Adaptive Interval Trapezoid Fuzzy Number for Recommendation Systems E-Learning

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Abstract. This research aims to develop decision making models for Multi Criteria Decision Making (MCDM) with Adaptive Interval Fuzzy Analytic Hierarchy Process (AIVFAHP) and Adaptive Interval Fuzzy Technique for Order Preference of Similarity Ideal Solution (AIVFTOPSIS) integration methods by constructing a decision-making model using trapezoid fuzzy number. The strength of the AIVFAHP method is to consult the value of logical consistency in the assessment. This logical consistency is to calculate the assessor and determine the costs in multi-criteria decision making. AIVFTOPSIS is based on the principle that the chosen alternative should be close to a positive ideal solution and far from the ideal solution. Contribution of this research is to conduct a research of decision making with Adaptive Interval Value Fuzzy Multi Criteria Decision Making (AIVFMCDM) and to improve interval points by modifying the midpoint and degree on the trapezoid fuzzy number function. This modeling provides more accurate, more effective linguistic representation and flexible in determining the point of the interval for optimal results. The research produced a new decision-making model based on the Adaptive Interval Trapezoid Fuzzy Number (AIVTFN) and recommendations for improvement of e-learning indicators.

Keywords: E-learning, Decision making, Adaptive interval, AIVFAHP, AIVFTOPSIS.

1. Introduction
Technology makes it easy for people to get information anytime and anywhere. Technology also contributes greatly to society for a fast-paced era in various sector. In the government sector there are e-government services, and education there are e-learning services. E-learning technology can be applied in schools, universities, companies, or government institutions. E-learning is distance learning (distance learning media) by utilizing computer network technology, internet media or intranet [1]. E-learning is able to provide changes in the concept of conventional learning, overcoming the limitations of space and time, and allowing users to learn independently [2]. There are several indicators in the use and selection of e-learning technology so that it requires a Decision Support System (DSS). Problem solving between criteria in DSS can be solved by the Multi Criteria Decision Making (MCDM) method. The MCDM method sets the best alternative from a number of alternatives based on certain criteria [3].

The problem of this study is that there are many e-learning service providers and indicators in e-learning measurement, making it difficult to determine e-learning improvement recommendations as
needed. The existence of individual decisions that are considered not objective so it needs group decision making. In the e-learning recommendation process, several steps are needed, namely e-learning modeling, determining the weighting criteria of several decision makers and e-learning recommendations. The method used in this study is an integration method in determining the weight of criteria and recommendations for e-learning. In determining weight criteria, AHP approach is able to describe complex multi-criteria problems into a hierarchical structure so a model produced is flexible and easy to understand. AHP considers the value of logical consistency in assessment, this logical consequence is used to test perceptions of assessors and determine optimal weight in multi-criteria decision making [4][5][6]. The fuzzy AHP scale is expressed in more detail and flexibly way with fuzzy set intervals [5][7].

This is what distinguishes AHP from other decision-making models. The use of logical consistency in AHP has been done [8][9] to measure performance of Small and Medium Enterprises (UKM) in Bangkalan, Indonesia. In determining recommendations, TOPSIS approach is very appropriate because it is able to make multi-criteria decision making based on concept that chosen alternative has closest distance from positive ideal solution and the farthest from negative ideal solution[10][11][12][13]. Based on the description above, the purpose of this study was to develop a group decision making model for e-learning recommendations using the integration of AIVFAHP and AIVFTOPSIS methods by developing trapezoid fuzzy number. The contribution of this research is to conduct a research of decision making with Adaptive Interval Value Fuzzy Multi Criteria Decision Making (AIVFMCMDM) and to improve interval points by modifying the midpoint and degree on the trapezoid fuzzy number function. The research resulted in the integration algorithm of the AIVFAHP and AIVFTOPSIS methods and information on recommendations for improving e-learning indicators.

2. Research Method

2.1. Interval-Valued Fuzzy (IVF)

Measuring an expert’s opinion is completely difficult. In fuzzy theory, measuring opinions are represented by interval numbers [0,1]. The appropriate interval is used to measure the decision in an opinion.[14]. Representation expresses linguistics in clearer intervals[12][15]. Fuzzy number interval values (IVFN) provide more complete operations and are used in real-world applications, such as for evaluating and supporting results. According to the study of Ashtiani, et al.[12][15], the value of the fuzzy interval provides more accurate model, and the value of the assessment of performance is better. Fuzzy interval values have a more effective representation and high flexibility [7][16][17]. Linguistic model and representation of linguistic expressions in the form of intervals fuzzy values are clearer and have better accuracy than fuzzy. The interval-valued Fuzzy set A is defined as follows[15][17]

\[ A = \{ \langle x, [\mu^U_A(x), \mu^L_A(x)] \rangle \mid x \in X \}, \quad (1) \]

\[ \forall x \in X, \mu^L_A(x) \leq \mu^U_A(x). \quad (2) \]

\[ \mu^U_A, \mu^L_A: X \rightarrow [0,1]; \quad (3) \]

\[ \hat{\mu}_A(x) = \{ [\mu^L_A(x), \mu^U_A(x)] \}, x \in X. \quad (4) \]

The interval value Fuzzy set A can be expressed as follows:

\[ A = \{ \langle x, \hat{\mu}_A(x) \rangle \mid \hat{\mu}_A: X \rightarrow [0,1]; x \in X. \quad (5) \]

Based on these definitions, interval value Fuzzy set A is represented by upper and lower limits.

2.2. Membership Function

The concept of interval fuzzy number is an extension of ordinary fuzzy sets. The ordinary fuzzy sets are very useful for determining proper membership function. Fuzzy sets membership function is two
dimensional, interval value fuzzy membership function has three dimensions, thus providing an additional degree of freedom that allows to directly model the uncertainty. Fuzzy interval set is used because of its simplicity and computation [7] [13] [18]. This study the use IVF method was developed in the AHP and TOPSIS methods. The trapezoidal interval curve or called Interval Value Trapezoid Fuzzy Number (IVTraFN) is given by Figure 1.

![Figure 1. Interval Value Trapezoid Fuzzy Number [17]](image)

According to Fuh, et al.[17], the membership function Interval Value Trapezoid Fuzzy Number (IVTraFN) is defined as follows:

\[
\begin{align*}
\mu_A(x) &= \begin{cases} 
\frac{(x-p_1^L)/(p_2^M-p_1^L)}{; p_1^L \leq x < p_2^M} \\
\frac{(p_3^M-x)/(p_4^M-p_3^M)}{; p_3^M \leq x < p_4^M} \\
0; x < p_1^L \text{ataux } \geq p_1^L \\
1; p_2^M \leq x < p_3^M 
\end{cases} \\
\mu_A(x) &= \begin{cases} 
\frac{(x-p_1^U)/(p_2^M-p_1^U)}{; p_1^U \leq x < p_2^M} \\
\frac{(p_3^M-x)/(p_4^M-p_3^M)}{; p_3^M \leq x < p_4^M} \\
0; x < p_1^U \text{ataux } \geq p_1^U \\
1; p_2^M \leq x < p_3^M 
\end{cases} 
\end{align*}
\]

(7) (8)

With \( A^L = (p_1^L, p_2^M, p_3^M, p_4^M), p_1^L < p_2^M < p_3^M < p_4^M. \)

With \( A^U = (p_1^U, p_2^M, p_3^M, p_4^M), p_1^U < p_2^M < p_3^M < p_4^M. \)

0 \leq \frac{A^L}{A} \leq \frac{A^U}{A} \leq 1, A^L \subset A^U.

3. Result and Discussion

The stages of this study are divided into three stages, namely modeling Stage, integration phase of the Adaptive Interval Value Fuzzy (AIVF) decision-making model and the last is analysis and implementation phase of the decision model for e-learning system recommendations. Modeling stage: stage decision modeling is based on the trapezoid fuzzy number model interval. This stage is identification of MCDM. This variable consists of criteria, alternatives, appraisers, and respondents. Measurement indicators of learning include concept for learning objectives, concept of content, dudactical concepts, organizational concepts, technical concepts, concepts for media and interaction design, concepts for test and evaluation, review of competency levels [18] [19][20][21]. The second stage is integration of the AIVFAHP and AIVFTOPSIS methods with the same and different middle points and different membership degrees in the Trapezoid Fuzzy Number function. The steps of integration of the IVFAHP and IVFTOPSIS methods are:

1. Constructing the M paired comparison matrix for criteria. Determine the rating scale and the results of the respondent’s assessment, normalize the matrix, and determine the consistency of the matrix. Consistency of the matrix with the smallest error value to be processed.
2. Convert the M matrix into an interval matrix with trapezoid fuzzy number interval model in accordance with Figure 2.

\[
M = \begin{bmatrix}
1 & m_1 & m_1 & \ldots & m_1 \\
m_2 & 1 & m_2 & \ldots & m_2 \\
m_3 & m_3 & 1 & \ldots & m_3 \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
m_n & m_n & m_n & \ldots & 1
\end{bmatrix}
\] (9)

![Figure 2. IVTraFN integration with different middle points](image)

Figure 2. Form of Interval Value Trapezoid Fuzzy Number (IVTraFN) decision making model with different middle points \((r^{m}_{ij} \neq r^{m}_{kl}, r^{m}_{ij} \neq r^{m}_{kl})\) and the degree of membership equal to the lower limit of less than the upper limit \((\mu^{m}_{ij} < \mu^{m}_{kl})\). Based on the paired comparison matrix defined in Step 2, namely the R matrix, the matrix will be converted to a fuzzy trapezoidal interval scale. The results of respondents’ evaluations on preferences of paired comparisons on a fuzzy scale using the Value Geometric Means Aggregation (IVGMA) value.

3. Calculate weight of the V matrix criteria with the same middle point. The weight of V matrix criteria is denoted by \(K^*\). The criteria weight for triangular Fuzzy numbers can be stated as follows:

\[
K^* = \begin{bmatrix}
k_1 \\
k_2 \\
k_3 \\
\vdots \\
k_n
\end{bmatrix}
\] (10)

With \(k_i = [(k^{l}_{1i}, k^{m}_{1i}, k^{u}_{1i}, \mu^{l}_{1i}), (k^{l}_{2i}, k^{m}_{2i}, k^{u}_{2i}, \mu^{l}_{2i}), \ldots, (k^{l}_{ni}, k^{m}_{ni}, k^{u}_{ni}, \mu^{l}_{ni})]\)

Determine the iteration of the interval point scale. This iteration is used to determine the new interval scale in determining the criteria weights.

4. In Step 4 this is the step of the IVFTOPSIS method, while Steps 1 through 3 are steps of the IVFAHP method. Step 2 is based on the fuzzy number trapezoidal interval model, the alternative decision matrix against the criteria denoted by Z can be stated as follows:

\[
Z = \begin{bmatrix}
z_1 & z_1 & \ldots & z_1 \\
z_2 & z_2 & \ldots & z_2 \\
\vdots & \vdots & \ddots & \vdots \\
z_n & z_n & \ldots & z_n
\end{bmatrix}
\] (11)

With \(z_i = [(z^{l}_{1i}, z^{m}_{1i}, z^{u}_{1i}, \mu^{l}_{1i}), (z^{l}_{2i}, z^{m}_{2i}, z^{u}_{2i}, \mu^{l}_{2i}), \ldots, (z^{l}_{ni}, z^{m}_{ni}, z^{u}_{ni}, \mu^{l}_{ni})]\)

5. Constructing the weighted normalization decision matrix., Calculate the weighting criteria of each alternative into the value of crisp from the matrix Y. Defuzzification is used to convert fuzzy output to crisp value using the Best No Interval Fuzzy Performance (BNIP) method.

6. Calculate the distance of each alternative from the ideal positive and negative solution, Calculating relative proximity distance.

7. Ranking alternatives.
The last stage is Analysis and Implementation. This stage is the evaluation stage of the e-learning system based on mathematical modeling and data analysis that has been collected through questionnaires, interviews, observations and literature studies to obtain the system requirements and indicators used in e-learning research. This stage uses the Trapezoid Fuzzy Number (TraFN) function with the same midpoint and different midpoints. Trapezoid 1 is a Trapezoid Fuzzy Number (TraFN) with the same midpoint point, Trapezoid 2 is a Trapezoid Fuzzy Number (TraFN) with a different midpoint point. This research trial uses 7 indicators of the same e-learning measurement. The consistency index used in this experiment was less than 0.1 with an assessor of 3 people. The results of ranking the alternative values of e-learning on the TraFN function with the same and different interval points are e-learning3, e-learning1, e-learning2 and e-learning4. Comparison of Trapezoid 1 and Trapezoid 2 ranking results in Table 1, and Figure 3. The ranking results are obtained based on the calculation of hybrid AIVFAHP and AIVFTOPSIS methods using trapezoidal functions of fuzzy numbers with the same and different midpoints.

Table 1. Comparison of Trapezoid 1 and Trapezoid 2 ranking results

| Name      | Trapezoid 1 | Trapezoid 2 |
|-----------|-------------|-------------|
| e-learning 1 | 0.181649    | 0.182257    |
| e-learning 2 | 0.181911    | 0.182551    |
| e-learning 3 | 0.183685    | 0.184263    |
| e-learning 4 | 0.134183    | 0.134575    |

Figure 3. Comparison graph alternative e-learning of trapezoid 1 and trapezoid 2

Based on the hybrid AIVFAHP and AIVFTOPSIS methods, the weights of each criteria and suggestions for improvement of each e-learning can be known. In the TFN function with the same middle point for improvement suggestions are taken based on the five lowest e-learning weight values, namely e-learning 1, there are 3 lowest values namely Concepts for Test and evaluation, Organizational Concepts, Concepts for Test and evaluation.

4. CONCLUSIONS

Based on the decision-making model of multi-criteria based on adaptive interval value fuzzy: The linguistic scale developed in interval-based decision-making models makes decision makers more flexible to make choices that have been provided. Integration of the AIVFAHP and AIVFTOPSIS methods with trapezoid function at the same middle point and different middle points produces the same criteria and alternative weights, but the range of values for different middle points is smaller than the same middle point. Accuracy produced at different middle points is higher than the same middle level in trapezoidal functions because the distance between criteria is smaller. The next research is to develop the concept of adaptive fuzzy value intervals in the group decision aggregation model with Ordered Weighted Averaging (OWA) or other aggregation methods.
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