Multi-Attribute Group Decision Making Using Fuzzy Numbers at Arithmetic Intervals for Determining Thesis Examination

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Abstract—**In general, thesis examiners have opposing viewpoints. Despite the fact that the assessment parameters are the same, each examiner can provide a different standard of evaluation. Group decision making can be used to solve problems in the assessment of thesis exams involving a large number of examiners. Group decision making can be used to solve problems in the assessment of thesis exams involving a large number of examiners. In the group's decision-making process, this paper provided fuzzy numbers at the arithmetic interval. Decisions that generally give a vague knowledge of decision-making information and cannot estimate their decision-making information with exact numerical values are used to determine the thesis exam. According to the case study, the fuzzy approach is used to solve the problem, and evaluation alternatives are used to determine the thesis exam. According to the results of the triangular fuzzy approach, the option to repeat the exam (A2) has the highest value and recommended to be a decision.**

Keywords—group decision making, triangular fuzzy numbers, examiner, thesis examination

I. INTRODUCTION

Decision making is currently still a field of research that is widely studied by researchers. This is because the field of decision making is needed in many aspects of life. The decision making process makes it easier for decision makers to make decisions on complex problems [1][2]. Decision makers are often confused when making appropriate and reasonable decisions, because the decision-making process involves identifying several criteria and evaluating many alternatives [3]. There may be more than one decision maker, because of the complexity of a problem or because it involves many aspects. More than one decision maker creates new problems to unite different opinions. The number of problems in the field of decision making that involve many decision makers has led to the development of a more complex research, namely Group Decision Making [4].

Multi-criteria decision making (MADM) and group decision making (GDM) are two approaches that are widely applied to solve decision-making problems to find the best alternative. Many applications of multi-attribute decision-making techniques to various problems show that this technique is suitable and can be used efficiently [5]. Multi-attribute decision making (MADM) is to make a choice between many alternatives which are often in conflict with each other. Group decision making combines the opinions of the decision maker into a coherent group decision. Group decision making is considered better because it has many advantages compared to multi attribute decision making. These advantages are more information or knowledge, a deeper level of understanding and more creative considerations obtained because it involves more than one decision maker. The decision-making process will run very easily if the alternative selection is based on only one parameter, but if the parameter given are quite a lot, where each alternative has a certain value on each criteria, then an aggregation method is needed to get a single value for each alternative [6].

The problem in MADM is that the decision maker (DM) must choose which alternative best meets the criteria. It is not easy for an alternative to meet all the criteria simultaneously so that a compromise solution is preferred. The complexity of the problem can increase if a number of DM do not have the same perception regarding the available alternatives [7]. The ambiguity and imprecision of human qualitative judgments influence the practical decision-making process. Opinions from several experts help improve human qualitative judgments that can provide a variety of yes, abstention, no and rejection answers that cannot be expressed in accurate critical values. This problem can be solved by using linguistic variables in a fuzzy set theory environment [8][9]. Several researchers have conducted research on fuzzy sets to solve decision-making cases. [3] proposed a picture fuzzy set (PFS) method, using some of the basic operations and properties of PFS. Fuzzy logic is generally used to provide information or structures that are not precise. Features of fuzzy logic and fuzzy sets have the ability to model problems of uncertainty and imprecision. The data in fuzzy numbers is more flexible and the calculation results are more accurate. To overcome the frequent uncertainty and ambiguity found in human subjective perceptions in the decision-making process, the evaluation method based on Fuzzy Multi-Attribute Decision-Making (FMADM) is used [10][11].

Exam failure is an important problem for students and educational institutions, including the results of the assessment of the exam. To obtain a bachelor's degree, students must pass a thesis exam. When a student conducts a thesis/final project, there are several examiners who will assess. There are 3 people who will give an assessment. They are the Chief Examiner, Examiner 1 and Examiner 2. The three examiners of course have different assessments. Further evaluation is carried out. Evaluation is the process of making decisions and giving marks to students' thesis exam results. It is in this evaluation process that the complexity of the problem occurs. The problem is the assessment by the head of the test team and two examiners. Thesis test assessors generally have different opinions from each other. Although the parameters used for the assessment are the same, each examiner can provide a different standard of assessment. This is because each individual has a different rationale from one another and because it is possible to have different backgrounds and fields of knowledge.

Problems in the assessment of thesis exams involving many examiners can be solved by group decision making. In this decision making also involves many parameters, alternative values and uncertainty problems, so Fuzzy Multi Attribute Group Decision Making (F-MAGDM) was developed.

II. RELATED WORKS

Research in the field of decision making, especially group decision making is growing. Many researchers have developed research in the field of group decision making [12]. Several previous studies have discussed quite a lot about fuzzy MCDM. [13] proposed a solution method for Fuzzy Multiple Criteria Decision Making (FMCDM) through a SWOT analysis approach. This study uses 2 matrices showing the strengths and weaknesses of each alternative, which is expected to help provide more information for decision makers. [14] introduced a new method in solving the problem of multiple person multiple attribute decision making based on subjective preferences given by decision makers and an objective decision matrix. [12] in their research developed fuzzy group decision making by combining AHP and social choice (SC) methods. [15] has conducted research involving a group of decision makers for the selection of cloud service models. This research is useful for IT managers in choosing the appropriate cloud service model for the organization. [13] in his research proposed the concept of a Group Decision Support System (GDSS) to evaluate the performance of Information and Communication Technology (ICT) Projects. This study aims to overcome possible inconsistencies that may occur in the decision-making process that presents the GDSS framework that integrates the Analytic Hierarchy Process (AHP) Method, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Copeland Score.[16] developed the Fuzzy MADM approach to solve the problem of selecting the most appropriate infrastructure in the Vehicular Ad-Hoc Network (VANET) network so as to improve the performance of the communication network infrastructure.

A. *Fuzzy Multi Attribute Decision Making*

Fuzzy set theory is growing very rapidly replacing the previous theory, namely probability in solving uncertainty problems. Fuzzy set theory is a mathematical framework used to represent uncertainty, ambiguity, imprecision and lack of information. Vagueness can also be used to describe something related to uncertainty given in the form of linguistic or intuitive information. Some of the reasons why fuzzy logic is widely used are because fuzzy logic is very flexible, has tolerance for imprecise data, is able to model very complex non-linear functions, fuzzy logic is based on natural language and can apply the experiences of experts without having to go through training process. In fuzzy set theory, the main component that plays a very important role is the membership function. The membership function represents the proximity of an object to certain attributes. The membership function is a curve that shows the mapping of data input points into their membership values. There are several approaches to the function, one of which is a triangular curve representation.

Three values in a fuzzy number are expressed as a Triangular Fuzzy Number (TFN). They are v_1, v_2, v_3. It can be defined as shown in equation 1 [17].

$$\mu_{(A)}(x) = \begin{cases} 0, & x < v_1 \\ \dfrac{x\text{-}v}{v_2\text{-}v_1}, & v_1 \le x \le v_2 \\ \dfrac{v_3\text{-}x}{v_3\text{-}v_2}, & v_2 \le x \le v_3 \\ 0, & x > v_3 \end{cases} \tag{1}$$

The basic concept of a fuzzy decision support system is the relationship between elements in sets. A fuzzy relation represents the degree of membership between elements of two or more sets. To aggregate the preferences of the experts into preference groups, a preference relation is needed. In the preference relation, each expert relates the preference value between each alternative.

The selection of the right alternative from the decision-making group includes several stages (a) determining the alternatives, (b) determining the selection criteria, (c) giving the performance rating of the alternatives and the weight of the criteria. (d) aggregation of performance ratings and criteria weights to produce an overall performance index for all alternatives and criteria and (e) selection of the best alternative [5]. Most of the MADM approaches are carried out in 2 steps: 1. Aggregating decisions that are responsive to all objectives on each alternative, 2. Ranking the decision alternatives based on the results of the decision aggregation [10]. The evaluation and selection process begins with each decision maker Dk (k=1, 2,..., s) providing a performance evaluation (rating) on each alternative decision Ai (i=1,2,..., n) formed from n completion criteria Cj (j=1, 2,..., m). The end result is a decision matrix containing each decision maker's preferences against each parameter, which is stated as:

$$D^k = \begin{matrix} y^{k_{11}} & y^{k_{12}} & y^{k_{1m}} \\ y^{k_{21}} & y^{k_{22}} & y^{k_{2m}} \\ \\ y^{k_{n1}} & y^{k_{n2}} & y^{k_{nm}} \end{matrix} \tag{2}$$

While the weight vector Wj which shows the influence of each criterion in decision making is stated as:

$$W_j = [W^{k_1} W^{k_2} \quad \dots \quad W^{k_m}] \tag{3}$$

The average wj weight given by each decision maker (Dk) against the Cj criteria can be calculated using:

$$w_i = \left(\frac{1}{k}\right) \otimes (w_{j1} \oplus w_{j2} \oplus \ldots \oplus w_{jk}) \quad (4)$$

and

$$a_j = \frac{\sum_{t=1}^{k} a_{jt}}{k} \quad b = \frac{\sum_{t=1}^{k} b_{jt}}{k} \quad c_j = \frac{\sum_{t=1}^{k} c_{jt}}{k} \quad (5)$$

These weights can be transformed by the formula:

$$w_i = \frac{wj}{\sum_{j=1}^{n} wj} \quad (6)$$

The average assessment for each alternative against certain parameter supplied by the decision maker can be calculated using the use:

$$x_{ii} = \left(\frac{1}{k}\right) \otimes (x_{ij1} \oplus x_{ij2} \oplus \ldots \oplus x_{ijk}) \quad (7)$$

and

$$e_{ij} = \frac{\sum_{t=1}^{k} e_{ijt}}{k} \quad f_{ij} = \frac{\sum_{t=1}^{k} f_{ijt}}{k} \quad g_{ij} = \frac{\sum_{t=1}^{k} g_{ijt}}{k} \quad (8)$$

There are several ranking methods that can be used on triangular fuzzy numbers. To get a single value from a triangular fuzzy number using the total integral value. Suppose F is a triangular fuzzy number, F = (a, b, c), then the total integral value can be formulated [9]:

$$I_T^{\alpha} = \frac{1}{2}\left((\alpha c + b + (1-\alpha)\, a)\right) \quad (9)$$

The value of is a degree of optimism that represents the level of optimism of decision makers. The value of the degree of optimism is in the range of $0 < \alpha < 1$. If the value obtained is large, it means that the decision maker has high optimism. To determine the order of each alternative, the following equation is used:

$$S_i = \sum_{j=1}^{n} r'ij \quad (10)$$

The Si value shows the ranking of the alternatives. The largest Si value is the best alternative that will be recommended by the decision maker as the best decision.

III. Method

The problem of determining the parameters of the thesis exam for students in obtaining a bachelor's degree is evaluated and selected to determine the right decision. In this thesis exam, three examiners are involved as decision makers. The problem to be solved is determining the level of importance of the parameters used in the thesis exam. Determination of the importance of these parameter is used as the basis for making decisions or considerations at the thesis exam, so that students are declared to pass, repeat or fail. There are three alternative graduation components: S1 (passing the exam), S2 (repeating the exam) and S3 (failing). Each of these alternatives is built from 5 parameters, namely P1 (presentation), P2 (oral exam), P3 (attitude), P4 (trial application/system), P5 (thesis report). There are 3 examiners involved as decision makers: E1, E2 and E3.

A linguistic form is used to facilitate the assessment of decision-makers when modeling uncertainty and imprecision in multi-attribute group decision-making problems (examiners). The respective decision makers provide the linguistic value of the relative level of importance or weight of each parameter (examiners). Table I shows the relative importance of five linguistic forms.

TABLE I. LINGUISTIC FORM OF PARAMETER WEIGHT

Linguistic Form	Very Low	Low	Medium	High	Very High
Membership Degree	(0, 0.1, 0.3)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.5, 0.7, 0.9)	(0.7, 0.9, 1)

The weight of each parameter of each decision maker (examiner) based on table II is as follows.

TABLE II. WEIGHT OF EACH PARAMETER FOR EACH EXAMINER

Parameter	Examiner		
	E1	E2	E3
P1	Medium	Low	Medium
P2	Low	Low	Low
P3	Low	Low	Medium
P4	Medium	Low	Medium
P5	High	High	Very High

The qualitative assessment guarantees each examiner to each alternative evaluation of the thesis exam represented by linguistic forms. Table III shows the linguistic form of each decision maker's relative importance or weight of each parameter.

TABLE III. LINGUISTIC FORM OF EXAMINER RATING

Linguistic Form	Very Poor	Poor	Medium	Good	Very Good
Membership Degree	(0,0,3)	(0,3,5)	(2,5,8)	(5,7,10)	(7,10,10)

Table IV shows how each examiner rated each alternative on each parameter based on table III.

TABLE IV. EACH EXAMINER'S RATING OF EACH ALTERNATIVE ON EACH PARAMETER

Parameter	Alternative	Examiner		
		E1	E2	E3
P1	A1	Good	Medium	Good
	A2	Medium	Medium	Medium
	A3	Good	Medium	Medium
P2	A1	Medium	Poor	Poor

	A2	Medium	Poor	Poor
	A3	Good	Medium	Medium
P3	A1	Medium	Poor	Poor
	A2	Medium	Poor	Poor
	A3	Good	Medium	Medium
P4	A1	Medium	Medium	Medium
	A2	Medium	Medium	Medium
	A3	Good	Medium	Goog
P5	A1	Good	Good	Very Good
	A2	Good	Good	Very Good
	A3	Very Good	Good	Very Good

The average weight of each parameter can be calculated using equation (5). Based on table II, the average weight for the first parameter (P1) is calculated as follows:

$$a_1 = \frac{\sum_{t=1}^{3} a_{1t}}{3} = \frac{0.3+0.1+0.3}{3} = 0.233$$

$$b_1 = \frac{\sum_{t=1}^{3} b_{1t}}{3} = \frac{0.5+0.3+0.5}{3} = 0.433$$

$$c_1 = \frac{\sum_{t=1}^{3} c_{1t}}{3} = \frac{0.7+0.5+0.7}{3} = 0.63$$

For other parameters can be calculated in the same way using equation (4). Table V shows the results of calculating the average weight for each parameter.

TABLE V. AVERAGE WEIGHT OF EACH PARAMETER

Parameter	Examiner			Average Weight (w_j)
	E1	E2	E3	
P1	Medium	Low	Medium	(0.23, 0.43, 0.63)
P2	Low	Low	Low	(0.1, 0.3, 0.5)
P3	Low	Low	Medium	(0.16, 0.36, 0.56)
P4	Medium	Low	Medium	(0,23, 0.43, 0.63)
P5	High	High	Very High	(0.56, 0.76, 0.93)

The average rating for each alternative on each parameter is calculated using equation (7). Based on this equation, the average rating for the first alternative for the first parameter is calculated according to table III as follows:

$$e_{11} = \frac{\sum_{t=1}^{3} e_{11t}}{3} = \frac{5+2+5}{3} = 4$$

$$f_{11} = \frac{\sum_{t=1}^{3} f_{11t}}{3} = \frac{7+5+7}{3} = 6.33$$

$$g_{11} = \frac{\sum_{t=1}^{3} g_{11t}}{3} = \frac{10+8+10}{3} = 9.33$$

Table VI shows the results of calculating the average rating of each alternative for each parameter, and table VII shows the weighted rating transformed for each alternative.

TABLE VI. EACH ALTERNATIVE'S AVERAGE RATING FOR EACH PARAMETER

Parameter	Alternative	Examiner			Average Weight (x_{ij})
		E1	E2	E3	
P1	A1	Good	Medium	Good	(4, 6.33, 9.33)
	A2	Medium	Medium	Medium	(2, 5, 8)
	A3	Good	Medium	Medium	(3, 5.66, 8.66)
P2	A1	Medium	Poor	Poor	(0.66, 3.66, 6)
	A2	Fair	Poor	Poor	(0.66, 3.66, 6)
	A3	Good	Medium	Fair	(3, 5.66, 8.66)
P3	A1	Medium	Poor	Poor	(0.66, 3.66, 6)
	A2	Medium	Poor	Poor	(0.66, 3.66, 6)
	A3	Good	Medium	Medium	(3, 5.66, 8.66)
P4	A1	Medium	Medium	Medium	(2, 5, 8)
	A2	Medium	Medium	Medium	(2, 2, 8)
	A3	Good	Fair	Good	(4, 6.33, 9.33)
P5	A1	Good	Good	Very Good	(5.66, 8, 10)
	A2	Good	Good	Very Good	(5.66, 8, 10)
	A3	Very Good	Good	Very Good	(6.33, 9, 10)

TABLE VII. WEIGHTED RATING FOR EACH ALTERNATIVE

Alternative	Parameter	a	b	c
A1	P1	0.0063	0.0378	0.2463
	P2	0.0047	0.0338	0.2287
	P3	0.0045	0.0320	0.2204
	P4	0.0022	0.0253	0.1889

	P5	0.0006	0.0198	0.2596
A2	P1	0.0025	0.0306	0.3750
	P2	0.0009	0.0242	0.2942
	P3	0.0042	0.0374	0.4250
	P4	0.0032	0.0381	0.2375
	P5	0.0064	0.0482	0.2771
A3	P1	0.0212	0.0572	0.2234
	P2	0.0187	0.0575	0.1981
	P3	0.0187	0.0575	0.1981
	P4	0.0209	0.0647	0.1981
	P5	0.0262	0.0676	0.1977

The next step is to prioritize decision-making alternatives based on the aggregation results. This priority is required to categorize decision-making alternatives. The aggregated results are represented by triangular widespread numbers. The total method of the total value, as written in the equation, is used (9). The levels of optimism (α) used to solve this case are α = 0, α = 0.5 and α = 1. For the level of optimism, α = 0, α = 0.5 and α = 1. Table VIII shows the results of the calculations.

TABLE VIII. CALCULATION RESULTS OF FUZZY ELEMENTS AT VARIOUS VALUES OF α

Alternative	Parameter	α = 0	α = 0.5	α = 1
A1	P1	0.02205	0.08205	0.041025
	P2	0.01925	0.07475	0.037375
	P3	0.01825	0.072225	0.036113
	P4	0.01375	0.060425	0.030213
	P5	0.0102	0.07495	0.037475
A2	P1	0.01655	0.109675	0.054838
	P2	0.01255	0.085875	0.042938
	P3	0.0208	0.126	0.063
	P4	0.02065	0.079225	0.039613
	P5	0.0273	0.094975	0.047488
	P1	0.0392	0.08975	0.044875
A3	P2	0.0381	0.08295	0.041475
	P3	0.0381	0.08295	0.041475
	P4	0.0428	0.0871	0.04355
	P5	0.0469	0.089775	0.044888

Each element of the triangular fuzzy number (a, b, c) is shown as the values in table VI. Based on the results in table VIII, for each degree of optimism, each alternative value can be calculated using equation (10). For the degree of optimism (α) = 0.5 then the results are as follows

$$A_1 = \sum_{j=1}^{5} r_{ij}$$

A_1 = 0.08205+0.07475+0.072225+0.060425+0.007495

A_1 = 0.3644

Furthermore, for alternatives A2 and A3 are calculated using the same equation obtained

A_2 = 0.49575

A_3 = 0.432525

Complete calculations for all alternatives with other degrees of optimism can be seen in Figure 1.

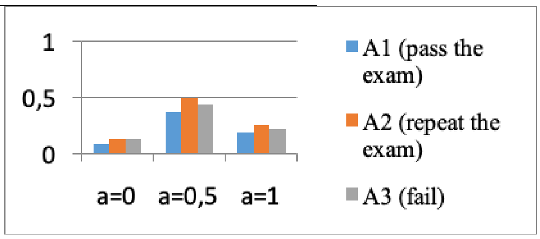

Fig.1. Alternative ranking results

Figure 1 shows that for each different degree of optimism, the highest rank is the second alternative (S2). The second alternative is a recommendation to repeat the thesis exam. The next alternative is S3 (fail) and the lowest rank is S1 (passed the exam).

IV. CONCLUSION

A fuzzy group decision making model was developed to assist decision makers in selecting the most preferred alternative while taking into account the preferences of the various decision makers. In the alternative ranking, the most efficient use of available knowledge, creativity, and the best understanding are considered advantages of the group's decision-making process (GDM) on the multi-attribute decision-making process. This paper offered fuzzy number at the arithmetic interval in the group's decision-making process. In determining the thesis exam, decisions that generally give a vague knowledge of decision-making information and cannot estimate their decision-making information with exact numerical values. It is more appropriate to provide your preferences through linguistic variables instead of numerical.

According to the case study, the fuzzy approach is used to solve the problem, and evaluation alternatives are used to determine the thesis exam. Based on the results of the triangular fuzzy approach to repeat the exam (S2) is the alternative that has the highest value after crossing the process of consent of 3 decision makers. The process of unifying the opinions of decisions uses released numbers at arithmetic intervals.

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