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A Multi-Criteria Decision-Making Approach for Teaching Quality Evaluation in University Music Programs Using Plithogenic Sets and Weighted Decision Models

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Abstract: Chinese colleges and universities have been studying and implementing quality monitoring systems for music art instruction as a key teaching management project. How to fairly and impartially evaluate the teaching skills of professors of art and music is a crucial problem in college and university administration. Evaluation of university music program have various criteria affecting the decision-making process. So, we used the multi-criteria decision-making methodology (MCDM) to deal with these criteria and select best program. We used the Plithogenic sets with the MCDM methodology to deal with uncertainty information. We used the operators of Plithogenic to combine the Plithogenic numbers. We use the weighted product model (WPM) to rank the alternatives. The weights of criteria are computed using the normalized crips values. The results show the Musical Performance Proficiency of Teachers criterion has the highest rate and Engagement with Music Industry and Professional Development criterion has the lowest rate. We compare the proposed methodology with other MCDM methods. The results show the proposed methodology is effective.

Keywords: Teaching Quality Evaluation; University Music Programs; Multi-criteria Decision Making; WPM Model; Uncertainty.

1. Introduction

A major teaching management initiative in Chinese colleges and universities over the past ten years has been the study and application of quality monitoring methods for music art instruction. The assessment and evaluation of the teaching state and effect of music art are crucial components of quality monitoring management. The quality evaluation of music and art training is the process of collecting a lot of sample data, analyzing, summarizing, and evaluating it[1], [2].

Every college must conduct a standard teaching assessment each academic year to determine the quality of instruction in music and art courses. It is crucial for college and university administration to assess the effectiveness of music and art instructors and promptly comprehend the actual educational environment. With the growth of the school and college, it is challenging to administer the evaluation questionnaire by hand. The new teaching situation's requirements can no longer be met by the manual evaluation. Among its many shortcomings are high ongoing capital costs, a significant organizational burden, difficult data statistics, low efficiency, a high error rate, and a lack of intuitive statistical analysis, querying, and browsing[3], [4].

Therefore, it is imperative that a practical, effective, rational, and scientific evaluation system for the quality of instruction in music and art courses be established at the technical level. This will have a significant impact on assessing the quality of instruction and promoting the teaching of art and music.

There are still certain issues and restrictions with the music art teaching quality assessment method currently in use at colleges and universities, which need to be resolved:

- There is no targeting of the system function. Every system is autonomous.
- The evaluation program only offers rudimentary statistical features. It does not fully utilize the vast amount of fundamental data that has been gathered over time to conduct an exhaustive assessment of the quality of instruction[5].

Smarandache created plithogenic sets as a generalization of intuitionistic, fuzzy, and crisp sets and advanced the concept of plithogeny[6], [7]. With set P, dominating attribute a, set of attribute values V, degree of appurtenance d, and degree of contradiction c, the plithogenic sets are represented as a quintuple of the form (P, a, V, d, c). The traits and attribute values that help resolve complex decision-making processes are used to characterize lithogenic sets[8], [9].

There are frequently several criteria that must be taken into account simultaneously while making decisions. It can be difficult to evaluate and position decisions based on several factors, whether you're choosing an individual option, a venture technique, or an unneeded item to ship. Strategies for Multi-Criteria Decision Making (MCDM) provide a structured method for addressing such problems[10], [11].

The Weighted Product Method (WPM) is one such tactic that provides a systematic approach to combining preferences and weighting criteria to arrive at the final decision. We will go into the intricacies of the Weighted Product Method in this piece, examining its essential elements, inclinations, challenges, and practical uses[12], [13].

The proposed approach is carefully applied to address the problem of evaluating teaching quality in university music programs. It includes a detailed explanation of the methodology and its implementation. Moving to Section 3, the results of the proposed model are thoroughly analyzed and compared, offering insights into its effectiveness. Section 4 builds on this by providing a comparative analysis, showing how the results align with or differ from other established methodologies. Finally, the conclusion wraps up the study by summarizing the main findings, discussing their significance, and suggesting areas for further research.

1.2 Importance of Plithogenic Sets

Plithogenic sets represent a significant advancement in the field of decision-making, providing a flexible and precise framework for handling uncertainty, contradiction, and complexity. Unlike traditional fuzzy, crisp, or intuitionistic sets, plithogenic sets allow for a more nuanced representation of data by incorporating degrees of appurtenance and contradiction simultaneously. Their importance can be summarized as follows:

- Plithogenic sets are uniquely equipped to model situations where data is uncertain or conflicting. This capability is critical in complex decision-making scenarios, such as teaching quality evaluation, where subjective opinions often vary.
- By extending intuitionistic and fuzzy sets, plithogenic sets offer a broader range of applications, making them versatile tools for addressing a variety of multi-criteria decision-making (MCDM) problems.
- By accounting for contradictory attributes and degrees of relevance, plithogenic sets improve the accuracy of decisions, leading to more reliable outcomes.
- Plithogenic sets have found applications in various fields, including education, engineering, healthcare, and business, demonstrating their adaptability and effectiveness in tackling diverse problems.

2. Methodology of the Proposed Decision Approach

A few definitions relevant to our work are presented in this section. Smarandache's writings provide the fundamental definitions of plithogenic sets. A generalized definition of the plithogenic accuracy is also provided. $P \subseteq \mathcal{U}$, the universal set, 'a' is the attribute, V is the set of attribute values, d is the degree of appurtenance, and c is the degree of contradiction. A quintuple of this kind is called a plithogenic set. Only attributes are used to create the plithogenic sets[14].

The steps in the suggested approach, which was developed by combining both combined plithogenic sets with MCDM techniques, are shown in this section. There are two stages to this decision-making process. In the first stage, a plithogenic accuracy matrix is created using a generalized plithogenic accuracy function and coupled plithogenic degrees of appurtenance. In the second stage, the choices are ranked using a WPM method[15], [16]. Figures. 1 and 2, respectively, provide a diagram of the procedures involved in each of the two phases.

Stage 1. Formulation of decision-making matrix

The first stage in the proposed methodology is the formulation of the decision-making matrix, a foundational step that structures the evaluation process by organizing data into a systematic format. This matrix is a vital tool in Multi-Criteria Decision-Making (MCDM) as it provides a clear and organized representation of the relationships between the alternatives under consideration and the criteria used for evaluation.

In this stage, the decision problem is defined by identifying two key components:

Criteria: These are the factors or attributes against which the alternatives are assessed. In the context of evaluating university music programs, criteria might include factors such as "Musical Performance Proficiency of Teachers," "Integration of Music Theory and Practice," or "Engagement with the Music Industry."
Alternatives: These represent the different options or entities being evaluated. For example, alternatives could be ten universities offering music programs.

Step 1. Problem definition

The first step involves identifying the criteria (e.g., teaching quality metrics) and alternatives (e.g., universities or music programs). The decision matrix is defined based on a set of criteria and alternatives.

Step 2. Evaluate the criteria and alternatives.

Experts assess each alternative against the criteria using plithogenic terms. These terms are then converted into plithogenic numbers, capturing degrees of appurtenance and contradiction. (we replace these terms with plithogenic numbers).

$$X^k = \begin{bmatrix} x_{11} & x_{12} & x_{13} & & x_{1j} & x_{1j} & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} & x_{2j} & x_{2n} \\ x_{31} & x_{32} & x_{33} & & x_{3n} & x_{3n} & x_{3n} \\ & \vdots & & \ddots & & \vdots & \\ x_{i1} & x_{ij} & x_{ij} & & x_{ij} & x_{ij} & x_{in} \\ x_{i2} & x_{ij} & x_{ij} & \cdots & x_{ij} & x_{ij} & x_{in} \\ x_{m1} & x_{mj} & x_{mj} & & x_{mj} & x_{mj} & x_{mn} \end{bmatrix} \quad (1)$$

Where k refers to the number of experts

Step 3. Combine the decision matrix.

We combine the plithogenic numbers using the plithogenic operators.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (2)$$

Step 4. Obtain crisp values.

We convert the plithogenic numbers into a crisp value.

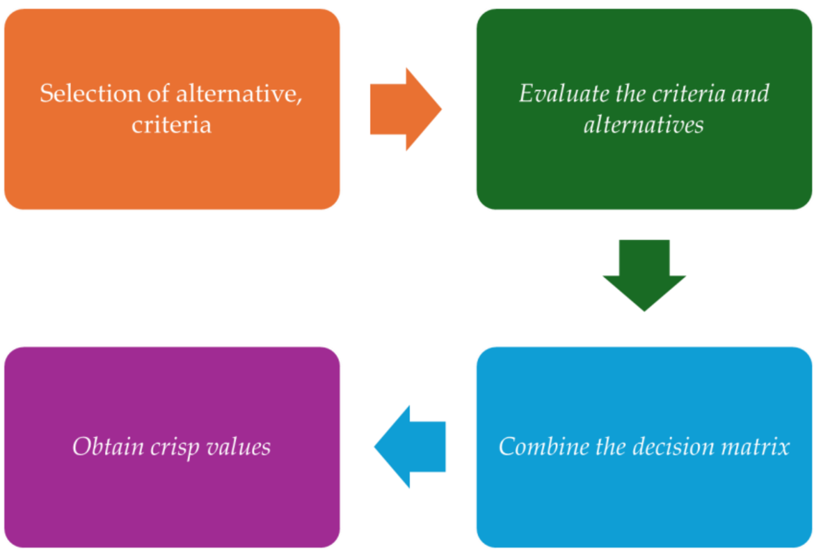

Figure 1. Steps of stage 1.

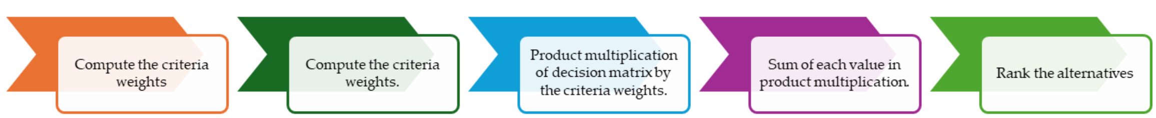

Figure 2. Steps of stage 2.

Stage 2. Ranking the alternatives.

In this stage, we applied the WPM methodology to rank the alternatives.

Step 5. Compute the criteria weights.

$$w = \sum_{j=1}^{n} w_j = 1 \quad (3)$$

Step 6. Product multiplication of decision matrix by the criteria weights.

$$q_{ij} = w_j x_{ij} \quad (4)$$

Step 7. Sum of each value in product multiplication.

$$r_i = \sum_{j=1}^{n} q_{ij} \quad (5)$$

Step 8. Rank the alternatives.

$$T_i = \max r_i \quad (6)$$

2.1 Advantages of Methodology

1. The use of plithogenic sets allows the framework to adapt to various types of data, including subjective and contradictory inputs.
2. By combining plithogenic sets with WPM, the methodology ensures precise and reliable rankings, even in complex scenarios.
3. The final rankings and weighted scores provide clear and actionable insights for decision-makers.

To demonstrate the methodology, the study applied it to evaluate the teaching quality of ten university music programs based on seven criteria. The results showed that "Musical Performance Proficiency of Teachers" was he most significant criterion, while "Engagement with the Music Industry" was the least impactful. Alternative A7 emerged as the best-performing program.

3. Illustration for Decision Making on Teaching Quality Evaluation in University Music Programs

This section shows the results of the proposed methodology to compute the criteria weights and rank the alternatives. Three experts collected the criteria and alternatives from previous studies. These experts and decision makers have expertise in the field of evaluation the university music programs. Seven criteria and ten universities are gathered in this study as shown in Table 1.

Table 1. The criteria and alternatives.

	Criteria		Alternatives
C_1	Individualized Instruction and Mentorship of Music	A_1	University 1
C_2	Integration of Music Theory and Practice	A_2	University 2
C_3	Musical Performance Proficiency of Teachers	A_3	University 3
C_4	Use of Technology in Music Education	A_4	University 4
C_5	Curriculum Design and Repertoire Selection of Music	A_5	University 5
C_6	Performance Opportunities and Ensemble Leadership of Music	A_6	University 6
C_7	Engagement with Music Industry and Professional Development	A_7	University 7
		A_8	University 8
		A_9	University 9
		A_{10}	University 10

Three experts have built the decision matrix table in Table 2. Then we combine these numbers using the plithogenic operators. Then we obtain the crisp values. Then we compute the criteria weights as shown in Figure 3.

Table 2. The decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)
A_2	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_3	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)
A_4	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_5	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_6	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)
A_7	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)
A_8	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)
A_9	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_{10}	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
A_2	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A_3	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)
A_4	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_5	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_6	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_7	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
A_8	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
A_9	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_{10}	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
	C_1	C_2	C_3	C_4	C_5	C_6	C_7

A_1	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)
A_2	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
A_3	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A_4	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_5	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_6	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_7	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A_8	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_9	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)
A_{10}	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)

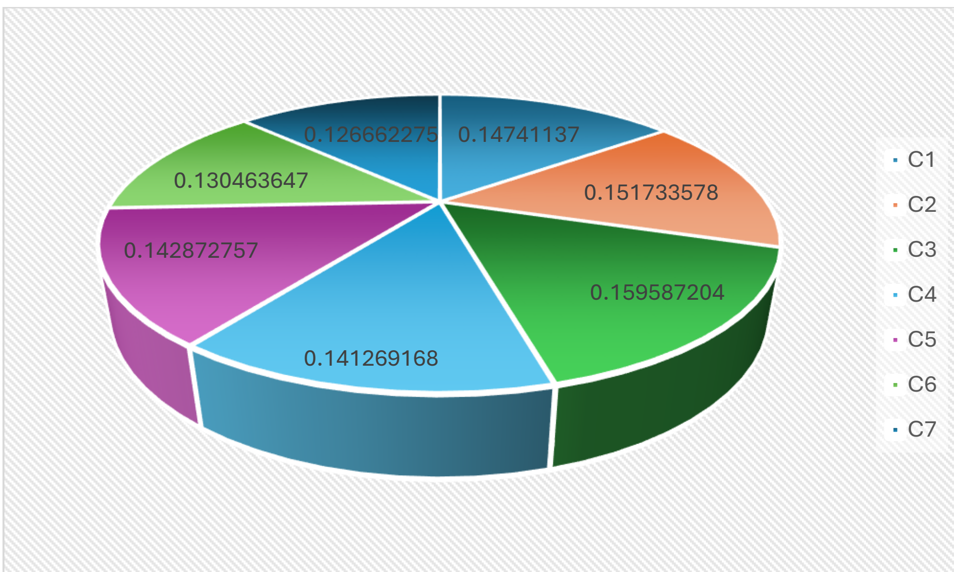

Figure 3. The criteria weights.

Then obtain the product multiplication of decision matrix by the criteria weights as in Table 3. Then we obtain the sum of each value in product multiplication. Then we obtain the rank of the alternatives as in Figure 4.

Table 3. Product multiplication of decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.110804	0.101661	0.085379	0.093897	0.149266	0.141292	0.055832
A_2	0.087697	0.069545	0.145417	0.09465	0.10475	0.069798	0.107336
A_3	0.129759	0.138261	0.140477	0.075579	0.130187	0.035638	0.149366
A_4	0.138075	0.176144	0.135237	0.128726	0.065483	0.11888	0.111494
A_5	0.129759	0.104766	0.085379	0.096899	0.170132	0.122201	0.11864
A_6	0.117118	0.093708	0.135237	0.150811	0.146165	0.046739	0.075353
A_7	0.110804	0.176144	0.153044	0.10969	0.179174	0.110557	0.111494

A_8	0.076384	0.142124	0.185261	0.132322	0.054042	0.131866	0.058054
A_9	0.148996	0.155274	0.181012	0.135477	0.0862	0.122201	0.058054
A_{10}	0.184866	0.150077	0.200136	0.115499	0.074032	0.067602	0.065632

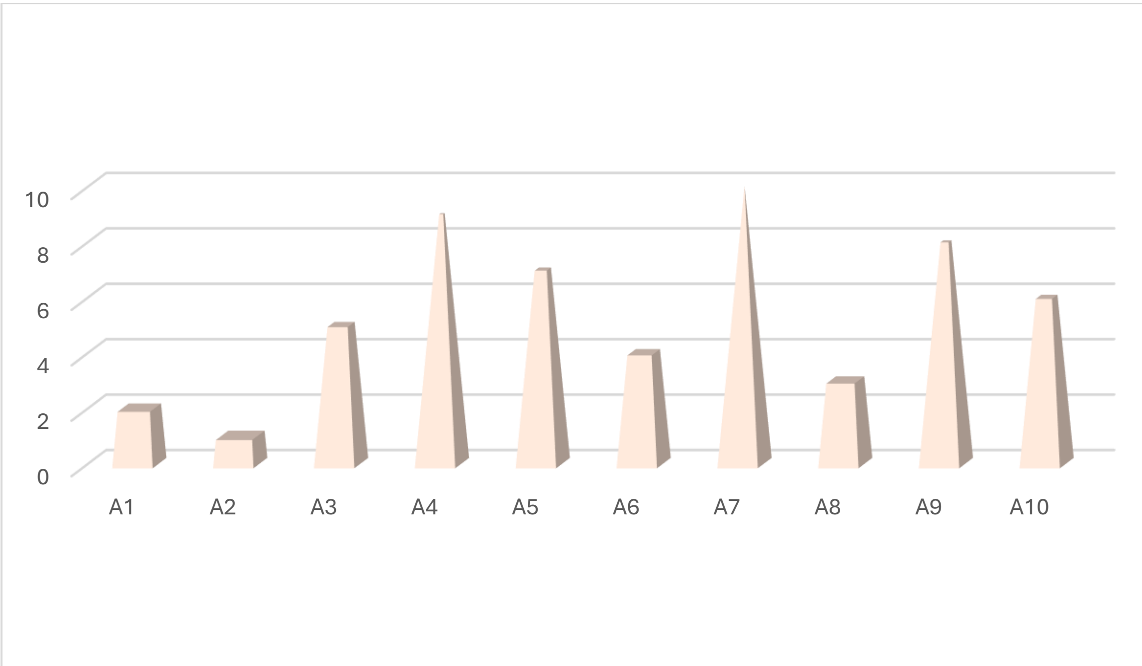

Figure 4. The rank of alternatives.

4. Comparative Analysis of the Proposed Methodology with Other MCDM Methods

This part compares the proposed methodology with other MCDM methods. Figure 5 shows this comparison. We compared our model with different MCDM methods to show different rank of alternatives from different MCDM methods. We show all methods show that the alternative 7 is the best and alternative 2 is the worst.

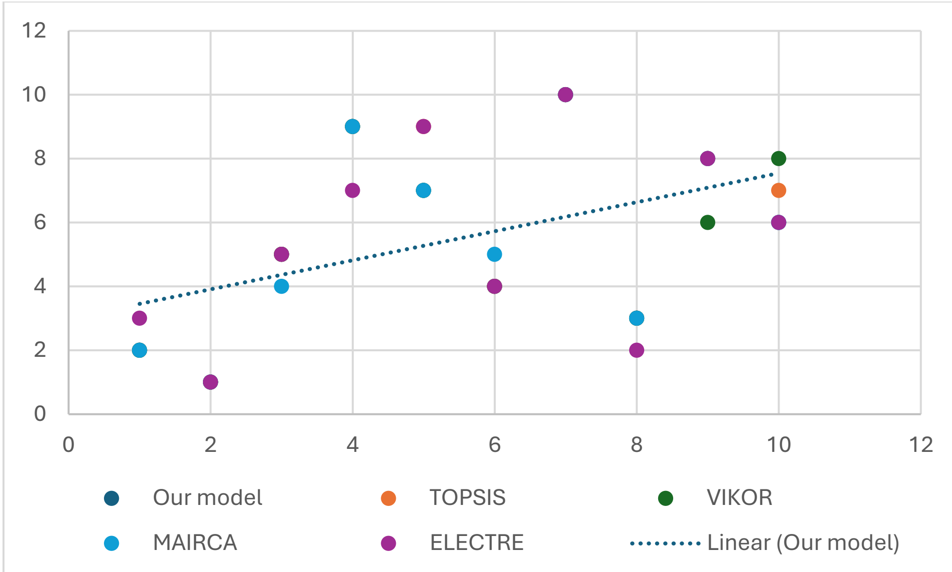

Figure 5. The correlation between our model and other MCDM methods.

5. Conclusions

For more than ten years, a major teaching management initiative in Chinese colleges and universities has been employed to research and put into place quality monitoring methods for teaching art and music. One of the most important tasks in college and university management is to accurately and truthfully assess the teaching skills of professors of art and music. This paper mandates that each university provides direction on the quantitative assessment methodology of music education art for music graduates in accordance with the national guidance on music graduates. This study developed a MCDM methodology with the WPM method to rank the university music programs. This method is integrated with plithogenic sets to deal with uncertainty and vague information. Three experts have evaluated the criteria and alternatives. This study used seven criteria and ten alternatives to be ranked by the WPM method. We compute the criteria weights and rank the alternatives. The results show alternative 7 is the best and alternative 2 is the worst.

5.1 Limitations of the Proposed Methodology

Although the proposed methodology offers notable strengths in managing uncertainties and effectively ranking alternatives, it is not without its limitations. These challenges must be acknowledged to provide a balanced perspective on its applicability and potential areas for improvement.

One key limitation lies in the dependence on expert input. The methodology relies heavily on the expertise and judgment of the evaluators who provide assessments for the criteria and alternatives. This reliance introduces a level of subjectivity, as any bias, inconsistency, or lack of expertise on the part of the evaluators can directly influence the outcomes. Consequently, ensuring the selection of qualified and unbiased experts becomes a crucial factor in the reliability of the methodology.

Another challenge is the complexity involved in calculations. The use of Plithogenic sets introduces intricate mathematical computations that require a solid understanding of the underlying principles. For individuals or organizations lacking adequate training or technical resources, implementing the methodology can be daunting. This complexity may limit its adoption and practical use, especially in settings where simpler tools or models are preferred.

Additionally, the methodology faces scalability issues. While it demonstrates efficiency and reliability when applied to a moderate number of criteria and alternatives, its performance tends to decline as the dataset grows larger. Managing large-scale decision-making problems with an extensive number of criteria and alternatives may require significant computational resources and further optimization of the model.

Lastly, the study is constrained by limited validation data. The analysis was based on the inputs of three experts and ten alternatives, which, while sufficient for demonstrating the methodology's viability, may not fully capture its robustness and generalizability. Broader datasets with a more diverse range of experts and alternatives are necessary to validate the methodology's performance across varied contexts and scenarios.

5.2 Recommendations for Future Research

Building on the findings of this study and addressing its limitations, several recommendations can be made to enhance the methodology's applicability and effectiveness in broader contexts.

One of the most significant recommendations is the development of automated tools. The complexity of implementing Plithogenic-based Multi-Criteria Decision-Making (MCDM) methods can pose a challenge, particularly for users with limited technical expertise. By creating software solutions or user-friendly platforms, the computational aspects of the methodology can be simplified, making it accessible to a wider audience. Such tools would streamline data input, facilitate calculations, and provide intuitive visualizations of results, encouraging broader adoption.

Another promising avenue for improvement is the incorporation of machine learning algorithms. By integrating advanced algorithms, the methodology could reduce its reliance on expert evaluations, which are prone to subjectivity and bias. Machine learning models could analyze historical data to identify patterns, refine criteria weights, and generate more consistent and objective evaluations. This would enhance both the reliability and scalability of the framework.

To further enrich the methodology, there is a need for expansion of criteria. While the current study focuses on specific teaching quality metrics, future research should consider additional factors such as student satisfaction, graduate success rates, and interdisciplinary collaboration opportunities. Incorporating these dimensions would provide a more holistic evaluation of teaching quality and ensure that the methodology aligns with evolving educational priorities.

Lastly, cross-cultural validation is essential to test the methodology's universal applicability. Applying the framework to evaluate music programs in different cultural and educational settings would help identify any context-specific challenges and validate their robustness across diverse environments. This would also allow researchers to explore how variations in cultural values and educational practices influence the relative importance of criteria.

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