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Fuzzy decision analysis for regional contextualization of global educational frameworks

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Abstract. The main aim of this research work is to identify a suitable educational framework, which can be implemented in the institutions of a specific region, so as to reform their educational system in a contextualized way. It is proposed to investigate the impact of unpredictable events on the instructional methodologies adopted by the globally accepted educational frameworks, by perceiving experts' opinion in linguistic terms, thus formulating a fuzzy decision matrix to derive the fuzzy set of alternatives. Expert opinions are gathered based on the cost, quality of education, and learning outcomes independently with respect to each imprecise event and the methodology to be considered. The educational framework that adopts the instructional methodology which has the highest grade of membership in the derived fuzzy set of alternatives, shall be considered for implementing educational reformation in the institutions of a specific region to match the global competency with respect to desirable graduate attributes. Fuzzy statistical methods have been applied to verify the closeness of the derived fuzzy set of alternatives towards making appropriate decisions. Fuzzy Hurwicz Rule is applied to balance the decision due to optimistic or pessimistic views of the experts about the imprecise events.

Keywords. Educational framework; fuzzy decision analysis; fuzzy Hurwicz rule; fuzzy statistical methods; instructional methodologies.

1. Introduction

The education system to be followed should be adaptable to the context of culture, the industrial revolution and the developmental growth of a specific region, which will be certainly influenced by many unpredictable factors. The system once implemented should withstand over a long period not only to cope with the technological changes but also to meet the global competency requirement. Universities in the USA and European countries have developed contextualized educational frameworks such as CDIO (conceive, design, implement and operate) [1–3, 9], NEET (new engineering education transformation) [10], etc., that are well-defined especially for technical education and have been implemented in their institutions to meet the challenges and requirement to dominate the world in the 21st century. In India, nearly 1.5 million candidates complete their graduation from technical institutions every year and hence it should not miss the opportunity to forecast the unprecedented challenges of the 21st century. In every region of India, there exists diversity of culture and hence adopting an educational framework for reformation of educational system in a specific region to meet the global competency requirement is a challenging task due to uncertainty in predicting the future events over the long term period.

Higher education, especially technical education in India is facing a lot of challenges due to many inadequacies. Efforts have been taken to improve the situation but due to irregularity and inconsistency in making the efforts, there are no significant changes in the current educational scenario. Due to unprecedented growth in technology, lot of diversifications with focus on specialization are required to meet the industrial as well as societal needs. Long since, it has been felt, there is a need for robust educational system to promote the practical skills of the faculty so as to cope with the rapidly changing technological developments. There is a long term inconsistency in understanding the depth and breadth of technological changes especially in higher learning institutions due to inadequate competency of faculty.

The phenomenal growth in technological development is to be monitored continuously and the emerging areas need to be identified from time to time accordingly. The curriculum, instructional strategies and the practical skills of the faculty are to be regularly updated. Over a long term period it emerges as a challenging task to predict the direction of technological developments, the political

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stability and its impact on the higher education system, financial stability and the interest of the young generation for higher education i.e., the probability of occurrence of the above stated facts cannot be predicted precisely. Even though, the government's support for higher education system especially in the area of applied research and development is adequate but sometimes it is lacking and uncertain due to the prevailing socio-economic conditions. The quantum of interaction between most of the engineering institutions and industries is also not known precisely due to inconsistency in attitude and examination oriented teaching-learning process.

The existing educational frameworks insist the need for a change from the old conventional and traditional way of teaching and learning process to more innovative instructional strategies and sophisticated active learning methodologies to cope with the new emerging trends. At present, many educational frameworks are being adopted by various Universities to enable the educators to embed global competence into the existing curriculum, assessment methods and instructional levels to face the challenges of rapid technological change and development. An appropriate policy is to be evolved to have an effective educational framework to meet the above requirements.

To cope with the rapid technological changes, it has become mandatory for any educational system to reassess the knowledge, skills and attitude of the students towards the need for success with global consent. The member states of the United Nations and the Organisation for Economic Co-operation and Development jointly conducted a Programme for International Student Assessment in 2018 for prioritizing learning towards global citizenship and global competency and also for supporting educators to integrate global competence into their teaching.

The educational system should provide a platform for the students to investigate and examine the issues of local, global and cultural significance with effective interactions across regions and understanding the views of others for collective well-being and sustainable development and for the educators to integrate the global competence into their teaching. An appropriate educational framework with more emphasis on active learning has to be adopted to enable the students to gain global competence by practising skill development and learning real-world topics. The educational frameworks differ from each other based on the instructional strategies adopted i.e., organizing debates, quizzes, discussions, learning from current situations and project based learning, etc. To meet the challenge of changes, the educational framework should develop the professional learning skills of the teachers and provide collaborative platforms so as to transform their teaching, their classrooms and each and every one of their students towards global competence.

To choose an appropriate educational framework based on the socio-economic and cultural contexts of a specific region and to implement the reformation of the educational system, fuzzy decision analysis is proposed to derive fuzzy set of instructional methodologies, where each methodology is associated with a grade of membership, considering the impact of imprecise events against each methodology over a long range period with respect to the parameters, cost of education, quality of education and learning outcomes by observing the experts' opinions which are in linguistic terms.

The work reported in this research article is divided into five sections including introduction. Section 2 delineates the work reported so far in the area of decision making for suitable identification of educational framework for a region to meet the global standards and presents the need for fuzzy decision analysis. The statistical methods applied in the decision making process have been briefed in section 3. The proposed fuzzy decision analysis for effective identification of educational framework suitable to specific region of study is outlined in section 4. In section 5, the conclusions are provided with the discussion of derived results based on the analysis.

2. State-of-the-art

Engineering students require quality learning so as to become successful engineers. The leaders of academia, industry and government are consistently addressing the necessity of reformation in engineering education by analysing the desired attributes i.e., knowledge, skill and attitude to enhance the level of global competency among the engineering graduates [1]. The educational system to be chosen for implementation should be a balanced one, which should withstand the unpredictable changes and moderate in maintenance even though there will be frequent changes in the teaching and learning methodologies. It should address how far the courses are good enough to imbibe the changes that may happen and the possible occurrence of imprecise events over a long range period. Further it should have clear views about what type of students the university wants to educate, various challenges the students will face after 10 or 15 years, the requirement of value added courses that the university shall deliver and the instructional methodologies that will help to sustain towards preparation of globally competent engineers in the future [2].

Various educational frameworks have been developed by many universities worldwide adopting various instructional methodologies to improve the quality of technical education. The CDIO syllabus is compared with UNESCO Four Pillars of Learning, ABET EC2010 Criteria, Canadian Engineering Accreditation Board (CEAB Graduate Attributes Criteria) and other national and international standards such as British UK-SPEC, Dublin Descriptors and European EUR-ACE for enhancing the educational system [3]. The current version of CDIO syllabus shall be customized to facilitate the curriculum design and pedagogic approaches to gain detailed insight into its content and objectives and to promote the assessment tools for betterment of outcome based assessment. In 2013, the University of Twente, Netherlands implemented the Twente Educational Model (TEM) using Project-led Education to improve the success rate and make their graduate programmes more opt for the students. Using the educational model TEM, the students will learn their own discipline in sufficient depth to become T-shaped Professionals and connect it to other disciplines and the society as a whole and hence become active learners [4]. In the year 2016, an educational paradigm called New Engineering Education Transformation (NEET) that adopts innovative, modern educational and pedagogical approaches using flexible curricular structure was launched by Massachusetts Institute of Technology that aimed at developing and delivering a world-leading programme of under graduate engineering education at the university level to face the challenges of engineering in the 21st century [5]. Eindhoven University of Technology has recently followed an educational framework, which is based on challenge-based learning to make their students to become Eindhoven engineers where they acquire in-depth knowledge in one or two disciplines with the skills to address the real-world challenges by experiencing inter-disciplinary learning [6]. Current education system is facing unprecedented challenges due to social, economic and environmental conditions which are induced by accelerating globalization and a faster rate of technological developments. In the year 2018, the Organisation for Economic Co-operation and Development (OECD) has launched a new project [7], "The Future of Education and Skills 2030" that addresses those unprecedented challenges and insists the students to develop curiosity, imagination, resilience and self-regulation to meet the requirement of global competency by the year 2030.

The technical universities in Netherlands have developed innovative frameworks to cope with the above requirement for a long period [8]. Recent technological advancements transform not only the life pattern of our students but also the way of their education. The effect of technological changes necessitates new and innovative curriculum design, digital access of course materials and online delivery mechanism, which in turn will transform the instructional methodologies. Teachers always play a predominant role in motivating the students for consistent and active learning with passion and make them to acquire necessary knowledge with appropriate skills and attitudes. Roskilde and Aalborg Universities practiced Problem/Project Based Learning (PBL) during initial stages of 1970s in a wide range of subject areas such as engineering, science, social science and humanities. The PBL model addresses the learning outcomes with respect to Knowledge, Skills and Competencies. CDIO and PBL models focus on wide range of learning outcomes to accelerate the students in the direction of attaining required knowledge, skills and attitude levels to become globally competent professionals [9]. Project based learning is an instructional approach in which students are working together as a group to create a product or presentation about the developed product and their individual performance is evaluated during the course of study. Problem based learning is an instructional approach in which the students are working together to investigate and find an optimal or a precise solution for the given problem. Students are able to apply prior knowledge and gain experience in problem solving process rather than outcome of the process [10].

Challenge Based Learning (CBL) is an interdisciplinary approach in which students have been encouraged to develop their deep skills in identifying complex challenges, problem formulation and sustainable development. In principle, CBL follows CDIO towards engineering education and provides more opportunity to the students to work actively with peers, teachers and stakeholders in the society so as to identify the complex challenges in the real-world problems [11, 12]. The University College Dublin (UCD) adopts Biggs Model of Constructive Alignment in curriculum design. Biggs model requires alignment between three areas namely teaching-learning process, intended learning outcomes and assessment. All aspects of teaching and assessment methods are encouraged to use higher order learning process with practical implementation for quality learning. Constructive alignment is a more prominent approach to achieve intended learning outcomes for individual courses as well as degree programmes at the institutional level with satisfying graduate attributes [13]. K-12 standards have led a pathway to improve the learning outcomes of the engineering students and focus on the achievements in the fields of Science, Technology, Engineering and Mathematics (STEM). In 2006, the National Academy of Engineering and National Research Council Center for Education established the committee on K-12 Engineering Education. The committee set forth three general principles for K-12 engineering education that emphasize engineering design, incorporate appropriate knowledge and skills in the fields of STEM and promote engineering habits of mind [14].

Punyabukkana *et al* [15] have done a case study in Thailand to analyse the teaching methods in engineering education and delineate the pros and cons of various instructional methodologies such as Active learning, Flipped classrooms and Traditional lecture. The outcome of their analysis portrays that active learning is a good way to improve students' learning outcomes even though few researchers support flipped class room learning. Students prefer active learning than flipped class room learning because it takes more time due to learning of same material before and after the class room sessions.

Active learning is the solution to make engineering education more interesting. Active learning is one among the 12 CDIO standards to increase the thinking skill and problem solving capability of students [16]. The New Engineering Education Transformation also ensures the active engagement of students in the class room with creative use of digital and professional experience in their learning. Twente Educational model is focused on active instructional methodologies and project-led education. In the University of Twente, Netherlands, a number of faculty members and academic support employees have carried out projects on active learning, peer feedback and instruction, flipping the class room and the classrooms of the future [17].

Sale *et al* [18] have presented a pedagogical framework in one of the CDIO conferences (2017), which is evidence-based flipped classroom that incorporates practical and core principles of learning, information and communication technologies to meet the proficiency expectations by activating the prior knowledge of the learners and connected to new learning paradigms. Bruniges [19] has also proposed evidence-based approach for teaching and learning to maximize the student outcomes. The author has proposed methodologies to assess the evidence through teacher observation, test, peer assessment and practical performance that constitutes the data for educational attainment and to measure the progress of individuals. Abdulwahed [20] has developed a novel model for technology innovation and engineering education by contextualizing the global educational frameworks regionally towards elevation of national knowledge based economy and sustainable development taking into consideration of Gulf Cooperation Council and Qatar Contextual needs. The Steering Committee of the National Engineering Education Research Colloquies has pointed out the importance of globalization and trans-continental enterprising, forthcoming challenges in sustainable engineering and especially the decline of interest in engineering education among school students. All of these and other reasons require radical change in curriculum and in the way of teaching and learning process in engineering education.

Numerous instructional methodologies have been adopted by several educational frameworks and implemented in various Universities worldwide. There is a necessity to investigate the region based solution for deciding an appropriate educational framework to balance technological innovation, economic competitiveness and environmental protection taking into consideration of social flourishing in future education and cultural significance. The investigation should consider the fact that certain events such as socio-economic status, unstable political condition and imbalance in financial situation etc., whose occurrence cannot be predicted accurately, which will have predominant impact on the implementation of the educational system that should exist for a long period in a specific region. Hence, fuzzy decision analysis has been proposed in this work by quantifying the occurrence of imprecise events by the subjective judgement of the experts based on the context of a specific region as well as considering the parameters "cost of education", "quality of education" and "learning outcomes" for the proposed decision analysis.

3. Statistical methods in decision making

There are several well proven statistical approaches to support decision makers for making conclusion about alterative chances. In general, any decision making problem will be considered under certainty, uncertainty and risky situations. The statistical methods such as Maximax, Maximin, Hurwicz, Minimax Loss and Worth Expectation criterion are used by the decision makers under various circumstances [21, 22]. Maximax criterion is an optimistic method which gives best of the best while Maximin criterion is pessimistic, which yields the best among the worst. The Hurwicz rule combines the Maximax and Maximin criterion using a relation with an optimism-pessimism index. The Minimax Loss or Regret principle is concerned about the regret of not choosing a better decision for the same set of events. The Worth Expectation criterion is all about the estimation of the worth of each decision taken. Fuzzy concepts have been applied to these statistical decision making approaches [23, 24] to verify the correctness of the derived decision based on the subjective opinion of the experts.

4. Fuzzy decision analysis for effective identification of an educational framework

The worldwide Engineering Professional Associations like European Society for Engineering Education (SEFI), Active Learning Engineering Education (ALE), National and International Accreditation Organization for engineering programmes such as Accreditation Board for Engineering and Technology (ABET), European Network for Accreditation of Engineering Education (ENAEE) and National Board of Accreditation (NBA) have implemented innovative strategic educational frameworks especially to enhance the engineering education by achieving desired graduate attributes with a common aim to produce globally competent professionals [1, 3]. The existing educational frameworks have seen profound changes and growth over a period, since many inadequacies are present due to rapid technological changes, political stability and its impact, financial stability, cost of education, industrial involvement, frequent changes of interest among young generation in higher education, non-availability of appropriate and adequate human resources and the sustainable challenges due to environmental changes and diversity of culture.

While implementing an academic system to bring educational reformation in the institutions of a specific region, the knowledge of the events that may occur over a long range period is not known precisely and hence the utilities associated with the different instructional methodologies are also not known precisely. The region selected for this study is the northern part of Chennai in Tamil Nadu constituting nine technical institutions including a private University and several small scale and medium level industries both private and public sectors. It is a challenging task to identify the best instructional methodology for a specific region that shall be adopted for implementation over a long period with optimal cost, which will enhance the quality of education and meet all the requirements of industrial growth and societal developments. It is proposed to derive a fuzzy set of instructional methodologies that represents the relative merits of all methodologies using grades of membership. The fuzzy decision making model proposed by S. B. Dhar [25] is utilized to derive the fuzzy decision set of instructional methodologies and hence to identify the appropriate educational framework that is fit for implementation in the institutions of a specific region. Fuzzy statistical methods [23, 24] have been applied to verify the correctness of the decision and to estimate the worth loss, which is the outcome of not considering the best decision.

In the proposed fuzzy decision making model, the subjective judgment of the experts is expressed in linguistic terms such as Very High, High, Medium and Low, which are assigned fuzzy triangular values [26, 27] as given in t The expert can choose a value from the range of fuzzy triangular values assigned for each linguistic term respectively to represent the possible occurrence of an imprecise event over a long range period.

Table 2 shows the possible events viz., technology change (e1), political stability (e2), industrial involvement (e3), human resource adequacy (e4) and socio-economic status (e5) that may occur over a long range period whose probability of occurrence cannot be predicted precisely.

They are represented as fuzzy events whose occurrences are subjectively defined by the experts and their respective grades of membership are obtained using Equation (1) with the triangular membership function given in figure 1. Let l, m and h be the real numbers with l < m < h. The Triangular Fuzzy Number represented as A = (l, m, h) is a fuzzy number, whose membership function $\mu_{\overline{A}}(x)$ is defined as follows [27]:

$$\mu_{\overline{A}}(x) = \begin{cases} 0, & l \leq 0 \\ \dfrac{x-l}{m-l} & l \leq x \leq m \\ \dfrac{h-x}{h-m} & m \leq x \leq h \\ 0, & x \geq h \end{cases} \tag{1}$$

The imprecise events over a long range period, which are to be considered in the context of deciding an appropriate futuristic educational framework is represented by the following fuzzy set ε using the subjective judgement of experts (Equation 2).

$$\varepsilon = [(e1,\ 0.9), (e2,\ 0.4), (e3,\ 0.8), (e4,\ 0.7), (e5,\ 0.3)] \tag{2}$$

The process of decision making to identify the appropriate educational framework considers the cost of education, quality of education and learning outcomes as major parameters in the context of socio-economic status of a specific region. The instructional methodologies adopted by various educational frameworks are being considered in the decision analysis as alternatives. Within the considered region of study, appropriate questionnaires have been populated with respect to each imprecise event (ei), its impact on each instructional methodology (*im*i) based on the above major parameters and opinions are gathered from 23 senior faculty and 9 industrial experts who are actively participated in answering the questionnaires. Since the educational system to be considered for implementation should withstand for a long period, the impact of each event on every instructional methodology i.e., the utility value associated with these two entities is not known precisely because the occurrence of events themselves are not known precisely over a long range period. By considering the cost of education as a predominant parameter, the utility values associated with all events and methodologies are subjectively defined by obtaining the opinion of the experts in linguistic terms and are given in table 3. The possible payoff values are derived from the subjective utility values using triangular fuzzy range of values (table 1) and are given in table 4.

The elements of the payoff matrix are awarded with grades of membership based on the subjective judgement of the events. The fuzzy payoff values ρ associated with each instructional methodology are given in Equation (3).

$$\begin{aligned}
\rho_1 &= [(0.90, 8), (0.40, 5), (0.80, 8), (0.70, 8), (0.30, 7)] \\
\rho_2 &= [(0.90, 5), (0.40, 3), (0.80, 4), (0.70, 5), (0.30, 4)] \\
\rho_3 &= [(0.90, 7), (0.40, 3), (0.80, 4), (0.70, 7), (0.30, 3)] \\
\rho_4 &= [(0.90, 5), (0.40, 3), (0.80,\ 6), (0.70, 4), (0.30, 3)] \\
\rho_5 &= [(0.90, 8), (0.40, 6), (0.80,\ 8), (0.70, 7), (0.30, 6)] \\
\rho_6 &= [(0.90, 6), (0.40, 4), (0.80,\ 5), (0.70, 6), (0.30, 4)] \\
\rho_7 &= [(0.90, 5), (0.40, 2), (0.80,\ 5), (0.70, 4), (0.30, 1)] \\
\rho_8 &= [(0.90, 5), (0.40, 3), (0.80,\ 5), (0.70, 5), (0.30, 3)] \\
\rho_9 &= [(0.90, 7), (0.40, 3), (0.80,\ 5), (0.70, 5), (0.30, 4)] \\
\rho_{10} &= [(0.90, 9), (0.40, 6), (0.80,\ 8), (0.70, 8), (0.30, 7)]
\end{aligned} \tag{3}$$

The set of possible payoff values is given as,

$$\begin{aligned} S &= \{\rho_1\} \cup \{\rho_2\} \cup \{\rho_3\} \cup \ldots \{\rho_{10}\} \\ &= (1, 2, 3, 4, 5, 6, 7, 8, 9) \end{aligned}$$

To evolve the maximizing sets {η} for all instructional methodologies, each payoff value in the payoff matrix is to be divided by the maximum payoff i.e., by ρ_{max} as estimated in Equation (4) and the result is the grades of membership of the actual payoff values as given Equation (5).

$$\rho_{max} = \mathrm{Sup}_{\rho}(S) = 9 \tag{4}$$

$$\begin{aligned}
\eta_1 &= [(0.89, 8), (0.56, 5), (0.89, 8), (0.89, 8), (0.78, 7)] \\
\eta_2 &= [(0.56, 5), (0.33, 3), (0.44, 4), (0.56, 5), (0.44, 4)] \\
\eta_3 &= [(0.78, 7), (0.33, 3), (0.44, 4), (0.78, 7), (0.33, 3)] \\
\eta_4 &= [(0.56, 5), (0.33, 3), (0.67, 6), (0.44, 4), (0.33, 3)] \\
\eta_5 &= [(0.89, 8), (0.67, 6), (0.89, 8), (0.78, 7), (0.67, 6)] \\
\eta_6 &= [(0.67, 6), (0.44, 4), (0.56, 5), (0.67, 6), (0.44, 4)] \\
\eta_7 &= [(0.56, 5), (0.22, 2), (0.56, 5), (0.44, 4), (0.11, 1)] \\
\eta_8 &= [(0.56, 5), (0.33, 3), (0.56, 5), (0.56, 5), (0.33, 3)] \\
\eta_9 &= [(0.78, 7), (0.33, 3), (0.56, 5), (0.56, 5), (0.44, 4)] \\
\eta_{10} &= [(1.0, 9), (0.67, 6), (0.89, 8), (0.89, 8), (0.78, 7)]
\end{aligned} \tag{5}$$

The fuzzy decision making sets are derived by taking the intersection between the sets of fuzzy payoff values using the subjective judgement of the events and the maximizing sets obtained using the maximum payoff value ρ_{max} , i.e., taking the intersection between the grades of membership of both sets $\{\rho\}$ and $\{\eta\}$. The grades of membership of fuzzy decision making sets $\int_{Đi}$ are obtained as follows:

$$\int_{Đi} = \int_{\rho i} \wedge \int_{\eta i} \tag{6}$$

where is minimum operator, $\int_{\rho i}$ and $\int_{\eta i}$ are grades of membership of ρ_i and η_i respectively; hence the fuzzy decision making sets ($Đ_i$) are:

$$\begin{aligned}
Đ_1 &= [(0.89, 8), (0.40, 5), (0.80, 8), (0.70, 8), (0.30, 7)] \\
Đ_2 &= [(0.56, 5), (0.33, 3), (0.44, 4), (0.56, 5), (0.30, 4)] \\
Đ_3 &= [(0.78, 7), (0.33, 3), (0.44, 4), (0.70, 7), (0.30, 3)] \\
Đ_4 &= [(0.56, 5), (0.33, 3), (0.67, 6), (0.44, 4), (0.30, 3)] \\
Đ_5 &= [(0.89, 8), (0.40, 6), (0.80, 8), (0.70, 7), (0.30, 6)] \\
Đ_6 &= [(0.67, 6), (0.40, 4), (0.56, 5), (0.67, 6), (0.30, 4)] \\
Đ_7 &= [(0.56, 5), (0.22, 2), (0.56, 5), (0.44, 4), (0.11, 1)] \\
Đ_8 &= [(0.56, 5), (0.33, 3), (0.56, 5), (0.56, 5), (0.30, 3)] \\
Đ_9 &= [(0.78, 7), (0.33, 3), (0.56, 5), (0.56, 5), (0.30, 4)] \\
Đ_{10} &= [(0.90, 9), (0.40, 6), (0.80, 8), (0.70, 8), (0.30, 7)]
\end{aligned} \tag{7}$$

The highest grade of membership for each fuzzy decision making set is determined (optimistic perception) as given in Equation (8),

$$\begin{aligned}
H\int_1 &\vee (0.89, 0.40, 0.80, 0.70, 0.30) = 0.89 \\
H\int_2 &\vee (0.56, 0.33, 0.44, 0.56, 0.30) = 0.56 \\
H\int_3 &\vee (0.78, 0.33, 0.44, 0.70, 0.30) = 0.78 \\
H\int_4 &\vee (0.56, 0.33, 0.67, 0.44, 0.30) = 0.67 \\
H\int_5 &\vee (0.89, 0.40, 0.80, 0.70, 0.30) = 0.89 \\
H\int_6 &\vee (0.67, 0.40, 0.56, 0.67, 0.30) = 0.67 \\
H\int_7 &\vee (0.56, 0.22, 0.56, 0.44, 0.11) = 0.56 \\
H\int_8 &\vee (0.56, 0.33, 0.56, 0.56, 0.30) = 0.56 \\
H\int_9 &\vee (0.78, 0.33, 0.56, 0.56, 0.30) = 0.78 \\
H\int_{10} &\vee (0.90, 0.40, 0.80, 0.70, 0.30) = 0.90
\end{aligned} \tag{8}$$

Therefore, the fuzzy set of instructional methodologies i.e., alternatives considering the "cost of education" as predominant parameter (A_{ce}) is given by,

Table 1. Assumed triangular fuzzy range of values for linguistic terms.

Linguistic terms	Triangular fuzzy range
Very High (VH)	(10.0, 9.5, 9.0)
High (H)	(8.0, 7.5, 7.0)
Medium (M)	(6.0, 5.0, 4.0)
Low (L)	(3.0, 1.5, 0.0)

$$\begin{aligned}
A_{ce} = [&0.89|im_1, 0.56|im_2, 0.78|im_3, 0.67|im_4, \\
&0.89|im_5, 0.67|im_6, 0.56|im_7, 0.56|im_8, 0.78|im_9, 0.90|im_{10}]
\end{aligned} \tag{9}$$

Alternative 10 (*im*$_{10}$) i.e., the instructional methodology, "Project/Problem Based Learning + K-12 Standards" has the highest grade of membership, therefore the educational framework that accomplishes the above group of instructional methodologies, CDIO (Conceive, Design, Implement and Operate) is the best strategy for implementation in the region of study considering the cost of education as the predominant parameter for decision analysis. This fuzzy set of alternatives (Equation 9) indicates the relative merits of all the alternatives. From the derived fuzzy decision set, it is observed that the alternate methodologies that shall be decided are im_1 and im_5, which are again the subcomponents of CDIO.

The lowest grade of membership for each fuzzy decision making set (Equation 7) is determined (pessimistic perception) as given in Equation (10),

$$\begin{aligned}
L\int_1 &\vee (0.89, 0.40, 0.80, 0.70, 0.30) = 0.30 \\
L\int_2 &\vee (0.56, 0.33, 0.44, 0.56, 0.30) = 0.30 \\
L\int_3 &\vee (0.78, 0.33, 0.44, 0.70, 0.30) = 0.30 \\
L\int_4 &\vee (0.56, 0.33, 0.67, 0.44, 0.30) = 0.30 \\
L\int_5 &\vee (0.89, 0.40, 0.80, 0.70, 0.30) = 0.30 \\
L\int_6 &\vee (0.67, 0.40, 0.56, 0.67, 0.30) = 0.30 \\
L\int_7 &\vee (0.56, 0.22, 0.56, 0.44, 0.11) = 0.11 \\
L\int_8 &\vee (0.56, 0.33, 0.56, 0.56, 0.30) = 0.30 \\
L\int_9 &\vee (0.78, 0.33, 0.56, 0.56, 0.30) = 0.30 \\
L\int_{10} &\vee (0.90, 0.40, 0.80, 0.70, 0.30) = 0.30
\end{aligned} \tag{10}$$

These optimistic and pessimistic perceptions can be balanced using fuzzy Hurwicz's rule with an optimism and pessimism index α. The fuzzy Hurwicz rule is defined as follows (Equation 11).

$$H = \alpha\,(H\int_i) + (1 - \alpha)\,L\int_i \tag{11}$$

Based on the value of optimism–pessimism index $\alpha = 0.5$, the fuzzy Hurwicz decision set is derived as follows:

Table 2. Grades of membership of imprecise events.

Events	Occurrence of possible events over a long period	Expert opinion in linguistic terms	Grade of membership
e1	Technology change	VH	0.9
e2	Political stability	M	0.4
e3	Industrial involvement	H	0.8
e4	Human resources	H	0.7
e5	Socio-economic status	L	0.3

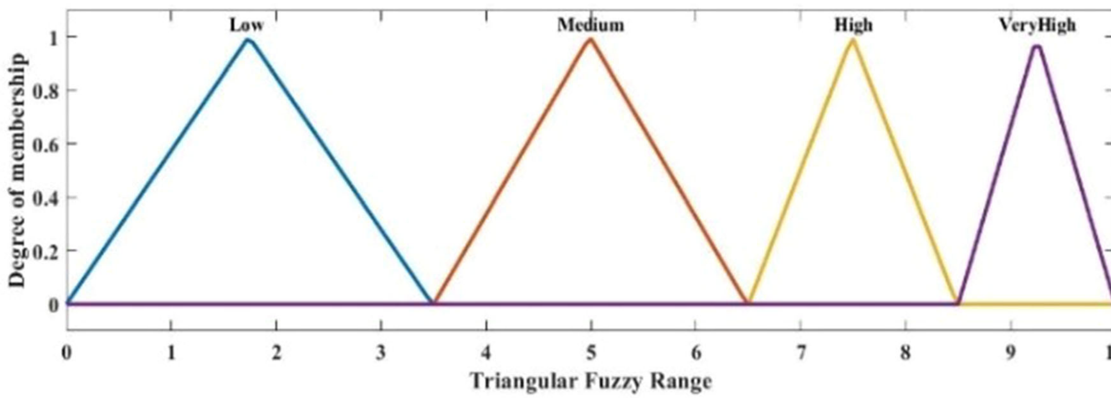

Figure 1. Representation of linguistic terms using triangular membership function.

$$= 0.5 * (0.89, 0.56, 0.78, 0.67, 0.89, 0.67, 0.56, 0.56, 0.78, 0.90$$
$$+ (1 - 0.5) * (0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.11, 0.30, 0.30, 0.30)$$
$$= (0.44, 0.28, 0.39, 0.33, 0.44, 0.33, 0.28, 0.28, 0.39, 0.45)$$
$$+ (0.15, 0.15, 0.15, 0.15, 0.15, 0.15, 0.06, 0.15, 0.15, 0.15)$$

According to the algebraic sum of two fuzzy sets [21], the fuzzy Hurwicz decision set is obtained as follows:

$$H = (0.528, 0.386, 0.481, 0.433, 0.528, 0.433, 0.318, 0.386, 0.481, 0.533)$$

Using the Hurwicz balancing criteria, it is observed that the instructional methodologies im_1, im_5 and im_{10} are having almost the same higher Hurwicz values and hence it has been proved the decision obtained using Equation (9), i.e., the instructional methodology im_{10} is the best strategy to be adopted for implementation.

Since the fuzzy decision analysis is carried out on the basis of subjective judgement of the experts about the imprecise events and further the utility values chosen for decision analysis are not known precisely, it is worth to evaluate the regret of not choosing the correct option for implementation. The fuzzy regret rule is utilized in which each grade of membership from the fuzzy decision sets ($Đ_i$) is subtracted from the largest value in its column. The fuzzy regret matrix is computed using Equation (7) and represented in table 5.

From the above table, the maximum fuzzy regret for each action is found and the alternative with the minimum value is chosen. The instructional methodology im_{10}, i.e., Project/ Problem Based Learning + K-12 Standards is chosen as the best one and hence no regret for the original decision.

Among the statistical decision making principles, the worth expectation criteria is the most used decision strategy that will give the maximum worth of the decision arrived. Fuzzy worth expectation criteria is applied on the fuzzy decision sets ($Đ_i$) to estimate the worth of the derived decision.

Let ω_i represent the expected worth of each instructional methodology im_i, then

$$\omega_i = \sum_{e=1}^{m} \mu_i * U_{ij} \tag{12}$$

where e = imprecise event that occurs over a long range period; m = number of possible events (specific to a region); U_{ij} = impact of each event on every instructional; methodology (utility value), considering "cost of education" as predominant parameter; μ_i = grade of membership or belief value of occurrence of each imprecise event occur over a long range period

The subject judgement of utilities (table 3) are quantified (table 4) and the belief of occurrence of events over a long range period is given in Equation (2). Hence the expected worth of each instructional methodology im_i can be computed directly using Equation (12). The vector ω_i is the expected worth for all methodologies in the set. The rule of

Table 3. Fuzzy utility matrix—subjective judgement based on “cost of education”.

Instructional methodologies	Events e1	e2	e3	e4	e5
Problem/project based learning (im_1)	H	M	H	H	H
Challenge based learning (im_2)	M	L	M	M	M
Biggs constructive alignment theory (im_3)	H	L	M	H	L
Competency based education (im_4)	M	L	M	M	L
K-12 standards (im_5)	H	M	H	H	M
Flipped classroom (im_6)	M	M	M	M	M
Evidence based learning (im_7)	M	L	M	M	L
Flipped + evidence based learning (im_8)	M	L	M	M	L
Competency + K-12 standards (im_9)	H	L	M	M	M
Project/problem based learning + K-12 Standards (im_{10})	VH	M	H	H	H

Table 4. Derived payoff matrix for fuzzy decision analysis.

Instructional methodologies	Events e1	e2	e3	e4	e5
im_1	8	5	8	8	7
im_2	5	3	4	5	4
im_3	7	3	4	7	3
im_4	5	3	6	4	3
im_5	8	6	8	7	6
im_6	6	4	5	6	4
im_7	5	2	5	4	1
im_8	5	3	5	5	3
im_9	7	3	5	5	4
im_{10}	9	6	8	8	7

maximum expected worth selects the best instructional methodology. In the fuzzy worth expectation criteria, the fuzzy belief vector is nothing but the subjective judgement of the imprecise events that occur over a long range period. The fuzzy belief vector is given as: μ_i = [0.9, 0.4, 0.8, 0.7, 0.3]. The expected worth for each instructional methodology (im_i) is estimated using Equation 12 and is given in the table 6.

From table 6, it is understood that the educational framework CDIO, which is the base for the instructional methodologies “Project/Problem Based Learning + K-12 Standards (im_{10})” has the highest expected worth and considering this decision for implementation to bring educational reformation in the institutions of a given region has no regret as proven by the fuzzy regret matrix given in table 5.

The decision analysis is being carried out to identify the appropriate educational framework to implement in the institutions of a specific region based on the context of certain events over a long range period whose probabilities of occurrence are not known precisely and considering the parameters of cost of education, quality of education and learning outcomes. The fuzzy set of instructional methodologies A_{ce} is obtained considering the cost of education as predominant parameter in decision analysis and is given in Equation (9).

A single parameter (cost of education) is considered and the fuzzy decision analysis is carried out to choose the appropriate instructional methodology to suit the need /

Table 5. Fuzzy regret matrix.

Instructional methodologies	Events e1	e2	e3	e4	e5	Max_i
im_1	0.01	0.00	0.00	0.00	0.00	0.01
im_2	0.34	0.07	0.36	0.14	0.00	0.36
im_3	0.12	0.07	0.36	0.00	0.00	0.36
im_4	0.34	0.07	0.13	0.26	0.00	0.34
im_5	0.01	0.00	0.00	0.00	0.00	0.01
im_6	0.23	0.00	0.24	0.03	0.00	0.24
im_7	0.34	0.18	0.24	0.26	0.19	0.34
im_8	0.34	0.07	0.24	0.14	0.00	0.34
im_9	0.12	0.07	0.24	0.14	0.00	0.24
im_{10}	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Expected worth calculation using fuzzy utility values.

Instructional methodologies	Events (possibility of occurrence)					ω_i
	e1 (0.9)	e2 (0.4)	e3 (0.8)	e4 (0.7)	e5 (0.3)	
im_1	8	5	8	8	7	23.3
im_2	5	3	4	5	4	13.6
im_3	7	3	4	7	3	16.5
im_4	5	3	6	4	3	14.2
im_5	8	6	8	7	6	22.7
im_6	6	4	5	6	4	16.4
im_7	5	2	5	4	1	12.4
im_8	5	3	5	5	3	14.1
im_9	7	3	5	5	4	16.2
im_{10}	9	6	8	8	7	24.6

requirement of specific region. In the similar way, the fuzzy set of instructional methodologies A_{qe} is obtained based on the context of a specific region by observing the experts' opinions, considering the quality of education as predominant parameter and is given in Equation (13). The fuzzy sets of instructional methodologies based on the learning outcomes are obtained considering industrial skills (*is*), higher studies (*hs*) and research interest (*ri*) as predominant parameters individually and are given as Equations (14), (15) and (16). A new fuzzy decision set has to be derived by combining all the fuzzy sets of instructional methodologies obtained using all parameters by taking fuzzy union of all the sets.

$$A_{qe} = [0.78\,|im_1, 0.90\,|im_2, 0.67\,|im_3, 0.70\,|im_4, 0.56\,|im_5, 0.56\,|im_6, 0.67\,|im_7, 0.70\,|im_8, 0.78\,|im_9, 0.89\,|im_{10}] \tag{13}$$

The fuzzy set of instructional methodologies A_{is} considering the learning outcome "industrial skills" as parameter is:

$$A_{is} = [0.80|im_1, 0.78|im_2, 0.56|im_3, 0.67|im_4, 0.44|im_5, 0.44|im_6, 0.67|im_7, 0.70|im_8, 0.78|im_9, 0.90|im_{10}] \tag{14}$$

The fuzzy set of instructional methodologies A_{hs} considering the learning outcome "higher studies" as parameter is:

$$A_{hs} = [0.88|im_1, 0.75|im_2, 0.63|im_3, 0.75|im_4, 0.75|im_5, 0.50|im_6, 0.63|im_7, 0.75|im_8, 0.63|im_9, 0.75|im_{10}] \tag{15}$$

The fuzzy set of instructional methodologies A_{ri} considering the learning outcome "research interest" as parameter is:

$$A_{ri} = [0.75|im_1, 0.88|im_2, 0.50|im_3, 0.63|im_4, 0.75|im_5, 0.75|im_6, 0.63|im_7, 0.75|im_8, 0.63|im_9, 0.75|im_{10}] \tag{16}$$

Taking fuzzy union of the sets [28] given in Equations (14), (15) and (16) i.e., A_{is} U A_{hs} U A_{ri}, the fuzzy set of instructional methodologies A_{lo} is obtained considering the learning outcomes as predominant parameter and is given in Equation (17).

$$A_{lo} = [0.88|im_1, 0.88|im_2, 0.63|im_3, 0.75|im_4, 0.75|im_5, 0.75|im_6, 0.67|im_7, 0.75|im_8, 0.78|im_9, 0.90|im_{10}] \tag{17}$$

The decisive fuzzy set of instructional methodologies $\boldsymbol{A}$ is obtained by taking union of the fuzzy sets A_{ce}, A_{qe} and A_{lo} which are given in Equations (9), (13) and (17).

$$\boldsymbol{A} = [0.89|im_1, 0.90|im_2, 0.78|im_3, 0.75|im_4, 0.89|im_5, 0.75|im_6, 0.67|im_7, 0.75|im_8, 0.78|im_9, 0.90|im_{10}] \tag{18}$$

The decisive fuzzy set of instructional methodologies (Equation 18) clearly indicates that the decision derived based on the parameter, cost of education i.e., from A_{ce} (Equation 9) holds good for all parameters collectively. The instructional methodologies im_1, im_2, im_5 and im_{10} are all having equal importance in the decisive fuzzy set, in which the instructional methodology im_2 (Challenge Based Learning) portraits the educational framework designed by Eindhoven University of Technology (TU/e Strategy 2030). The decision im_2 is based on the parameter "quality of education". The rest of the methodologies im_1, im_5 and im_{10} are purely based on the education framework CDIO. The fuzzy set of instructional methodologies based on the parameter "learning outcomes" also yields the im_{10} as the best strategy similar to fuzzy decision set based on the parameter, "cost of education".

5. Conclusion

In this work, the feasibility of implementing appropriate educational framework has been explored by choosing an appropriate instructional methodology to map the global standards devised by the competent authorities such as National Board of Accreditation in our country. All the ten instructional methodologies selected for investigation have been designed to meet the global competency. The factors which will have direct impact on the educational system are carefully chosen i.e., socio-economic status, political stability in the stand of higher education, technological advancements and to certain extent the environmental conditions with due consideration of cost of education, quality of education and learning outcomes as predominant parameters towards implementation of an educational framework over a long range period. The study is applicable only to the specific region taking into consideration of the above stated context since the factors mentioned will differ from one region to other region even within the State. As the aim is to map the regional educational framework with the global standards as recommended by the Board of Accreditation, there will not be any difference in the conceptual framework which shall be adopted by the higher educational institutions in a specific region. Hence the study is limited to the specific region and focus is made to map the global standards within the context of the region.

Since educational system implementation is based on the context of a specific region, the opinion on the instructional methodologies by the experts may differ from place to place obviously. The fuzzy decision analysis is carried out by considering the above stated imprecise events and their utility values i.e., the impact of the imprecise events on each instructional methodology with respect to each parameter. It is observed that the educational framework, which is suitable for one place will not contribute much in another place, i.e., in certain regions, there should be a balance between cost of education and quality of education. The Challenge based Learning, which is more suitable in the western countries may not be fit to be implemented in underdeveloped or developing regions. The parameters, cost of education, quality of education and learning outcomes are directly dependent on each other. The derived fuzzy set will indicate the feasibility of implementing an educational framework which comprises the instructional methodology with the highest grade of membership. If it is not possible to implement the educational framework which encompasses the instructional methodology with the highest grade of membership, the second methodology in the derived fuzzy set which has the next highest grade of membership shall be considered for implementation. For the region of study considered in this work, the instructional methodology "problem/project based learning + K-12 standards" has been evolved as the best strategy and hence the educational framework CDIO is decided for implementation. The decision is purely based on the regional contexts where the institution or the university is located.

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