

An Intelligent Approach to CAM Software Selection

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Abstract-In this paper, an intelligent approach is presented to help the companies select most suitable CAM software for their current and future needs. For this purpose, fuzzy AHP method is used to carry out CAM selection process more effectively, easily and applicable for a company. Shortly, the objectives of the research are; to define a step-by-step approach for an effective CAM software selection. The proposed approach is also illustrated on a case study.

I. INTRODUCTION

The computer-aided design and manufacturing (CAD/CAM) systems as integrated parts of a computer-integrated manufacturing (CIM) system, realizes all kinds of design and manufacturing activities in a product development environment (PDE) by using computer technology in a good manner. The implementation process of a CAD/CAM system can be difficult due to the fact that the amount of investment required is generally high relating to the degree of integration. That is why that designing, planning and realizing of these systems have received substantial attention in recent years due to high initial investment cost of such systems as well as unprecedented mixture of success and horror stories on their implementations [1]. On the other hand, one of the most important issues in a CAD/CAM implementation is to select the most satisfying software packages based upon the needs and expectations of a company. In the presence of multiple-criteria and alternatives for proper software selection, the multiple-criteria decision making (MCDM) problem arises. There are various MCDM methods in current literature, one of which is the analytic hierarchy process (AHP) is selected.

The conventional AHP invented by Reference [2] has been used for various MCDM problems for years. But, in the conventional AHP, the pair wise comparisons for each level with respect to the goal of the best alternative selection are conducted using a nine-point scale. That is why the application of Saaty's AHP has some shortcomings as follows [2]; (i) the AHP method is mainly used in nearly crisp decision applications, (ii) the AHP method creates and deals with a very unbalanced scale of judgment, (iii) the AHP method does not take into account the uncertainty associated with the mapping of one's judgment to a number, (iv) ranking of the AHP method is rather imprecise, (v) the subjective judgment, selection and preference of decision-makers have great influence on the AHP results.

In addition, a decision maker's requirements on evaluating process always contain ambiguity and multiplicity of meaning. Furthermore, it is also recognized that human assesment on qualitative attributes is always subjective and thus imprecise. Therefore, conventional AHP seems inadequate to capture decision maker's requirements explicitly. In order to model this kind of uncertainty in human preference, fuzzy sets could be incorporated with the pair wise comparison as an extension of AHP, called *fuzzy AHP*.

The fuzzy AHP approach allows a more accurate description of the decision making process. The earliest work in fuzzy AHP appeared in [3] which compared fuzzy ratios described by triangular membership functions. Logarithmic least square was used to derive the local fuzzy priorities. Later, using geometric mean, Reference [4] determined fuzzy priorities of comparison, whose membership functions were trapezoidal. By modifying the reference [3]'s method, Reference [5] presented a more robust approach to the normalization of the local priorities.

The main objective of this paper is to propose an approach for effectively evaluating computer-aided manufacturing (CAM) software selection alternatives in terms of a set of evaluation criteria. Moreover, in final section, the proposed approach was applied to a manufacturing company as a case study in order to prove its applicability on a real-life system.

II. RELATED RESEARCH

Fuzzy set theory is a mathematical theory designed to model the vagueness or imprecision of human cognitive processes that pioneered by Reference [6]. This theory is basically a theory of classes with unsharp boundaries. What is important to recognize is that any crisp theory can be fuzzified by generalizing the concept of a set within that theory to the concept of a fuzzy set. The stimulus for the transition from a crisp theory to a fuzzy one derives from the fact both the generality of a theory and its applicability to real world problems are enhanced by replacing the concept of a crisp set with a fuzzy set [7].

The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set [8-9]. The membership function represents the grade of membership of an element in a set. The membership values of an element vary between 0 and 1. Elements can belong to a set in a certain degree and elements can also belong to multiple set. Fuzzy set allows the partial membership of elements. Transition between membership and non-membership is gradually. Membership function maps the variation of value of linguistic variables into different linguistic classes. The adaptation of membership function for a given linguistic variable under a given situation is done in three ways; a) experts previous knowledge about the linguistic variable; b) using simple geometric forms having slopes (triangular, trapezoidal or s-functions) as per the nature of the variable; and c) by trial and error learning process.

The concept of fuzzy extent analysis used in this work is applied to solve the fuzzy reciprocal matrix for determining the criteria importance and alternative performance. To avoid the complex and unreliable process of comparing fuzzy utilities, the alpha-cut concept is used to transform the fuzzy performance matrix representing the overall performance of all alternatives with respect to each criterion into an interval performance matrix. Incorporated with the decision maker's attitude towards risk, an overall performance index is obtained for each alternative across all criteria by applying the

concept of the degree of similarity to the ideal solution using the vector matching function.

Because of the accuracy of fuzzy AHP method in a decision making process, it has been applied to many different areas such as; Reference [10] developed a decision support system using the fuzzy AHP to locate new convenience store. Reference [11] presented a fuzzy version of AHP to country risk assessment problem. Reference [12] used a fuzzy extension of the AHP for project selection and focused on the constraints that have to be considered within fuzzy AHP in order to take in account all the available information. Reference [13] evaluated alternative production cycles using the extended fuzzy AHP method. References [15-16] also presented an integrated approach to evaluating conceptual design alternatives in a new product development (NPD) environment using AHP-simulation and fuzzy AHP-simulation. Reference [17] used group decision support system (GDSS) for a real-life CAD-system selection application for an industrial company. Reference [18] developed an AHP-based simulation model for implementation and analysis of computer-aided systems. Reference [19] evaluated weapon system by AHP based on fuzzy scales. Reference [20] criticized on the invalidity of fuzzifying numerical judgments in the AHP. They mention that the judgments are themselves already fuzzy when they are allowed to vary in choice over the values of a fundamental scale, as in the AHP. Reference [21] applied the AHP to build a strategic framework for technology road-mapping. The paper emphasizes how the AHP is applied as a part of the development of a new concept called the technology development envelope (TDE). Reference [22] used the AHP and TOPSIS methods under fuzzy environment for weapon selection problem. Reference [23] utilized fuzzy AHP methodology for strategic analysis of healthcare service quality. Reference [24] studied on the order of the preference intensities in fuzzy AHP. Reference [25] proposed an integrated framework for analysis of electricity supply chain using an integrated SWOT-fuzzy TOPSIS methodology combined with the AHP method. They applied this method to Turkey as a case study. Reference [26] used fuzzy AHP and particle swarm optimization for multiple-criteria decision making problems. Reference [27] also used fuzzy AHP method for multiple-criteria supplier segmentation problem. Reference [28] proposed a hybrid approach using two-level SOM and combined AHP rating and AHP/DEA-AR method for selecting optimal promising emerging technology. Reference [29] also proposed a comprehensive decision-making method for wind power integration projects based on improved fuzzy AHP. Reference [30] studied on the effects of increasing fuzziness on AHP for spatial multi-criteria decision analysis. Reference [31] used a two-stage fuzzy AHP model for risk assessment of implementing green initiatives in the fashion supply chain. Reference [32] integrated QFD and fuzzy AHP for strategic logistics outsourcing. Reference [33] used the fuzzy AHP with opportunities, costs, and risks for evaluating hydrogen production methods.

III. PROPOSED APPROACH

In this paper, an intelligent approach, where fuzzy logic and the AHP method are used together for CAM software selection problem is proposed. In Fig. 1, this proposed approach is summarized step-by-step. In practice, the fuzzy AHP method has quite time-consuming implementation steps, especially if they are carried out manually. For instance, as the numbers of criteria and alternatives increase, the dimension of problem naturally expands such as an evaluation matrix with great deal of the columns and lines. This means too long and boring calculation process. Therefore, in this study, an Excel template is developed to facilitate these efforts required for both techniques.

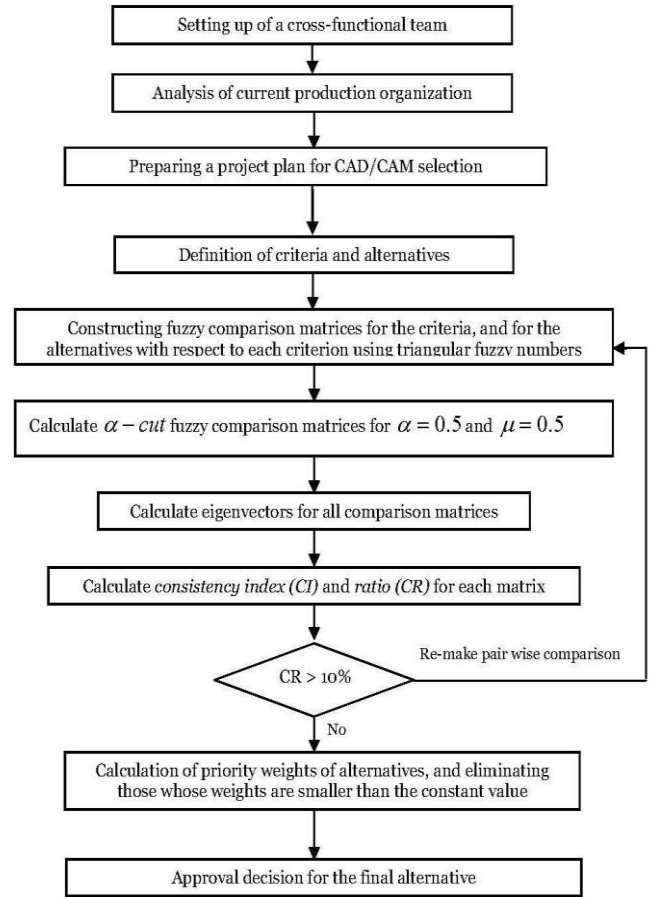


Fig.1. Integrated approach to CAM software selection

Fuzzy AHP approach: to use this approach, first the criteria and alternatives for each system should be well-defined. These criteria are used to evaluate the number of software alternatives for each system in market as a critical part of CAM software selection. These criteria that may change from a company to another should be well-defined by the project team according to the needs and the goals of company. Alternatives can be obtained from both their vendors and other sources in the market. Second, the fuzzy AHP is introduced (i.e. fuzzy pair wise comparison and the steps of the process) as follows;

Fuzzy representation of pair wise comparison; a hierarchy of software selection problem of a CAM system needs to be established before performing the pair wise comparison of AHP. After constructing a hierarchy for the problem, the decision maker is asked to compare the elements at a given level on a pair wise basis to estimate their relative importance in relation to the element at the immediate preceding level. In conventional AHP, the pair wise comparison is made by using a ratio scale. A frequently used scale is the nine-point scale [34] which shows the participants' judgments or preferences among the options such as equally important, weakly more important, strongly more important, very strongly more important, and absolutely more important preferred. Even though the discrete scale of 1-9 has the advantages of simplicity and easiness for use, it does not take into account the uncertainty associated with the mapping of one's perception or judgment to a number.

In this study, triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, are used to represent subjective pair wise comparisons of selection process in order to capture the vagueness. A fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \in R\}$, where x takes its values on the real line, $R: -\infty < x < +\infty$ and $\mu_F(x)$ is a continuous mapping from R to the closed interval $[0, 1]$. A triangular fuzzy number denoted as $\tilde{M} = (l, m, u)$, where $l \leq m \leq u$, has the following triangular type membership function;

$$\mu_F(x) = \begin{cases} 0 & x < l \\ x-l/m-l & l \leq x \leq m \\ u-x/u-m & m \leq x \leq u \\ 0 & x > u \end{cases}$$

Alternatively, by defining the interval of confidence level α , the triangular fuzzy number can be characterized as:

$$\forall \alpha \in [0,1] \tilde{M}_\alpha = [l^\alpha, u^\alpha] = [(m-l)\alpha + l, -(u-m)\alpha + u] \quad (1)$$

Some main operations for positive fuzzy numbers are described by the interval of confidence, by Reference [35] as given below;

$$\forall m_L, m_R, n_L, n_R \in R^+, \tilde{M}_\alpha = [m_L^\alpha, m_R^\alpha], \tilde{N}_\alpha = [n_L^\alpha, n_R^\alpha], \alpha \in [0,1]$$

$$\tilde{M} \oplus \tilde{N} = [m_L^\alpha + n_L^\alpha, m_R^\alpha + n_R^\alpha], \tilde{M} \ominus \tilde{N} = [m_L^\alpha - n_L^\alpha, m_R^\alpha - n_R^\alpha]$$

$$\tilde{M} \otimes \tilde{N} = [m_L^\alpha n_L^\alpha, m_R^\alpha n_R^\alpha], \tilde{M} / \tilde{N} = [m_L^\alpha / n_L^\alpha, m_R^\alpha / n_R^\alpha]$$

The triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, are utilized to improve the conventional nine-point scaling scheme. In order to take the imprecision of human qualitative assessments into consideration, the five triangular fuzzy numbers are defined with the corresponding membership function.

Steps of fuzzy AHP approach; The AHP method is also known as an eigenvector method. It indicates that the eigenvector corresponding to the largest eigenvalue of the pair wise comparisons matrix provides the relative priorities of the factors, and preserves ordinal preferences among the alternatives. This means that if an alternative is preferred to another, its eigenvector component is larger than that of the other. A vector of weights obtained from the pair wise comparisons matrix reflects the relative performance of the various factors. In the fuzzy AHP, triangular fuzzy numbers are utilized to improve the scaling scheme in the judgment matrices, and interval arithmetic is used to solve the fuzzy eigenvector [19]. In this study, the five-step-procedure is defined for fuzzy AHP as follows;

Step 1. Comparing the performance score: Triangular fuzzy numbers ($\tilde{1}$, $\tilde{3}$, $\tilde{5}$, $\tilde{7}$, $\tilde{9}$) are used to indicate the relative strength of each pair of elements in the same hierarchy.

Step 2. Constructing the fuzzy comparison matrix: By using triangular fuzzy numbers, via pair wise comparison, the fuzzy judgment matrix $\tilde{A} (a_{ij})$ is constructed as given below;

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \dots & 1 \end{bmatrix}$$

where, $\tilde{a}_{ij}^\alpha = 1$, if i is equal j , and $\tilde{a}_{ij}^\alpha = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$, if i is not equal j

Step 3. Solving fuzzy eigenvalues: A fuzzy eigenvalue, $\tilde{\lambda}$, is a fuzzy number solution to

$$\tilde{A}x = \tilde{\lambda}x \quad (2)$$

where \tilde{A} is a $n \times n$ fuzzy matrix containing fuzzy numbers \tilde{a}_{ij} and \tilde{x} is

a non-zero $n \times 1$ fuzzy vector containing fuzzy numbers \tilde{x}_i . To perform fuzzy multiplications and additions using the interval arithmetic and α -cut, the equation $\tilde{A}x = \tilde{\lambda}x$ is equivalent to

$$[a_{i1l}^\alpha x_{1l}^\alpha, a_{i1u}^\alpha x_{1u}^\alpha] \oplus \dots \oplus [a_{inl}^\alpha x_{nl}^\alpha, a_{inu}^\alpha x_{nu}^\alpha] = [\lambda x_{il}^\alpha, \lambda x_{iu}^\alpha]$$

$$\text{where, } \tilde{A} = [\tilde{a}_{ij}], x^t = (x_1, \dots, x_n)$$

$$a_{ij}^\alpha = [a_{ijl}^\alpha, a_{iju}^\alpha], x_i = [x_{il}^\alpha, x_{iu}^\alpha], \lambda = [\lambda_l^\alpha, \lambda_u^\alpha] \quad (3)$$

for $0 < \alpha \leq 1$ and all i, j , where $i=1,2,\dots,n, j=1,2,\dots,n$

α -cut is known to incorporate the experts or decision maker(s) confidence over his/her preference or the judgments. Degree of

satisfaction for the judgment matrix \tilde{A} is estimated by the index of optimism μ . The larger value of index μ indicates the higher degree of optimism. The index of optimism is a linear convex combination [14] defined as;

$$\tilde{a}_{ij}^\alpha = \mu a_{iju}^\alpha + (1 - \mu) a_{ijl}^\alpha, \quad \forall \mu \in [0,1] \quad (4)$$

While α is fixed, the following matrix can be obtained after setting the index of optimism, μ , in order to estimate the degree of satisfaction.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \dots & \tilde{a}_{1n}^\alpha \\ \tilde{a}_{21}^\alpha & 1 & \dots & \dots & \tilde{a}_{2n}^\alpha \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{a}_{n1}^\alpha & \tilde{a}_{n2}^\alpha & \dots & \dots & 1 \end{bmatrix}$$

The eigenvector is calculated by fixing the μ value and identifying the maximal eigenvalue.

Step 4. Normalization of the matrices: Normalization of both the matrix of paired comparisons and calculation of priority weights (approx. criteria weights), and the matrices and priority weights for alternatives with respect to each criterion are also done before calculating λ_{\max} . In order to control the result of the method, the consistency ratio for each of the matrices and overall inconsistency for the hierarchy calculated. The deviations from consistency are expressed by the following equation consistency index and the measure of inconsistency is called the consistency index (CI); $CI = \frac{\lambda_{\max} - n}{n - 1}$ (5). The consistency ratio (CR) is used to estimate directly the consistency of pair wise comparisons. The CR is computed by dividing the CI by a value obtained from a table of Random Consistency Index (RI); $CR = \frac{CI}{RI}$ (6). If the CR value is less than 10%, the comparisons are acceptable; otherwise they should

be repeated until reached to the CR, less than 10%. RI is the average index for randomly generated weights [2].

Step 5. Calculation of priority weights for each alternative: The priority weight of each alternative can be obtained by multiplying the matrix of evaluation ratings by the vector of criterion weights and summing over all criteria. Expresses in conventional mathematical notation; Weighted evaluation for alternative:

$$k = \sum_{i=1}^t (\text{criterion weight}_i * \text{evaluation rating}_{ik}) \quad (7)$$

for $i=1,2,\dots,t$ (t : total number of criteria)

After calculating the weight for each alternative, the overall consistency index is also calculated that it should be less than 10% for consistency on all judgments.

IV. CASE STUDY

In this section, a case study is presented to prove its applicability and validity. Therefore, a cutting tool manufacturer, a leading company in designing and manufacturing of all kinds of cutting tools (i.e. twist drills, reamers, taps, nuts, carbide-tipped tool holders, center drills, masonry drills) was selected. The company management decided to select the best satisfying CAM software in order to reduce the lead times of design and engineering-related activities. Firstly, a cross-functional project team was set up to select CAM software. Then, the criteria and alternatives were defined for each system and five alternatives (CATIA, I-DEAS, PRO-ENGINEER, CIMATRON, and UNIGRAPHICS) defined (Table I).

TABLE I
LIST OF CRITERIA AND SUB-CRITERIA FOR CAM SOFTWARE SELECTION

Main Criteria	Criteria	Code
Cost	System cost (installation, training, software and hardware)	C1
	Annual maintenance cost	C2
Vendor	Vendor performance (On-line support and service on-time, R&D investment efforts, Quality of sales and support team, Global support coverage)	C3
Technical features	Compatibility to existing software and hardware	C4
	Simulation capability	C5
	Simplicity of tool path creation and accuracy of post processing	C6
Others	Easy of use and learning	C7

Next the fuzzy AHP was carried out to evaluate the CAD software alternatives and ranked them by weight. Fuzzy triangular numbers (TFNs) was used to weight the evaluation criteria as given in Table II. Later, the lower limit and upper limit of the fuzzy numbers with respect to the α were defined as follows by applying (3), and all calculations are shown in Table III;

$$\tilde{1}_\alpha = [1, 3 - 2\alpha], \tilde{3}_\alpha = [1 + 2\alpha, 5 - 2\alpha], \tilde{3}_\alpha^{-1} = \left[\frac{1}{5 - 2\alpha}, \frac{1}{1 + 2\alpha} \right]$$

$$\tilde{5}_\alpha = [3 + 2\alpha, 7 - 2\alpha], \tilde{5}_\alpha^{-1} = \left[\frac{1}{7 - 2\alpha}, \frac{1}{3 + 2\alpha} \right],$$

$$\tilde{7}_\alpha = [5 + 2\alpha, 9 - 2\alpha], \tilde{7}_\alpha^{-1} = \left[\frac{1}{9 - 2\alpha}, \frac{1}{5 + 2\alpha} \right],$$

$$\tilde{9}_\alpha = [7 + 2\alpha, 11 - 2\alpha], \tilde{9}_\alpha^{-1} = \left[\frac{1}{11 - 2\alpha}, \frac{1}{7 + 2\alpha} \right]$$

The values, $\alpha = 0.5$ and $\mu = 0.5$ were substituted above expression into fuzzy comparison matrices, all the α -cut fuzzy comparison matrices were obtained as follows; Equation (4) was used to calculate eigenvectors for all comparison matrices. All the necessary calculation (synthesizing the pair wise comparison matrix, calculating the priority vector of a criterion, the CR, λ_{\max} using (2) and the CI,

selecting appropriate value of the RC and checking the consistency of the pair wise comparison matrix to check out whether the comparisons of the decision-maker were consistent or not) were carried out. Synthesizing the pair wise comparison matrix of the

criteria is performed by dividing each element of the matrix by its column total. The priority vector of the criteria can be obtained by finding the row averages (Table IV)

TABLE II
FUZZY COMPARISON MATRIX FOR THE CRITERIA USING TFNS

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	1	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{9}$
C2	$\tilde{1}^{-1}$	1	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
C3	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	1	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{7}$
C4	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	1	$\tilde{3}$	$\tilde{1}$	$\tilde{5}$
C5	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$	$\tilde{5}$
C6	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{1}$
C7	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}^{-1}$	1

TABLE III
 α - cuts FUZZY COMPARISON MATRIX FOR THE CRITERIA ($\alpha = 0.5$)

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	1	[1, 2]	[1, 2]	[2, 4]	[2, 4]	[4, 6]	[8, 10]
C2	[1/2, 1]	1	[1, 2]	[2, 4]	[1, 2]	[2, 4]	[2, 4]
C3	[1/2, 1]	[1/2, 1]	1	[1, 2]	[2, 4]	[2, 4]	[6, 8]
C4	[1/4, 1/2]	[1/4, 1/2]	[1/2, 1]	1	[2, 4]	[1, 2]	[4, 6]
C5	[1/4, 1/2]	[1/2, 1]	[1/4, 1/2]	[1/4, 1/2]	1	[2, 4]	[4, 6]
C6	[1/6, 1/4]	[1/4, 1/2]	[1/4, 1/2]	[1/2, 1]	[1/4, 1/2]	1	[1, 2]
C7	[1/10, 1/8]	[1/4, 1/2]	[1/8, 1/6]	[1/6, 1/4]	[1/6, 1/4]	[1/2, 1]	1

TABLE IV
EIGENVECTOR FOR COMPARISON MATRIX OF THE CRITERIA

Criteria	C1	C2	C3	C4	C5	C6	C7	e-Vector
C1	1,000	1,500	1,500	3,000	3,000	5,000	9,000	0,281
C2	0,750	1,000	1,500	3,000	1,500	3,000	3,000	0,196
C3	0,750	0,750	1,000	1,500	3,000	3,000	7,000	0,190
C4	0,375	0,375	0,750	1,000	3,000	1,500	5,000	0,130
C5	0,375	0,750	0,375	0,375	1,000	3,000	5,000	0,110
C6	0,208	0,375	0,375	0,750	0,375	1,000	1,500	0,059
C7	0,113	0,375	0,146	0,208	0,208	0,750	1,000	0,035
							λ_{max}	7.751
							CI	0.125
							RI	1.32
							CR	0.095

TABLE V
FINAL RANKING OF CAM SOFTWARE ALTERNATIVES

Alternative	C1 (0.281)	C2 (0.196)	C3 (0.190)	C4 (0.130)	C5 (0.110)	C6 (0.059)	C7 (0.035)	Overall e-Vector
CATIA*	0.440	0.394	0.459	0.498	0.505	0.424	0.487	0.450
I-DEAS	0.192	0.300	0.203	0.182	0.185	0.247	0.203	0.217
Pro-ENGINEER	0.249	0.176	0.193	0.173	0.134	0.143	0.159	0.192
CIMATRON	0.068	0.069	0.090	0.090	0.110	0.114	0.079	0.083
UNIGRAPHICS	0.051	0.061	0.055	0.057	0.066	0.072	0.072	0.058
CR	0.099	0.087	0.088	0.084	0.097	0.082	0.072	

* Best alternative with highest weight.

By following the same way, first we created for the fuzzy pairwise matrix of the alternatives with respect to each criterion and further calculations. Total of 7 matrices are built and later, the CR values for

each matrix was calculated by using (5) an (6), and their CRs were found out less than 0.10, which means all judgments done by the decision-makers are consistent. Finally, the overall priority weight

for each alternative was calculated by using (7). All results are presented in Table V. As seen in the table, the best alternative with highest weight is found out as *CATIA*.

V. CONCLUSIONS

In this paper, an intelligent approach to a CAM software selection problem has been presented, which includes using the fuzzy AHP to evaluate a set of software alternatives for CAM. In the approach, triangular fuzzy numbers were introduced into the conventional AHP in order to improve the degree of judgments of decision maker(s). The central value of a fuzzy number is the corresponding real crisp number. The spread of the number is the estimation from the real crisp number. Using of fuzzy AHP approach to evaluating alternatives for CAM systems in the following two major advantages; (i) Fuzzy numbers are preferable to extend the range of a crisp comparison matrix of the conventional AHP method, as human judgment in the comparisons of selection criteria and alternatives is really fuzzy in nature, (ii) Adoption of fuzzy numbers can allow decision maker(s) to have freedom of estimation regarding the software selection problem of CAD and CAM. In the light of many related studies done in literature, we can say that the fuzzy AHP method is a still powerful tool to solve MCDM making problems by improving the Saaty's nine-point scale, although Saaty and Tran mentions that the fuzzy support is not necessary for the success of the AHP study. In the case study realized to show the applicability of the proposed approach, five alternatives were evaluated in terms of a set of evaluation criteria. Fuzzy AHP method gave an important advantage of evaluating alternatives and reach to the ultimate one, *CATIA*. Finding this result is also reasonable because *CATIA* with weight of 0.450 is currently the most important software used by the companies (i.e. Boeing, Toyota, and Ford) in their CAM applications. On the other hand, the proposed method has also no restriction (i.e. number of alternatives, number of criteria). But, as the number of criteria and alternatives increases, the dimension of the problem gets more complicated and needs a support of computer software. For future research, an expert system can be developed to help the decision-makers discuss on the results of the analysis.

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