THE MULTI-CRITERIA DECISION-MAKING METHOD: SELECTION OF SUPPORT EQUIPMENT FOR CLASSROOM INSTRUCTORS

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Abstract:
This research illustrates the application of the MCDM (Multi-Criteria Decision Making) method in education, specifically in the context of selecting supportive equipment for classroom instructors, as detailed below. The study aims to determine the optimal equipment to assist instructors in their teaching activities. The research is centered around classrooms within a university in Vietnam. Two MCDM methods, namely the FUCA (Faire Un Choix Adéquat) method and the CURLI (Collaborative Unbiased Rank List Integration) method, were employed to select the most suitable equipment options available in the market. The recommended quantities for the respective equipment are 4, 12, and 5, with 5, 12, and 10 evaluation criteria for each type. Notably, the optimal solutions obtained through the FUCA method align with those derived from the CURLI method for each type of equipment. The findings of this study can be leveraged to conduct further research on teaching methodologies, textbook selection, equipment choices for practical exercises, and various other aspects within the field of education.

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1. INTRODUCTION

The instructional activities of educators are subject to a range of factors, among which the auxiliary equipment utilized during the teaching process holds significant sway. The instructor's desk and chairs set, projector, and sound system are indispensable elements within university lecture hall classrooms. The instructor's desk and chair set functions as a platform for instructors to position their devices like laptops, instructional materials, and presentation aids. Moreover, it furnishes them with comfort during the teaching endeavor. The projector constitutes a tool that empowers educators to impart valuable knowledge to their learners. Numerous concepts would remain inadequately communicated to students without a projector, including intricate images, extensive datasets, complex mathematical formulas, pertinent lesson-related videos, and more. Conversely, the sound system represents an audio apparatus that bolsters instructors in disseminating knowledge to their learners. It ensures clear audibility of the instructor's ideas and mitigates the depletion of the instructor's energy during teaching duties.

When equipping these devices within universities, university administrators often need to acquire them in substantial quantities to ensure comprehensive coverage for all classrooms. Consequently, the selection of product codes within each category for procurement assumes paramount importance. This decision significantly impacts the financial landscape and the efficiency of deploying these devices across the entire educational institution. A survey conducted at a university in Vietnam revealed that the choice of these equipment types frequently hinges on the subjective viewpoints of those in authority (university leaders or authorized individuals). This

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predicament can potentially result in the chosen products not representing the optimal offerings available in the market. The notion of "best" cannot be simplistically equated with the product boasting the highest technical quality; it necessitates evaluation across diverse parameters, encompassing purchase costs, warranty durations, user convenience, and more. A recurrent challenge surfaces with any given product category: if a product exhibits commendable quality, its price tends to escalate, or conversely, a product with subpar quality might entail a truncated warranty period. Hence, the question arises: how can one ascertain a product as the best, signifying that it meets the dual criteria of being "superlative" in technical facets and "minimal" in cost-related dimensions? MCDM methods are valuable tools for tackling issues arising from criteria conflicts [1]. In the contemporary landscape, the count of MCDM methods has surged beyond 200, and their application spans diverse domains, aiding in selecting optimal alternatives from a plethora of options [2]. Yet, when utilizing MCDM methods to rank alternatives, deciding which method to employ for data standardization often presents a challenge for decision-makers. This quandary stems from the fact that the chosen data standardization approach significantly impacts the relative ranking of alternatives. Interestingly, when two distinct data standardization methods are employed, an alternative deemed the best under one method might transform into the worst under another [3]. Certain MCDM methodologies have emerged that obviate the need for data standardization [4]. Among these, the FUCA and CURLI methods stand out as they enable decision-makers to bypass data standardization when applying them [5, 6]. Lately, the FUCA method has found widespread application in diverse fields of multi-criteria decision-making. Notable instances include its utilization in determining a company's financial structure [7-9], the selection of chemical production processes [10], and the choice of mechanical processing techniques [11]. Recently, the CURLI method has seen extensive application in ranking alternatives within material in mechanical processing [12], and the selection of grinding stones and suppliers [13]. The burgeoning interest from the scientific community in these two methods has also captured the attention of the authors of this article. The first objective of this article is to compare two methods, FUCA and CURLI, in finding the best solutions for each type of product (teacher's desks, projectors, and amplifiers). The second objective of this study is to determine the best solution for each type of product The procedural sequence for ranking alternatives employing the FUCA and CURLI methods, along with the techniques for determining criteria weights, is elaborated upon in Chapter 2 of this article. Chapter 3 delves into the content pertaining to the selection of instructor's desk and chair sets, projectors, and sound systems using various MCDM methods. Ultimately, the research culminates in drawing conclusions and presenting suggestions for prospective studies.

2. MATERIALS AND METHODS

In this section, the sequence of steps for ranking the solutions using the FUCA and CURLI methods has been presented. Additionally, in this section, the sequence of steps for calculating the criteria weights using three different methods has also been discussed.

2.1 FUCA Method

To rank alternatives using the FUCA method, a three-step procedure needs to be followed as follows [5]:

Step 1: It is necessary to rank the alternatives for each criterion. Let rij represent the ranking of the alternatives, where $r_{ij} = 1$ if alternative i is the best for criterion j. Conversely, $r_{ij} = m$ if alternative i is the worst for criterion j, where m is the total number of alternatives to be ranked.

Step 2: It is necessary to use formula (1) to calculate the scores for each alternative, where: w_j is the weight of criterion *j*, and *n* is the number of criteria.

$$v_i = \sum_{j=1}^{n} r_{ij}.w_j \quad (1)$$

***Step 3*:** The ranking of alternatives is determined in ascending order of their scores.

2.2 CURLI Method

The sequence for applying the CURLI method is as follows [6]:

Step 1: For each criterion, it is necessary to create a square matrix of size *m* (number of alternatives) and proceed to score the alternatives. Scoring the alternatives (for each criterion) is done as follows: For example, in the cell corresponding to column 1 and row 2, if the value of alternative 1 is better than that of alternative 2, then a score of 1 is

assigned to that cell. In another example, if in the cell corresponding to column 2 and row 1, the value of alternative 2 is worse than that of alternative 1, then a score of -1 is assigned to that cell. Furthermore, if in the cell corresponding to column 2 and row *m*, the value of alternative 2 is equal to that of alternative *m*, then a score of 0 is assigned to that cell, and so on. A score of 0 is also assigned to cells along the main diagonal of the matrix. The scoring matrix for criterion *j* is denoted as matrix Q_j.

Step 2: The scoring matrices for all criteria will be formed by summing up all the individual matrices Q_j. This resulting matrix is denoted as matrix Q_A, which means $Q_A = Q_1 + Q_2 + \ldots + Q_j + \ldots + Q_n$.

Step 3: It is necessary to sort matrix Q_A by rearranging the positions of rows and columns in a way that the upper portion above the main diagonal does not contain cells with positive scores. After sorting, the alternative placed in row 1 (which corresponds to column 1 as well) is considered the best alternative.

2.3 Weights for Criteria

Three methods, ROC (Rank Order Centroid), RS (Rank Sum), and MEAN, were employed to calculate weights for the criteria.

The ROC and RS methods are utilized to calculate the weights of criteria using the respective formulas (2) and (3).

$$w_j = \frac{1}{n}\sum_{k=i}^{n}\frac{1}{k} \quad (2)$$

$$w_j = \frac{2\,(n+1-i)}{n(n+1)} \quad (3)$$

The MEAN weight method is a technique in which the weights of all criteria are equal.

3. CLASSROOM EQUIPMENT

The selection of classroom equipment has been carried out in this section. Three types of equipment have been addressed, including teacher's desks, projectors, and amplifiers. For each product type, information collection on the solutions was performed through the supplier's website. Two methods, FUCA and CURLI, were used to select the best solutions for each product type.

3.1 Desks and Chairs

Xuan Hoa Furniture Company is a well-known company in Vietnam that offers a wide range of products, such as desks, chairs, beds, wardrobes, kitchen products, bathroom products, classroom furniture, and more. The company's products are not only supplied in large quantities to the Vietnamese market annually but are also exported to many countries worldwide. Most of the student desks and teacher desks in Vietnamese universities utilize the company's products. Four types of teacher desks commonly used in Vietnamese universities are labeled with corresponding product codes: BGGV1, BGGV2, BGGV3, BGGV4, and BGGV5. Various specifications are used to describe each product type, including table dimensions, tabletop material, chair seat material, table frame material, chair frame material, price, and more. However, there are numerous specifications that have identical values across all product codes. Therefore, selecting one of the four product codes only requires focusing on specifications with differing values among all four options. The five specifications with distinct values among the options are prices (C1), table frame (C2), chair frame (C3), tabletop thickness (C4), and backrest cushion thickness (C5). Notably, only C1 is a minimization criterion, while the remaining four criteria are maximization criteria. The values of these five criteria for the four product codes have been compiled in Table 1 [14]. According to the data in Table 1, it is evident that the lowest price (criterion C1) belongs to the product with code BGGV1. Among the products, BGGV1, BGGV3, and BGGV4 have the largest value for criterion C2; BGGV3 and BGGV4 have the largest value for criterion C3. Among the products, BGGV2, BGGV3, and BGGV4 have a thickness of 18 mm for criterion C4, which is the largest. For criterion C5, BGGV3 and BGGV4 have a thickness of 18 mm, which is the largest. Thus, it is clear that there is no single product that excels in all five criteria. In other words, there is only one type of product that can be considered the "best" across all five criteria. Of course, this task cannot be accomplished by merely observing the data in Table 1. Instead, MCDM methods need to be employed to achieve this goal. The FUCA and CURLI methods will be used to address this issue.

Table 1. Types of Teacher Desks and Chairs [14]

Code \ Criteria	Prices (VND)	Table Frame (mm)	Chair Frame (mm)	Tabletop Thickness (mm)	Backrest Cushion Thickness (mm)
	C1	C2	C3	C4	C5
BGGV1	1.4510	30x30	25x25	15	15
BGGV2	1.7690	25x25	25x25	18	15
BGGV3	2.2630	30x30	30x30	18	18
BGGV4	2.9300	30x30	30x30	18	18

For using the FUCA method, the first step is to calculate the weights for the criteria. Formula (2) has been utilized to calculate the criterion weights using the ROC method. The criterion weights are calculated using the RS weight method by applying formula (3). For the five criteria, according to the MEAN weight method, each criterion weights 0.2. In Table 2, the weight values for the criteria have been calculated using three different methods.

The rankings of the alternatives have been determined, and the results are shown in Table 3.

Formula (1) has been used to calculate the scores (v_i) for each product. Table 4 has compiled the scores and rankings of the products corresponding to the three different weight calculation methods.

Therefore, the ranking of the types of teacher desks and chairs using the *FUCA* method has been completed. The set of furniture with product code BGGV3 is consistently identified as the best option, even when using three different methods for determining the weight. To provide a firm basis for asserting that BGGV3 is the best choice, another *MCDM* method, the *CURLI* method, has also been employed to rank the options.

Table 2. Weights of the Criteria

Weight method	w_j				
	C1	C2	C3	C4	C5
ROC	0.4567	0.2567	0.1567	0.0900	0.0400
RS	0.3333	0.2667	0.2000	0.1333	0.0667
MEAN	0.2000	0.2000	0.2000	0.2000	0.2000

Table 3. Rankings of the Alternatives

Code	r_{ij}				
	C1	C2	C3	C4	C5
BGGV1	1	2	3.5	4	3.5
BGGV2	2	4	3.5	2	3.5
BGGV3	3	2	1.5	2	1.5
BGGV4	4	2	1.5	2	1.5

Table 4. Scores and Rankings of the Products

Code	Weight method					
	ROC		RS		MEAN	
	v_{ij}	Rank	v_{ij}	Rank	v_{ij}	Rank
BGGV1	2.3583	2	2.3333	2	2.8000	3
BGGV2	2.8083	3	2.9333	4	3.0000	4
BGGV3	2.0183	1	2.2000	1	2.0000	1
BGGV4	2.8150	4	2.5333	3	2.2000	2

Step 1 of the CURLI method has been used to score the products for each criterion. The scoring matrices for criteria C1, C2, C3, C4, and C5 are presented in the respective Tables 5, 6, 7, 8, and 9.

Step 2 of the CURLI method has been applied. The scoring matrix for all criteria is presented in Table 10.

Applying step 3 of the CURLI method to rearrange the rows and columns in the QA matrix, the results are presented in Table 11.

Table 5. Matrix Q_1

Score / Code	S1	S2	S3	S4
BGGV1	0	-1	-1	-1
BGGV2	1	0	-1	-1
BGGV3	1	1	0	-1
BGGV4	1	1	1	0

Table 6. Matrix Q_2

Score / Code	S1	S2	S3	S4
BGGV1	0	-1	0	0
BGGV2	1	0	1	1
BGGV3	0	-1	0	0
BGGV4	0	-1	0	0

Table 7. Matrix Q_3

Score / Code	S1	S2	S3	S4
BGGV1	0	0	1	1
BGGV2	0	0	1	1
BGGV3	-1	-1	0	0
BGGV4	-1	-1	0	0

Table 8. Matrix Q_4

Score / Code	S1	S2	S3	S4
BGGV1	0	1	1	1
BGGV2	-1	0	0	0
BGGV3	-1	0	0	0
BGGV4	-1	0	0	0

Table 9. Matrix Q_5

Score / Code	S1	S2	S3	S4
BGGV1	0	0	1	1
BGGV2	0	0	1	1
BGGV3	-1	-1	0	0
BGGV4	-1	-1	0	0

Table 10. Matrix Q_A

Score / Code	S1	S2	S3	S4
BGGV1	0	-1	2	2
BGGV2	1	0	2	2
BGGV3	-2	-2	0	-1
BGGV4	-2	-2	1	0

Table 11. Matrix Q_A after rearranging the rows and columns

Score / Code	S3	S4	S1	S2	Rank
BGGV3	0	-1	-2	-2	1
BGGV4	1	0	-2	-2	2
BGGV1	2	2	0	-1	3
BGGV2	2	2	1	0	4

In Table 11, all cells with negative values are located above the main diagonal of the matrix, and all cells with positive values are located below the main diagonal of the matrix. Therefore, the rearrangement of rows and columns has been completed. The rankings of the alternatives have also been consolidated in the last column of Table 11. Accordingly, the furniture set with product code BGGV3 has been determined as the best among the four alternatives. To facilitate the comparison between the FUCA and CURLI methods in ranking the furniture sets, the ranking results of the alternatives have been illustrated in a chart in Fig. 1.

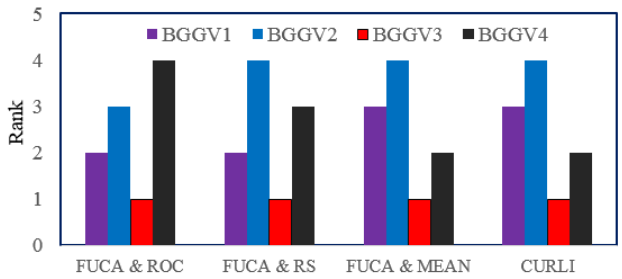

Fig. 1. Ranking of Teacher's Desks and Chairs Sets

Some observations can be made when looking at Fig. 1:

- The rankings of alternatives are not entirely consistent when using different MCDM methods. This aligns with statements made in numerous studies [15, 16].

- Even when using the same FUCA method for ranking alternatives, the rankings might differ when using different methods to determine the weights. This also aligns with statements made in various studies [17-19].

- Among all the cases studied, BGGV3 consistently stands out as the best option among the four considered. This enables us to assert that BGGV3 is the best choice confidently. Also, it is observed that the FUCA and CURLI methods have equivalent efficacy in finding the best solutions in this case.

3.2 Choosing a Projector

Panasonic is a renowned conglomerate from Japan, with its headquarters located in Kadoma, Osaka. The corporation has branches in most countries around the world. Many electrical and electronic products have contributed to the reputation of this conglomerate, such as TVs, refrigerators, washing machines, electric fans, microwaves, and more. Their projector products are also popularly used in lecture halls at universities in Vietnam. When purchasing a projector, customers need to consider various specifications of the product. Of course, if the criteria have the same values across all alternatives, those criteria need not be considered when comparing them. In Table 12, information about twelve types of Panasonic projectors introduced by a supplier in Vietnam is provided. Each projector has chosen twelve criteria for its evaluation. These twelve criteria have different values across all alternatives, and only the price (criterion C1) follows the "lower is better" principle, while all other criteria are "higher is better".

In Table 12, it can be seen that the best values for the criteria are in different solutions. For instance, the smallest C1 value belongs to the PT-

LB303 solution, the largest C2 value is for PT-TW371R and PT-VW360, the largest C3 value is shared by four solutions: PT-LB426, PT-LB386, PT-VW360, and PT-VX430, the largest C5 value is for PT-TW371R, the largest C6 value is shared by two solutions: PT-LB426 and PT-LB305, etc. So, there is no single projector model where all its criteria are the best. This means that in the case of observation only Table 12, the best type of projector cannot be determined. The best alternative can only be identified after applying the FUCA and CURLI methods to rank the alternatives.

The ranking of projector types was conducted similarly to the method used for ranking teacher desks and chairs (as performed in section 3.1). The summarized ranking results of projector types using different methods are presented in the chart in Fig. 2.

Table 12. The types of projectors [20]

Code \ Criteria	Prices (milionVND)	Resolution (XGA)	Contrast Ratio (:1)	Lamp Life (h)	Speaker Power (w)	Lamp Power (w)	Dimensions (mm)	Weight (kg)	Machine body warranty (month)	Lamp module warranty (month)	Lam warranty (month)	Brightness (Ansi lumens)
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
PT-LB426	18.5	1024×768	20000	10000	10	300	335 x 96 x 252	2.9	24	12	6	4100
PT- LB386	14.65	1024×768	20000	10000	10	230	335x96x252	2.9	24	12	6	3800
PT-VX610	23.5	1024x768	16000	20000	14	270	389x125x332	4.8	24	12	6	5500
PT-LB305	11.99	1024x768	16000	20000	2	300	335x96x252	2.9	12	12	6	3100
PT-TW371R	42.639	1280x800	16000	40000	20	230	335 x 134.1 x 329	3.9	24	24	12	3300
PT-TX430	32.55	1024x768	16000	20000	14	230	335 x 134.1 x 329	3.9	24	24	12	3800
PT-TX340	29.03	1024x768	16000	20000	10	230	335 x 134.1 x 329	3.9	12	12	12	3200
PT-VW360	18.8	1280x800	20000	7000	2	240	352 x 98 x 279.4	3.3	24	12	6	4000
PT-VX430	34.46	1024x768	20000	36000	10	240	352 x 98 x 279.4	3.3	12	24	6	4500
PT-LB425	32.22	1024x768	16000	36000	8	230	335 x 96 x 252	2.9	18	12	12	4100
PT-LB355	13.5	1024x768	16000	20000	0	230	335 x 96 x 252	2.9	12	12	6	3300
PT-LB303	10.5	1024x768	16000	10000	2	230	335 × 96 × 252	2.8	24	12	6	3100

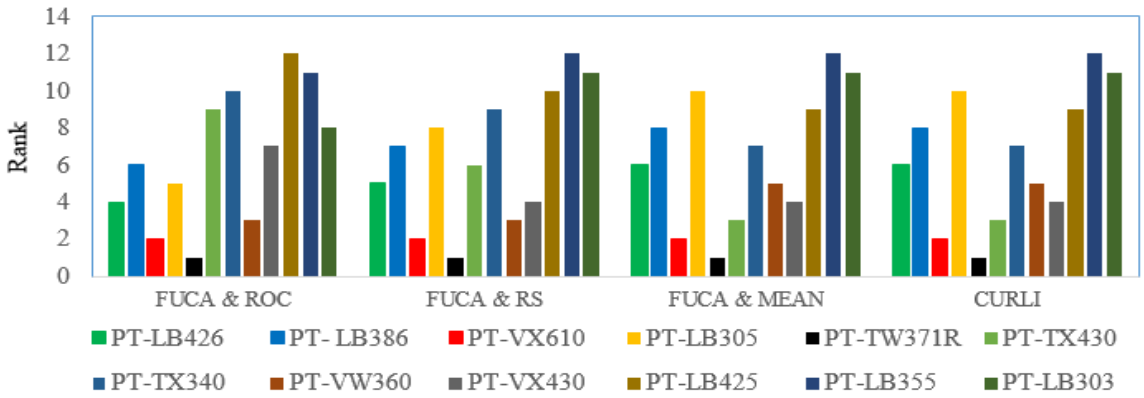

Fig. 2. Ranking of Projector Types

Observing the chart in Fig. 2, it can be noticed that the rankings of alternatives are not exactly the same across all four cases. This is consistent with observations made in previous studies [15, 16]. However, the combination of the FUCA method with the MEAN weight method (denoted as FUCA & MEAN) yields rankings that are completely identical to using the CURLI method. Furthermore, it is also noted that the best solution found consistently coincides when using different methods. Notably, in all the cases examined, PT-TW371R consistently ranks 1st, and PT-VX610 consistently ranks 2nd. From these results, it can be confidently asserted that PT-TW371R is the best projector type among the twelve considered options.

3.3 Selecting an Amplifier

Five amplifier models are introduced by a reputable supplier and used for ranking in this case [20]. The product codes of these five amplifier models are Aplus AS-50E, Aplus AP-2650, Aplus AP-

2350, Aplus AP-2120, and Aplus FL-5060A. All the parameters with the same values across all alternatives are not necessary to be considered (power source, frequency response, Bass equalization range, Treble equalization range, etc.). Only the parameters with non-uniform values across all alternatives need to be evaluated. In Table 13, the values of ten parameters with non-uniform values across all five alternatives are presented. For example, the best C1 value belongs to the Aplus AS-50E, Aplus AP-2650 has the best C2 and C3 values, and the best C4 value is for Aplus AP-2350, etc. Therefore, it is not possible to determine the best solution based solely on the data in this table. To identify the best alternative among the five available options, both FUCA and CURLI methods are applied.

Furthermore, it is necessary to rank the amplifier models using the same approach as carried out in Section 3.1, and the results are presented in the graph shown in Fig. 3.

Table 13. Type of amplifier [20]

Code \ Criteria	Prices (million VND)	Power (W)	Weight (Kg)	Dimension (mm)	Warranty (year)	SD card Interface	Bluetooth Connectivity	Microphone Port	AUX Port	Recount Port
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Aplus AS-50E	4.2	60	6	484 × 240 × 66	2	Yes	Yes	2	2	0
Aplus AP-2650	15.38	650	21	480 × 440 × 100	3	Yes	Yes	2	3	1
Aplus AP-2350	11.56	350	17.5	484 × 485 × 88	3	Yes	Yes	2	3	1
Aplus AP-2120	7.75	120	11.5	480 × 380 × 100	3	Yes	Yes	2	3	1
Aplus FL-5060A	4.21	60	5.5	485 × 340 × 88	3	No	No	1	2	1

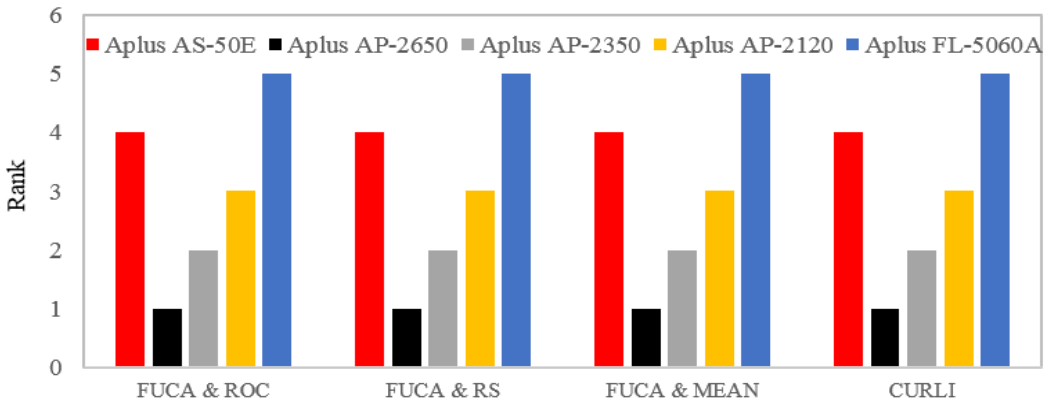

Fig. 3. Ranking of Amplifier Models

In this case, something remarkable has happened: the rankings of the amplifier models are completely consistent across different ranking methods. Accordingly, the priority level when selecting the five amplifier models decreases in the following order: Aplus AP-2650, Aplus AP-2350, Aplus AP-2120, Aplus AS-50E, Aplus FL-5060A.

4. CONCLUSIONS

The set of teacher desks and chairs, projectors, and amplifiers are three essential types of equipment that play a crucial role in supporting educators during their teaching activities in classrooms. In this study, for the first time, these products were selected using MCDM methods. Illustrative examples were applied within a Vietnamese university setting. The two MCDM methods utilized were FUCA and CURLI. The conclusions drawn from this study are as follows:

- ✓ In all examined cases, the best product determined using the FUCA method consistently aligns with the outcome from the CURLI method. This finding instills a high level of confidence in the use of either of these methods or a combination of both for MCDM across diverse

fields.

- ✓ The teacher desk and chair set with product code BGGV3 is the best among the four available options. Among the twelve projector models, the one with product code PT-TW371R is the best. The Aplus AP-2650 amplifier is the top choice among the five evaluated options.
- ✓ The ranking results for teacher desk and chair sets, projectors, and amplifiers might differ if the weighting of criteria considers the preferences of users (specifically, educators). In such a scenario, the PIPRECIA (PIvot Pairwise RElative Criteria Importance Assessment) method should be used to assign weights to the criteria [21].
- ✓ Both FUCA and CURLI methods inspire confidence and can be applied to selecting other types of products, such as computers, textbooks, teaching methods, classroom layouts, lecture hall designs, and more. In the future, these topics should be addressed to enhance the quality of teaching and learning across all educational levels.

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