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Multi-Criteria Decision-Making for Information Science Program Ranking Using the ELECTRE Method

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ABSTRACT

This study applies a Multi-Criteria Decision-Making (MCDM) technique called ELECTRE (Elimination and Choice Expressing Reality), to rank and assess the quality of Information Scienceal programs based on multiple and often conflicting criteria. ELECTRE utilizes concordance and discordance matrices to create an outranking relation matrix to identify the dominance relationships among various alternatives. The analysis identifies most favorable alternatives through to the least favorable ones by ranking them. The study demonstrates the effectiveness of ELECTRE in evaluating alternatives in complex decision-making environments and provides a systematic approach for decision-makers to rank alternatives based on both qualitative and quantitative criteria. This approach and the subsequent findings can aid in the strategic planning, quality assessment, and accreditation processes of Information Science programs, ensuring robust and data-driven decisions.

KEYWORDS
Multi-Criteria Decision-Making, Information Science Program Ranking, ELECTRE

Introduction

The ranking of alternatives in decision-making processes is a critical task in various fields, from education to industry.

In the presence of multiple options, each evaluated across several criteria, decision-makers require systematic approaches to assess and rank these alternatives effectively. Conventional decision-making approaches may not always work, especially when criteria are conflicting, non-quantifiable, or involve complex interrelationships. In such scenarios, Multiple Criteria Decision-Making (MCDM) techniques provide robust frameworks for evaluating and ranking alternatives [1].

Among the well-known MCDM techniques, ELECTRE (Elimination and Choice Expressing Reality) stands out for its ability to handle decision problems involving conflicting criteria. Unlike methods such as the Analytic Hierarchy Process (AHP) or Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELECTRE is based on outranking relations. It assesses whether one alternative is significantly better than another in terms of a set of criteria. This makes it particularly useful for ranking when there are tradeoffs involved, and precise quantification of preferences is difficult [2, 3].

In higher education, Decision Support Systems (DSS) are essential tools that help institutions manage intricate decision-making processes by combining intelligence and data to produce informed decisions. Higher education institutions face increasing pressure due to global competition, leading them to adopt DSS for improved management of educational strategies, research activities, and teaching quality. A DSS tool, PROF-XXI designed to support decision-making for teaching and learning innovation in higher education institutions. It has the potential to positively impact decision-making processes in educational institutions, offering valuable insights and practical implications for policymakers [4, 5, 6].

A hybrid model (AHP/ANP, ELECTRE TRI, and a method based on multiple regression analysis) that integrates

multiple decision support methods to enhance the decision-making process. Such model serves as the foundation for a decision-making dashboard, a key component of the prototype version of the multi-criteria decision support system (DSS 3.0) [7].
This work aims to demonstrate the application of the ELECTRE method for ranking educational programs based on multiple criteria. By constructing concordance and discordance matrices and applying an exploitation procedure, the ELECTRE method provides a systematic approach to identify the dominance relations among alternatives. This ranking approach can be applied in various contexts where decision-makers need to prioritize alternatives. It offers flexibility in handling qualitative and quantitative data.
This paper focuses on and captures the details involved in applying ELECTRE for ranking. It provides the step-by-step computation of concordance and discordance indices, and discusses the interpretation of the final rankings. These insights can be valuable for stakeholders who need to rank the Information Science program alternatives involving multiple complexes, and often conflicting criteria.

1. Literature Review

Multiple Criteria Decision-Making (MCDM) techniques have gained significant attention in over the years for their ability to address complex decision problems. A study investigated the application of Multi-Criteria Decision-Making (MCDM) techniques in higher education, which is increasingly influenced by globalization and technological advancements. The study underlines the necessity of modern teaching and learning strategies that align with these developments, requiring new tools to support decision-making processes in education. MCDM techniques—which take into account both quantitative and qualitative factors—provide an outline for more effective decision-making. It also focuses on identifying the MCDM methods most commonly used in higher education and classifies them through a systematic taxonomy.[8, 9, 10, 11, 12]. Another study evaluate academic departments in terms of research output in a university using the multi-criteria decision-making (MCDM) methods and mention a comparative study conducted applying fuzzy TOPSIS, fuzzy SAW, and fuzzy EDAS to rank the departments. In that study, six criteria were identified, while the greatest weight was the citation criterion[13]. Some widely used techniques find a mention in this section.

Analytic Hierarchy Process (AHP) was developed by Saaty in 1980. It structures decision problems hierarchically and uses pairwise comparisons to derive the relative importance of criteria. It is particularly effective in situations requiring both qualitative and quantitative assessments. The most often used approach is the Analytical Hierarchy Process (AHP), particularly in fields like e-learning. [8, 14]

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was introduced by Hwang and Yoon in 1981. It ranks alternatives by calculating their geometric distances from an ideal solution and a negative ideal solution. It is known for its simplicity and efficiency in handling large datasets.

ELECTRE (Elimination and Choice Expressing Reality) is a family of outranking methods. It was first proposed by Roy in 1968. It is used to compare alternatives based on concordance and discordance indices. It is highly suitable for dealing with complex problems with conflicting criteria.

VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) was developed by Opricovic in 1998. It focuses on identifying compromise solutions by considering the utility and regret of alternatives. It is particularly useful when decision-makers aim for a consensus.

Fuzzy AHP is the extensions of AHP. It incorporates fuzzy logic to handle uncertainty and vagueness in decision-making. It was proposed by Laarhoven and Pedrycz (1983). It allows more flexibility in expressing preferences using linguistic variables.

All of these techniques have proven versatile across numerous fields, including engineering, healthcare, environmental management, and education, enabling decision-makers to make informed, data-driven choices even in the presence of conflicting criteria. However, our problem of ranking Information Science programs involves various conflicting criteria. For example, programs focused heavily on employability tend to prioritize practical skills and industry connections over academic research, potentially reducing research output. So, both research output and employability, though important in their own place, are mutually conflicting. Therefore, we have chosen ELECTRE over other techniques because of its obvious advantage in dealing with conflicting criteria.

In their study, Das, Sarkar, and Ray (2012) focus on the performance evaluation of seven leading Indian technical institutions, recognizing the growing demand for quality education driven by liberalization, privatization, and globalization. The study addresses the challenge of evaluating institutions in a multi-criteria environment, considering various factors important to stakeholders. To achieve this, the authors propose a fuzzy multi-criteria decision-making (FMCDM) approach, combining the Fuzzy Analytic Hierarchy Process (FAHP) with the Multi-Objective Optimization based on Ratio Analysis (MOORA) method. FAHP is used to determine the significance of various evaluation criteria, while MOORA ranks the institutions based on these criteria. This integrated approach offers a systematic way to address subjective judgments and stakeholder preferences in the ranking process, providing valuable insights into the comparative performance of Indian technical institutions [15].

Numerous studies have been carried out recently applying scientometric analysis to determine the growth of research production.

Aydin (2017) conducted the research on "Research Performance of Higher Education Institutions", the article intends to raise awareness of "research performance," which plays a crucial role in university competition. The study makes an effort to summarize the findings of a thorough literature evaluation in the area of higher education research performance in order to achieve this goal. First, basic literature on research performance is discussed together with its concept definition and indicators. Then, a thorough presentation of the variables affecting research performance followed. The study concludes with the provision of a conceptual framework that will be useful to all university staff.

2. Methods

We have described our methods in this section by summarizing the framework of activities carried out in the Fig. 1, followed by a detailed description of the activities with all the relevant equations and matrices.

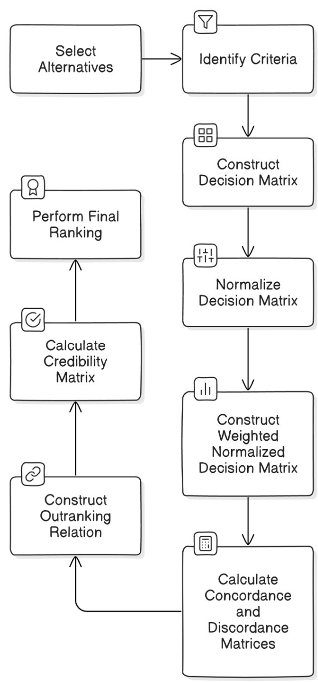

Fig. 1: Framework of activities

Define the Alternatives and Criteria

Alternatives: Our alternatives are different Information Science Programs or institutions being assessed for quality and accreditation. We are not naming any specific program. Rather we prefer to call these Programs A, B, C, D, and E. Stakeholders can apply the proposed methods on specific programs and they can increase or decrease the number of alternatives as the situation may demand.

Criteria: We have established the following criteria for assessment:

1. Curriculum quality
2. Faculty qualification
3. Research output
4. Infrastructure
5. Student satisfaction
6. Industry collaboration
7. Employability of graduates

The stakeholders can add or remove some criteria according to their priorities. However, the proposed approach will still work.

Construct the Decision Matrix

We formulate a decision matrix where each row represents an alternative (in our case, a Information Science Program), and each column represents a criterion.

The matrix is populated with the performance scores of each alternative against each criterion. Scores can be obtained through surveys, expert evaluations, or quantitative data. Table 1 represents the decision matrix involving our criteria and alternatives.

Table 1. Decision Matrix

	Curriculum	Faculty	Research	Infrastructure	Satisfaction	Employability
A	80	75	70	85	90	95
B	85	80	75	80	85	90
C	90	85	80	75	80	85
D	70	65	60	90	95	100
E	75	70	65	70	75	80

Normalize the Decision Matrix

We normalize the decision matrix to ensure that criteria are comparable. Considering the beneficial criteria, where higher values are better, normalization is carried out using equation (1):

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (1)$$

Table 2. Normalized Decision Matrix

	Curriculum	Faculty	Research	Infrastructure	Satisfaction	Employability
A	0.446	0.445	0.442	0.480	0.482	0.486
B	0.473	0.475	0.475	0.452	0.455	0.460
C	0.501	0.505	0.508	0.424	0.429	0.434
D	0.390	0.386	0.381	0.508	0.511	0.510
E	0.417	0.415	0.413	0.395	0.403	0.408

Construct the Weighted Normalized Decision Matrix

We assign weights to each criterion based on their importance. Weights can be determined through expert opinion, stakeholder consultation, or methods like Analytic Hierarchy Process (AHP). The sum of the weights must be equal to 1.

Let's assume the following random weights for the criteria:

Curriculum Quality: 0.25
Faculty Qualifications: 0.15
Research Output: 0.20
Infrastructure: 0.10
Student Satisfaction: 0.15
Employability: 0.15

As given in equation (2), we multiply each element of the normalized decision matrix (represented by Table 2) by the corresponding criterion weight to obtain the weighted normalized decision matrix in the form of Table 3.

$$V_{ij} = W_j \times N_{ij} \qquad (2)$$

Here, W_j is the weight of criterion j.**Table 3. Weighted Normalized Decision Matrix**

	Curriculum	Faculty	Research	Infrastructure	Satisfaction	Employability
A	0.111	0.067	0.088	0.048	0.072	0.073
B	0.118	0.071	0.095	0.045	0.068	0.069
C	0.125	0.076	0.102	0.042	0.064	0.065
D	0.098	0.058	0.076	0.051	0.077	0.077
E	0.104	0.062	0.082	0.040	0.060	0.061

Calculate Concordance and Discordance Matrices

Concordance Matrix: It measures the degree to which one alternative is at least as good as another across all criteria. We obtain it (Table 4) using equation (3):

$$C_{kl} = \sum_{j \in J_{kl}} W_j \qquad \textbf{(3)}$$

J_{kl} is the set of criteria where alternative k is better than or equal to alternative l.

Table 4. Concordance Matrix

	A	B	C	D	E
A	−	0.65	0.50	0.80	0.65
B	0.35	−	0.65	0.65	0.80
C	0.50	0.35	−	0.35	0.50
D	0.20	0.35	0.65	−	0.65
E	0.35	0.20	0.50	0.35	−

Discordance Matrix: It measures the degree of dissatisfaction for each pair of alternatives. We obtain it (Table 4) using equation (4):

$$D_{kl} = \frac{max_{j \in J'_{kl}}(V_{lj} - V_{kj})}{max_j(V_{ij} - V_{kj})} \qquad \textbf{(4)}$$

J'_{kl} is the set of criteria where alternative l is better than alternative k.

Table 5. Discordance Matrix

	A	B	C	D	E
A	−	0.08	0.14	0.06	0.08
B	0.08	−	0.14	0.14	0.10
C	0.14	0.14	−	0.14	0.10
D	0.06	0.14	0.14	−	0.14
E	0.08	0.10	0.10	0.14	−

Identify the Credibility Matrix

We calculate the credibility matrix S by combining the concordance and discordance matrices using equation (5):

$$S_{kl} = C_{kl} \times (1 - D_{kl}) \qquad \textbf{(5)}$$

The credibility matrix, after combining the concordance and discordance matrices is expressed by Table 6 as follows:

Table 6. Credibility Matrix

	A	B	C	D	E

A	−	0.68	0.38	0.62	0.63
B	0.23	−	0.47	0.47	0.67
C	0.47	0.38	−	0.34	0.50
D	0.33	0.38	0.54	−	0.51
E	0.27	0.29	0.41	0.34	−

Construct the Outranking Relation

We define thresholds for concordance and discordance to determine if one alternative outranks another.

Assuming the concordance threshold ($C_{threshold}$) to be 0.6 and the discordance threshold ($D_{threshold}$) to be 0.1, the outranking relation matrix E is calculated using equation (6):

$$E_{kl} = \begin{cases} 1 \ if \ C_{kl} \geq C_{threshold} \\ and \ D_{kl} \leq D_{threshold} \\ 0 \qquad otherwise \end{cases} \qquad (6)$$

Table 7. Outranking Relation Matrix

	A	B	C	D	E
A	−	1	0	1	1
B	0	−	0	0	1
C	1	0	−	0	0
D	0	0	1	−	1
E	0	0	1	0	−

Determine the Final Ranking

We use the credibility matrix to rank the alternatives. Alternatives with higher credibility scores are preferred.

Exploitation procedure is applied to derive a final ranking of the alternatives.

Net Dominance score (shown in Table 8) for each alternative is calculated by equation (7):

Dominance Score = (No.of 1s in row) −(No.of 1s in column) *(8)*

Table 8. Dominance Scores

Alternatives	Outranks others	Outranked by others	Net Dominance Score
A	3	1	+2
B	1	3	−2
C	1	3	−2
D	2	1	+1
E	1	2	−1

3. Result and Discussion

In this study, the ELECTRE method was applied to evaluate and rank five Information Science program alternatives (A, B, C, D, and E) based on multiple conflicting criteria. The decision-making process involved the calculation of concordance and discordance matrices, which were used to derive an outranking relation matrix. Finally, the exploitation procedure was employed to rank the alternatives based on their net dominance scores.

The outranking relation matrix was constructed based on the concordance and discordance thresholds. It identifies which alternatives outrank others, as shown in Table 7. In this matrix, A outranks B, D, and E; B outranks E; C outranks A; D outranks C and E; E outranks C.

On the basis of the outranking relation matrix, the net dominance score for each alternative was calculated. It represents the difference between the number of alternatives an alternative outranks and the number of alternatives that outrank it. The calculated net dominance scores are shown in Table 8.

The alternatives were ranked based on their net dominance scores. The final ranking of alternatives is:

1. A (net dominance score: +2).

2. D (net dominance score: +1).
3. E (net dominance score: -1).
4. B (net dominance score: -2).
5. C (net dominance score: -2).

In the case of B and C, which both had the same net dominance score (-2), further criteria (such as concordance or discordance indices or additional qualitative factors) could be used to differentiate them if needed. However, for the purposes of this analysis, they have been assigned the same rank.

4. Conclusion

The application of the ELECTRE method provides a clear and systematic approach for evaluating alternatives based on conflicting criteria. Alternative A emerged as the most favorable, followed by D and E. Alternatives B and C were found to be less desirable. This result provides actionable insights for decision-makers in choosing among the alternatives.

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