x" the third item (8.1-iii) are different, in this case, the equations documented and implemented were made separately even though they are represented by the same function, F5. (Equation 5)

$$\mu_{F5_{8.1-iii)_{Doc}}}(5) = \left\{\left(\frac{0,1 * (5)^2}{10}\right) \rightarrow \ \mu_{F5_{8.1-iii)_{Doc}}}(5) = 0,250\right.$$

$$\mu_{F5_{8.1-iii)_{Imp}}}(4) = \left\{\left(\frac{0,1*(4)^2}{10}\right) \rightarrow \ \mu_{F5_{8.1-iii)_{Imp}}}(4) = 0,160\right. \quad (5)$$

Then the application of fuzzy aggregation operator "and" between the documented, implemented, is shown at the equation 1. (Equation 6)

$$\mu_{Doc\cap Imp_{8.1-iii)}} = \min\left[\mu_{Doc}(5), \mu_{Imp}(4)\right] \rightarrow\}$$

$$\mu_{Doc\cap Imp_{8.1-iii)}} = \min[0,250\ , 0,160] \rightarrow \ \mu_{Doc\cap Imp_{8.1-iii)}} = 0,160 \quad (6)$$

After the pertinence be obtained representing each item requirement was performed effecting the second fuzz aggregation operator named "compensatory and", to reveal the level of formalized requirement, shown by using the equation 2. The value of 0,85 was used in this range operator (γ=0,85). (Equation 7) $\mu Formal.i(x)=(\Pi\mu Doc\cap Imp.i(x)mi=1)(1-\gamma)$

$$\mu_{Formal\ i}(x) = \left(\prod_{i=1}^{m} \mu_{Doc\cap Imp\ i}(x)\right)^{(1-\gamma)} \left(1 - \prod_{i=1}^{m}\left(1 - \mu_{Doc\cap Imp\ i}(x)\right)\right)^{\gamma} \rightarrow$$

$$\mu_{Formal\ 8.1} = (0,165 * 0,286 * 0,160)^{(1-0,85)} \left(1 - (1 - 0,165) * (1 - 0,286) * (1 - 0,160)\right)^{0,85} \rightarrow$$

$$\mu_{Formal\ 8.1} = 0,266 \quad (7)$$

The result of effectuations of all calculations shows the degree requirement of attendance 8.1, the value was 0,266, which is classified in a poor state of service, to be far from acceptable. Returning to the sequencing phase of the approach, after being completed the second stage called "realization of self-assessment", go to the next stage, the analysis of the results of self-assessment. Overall, the results of this first evaluation of compliance with the requirements of the items are very far from satisfactory, presenting mostly the state of dissatisfaction. Thus, those who had low levels of formal, prioritizing order follows the lower considered unsatisfactory until the last figure considered partially satisfactory, adopting increasingly.

To analyze the degree of importance of the requirements, relating them among them, we adopted aspects of importance by professionals consulted in work of (Sobenes, 2008) evaluated the requirements in their study, they are sorted in descending order. Thus, to relate the two aspects was adopted that the degree of importance would have greater relevance prioritization compared to the aspect of the degree of formalized, ie, it is first evaluated the aspect of importance and then the appearance of the degree of formalized, wages, both aspects, in descending and ascending order respectively.

Where it was not possible to obtain the analysis of the importance of the requirement given by specialists participating in the working (Sobenes, 2008), we have adopted the symbols (-) corresponding, in this study, as indifferent. The service priority of these requirements follows only in the aspect of the degree of formalized. The ordering of these requirements considering both aspects, lower grades and importance of the requirements, then, in (Table 3) shows the priority order of improvement of these requirements to be worked out in this study.

Table 3. Priority of requirements to be improved the level C – First Cycle

Priority	Requirement	Formalization degree	Degree of importance
1	7.5	0,0004	Much
2	8.5	0,014	Much
3	8.2	0,015	Much
4	5.6	0,041	Much
5	7.1	0,144	Much
6	7.4	0,015	Minor
7	6.2	0,395	Minor
8	4.2	0,433	Minor
9	8.3	0,057	-
10	8.4	0,153	-
11	5.4	0,261	-
12	8.1	0,266	-
13	7.6	0,335	-
14	5.2	0,449	-
15	5.1	0,886	-
16	7.2	0,898	-
17	5.5	0,901	-
18	4.1	0,928	-

As shown in (Table 3), the requirement 7.5 is one that urgently needs to be improved by having a high degree of importance and have the lowest degree of formalized, that is, is that the company needs to act more extremely hard to be obtained from the state satisfactory. Whereas the requirement 4.1 is the least that needs compared to other requirements, emergency care, causing this requirement a lower intensity of effort to reach your satisfaction.

In possession of prioritization of requirements table, we started to develop actions to promote the improvement of the state of compliance with these requirements, an action plan aiming improvements aimed at evolving the state of satisfaction. Then we elaborate the plan and applied the 2nd cycle of self-assessment.

4.2 Formalization Degrees of Level C Requirements During the 2nd Cycle

Adopting the same methodology described in the previous section, and now the company is in the second cycle of your self-assessment to Level C requirements, following the questionnaire of this cycle. It should be noted that the effort relevance functions are different from those that were in the first cycle, since the difficulty of meeting the items is far less due to the experience of the construction and applications of the action plan of improvements; and also the 5.3 and 6.1 requirements need not be retested because the satisfaction reached earlier.

Noting the outcome of requirement 4.1 of the C level the company achieved a small degree of formalized the increase compared to the first cycle, however enough to attain satisfaction. In Requirement 4.2 the company achieved good development to improve the requirement of action, obtaining an increase of 0,474. However it did not get also the state of satisfaction, meeting the requirement in part. Among the requirements 5.1, 5.2, 5.4, 5.5 and 5.6 those who presented satisfactory requirements were only 5.1 and 5.5. But in the matter of development, to be analyzed the degree of formalized requirements in the first cycle with the second cycle is identified developments requirements of 5.2, 5.4 and 5.6, achieving good attendance rates.

Among the items 6.2, 7.1, 7.2 and 7.4, there is the significant growth of state meeting requirements where the most representative were the requirements 6.2, 7.1 and 7.4, compared to the cycle, leaving the state of dissatisfaction to partially satisfied most. The requirements 7.5, 7.6 and 8.1, there was a gradual transformation of the degree of care but did not reach the ideal state. Requirements 8.2 and 8.3 were those who more got bigger evolution of the degree of formalized these data, results of the company's efforts to meet them. However, they are in a partial state on the full satisfaction of the requirements, and also measuring efforts to achieve the goal.

Requirements 8.4 and 8.5 had good development for the application of measures to improve their satisfaction. They spent dissatisfaction from state to state partial satisfaction. As assessment addressing all the requirements that participated in the second evaluation cycle, among the 18 requirements, in total, four reached the desired, while

seven were in the state of partial satisfaction and also seven in the state of dissatisfaction. All requirements can be seen in (Appendix 2) regarding the Results of calculations related to Level C requirements the 2st Cycle.

From the results of calculations related to Level C requirements the 2st Cycle, it was possible to verify, through descriptive statistics, that only 10% of the requirements (items 7.5 and 8.1) were classified as unsatisfactory, 25% of the requirements (items 4.1, 5.1, 5.3, 5.5 and 6.1) presented a state of satisfaction and 65% of the requirements (items 4.2, 5.2, 5.4, 5.6, 6.2, 7.1, 7.2, 7.4, 7.6, 8.2, 8.3, 8.4 and 8.5) were classified as partially satisfactory. Overall, there was a good evolution of requirements with only a few key points to improvements in the requirements obtained also low levels of formal and it must therefore, to construction take other actions of improvements for better harmony merits of efficiency and effectiveness of meeting the requirements of this level development, fitting again, the implementation of the third cycle for analysis.

In the general analysis of formalizing the company would be closer to meet all adjustments this level, although they have in some cases low levels in the degree of formalized, according to data from the calculations. At that time, the company was not prepared for an audit certification program C level, at risk, even if it is small, not certification. However, would be more confident and enthusiastic than in the first cycle period.

Among the requirements that the simulated construction company shall pay attention in your satisfaction are the 4.2, 5.2, 5.4, 5.6, 6.2, 7.1, 7.4, 7.5, 7.6, 8.1, 8.2, 8.3, 8.4 and 8.5, as are those who do not. They are acceptable as their degrees of formalized. It is important to mention that the first Cycle is the application to know the status of their compliance with the requirements and focus their efforts on those that are considered critical. While the second onwards the feedback of the improvements made to achieve the fullness of satisfaction of the requirements.

5. Conclusions

As the Micro and Small buildings construction companies continue to be extrapolated for larger and present difficulties of financial resources was proposed in this paper one approach for evaluating these companies to the requirements of levels of PBQP-H/SiAC technical expertise, execution of works for contribute to your business development and improvement of its QMS. Companies may benefit from the application of the model in its internal audits for assessment of his quality management system, enabling the maintenance intervals and the promotion of improvements required to remain satisfactory.

Among the levels of implementation of the approach, the choice of the function pertinence of effort, which will represent the effort to meet particular item requirement, be examined by the company's manager to predefined their concepts of administrative profiles and production, to selecting a function quality management approach to enable their market position. The calculations for obtaining the degrees of formalized using fuzzy aggregators provided good visualization of the contents in the development QMS through analysis between first and second cycle evaluation, as can be seen in satisfactory quantity requirements between cycles.

To differentiate between two evaluations of cycles: first served to know the state in which the company was at the time of the evaluation, while the second is evaluated after the improvements made in the first cycle. Another item, differentiation between the two cycles is the change of membership functions and data evaluation manager's requirement of item. Overall, this approach has achieved Micro and Small Enterprises goals, demonstrating the degree of formalization of requirements. This approach uses the manager subjectivism to conduct the improvements according more consistent results, especially when we comparing the results of this method with traditional methods of assessment.

6. Aknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, the Conselho Nacional de Desenvolvimento Científico e Tecnológico – Brasil (CNPQ) and the Fundação de Amparo a Ciência e Tecnologia de PE.

7. References

Adedeji, P. A.; Akinlabi, S. A.; Madushele, N.; Olatunji, O. O. (2020). Hybrid neurofuzzy wind power forecast and wind turbine location for embedded generation. International Journal of Energy Research, 6, 1-16.

Akhmetova, S. O.; Baibolova, L. K.; Serikkyzy, M. S. (2019). Integrated quality management system for food production: a case of dairy products' enterprise. Entrepreneurship and Sustainability Issues, 6(4), 1807-1822.

Ahmad, I.; Dar, M. A.; Teka, A. H.; Teshome, M.; Andualem, T. G.; Tehsome, A.; Shafi, T. (2020). GIS and fuzzy logic techniques-based demarcation of groundwater potential zones: A case study from Jemma River basin, Ethiopia. Journal of African Earth Sciences, 103860.

ENGLISH VERSION

Aquino, J. T.; Melo, F. J. C.; Jerônimo, T. B.; Medeiros, D. D. (2019). Evaluation of quality in public transport services: the use of quality dimensions as an input for Fuzzy Topsis. International Journal of Fuzzy Systems, 21(1), 176-193.

Awais, M.; Khan, L.; Ahmad, S.; Mumtaz, S.; Badar, R. (2020). Nonlinear adaptive NeuroFuzzy feedback linearization based MPPT control schemes for photovoltaic system in microgrid. Plos one, 15(6), e0234992.

Batista, D. A.; Medeiros, D. D. (2014) Assessment of quality services through linguistic variables, Benchmarking: An International Journal, 21(1), 28 – 45.

Chen, F.; Jiao, H.; Han, L.; Shen, L.; Du, W.; Ye, Q.; Yu, G. (2020). Real-time monitoring of construction quality for gravel piles based on Internet of Things. Automation in Construction, 116, 103228.

Cui, J. (2015) Enterprise Resources Planning System for Multinational Construction Enterprises in Business Development Stage. LISS 2013, 1293-1298.

Díaz, L.; de Oliveira, M.; Pucharelli, P.; Pinzón, J. (2019) Integration between the last planner system and the quality management system applied in the civil construction sector. Revista Ingeniería de Construcción, 34(2), 146-158.

Díaz, I.; Nojima, Y. (2020) Fuzzy sets for decision making in emerging domains. Fuzzy Sets and Systems. 395, 197-198.

Eraslan, E.; Iç, Y. T. (2011). A multi-criteria approach for determination of investment regions: Turkish case. Industrial Management & Data Systems, 111(6), 890-909.

Finger, F. B.; González, M. S., Kern, A. P. (2015) Control of Finished Work - Final Quality Inspection in a Social Housing Project. Revista Ingeniería de Construcción, 30(2), 147-153.

Fofan, A. C.; Oliveira, L. A. B. D.; Melo, F. J. C. D.; Jerônimo, T. D. B.; Medeiros, D. D. (2019) An Integrated Methodology Using PROMETHEE and Kano's Model to Rank Strategic Decisions. Engineering Management Journal, 31(4), 270-283.

García, J. A.; Rama, M. L. D. R.; González-Vázquez, E.; Lindahl, J. M. M. (2014) Motivations for Implementing a System of Quality Management in Spanish Thalassotherapy Centers. Health and Wellness Tourism. 101-115.

Genaro Chiroli, D. M.; Volante, E. J.; Trierweiller, A. C.; Campos, L. (2015) Evaluation of Environmental Management: A Survey in Construction Enterprises in the City of Maringa-Pr, Brazil. Interciencia, 40(1), 8-15.

Hossain, M. U.; Ng, S. T. (2019) Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle. Resources, Conservation and Recycling, 142, 10-23.

ISO - International Organisation for Standardization (2008) NBR ISO 9001:2008 - Quality management systems - Requirements. Genebra.

Kahraman, C.; Kaya, İ. (2012) A fuzzy multiple attribute utility model for intelligent building assessment, Journal of Civil Engineering and Management, 18(6), 811-820.

Lordsleem Jr, A. C.; Melhado, S. B. (2014) Scope of design for production of wall partitions, Journal of Engineering, Design and Technology, 12(2), 263 – 279.

Marasini, D.; Quatto, P.; Ripamonti, E. (2016) Intuitionistic fuzzy sets in questionnaire analysis. Quality & Quantity. 50(2), 767-790.

Markiewicz, M.; Muślewski, Ł. (2020) Survey performance and emission parameters of diesel engine powered by diesel oil and fatty acid methyl esters using fuzzy logic techniques. Fuel, 277, 118179.

Medeiros, D. D. (2009) A fuzzy model to evaluate the motivation to quality programs. Internacional Journal of Computers, 3(2), 230-237.

Megahed, M.; Mohammed, A. (2020) Modeling adaptive E-Learning environment using facial expressions and fuzzy logic. Expert Systems with Applications, 157, 113460.

Ministry of Cities (2011). Brazilian Quality and Productivity Program of Habitat. Available in: < http://www.cidades.gov.br/pbqp-h/ >. Access: 16 nov. 2011.

Nguyen, T. H.; Shehab, T.; Gao, Z. (2008) Selecting an architecture-engineering team by using fuzzy set theory. Engineering, Construction and Architectural Management, 15(3), 282-298.

Orozco, M.; Avila, Y.; Restrepo, S.; Parody, A. (2018) Factors influencing concrete quality: a survey to the principal actors of the concrete industry. Revista Ingeniería de Construcción, 33(2), 161-172.

Park, M.; Jang, Y.; Lee, H.; Ahn, C.; Yoon, Y. (2013) Application of knowledge management technologies in Korean small and medium-sized construction companies. KSCE Journal of Civil Engineering. 17(1), 22-32.

Park, S.; Lee, J. S.; Nicolau, J. L. (2020) Understanding the dynamics of the quality of airline service attributes: Satisfiers and dissatisfiers. Tourism Management, 81, 104163.

R**amasamy, N. R.; Selladurai, V. (2004)** Fuzzy logic approach to prioritise engineering characteristics in quality function deployment (FL-QFD). International Journal of Quality & Reliability Management, 21(9), 1012-1023.

Rheingantz, P. A. (2003) Cosenza hierarchical analysis model for the performance assessment of office buildings. Facilities, 21(13/14), 333-346.

Santos, A.; Powell, J. A. (2001) Assessing the level of teamwork in Brazilian and English construction sites, Leadership & Organization Development Journal, 22(4), 166 – 174.

Seth, F. P.; Mustonen-Ollila, E.; Taipale, O.; Smolander, K. (2015) Software quality construction in 11 companies: an empirical study using the grounded theory. Software Quality Journal. 23(4), 627-660.

Silva, C. F. D.; Batista, D. A.; Medeiros, D. D. (2014) A proposed method to evaluate the quality of services using Fuzzy sets theory. Quality & Quantity. 48, 871-885.

Sobenes Filho, J. C. (2008) Avaliação das não-conformidades levantadas em auditorias de implementação do PBQP-H em construtoras de pequeno e médio porte do Paraná. Programa de Pós-Graduação em Engenharia Civil. Dissertação de Mestrado. Florianópolis: UFSC.

Suh, Y. A.; Kim, J. (2020) Estimation of the likelihood of severe accident management decision-making using a fuzzy logic model. Annals of Nuclear Energy, 144, 107581.

Tan, Y.; Shen, L. Y.; Langston, C. (2011) A fuzzy approach for assessing contractors' competitiveness. Engineering, Construction and Architectural Management, 18(3), 234-247.

Tokuori, T. (2014) Local Construction Enterprises in Transition: Empirical Evidence from Burkina Faso (2004–2010). Delivering Sustainable Growth in Africa. 174-214.

Willar, D.; Coffey, V.; Trigunarsyah, B. (2015) Examining the implementation of ISO 9001 in Indonesian construction companies", The TQM Journal, 27(1), 94 – 107.

Yu, J.; Jeon, M.; Kim, T. (2015) Fuzzy-based composite indicator development methodology for evaluating overall project performance, Journal of Civil Engineering and Management, 21(3), 343-355.

Zadeh, L. A. (1965) Fuzzy sets. Information and Control, 8(3), 338-353.

Zadeh, L. A. (1975) The concept of a linguistic variable and its application to approximate reasoning I. Information Sciences, 8, 199-249.

ENGLISH VERSION

Zandi, F.; Tavana, M. (2011) A fuzzy goal programming model for strategic information technology investment assessment. Benchmarking: An International Journal, 18(2), 172-196.

Zou, X. Y.; Chen, S. M.; Fan, K. Y. (2020) Multiple attribute decision making using improved intuitionistic fuzzy weighted geometric operators of intuitionistic fuzzy values. Information Sciences, 535, 242-253.

Appendix 1. Results of calculations related to Level C requirements – First Cycle

Requirements	Requirements / Items/ questions	Questionnaire answers		Function of effort chosen	Responses of functions		Aggregation of the degrees of pertinence Doc. And Imp. Functions	Aggregation between the pertinence of the requirement of questions
		Documented	Implemented	Is the output of the degree of pertinence about the answer data with the effort to conclusion the question	Is the output of the degree of pertinence about answer data with the effort to conclusion the question		Operator and: $\mu_{Doc \cap Imp}(x) = \min[\mu_{Doc}(x), \mu_{Imp}(x)]$	Operator compensatory and: $\mu_{Formalizado_i}(x) = \left(\prod_{i=1}^{m} \mu_{Doc \cap Imp_i}(x)\right)^{(1-\gamma)} \left(1 - \prod_{i=1}^{m} (1 - \mu_{Doc \cap Imp_i}(x))\right)^{\gamma}$
					Documented $\mu_{Doc}(x)$	Implemented $\mu_{Imp}(x)$		
4.1	4.1-i)	8	8	F2	0,854	0,854	0,854	0,928
	4.1-ii)	10	9	F3	1,000	0,964	0,964	
	4.1-iii)	9	8	F3	0,964	0,921	0,921	
	4.1-iv)	9	8	F3	0,964	0,921	0,921	
	4.1-v)	9	9	F4	0,951	0,951	0,951	
	4.1-vi)	10	10	F4	1,000	1,000	1,000	
	4.1-vii)	9	8	F3	0,964	0,921	0,921	
	4.1-viii)	10	10	F2	1,000	1,000	1,000	
	4.1-ix)	10	10	F2	1,000	1,000	1,000	
	4.1-x)	10	10	F3	1,000	1,000	1,000	
4.2	4.2.1-i)	10	10	F1	1,000	1,000	1,000	0,433
	4.2.1-ii)	6	5	F3	0,792	0,500	0,500	
	4.2.1-iii)	9	9	F3	0,964	0,964	0,964	
	4.2.1-iv)	8	8	F1	0.895	0,895	0,895	
	4.2.1-v)	5	5	F2	0,585	0,585	0,585	
	4.2.2-i)	10	9	F2	1,000	0,930	0,930	
	4.2.2-ii)	10	8	F2	1,000	0,854	0,854	
	4.2.2-iii)	10	9	F3	1,000	0,964	0,964	
	4.2.2-iv)	9	7	F3	0,964	0,868	0,868	
	4.2.3-i)	10	10	F4	1,000	1,000	1,000	
	4.2.3-ii)	8	7	F5	0,640	0,490	0,490	
	4.2.3-iii)	9	9	F2	0,930	0,930	0,930	
	4.2.3-iv)	9	8	F1	0,949	0,895	0,895	
	4.2.3-v)	9	8	F1	0,949	0,895	0,895	

	4.2.3-vi)	9	8	F1	0,949	0,895	0,895	
	4.2.3-vii)	7	7	F3	0,868	0,868	0,868	
	4.2.4-i)	9	9	F2	0,930	0,930	0,930	
	4.2.4-ii)	10	10	F1	1,000	1,000	1,000	
	4.2.4-iii)	5	3	F4	0,286	0,086	0,086	
5.1	5.1-i)	10	10	F1	1,000	1,000	1,000	0,886
	5.1-ii)	10	10	F3	1,000	1,000	1,000	
	5.1-iii)	8	6	F4	0,818	0,449	0,449	
5.2	5.2-i)	7	6	F4	0,637	0,449	0,449	0,449
5.3	5.3-i)	10	10	F1	1,000	1,000	1,000	0,971
	5.3-ii)	10	10	F3	1,000	1,000	1,000	
	5.3-iii)	10	10	F4	1,000	1,000	1,000	
	5.3-iv)	9	9	F4	0,951	0,951	0,951	
	5.3-v)	8	7	F3	0,921	0,868	0,868	
5.4	5.4.1-i)	3	2	F3	0,131	0,078	0,078	0,261
	5.4.1-ii)	2	2	F5	0,040	0,040	0,040	
	5.4.2-i)	6	5	F4	0,449	0,286	0,286	
	5.4.2-ii)	9	8	F5	0,810	0,640	0,640	
5.5	5.5.1-i)	10	10	F3	1,000	1,000	1,000	0,901
	5.5.2-i)	10	10	F2	1,000	1,000	1,000	
	5.5.2-ii)	7	5	F3	0,868	0,500	0,500	
5.6	5.6.1-i)	3	3	F4	0,086	0,086	0,086	0,041
	5.6.1-ii)	7	6	F3	0,868	0,792	0,792	
	5.6.1-iii)	5	5	F4	0,286	0,286	0,286	
	5.6.2-i)	4	4	F4	0,165	0,165	0,165	
	5.6.2-ii)	4	4	F4	0,165	0,165	0,165	
	5.6.2-iii)	3	3	F4	0,086	0,086	0,086	
	5.6.2-iv)	3	3	F4	0,086	0,086	0,086	
	5.6.2-v)	3	3	F4	0,086	0,086	0,086	
	5.6.3-i)	2	2	F3	0,078	0,078	0,078	
	5.6.3-ii)	2	1	F3	0,078	0,035	0,035	
6.1	6.1-i)	9	9	F6	0,959	0,959	0,959	0,959
6.2	6.2.1-i)	8	6	F2	0,854	0,681	0,681	0,395
	6.2.2-i)	8	8	F3	0,921	0,921	0,921	
	6.2.2-ii)	5	4	F4	0,286	0,165	0,165	
	6.2.2-iii)	3	3	F5	0,090	0,090	0,090	
	6.2.2-iv)	6	6	F4	0,449	0,449	0,449	
	6.2.2-v)	8	7	F6	0,818	0,507	0,507	
7.1	7.1.1-i)	9	9	F4	0,951	0,951	0,951	0,144
	7.1.1-ii)	4	3	F5	0,160	0,090	0,090	
	7.1.1-iii)	4	3	F3	0,207	0,131	0,131	
	7.1.1-iv)	5	5	F6	0,055	0,055	0,055	
	7.1.1-v)	5	5	F6	0,055	0,055	0,055	
	7.1.1-vi)	4	3	F5	0,160	0,090	0,090	
7.2	7.2.1-i)	9	8	F4	0,951	0,818	0,818	0,898
	7.2.1-ii)	8	8	F5	0,640	0,640	0,640	
	7.2.1-iii)	10	9	F4	1,000	0,951	0,951	
7.4	7.4.1-i)	4	3	F7	0,072	0,031	0,031	0,015
	7.4.1.1-i)	4	4	F6	0,013	0,013	0,013	
	7.4.1.1-ii)	2	2	F4	0,040	0,040	0,040	
	7.4.2.1-i)	3	3	F4	0,086	0,086	0,086	

	7.4.2.2-i)	2	2	F4	0,040	0,040	0,040	
	7.4.3-i)	3	3	F5	0,090	0,090	0,090	
	7.4.3-ii)	3	3	F5	0,090	0,090	0,090	
7.5	7.5.1-i)	3	3	F4	0,086	0,086	0,086	0,0004
	7.5.1-ii)	5	5	F4	0,286	0,286	0,286	
	7.5.1-iii)	5	4	F5	0,250	0,160	0,160	
	7.5.1-iv)	4	4	F6	0,013	0,013	0,013	
	7.5.1-v)	4	4	F6	0,013	0,013	0,013	
	7.5.1-vi)	4	3	F5	0,160	0,090	0,090	
	7.5.1-vii)	3	3	F7	0,031	0,031	0,031	
	7.5.1.1-i)	3	3	F4	0,086	0,086	0,086	
	7.5.1.1-ii)	3	2	F7	0,031	0,009	0,009	
	7.5.1.1-iii)	9	9	F6	0,959	0,959	0,959	
	7.5.3.1-i)	3	3	F5	0,090	0,090	0,090	
	7.5.3.1-ii)	3	3	F4	0,086	0,086	0,086	
	7.5.3.1-iii)	3	2	F4	0,086	0,040	0,040	
	7.5.3.1-iv)	4	3	F4	0,165	0,086	0,086	
	7.5.3.1-v)	4	3	F5	0,160	0,090	0,090	
	7.5.5-i)	4	4	F6	0,013	0,013	0,013	
	7.5.5-ii)	4	4	F6	0,013	0,013	0,013	
	7.5.5-iii)	3	2	F5	0,090	0,040	0,040	
7.6	7.6-i)	9	8	F5	0,810	0,640	0,640	0,335
	7.6-ii)	5	4	F6	0,055	0,013	0,013	
8.1	8.1-i)	4	4	F4	0,165	0,165	0,165	0,266
	8.1-ii)	5	5	F4	0,286	0,286	0,286	
	8.1-iii)	5	4	F5	0,250	0,160	0,160	
8.2	8.2.1-i	3	3	F4	0,086	0,086	0,086	0,015
	8.2.1-ii)	2	2	F5	0,040	0,040	0,040	
	8.2.2-i)	5	5	F3	0,500	0,500	0,500	
	8.2.2-ii)	5	5	F4	0,286	0,286	0,286	
	8.2.2-iii)	8	7	F4	0,818	0,637	0,637	
	8.2.2-iv)	8	7	F6	0,818	0,507	0,507	
	8.2.2-v)	9	9	F3	0,964	0,964	0,964	
	8.2.2-vi)	5	5	F3	0,500	0,500	0,500	
	8.2.2-vii)	4	4	F6	0,013	0,013	0,013	
	8.2.2-viii)	4	4	F5	0,160	0,160	0,160	
	8.2.2-ix)	5	4	F4	0,286	0,165	0,165	
	8.2.4-i)	5	4	F7	0,137	0,072	0,072	
	8.2.4-ii)	4	3	F6	0,013	0,003	0,003	
	8.2.4-iii)	4	4	F5	0,160	0,160	0,160	
8.3	8.3-i)	4	3	F5	0,160	0,090	0,090	0,057
	8.3-ii)	5	5	F6	0,055	0,055	0,055	
	8.3-iii)	5	5	F5	0,250	0,250	0,250	
	8.3-iv)	4	4	F5	0,160	0,160	0,160	
	8.3-v)	4	4	F5	0,160	0,160	0,160	
	8.3-vi)	3	3	F4	0,086	0,086	0,086	
	8.3-vii)	3	3	F3	0,131	0,131	0,131	
	8.3-viii)	3	3	F3	0,131	0,131	0,131	
8.4	8.4-i)	5	5	F7	0,137	0,137	0,137	0,153
	8.4-ii)	5	4	F5	0,250	0,160	0,160	
	8.4-iii)	4	4	F5	0,160	0,160	0,160	

	8.4-iv)	4	4	F5	0,160	0,160	0,160	
	8.4-v)	5	4	F5	0,250	0,160	0,160	
8.5	8.5.1-i)	4	4	F7	0,072	0,072	0,072	0,014
	8.5.2-i)	4	4	F6	0,013	0,013	0,013	
	8.5.2-ii)	3	3	F5	0,090	0,090	0,090	
	8.5.2-iii)	3	3	F5	0,090	0,090	0,090	
	8.5.2-iv)	3	3	F5	0,090	0,090	0,090	
	8.5.2-v)	3	2	F5	0,090	0,040	0,040	
	8.5.2-vi)	3	2	F3	0,131	0,078	0,078	
	8.5.2-vii)	3	2	F4	0,086	0,040	0,040	

Appendix 2. Results of calculations related to the Level C requirement - Second Cycle

Requirements	**Requirements / Items/ questions**	**Questionnaire answers**		**Function of effort chosen**	**Responses of functions**		**Aggregation of the degrees of pertinence Doc. And Imp. functions**	**Aggregation between the pertinence of the requirement of questions**
		Documented	Implemented	Is the output of the degree of pertinence about the answer data with the effort to conclusion the question	Is the output of the degree of pertinence about answer data with the effort to conclusion the question		Operator *and*: $\mu_{Doc \cap Imp}(x) = \min[\mu_{Doc}(x), \mu_{Imp}(x)]$	Operator *compensatory and*: $\mu_{Formalizado_i}(x) = \left(\prod_{i=1}^{m} \mu_{Doc \cap Imp_i}(x)\right)^{(1-\gamma)} \left(1 - \left(\prod_{i=1}^{m} (1 - \mu_{Doc \cap Imp_i}(x))\right)^{m}\right)^{\gamma}$
					Documented $\mu_{Doc}(x)$	Implemented $\mu_{Imp}(x)$		
4.1	4.1-i)	9	9	F1	0,949	0,949	0,949	0,963
	4.1-ii)	10	10	F2	1,000	1,000	1,000	
	4.1-iii)	9	9	F2	0,930	0,930	0,930	
	4.1-iv)	9	9	F2	0,930	0,930	0,930	
	4.1-v)	10	9	F3	1,000	0,951	0,951	
	4.1-vi)	10	10	F3	1,000	1,000	1,000	
	4.1-vii)	10	10	F2	1,000	1,000	1,000	
	4.1-viii)	10	10	F1	1,000	1,000	1,000	
	4.1-ix)	10	10	F1	1,000	1,000	1,000	
	4.1-x)	10	10	F2	1,000	1,000	1,000	
4.2	4.2.1-i)	10	10	F1	1,000	1,000	1,000	0,917
	4.2.1-ii)	9	9	F2	0,930	0,930	0,930	
	4.2.1-iii)	10	10	F2	1,000	1,000	1,000	
	4.2.1-iv)	10	10	F1	1,000	1,000	1,000	
	4.2.1-v)	8	8	F1	0,895	0,895	0,895	
	4.2.2-i)	10	10	F1	1,000	1,000	1,000	

	4.2.2-ii)	10	10	F1	1,000	1,000	1,000	
	4.2.2-iii)	10	10	F2	1,000	1,000	1,000	
	4.2.2-iv)	10	9	F2	1,000	0,930	0,930	
	4.2.3-i)	10	10	F3	1,000	1,000	1,000	
	4.2.3-ii)	10	9	F3	1,000	0,964	0,964	
	4.2.3-iii)	10	10	F1	1,000	1,000	1,000	
	4.2.3-iv)	10	10	F1	1,000	1,000	1,000	
	4.2.3-v)	10	10	F1	1,000	1,000	1,000	
	4.2.3-vi)	10	10	F1	1,000	1,000	1,000	
	4.2.3-vii)	10	9	F2	1,000	0,930	0,930	
	4.2.4-i)	10	9	F1	1,000	0,949	0,949	
	4.2.4-ii)	10	10	F1	1,000	1,000	1,000	
	4.2.4-iii)	8	8	F2	0,854	0,854	0,854	
5.1	5.1-i)	10	10	F1	1,000	1,000	1,000	0,987
	5.1-ii)	10	10	F2	1,000	1,000	1,000	
	5.1-iii)	9	8	F3	0,964	0,921	0,921	
5.2	5.2-i)	8	8	F3	0,921	0,921	0,921	0,921
5.4	5.4.1-i)	6	5	F1	0,775	0,707	0,707	0,876
	5.4.1-ii)	6	6	F3	0,792	0,792	0,792	
	5.4.2-i)	8	7	F2	0,854	0,771	0,771	
	5.4.2-ii)	9	9	F3	0,964	0,964	0,964	
5.5	5.5.1-i)	10	10	F1	1,000	1,000	1,000	0,992
	5.5.2-i)	10	10	F1	1,000	1,000	1,000	
	5.5.2-ii)	9	9	F1	0,949	0,949	0,949	
5.6	5.6.1-i)	7	6	F2	0,771	0,681	0,681	0,621
	5.6.1-ii)	9	8	F2	0,930	0,854	0,854	
	5.6.1-iii)	8	8	F2	0,854	0,854	0,854	
	5.6.2-i)	8	7	F2	0,854	0,771	0,771	
	5.6.2-ii)	7	7	F2	0,771	0,771	0,771	
	5.6.2-iii)	8	6	F2	0,854	0,681	0,681	
	5.6.2-iv)	8	7	F2	0,854	0,771	0,771	
	5.6.2-v)	7	6	F2	0,771	0,681	0,681	
	5.6.3-i)	6	6	F2	0,681	0,681	0,681	
	5.6.3-ii)	7	5	F2	0,771	0,585	0,585	
6.2	6.2.1-i)	9	8	F1	0,949	0,895	0,895	0,872
	6.2.2-i)	9	9	F2	0,930	0,930	0,930	
	6.2.2-ii)	8	7	F3	0,921	0,868	0,868	
	6.2.2-iii)	8	7	F4	0,818	0,637	0,637	
	6.2.2-iv)	8	8	F3	0,921	0,921	0,921	
	6.2.2-v)	9	9	F4	0,951	0,951	0,951	
7.1	7.1.1-i)	10	10	F3	1,000	1,000	1,000	0,932
	7.1.1-ii)	8	8	F3	0,921	0,921	0,921	
	7.1.1-iii)	8	8	F3	0,921	0,921	0,921	
	7.1.1-iv)	9	9	F4	0,951	0,951	0,951	
	7.1.1-v)	9	9	F4	0,951	0,951	0,951	
	7.1.1-vi)	8	8	F4	0,818	0,818	0,818	
7.2	7.2.1-i)	10	10	F3	1,000	1,000	1,000	1,000
	7.2.1-ii)	10	10	F4	1,000	1,000	1,000	
	7.2.1-iii)	10	10	F3	1,000	1,000	1,000	
7.4	7.4.1-i)	7	7	F5	0,490	0,490	0,490	0,687
	7.4.1.1-i)	7	7	F5	0,490	0,490	0,490	

	7.4.1.1-ii)	7	6	F3	0,868	0,792	0,792	
	7.4.2.1-i)	7	6	F3	0,868	0,792	0,792	
	7.4.2.2-i)	7	7	F3	0,868	0,868	0,868	
	7.4.3-i)	7	6	F3	0,868	0,792	0,792	
	7.4.3-ii)	7	6	F3	0,868	0,792	0,792	
7.5	7.5.1-i)	8	7	F3	0,921	0,868	0,868	0,364
	7.5.1-ii)	9	9	F3	0,964	0,964	0,964	
	7.5.1-iii)	9	9	F4	0,951	0,951	0,951	
	7.5.1-iv)	8	8	F5	0,640	0,640	0,640	
	7.5.1-v)	8	8	F5	0,640	0,640	0,640	
	7.5.1-vi)	8	8	F5	0,640	0,640	0,640	
	7.5.1-vii)	8	7	F6	0,818	0,507	0,507	
	7.5.1.1-i)	8	7	F4	0,818	0,637	0,637	
	7.5.1.1-ii)	8	7	F6	0,818	0,507	0,507	
	7.5.1.1-iii)	10	10	F6	1,000	1,000	1,000	
	7.5.3.1-i)	7	7	F4	0,637	0,637	0,637	
	7.5.3.1-ii)	7	7	F4	0,637	0,637	0,637	
	7.5.3.1-iii)	7	7	F4	0,637	0,637	0,637	
	7.5.3.1-iv)	8	7	F4	0,818	0,637	0,637	
	7.5.3.1-v)	8	8	F4	0,818	0,818	0,818	
	7.5.5-i)	8	8	F5	0,640	0,640	0,640	
	7.5.5-ii)	8	8	F5	0,640	0,640	0,640	
	7.5.5-iii)	8	8	F5	0,640	0,640	0,640	
7.6	7.6-i)	10	10	F5	1,000	1,000	1,000	0,903
	7.6-ii)	7	7	F6	0,507	0,507	0,507	
8.1	8.1-i)	6	6	F4	0,449	0,449	0,449	0,612
	8.1-ii)	7	6	F4	0,637	0,449	0,449	
	8.1-iii)	7	7	F5	0,490	0,490	0,490	
8.2	8.2.1-i	7	7	F3	0,868	0,868	0,868	0,844
	8.2.1-ii)	7	7	F3	0,868	0,868	0,868	
	8.2.2-i)	9	8	F3	0,964	0,921	0,921	
	8.2.2-ii)	9	9	F3	0,964	0,964	0,964	
	8.2.2-iii)	10	9	F3	1,000	0,964	0,964	
	8.2.2-iv)	10	9	F4	1,000	0,951	0,951	
	8.2.2-v)	10	10	F3	1,000	1,000	1,000	
	8.2.2-vi)	9	9	F3	0,964	0,964	0,964	
	8.2.2-vii)	9	8	F4	0,951	0,818	0,818	
	8.2.2-viii)	9	8	F3	0,964	0,921	0,921	
	8.2.2-ix)	10	9	F3	1,000	0,964	0,964	
	8.2.4-i)	10	9	F5	1,000	0,810	0,810	
	8.2.4-ii)	9	9	F3	0,964	0,964	0,964	
	8.2.4-iii)	9	9	F3	0,964	0,964	0,964	
8.3	8.3-i)	7	7	F4	0,637	0,637	0,637	0,722
	8.3-ii)	8	8	F4	0,818	0,818	0,818	
	8.3-iii)	8	8	F4	0,818	0,818	0,818	
	8.3-iv)	8	7	F4	0,818	0,637	0,637	
	8.3-v)	8	8	F4	0,818	0,818	0,818	
	8.3-vi)	7	7	F3	0,868	0,868	0,868	
	8.3-vii)	7	7	F2	0,771	0,771	0,771	
	8.3-viii)	7	7	F2	0,771	0,771	0,771	
8.4	8.4-i)	8	8	F6	0,818	0,818	0,818	0,767

	8.4-ii)	8	7	F4	0,818	0,637	0,637	
	8.4-iii)	7	7	F4	0,637	0,637	0,637	
	8.4-iv)	7	7	F4	0,637	0,637	0,637	
	8.4-v)	8	8	F4	0,818	0,818	0,818	
8.5	8.5.1-i)	9	8	F5	0,810	0,640	0,640	0,773
	8.5.2-i)	9	8	F4	0,951	0,818	0,818	
	8.5.2-ii)	8	8	F3	0,921	0,921	0,921	
	8.5.2-iii)	8	8	F3	0,921	0,921	0,921	
	8.5.2-iv)	7	7	F3	0,868	0,868	0,868	
	8.5.2-v)	7	7	F3	0,868	0,868	0,868	
	8.5.2-vi)	7	6	F2	0,771	0,681	0,681	
	8.5.2-vii)	7	6	F3	0,868	0,792	0,792	