A Comparative Mapping Framework for Evaluating Success Factors of ABET Accreditation

NAZLI GOKER and MEHTAP DURSUN

Abstract— The Accreditation Board for Engineering and Technology (ABET) provides the accreditation of the tertiary education programs in the fields of applied and natural science, computing, engineering, and technology. Although ABET accreditation is voluntary, graduates of the ABET-accredited programs are considered as equivalent in knowledge, behaviours, and attitude with global standards. In this study, the factors that affect the success of ABET process are evaluated, and their importance weights are determined. Causal links among the factors, positive as well as negative relations between pair of criteria, and lack of crisp data lead to employ fuzzy cognitive map as an appropriate methodology to assess success factors of ABET process. The presence of hesitation in data led us to utilize intuitionistic fuzzy cognitive map (IFCM) technique to provide a comparative analysis. The application is illustrated through a case study, which is conducted in a university located in Turkey..

Index Terms— Fuzzy cognitive map, Intuitionistic fuzzy cognitive map, Education, Accreditation, ABET process, Success evaluation.

I. Introduction

Engineering education has historically undergone many stages of evolution, regulation, and quality control via accreditation. To assure similarity and quality in the study programs, accreditation of engineering and computing education through some global benchmarks has become crucial. In addition to their individual national accreditation bodies, the universities in the Gulf Cooperative Council (GCC) region are gradually acquiring Accreditation Board for Engineering and Technology (ABET) accreditation for their engineering and computing programs. A member of the International Engineering Alliance, ABET is one of the initial signatory organizations from the United States for the Washington Accord. At the associate, bachelor's, and master's degree levels, ABET accredits college and university programs in the fields of applied and natural science, computing, engineering, and engineering technology [1]. The ABET Accreditation procedure has been extremely systematic and regulated. It has aided in comparing various engineering and computing programs to international standards and addressing any deficiencies.

This work introduces a fuzzy cognitive map (FCM) and an intuitionistic fuzzy cognitive map (IFCM) techniques to determine the importance degrees of success factors of ABET process. Interrelations between pair of criteria, and lack of crisp data lead to employ FCM as an appropriate methodology for assessing success factors of ABET. In addition, the presence of hesitation in data shows that IFCM is a suitable tool to compare the outcomes of FCM.

The remaining part of the study is organized as follows. FCM is explained in Section 2. IFCM is delineated in Section 3. Section 4 illustrates the case study. Conclusions are provided in the last section.

II. Fuzzy Cognitive Maps

Fuzzy cognitive map (FCM) is a causal information-based tool that combines fuzzy logic and neural networks. The extension of the tool is provided by including fuzzy numbers or linguistic variables for expressing the causal links among concepts in the map. These concepts represent an entity, a state, a variable or a characteristic of a system, a behavior of the information-based system is denoted by concepts in FCM [4]. Concept nodes and weighted arcs are the elements of FCM which can be graphically showed with feedback. Signed arcs indicate the sign of causality: whether the causal relationship is positive, negative or null; and connected nodes produce causal relationships among concepts [5]. $C = \{C_1, C_2, \dots, C_n\}$ is the set of concepts, arcs demonstrate how concept C_j causes concept C_i, and are used for causal relationships between concepts. The weights of causality links range can be represented with linguistic variables such as "negatively medium", "zero", "positively medium", etc. The value of each concept is computed, taking into account the effect of the other concepts on the under-evaluation concept, by applying the following iterative formulation.

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} A_j^{(k)} w_{ji}\right) \quad (1)$$

Where $A_i^{(k)}$ is the value of concept C_i at k^{th} iteration, w_{ji} is the weight of the connection from C_j to C_i and f is a threshold function.

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III. INTUITIONISTIC FUZZY COGNITIVE MAPS

Intuitionistic fuzzy cognitive map (IFCM) technique includes intuitionistic fuzzy numbers into cognitive maps in order to determine the power of cause-and-effect relationships [4]. First, concept nodes and power of causal links among them are defined by obtaining experts' opinions. Second, the power of causal links is represented by intuitionistic fuzzy numbers that are associated with intuitionistic fuzzy scale. Hence, membership, non-membership, and hesitation values are identified. Finally, N x N weight matrix is formed by employing the information collected from the experts.

The following iterative formulation of IFCM is run until the system will be stabilized, in other words, all factor weights will converge [4]. In this way, the concepts' values are computed.

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} \left(A_j^{(k)} w_{ji}^{\mu} - A_j^{(k)} w_{ji}^{\pi}\right)\right) \quad (2)$$

where w_{ji}^{μ} and w_{ji}^{π} denote the weight matrices that show membership values and hesitation values of causal links, respectively, and f is a threshold function, which is considered as sigmoid function for this work..

IV. CASE STUDY

This work presents a FCM approach for evaluating success factors of ABET process. The case study is conducted in a university located in Turkey through three professors' opinions. Initially, success factors that are determined by interviewing the decision makers of the case institution, are delineated in Table I.

TABLE I: SUCCESS FACTORS OF ABET

Label	Factor
C1	Student management
C2	Program vision, mission and objectives
C3	Continuous quality improvement
C4	Quality steering team and leader
C5	Document orientation and knowledge sharing
C6	Academic and research excellence
C7	Top management support
C8	Institutional quality compliance

The decision-makers indicate the direction of causal relationships in three categories: positive, negative, null. Afterwards, experts decide the degree of causal links by using linguistic variables; subsequently linguistic variables are transformed into fuzzy numbers. In this study, nine linguistic terms are used as negatively very strong (nvs), negatively strong (ns), negatively medium (nm), negatively weak (nw), zero (z), positively weak (pw), positively medium (pm), positively strong (ps), positively very strong (pvs). The corresponding triangular fuzzy numbers for these linguistic variables are reported in Table II.

TABLE II: SCALE OF FUZZY NUMBERS [3]

Linguistic term	Triangular fuzzy number
nvs	(-1,-1,-0.75)
ns	(-1,-0.75,-0.5)
nm	(-0.75,-0.5,-0.25)
nw	(-0.5,-0.25,0)
z	(-0.25,0,0.25)
pw	(0,0.25,0.5)
pm	(0.25,0.5,0.75)
ps	(0.5,0.75,1)
pvs	(0.75,1,1)

The matrix of power of causalities according to the experts are given in Tables III, IV and V.

TABLE III: POWER OF CAUSALITIES ACCORDING TO EXPERT 1

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	pvs	0	0	0	0	pw
C2	pvs	0	ps	0	0	0	0	0
C3	0	pm	0	pm	0	0	0	0
C4	pw	0	0	0	pw	0	pm	pm
C5	0	pw	0	0	0	0	0	0
C6	0	0	0	0	0	0	pm	pm
C7	0	0	0	pvs	0	0	0	0
C8	0	0	0	pw	0	0	pw	0

TABLE IV: POWER OF CAUSALITIES ACCORDING TO EXPERT 2

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	ps	0	0	0	0	pm
C2	ps	0	pm	0	0	0	0	0
C3	0	ps	0	ps	0	0	0	0
C4	pm	0	0	0	pm	0	pm	ps
C5	0	pw	0	0	0	0	0	0
C6	0	0	0	0	0	0	ps	ps
C7	0	0	0	ps	0	0	0	0
C8	0	0	0	pw	0	0	pm	0

TABLE V: POWER OF CAUSALITIES ACCORDING TO EXPERT 2

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	ps	0	0	0	0	pm
C2	ps	0	ps	0	0	0	0	0
C3	0	pm	0	pm	0	0	0	0
C4	pw	0	0	0	pm	0	pm	pm
C5	0	pw	0	0	0	0	0	0
C6	0	0	0	0	0	0	pm	pm
C7	0	0	0	ps	0	0	0	0
C8	0	0	0	pw	0	0	pm	0

The linguistic data collected by the experts are converted into triangular fuzzy numbers according to the fuzzy scale given in Table II. The matrices of power of causalities that are transformed into triangular fuzzy numbers with regard to three experts. Afterwards, these triangular fuzzy numbers are aggregated via MAX aggregation, and then defuzzified by using center of gravity (COG) method, and the weight matrix is obtained as in Table VI. MATLAB fuzzy toolbox is used for these operations.

TABLE VI: WEIGHT MATRIX

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	0.798	0	0	0	0	0.375
C2	0.798	0	0.625	0	0	0	0	0
C3	0	0.625	0	0.625	0	0	0	0
C4	0.375	0	0	0	0.375	0	0.5	0.625
C5	0	0.25	0	0	0	0	0	0
C6	0	0	0	0	0	0	0.625	0.625
C7	0	0	0	0.798	0	0	0	0
C8	0	0	0	0.25	0	0	0.375	0

The iterative formulation of FCM is run via FCMapper software for obtaining the importance degrees of success factors on achieving ABET. The resulting importance values are listed in Table VII.

TABLE VII: IMPORTANCE VALUES

Label	Importance degree
C1	0.866639
C2	0.828089
C3	0.890907
C4	0.917639
C5	0.748960
C6	0.659046
C7	0.890861
C8	0.901297

In order to provide a comparative study, IFCM technique is employed. In the application of this method, the experts provide their opinions by reaching a consensus, and hence they used the linguistic scale shown in Table VIII.

TABLE VIII: SCALE OF FUZZY NUMBERS [4]

Linguistic term	Intuitionistic fuzzy number
VH	<0.95,0.05>
H	<0.70,0.25>
M	<0.50,0.40>
L	<0.25,0.70>
VL	<0.05,0.95>

The linguistic data, membership values, non-membership values, and hesitation values for causal relationships, are given in Tables IX, X, and XI, respectively.

TABLE IX: MEMBERSHIP VALUES

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	0.7	0	0	0	0	0.25
C2	0.95	0	0.5	0	0	0	0	0
C3	0	0.7	0	0.5	0	0	0	0
C4	0.5	0	0	0	0.5	0	0.5	0.5
C5	0	0.05	0	0	0	0	0	0
C6	0	0	0	0	0	0	0.5	0.7
C7	0	0	0	0.95	0	0	0	0
C8	0	0	0	0.25	0	0	0.25	0

TABLE X: NON-MEMBERSHIP VALUES

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	0.25	0	0	0	0	0.7
C2	0.05	0	0.4	0	0	0	0	0
C3	0	0.25	0	0.4	0	0	0	0
C4	0.4	0	0	0	0.4	0	0.4	0.4
C5	0	0.95	0	0	0	0	0	0
C6	0	0	0	0	0	0	0.4	0.25
C7	0	0	0	0.05	0	0	0	0
C8	0	0	0	0.7	0	0	0.7	0

TABLE XI: HESITATION VALUES

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0	0.05	1	1	1	0	0
C2	0	0	0	0	1	0	0	0
C3	0	0	0	0.1	0	0	0	0
C4	0	0	0	0	0.1	0	0	0
C5	0	0	0	1	0	0	0	0
C6	1	0	1	0	0	0	0	0.05
C7	1	0	1	0	0	0	0	0
C8	1	0	0	0	0	0	0.05	0

IFCM technique is employed and importance weights are obtained by running the formulation (2) until it will be stabilized, and the values of concepts will remain same. FCMapper software is used for these operations. The factors' values are given in Table XII.

TABLE XII: FACTORS VALUES

Label	Importance degree
C1	0.892496
C2	0.810453
C3	0.864057
C4	0.908137
C5	0.753360
C6	0.659046
C7	0.860565
C8	0.879188

V. CONCLUSION

To obtain the importance weights of success factors of ABET, evaluation criteria that influence the success of achieving the accreditation are determined through expert opinions and then algorithm of the work is reported by considering FCM technique. Importance weights of factors are assigned by applying FCM methodology, "quality steering team and leader" and "institutional quality compliance" are the most effective factors however "document orientation and knowledge sharing culture" and "academic and research excellence" are the least influential criteria.

In order to reveal a comparative analysis to demonstrate the robustness of the employed technique, IFCM method is utilized, and very similar importance values are obtained with

FCM results. Future research will focus on proposing a multi-criteria decision making based selection process, in which a determination whether a university may achieve ABET or not, will be provided

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