Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control
Journal homepage: http://kinetik.umm.ac.id
ISSN: 2503-2267
Vol. 9, No. 4, November, Pp. 341-352

The application of PROMETHEE method in determining scholarship recipients at university

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Article Info
Keywords:
Decision Support System, Promethee, Scholarship

Article history:
Received: April 18, 2024
Accepted: July 21, 2024
Published: November 01, 2024

Cite:
W. Prima, F. Putra, S. Sapriadi, and R. Hayati, "The Application of PROMETHEE Method in Determining Scholarship Recipients at University", KINETIK, vol. 9, no. 4, Nov. 2024.
https://doi.org/10.22219/kinetik.v9i4.2014

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Abstract
This study aims to use PROMETHEE method as a decision support system in determining the recipients of the Academic Achievement Improvement Scholarship at Universitas Dharmas Indonesia (UNDHARI). The methodological steps include problem identification, analysis, goal setting, and the application of PROMETHEE method. In this study, the criteria and alternatives have been identified to evaluate the scholarship recipients. The criteria weights are set, and the criteria preference types are determined. After obtaining the baseline data from the questionnaire assessments, pairwise preference values and multicriteria preference index values are calculated. Then, the rankings are compiled using Leaving Flow, Entering Flow, and Net Flow methods, resulting in the priority order of the scholarship recipients. The ranking results show that alternative 3 (IS) has the highest Net Flow value (0.30), while alternative 2 (AV) has the lowest Net Flow value (-0.35). Thus, the priority order from highest to lowest is IS, AV, RD, YM, and AV. In the context of Net Flow scores, these results indicate that alternative 3 (IS) has the greatest chance of receiving the academic achievement improvement scholarship. This study provides important insights for UNDHARI in the scholarship recipient determination process using the PROMETHEE method as a decision-making tool.

1. Introduction

The competition among private universities is becoming increasingly fierce due to the large number of private universities in Indonesia. Various efforts have been made by private universities to attract prospective students. Among the strategies implemented by private universities to recruit prospective students are various scholarship programs, which aim to attract the interest of new students and their parents to continue their higher education at private universities [1], [2]. Scholarships are financial aid provided to individuals who are economically disadvantaged to obtain proper education [3], [4]. Scholarships are usually offered by government agencies, companies, or foundations with the goal of alleviating the financial burden of students during their studies [5]. Educational institutions currently offer many scholarship programs to underprivileged students or students who excel academically or in non-academic fields. In addition, many higher education institutions offer both internal and external scholarship programs [6]. Internal scholarships are those whose funding comes from the educational institution, such as academic achievement scholarships (full and partial), final project scholarships, and non-academic achievement scholarships like sports, arts, and others. External scholarships are those whose funding comes from outside the institution, such as the Academic Achievement Improvement Scholarship, Education Cost Assistance, and the Smart Indonesia Card [7].

Universitas Dharmas Indonesia (UNDHARI) is one of the higher education institutions that provide opportunities for its students to obtain scholarships. There are several scholarships available at Universitas Dharmas Indonesia, one of which is the academic achievement improvement scholarship. This scholarship, managed by the Ministry of Research, Technology, and Higher Education (Kemenristekdikti), has provided significant financial support for students in need [8]. To be eligible for this scholarship, the applicants must follow and meet the established criteria and regulations. From the preliminary research conducted earlier, the process of determining the recipients of the academic achievement improvement scholarships at UNDHARI involve reviewing the students' academic data, information from the Head of Study Program, and the results of direct interviews with the scholarship applicants. However, this process might face several difficulties due to the large number of applicants and the criteria used to determine the eligible scholarship recipients. Therefore, a decision support system is needed to help, expedite, and simplify the decision-making process. [9], [10].

Decision Support System (DSS) is a computer-based system that can be utilized in making decisions [11], [12]. The purpose of a DSS is to provide accurate predictions in offering a solution [13], [14]. DSS can also serve as a tool for organizations in making better decisions [15], [16]. Moreover, DSS can manipulate data using a model to produce

decision alternatives [17], [18]. Several methods can be used in DSS, such as: Analytic Hierarchy Process (AHP), Fuzzy Multiple Attribute Decision Making (FMADM), Simple Additive Weighting (SAW), Analytic Network Process (ANP), Simple Multi-Attribute Rating Technique (SMART), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the Preference Ranking Organization for Enrichment Evaluation (PROMETHEE) method.

PROMETHEE is a method used for multi-criteria decision-making [19], [20], [21]. This method assists in comparing and ranking alternatives based on a set of predefined criteria [22], [23]. Additionally, PROMETHEE is used in situations where there are multiple alternatives that need to be evaluated based on several conflicting criteria. Several research findings also mention that PROMETHEE can provide significant contributions in making decisions, such as: providing alternative employees for promotion at Nusa Agung Garment [24], assisting catering in selecting suppliers for raw materials [25], helping customers in choosing laptops according to their needs and hardware specifications [26], and providing alternatives for the headmaster position at Private Vocational High School Nurul Amaliyah Tanjung Morawa [27]. From these studies, it can be concluded that the PROMETHEE method is simpler, clearer, and more stable. [28], [29].

Therefore, this method is effective for selecting scholarship recipients at UNDHARI, as the aim of this research is to assist higher education institutions, specifically UNDHARI, in providing alternative recipients for the academic achievement improvement scholarship. This will enable UNDHARI to quickly, accurately, and precisely award scholarships to students. It is hoped that this research can contribute to future studies by offering a fast, accurate, precise, and stable alternative for decision-making.

This research brings several significant aspects of novelty. First, it integrates the PROMETHEE method in the context of scholarship recipient selection, which has rarely been done until now. Second, the implementation of this method is expected to improve the efficiency and accuracy of the selection process, reduce subjective bias, and enable more transparent and accountable decision-making. Third, this research provides a practical solution that can be adopted by other educational institutions facing similar issues in their scholarship recipient selection process.

Thus, this research is not only relevant for UNDHARI but also has broader implications for scholarship management in other universities. It is hoped that the results of this study will contribute significantly to the development of better scholarship selection methods and serve as a reference for future research.

2. Research Method

2.1 Research Stages

This study is structured into several logical steps as depicted in Figure 1.

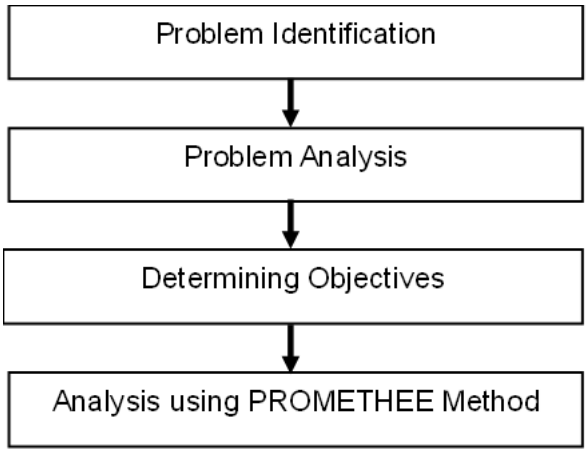

Figure 1. Research Stages

In Figure 1, the research stages described are as follows: a) Identification of the existing problems at the university, especially UNDHARI; b) Problem analysis which is carried out by collecting related data; c) Determining the objectives, which aims to make the research more focused on the problems to be solved; d) Analysis using the PROMETHEE Method.

2.2 PROMETHEE Method

The PROMETHEE method has several stages as depicted in Figure 2.

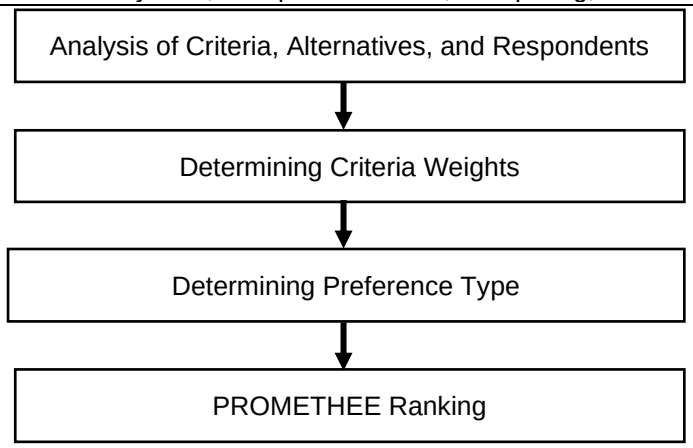

Figure 2. Stages of the PROMETHEE Method

In Figure 2, several stages are carried out in the modeling of the PROMETHEE method, namely:

a. Analysis of Criteria, Alternatives, and Respondents
The criteria, alternatives, and respondents are determined based on the field observation, interviews with stakeholders, and review of documents related to the research object.

b. Determining Criteria Weights
After the criteria, alternatives, and respondents have been established, the weight of each criterion is set.

c. Determining Preference Types
The PROMETHEE method has 6 common preference types that can be used [30], namely:

1. Usual Criteria
The preference for this type uses Equation 1.

$$H(d) = \begin{cases} 0 \; if \; d = 0 \\ 1 \; if \; d \neq 0 \end{cases} \quad (1)$$

The value of *d* is the result of the difference between the criteria values, represented by the formula d = f(a) - f(b). The function H(d) illustrates the function that takes into account the difference in criteria between two alternatives, allowing evaluation or measurement of the difference in values between the related criteria, as seen in Figure 3.

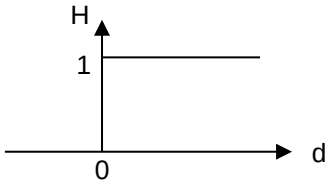

Figure 3. Usual Criteria

2. U-Shape Criteria
The preference for this type uses Equation 2.

$$H(d) = \begin{cases} 0 \; if \; d \leq q \\ 1 \; if \; d > q \end{cases} \quad (2)$$

The function H(d) represents the relationship between the difference in criteria values and alternatives represented by *d*, which is calculated as the result of the difference between f(a) and f(b). Meanwhile, the parameter (q) is the value of the tendency above, which plays a role in the context of evaluating preferences or positive tendencies towards a criterion greater than other alternatives, as seen in Figure 4.

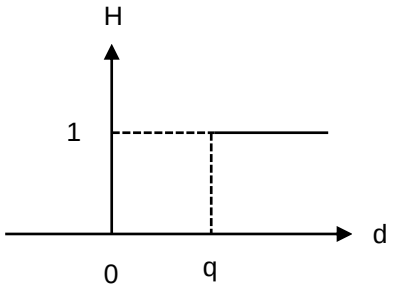

Figure 4. U-Shape Criteria

3. V-Shape Criteria
   The preference for this type uses Equation 3.

$$H(d) = \begin{cases} 0 \; if \; d \leq 0 \\ \frac{d}{p} \; if \; 0 < d \leq p \\ 1 \; if \; d > 0 \end{cases} \quad (3)$$

The function H(d) is a mathematical representation of the difference in criteria values between two alternatives. The value of *d* represents the difference between the criteria values f(a) and f(b), while the parameter *p* refers to the upper tendency value towards the criterion, as seen in Figure 5.

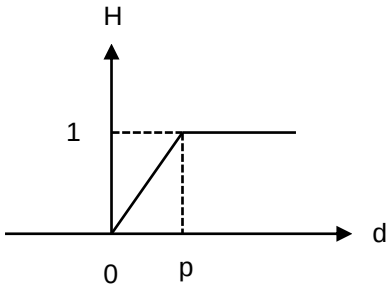

Figure 5. V-Shape Criteria

4. Level Criteria
   The preference for this type uses Equation 4.

$$H(d) = \begin{cases} 0 \; if \; d \leq 0 \\ \frac{1}{2} \; if \; q < d \leq p \\ 1 \; if \; d > p \end{cases} \quad (4)$$

The function H(d) depicts the difference in criteria values between alternatives, while *p* refers to the upper tendency value towards the considered criterion. The parameter (q) must be consistent and have a fixed value, as seen in Figure 6.

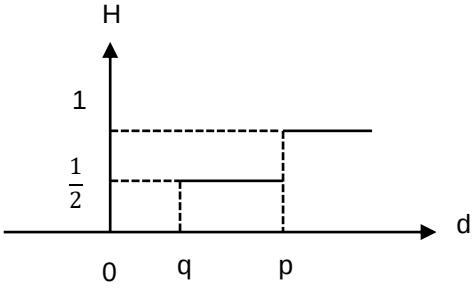

Figure 6. Level Criteria

5. V-Shape with Indifference Preference
   The preference for this type uses Equation 5.

$$H(d) = \begin{cases} 0 \; if \; d \leq q \\ \frac{d-q}{p-q} \; if \; q < d \leq p \\ 1 \; if \; d > q \end{cases} \quad (5)$$

The function H(d) is a representation of the difference in value between criteria and alternatives represented by *d*, which is calculated as the difference between f(a) and f(b). The parameter *p* refers to the upper tendency value towards the considered criterion, while the parameter *q* must maintain a fixed value, as seen in Figure 7.

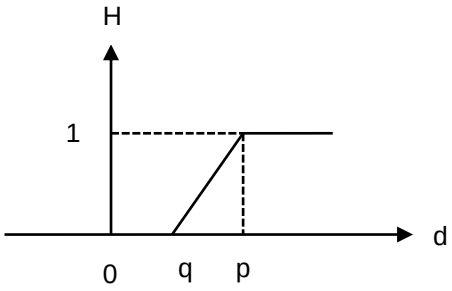

Figure 7. V-Shape with Indifference Preference

6. Gaussian Criteria
   The preference for this type uses Equation 6.

$$H(d) = \begin{cases} 0 \; if \; d \leq 0 \\ 1 - e^{\frac{-d^2}{2s^2}} \; if \; d < 0 \end{cases} \quad (6)$$

If the value of σ has been determined according to the normal distribution in statistics, then the value of H(d) will not be equal to one for this function, which is conditional, as seen in Figure 8.

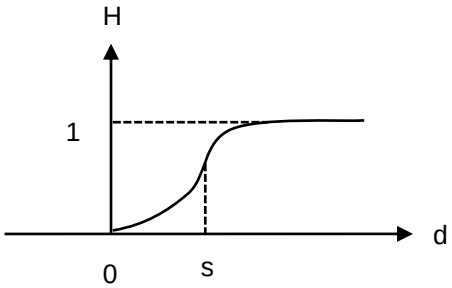

Figure 8. Gaussian Criteria

d. Calculating Preference Values
   At this stage, there are two steps carried out, namely: calculating the pairwise preference values and calculating the multicriteria preference index values. Where the calculation of pairwise preference values is calculated according to the previously determined preference type, while the calculation of multicriteria preference index uses Equation 7:

$$\varphi\,(a,b) = \sum_{i-1}^{n} \pi \; Pi(a,b) : \forall a,b \in A \quad (7)$$

e. PROMETHEE Ranking

The PROMETHEE method has three types of ranking [31],namely:

1. Leaving Flow

The Leaving Flow value can be calculated using Equation 8.

$$\Phi^{+}(a) = \frac{1}{n-1}\sum_{x\epsilon A} \wp(a,x) \tag{8}$$

In this context, $\varphi(a, x)$ is a representation of preference where the value a is considered superior or more desirable compared to the value x. The symbol n is used to indicate the total number of alternatives available in a situation or comparison. The mathematical symbol $\sum x\varepsilon A$ represents the horizontal summation operation of alternative values contained in the preference table.

2. Entering Flow

The Entering Flow value can be calculated using Equation 9.

$$\Phi^{-}(a) = \frac{1}{n-1}\sum_{x\epsilon A} \wp(a,x) \tag{9}$$

The symbol $\varphi(a, x)$ represents the preference where the value a is considered better than the value x in a comparison. In a dataset consisting of n alternatives, the representation of these values in the preference table allows for vertical comparison with the summation $\sum x\varepsilon A$. This process enables a deeper analysis in evaluating preferences between existing values, allowing the determination of choices or decisions based on the set preferences.

3. Net Flow

The Net Flow value can be calculated using Equation 10.

$$\Phi(a) = \varphi + (a) - \varphi - (a) \tag{10}$$

The symbol θ+(a) represents the mathematical representation of the leaving flow formula in the Promethee I method, while θ-(a) reflects the entering flow formula in the same context. On the other hand, $\theta(a)$ represents the net flow formula in the Promethee II method.

3. Results and Discussion

3.1 Analysis of Criteria, Alternatives, and Respondents

The results obtained from document reviews, observations, and interviews at UNDHARI reveal four criteria, five alternatives, and the participation of respondents from both lecturers and students in determining the recipients of the Academic Achievement Improvement Scholarship. Among the five criteria, two are sourced from the academic department, namely GPA and has never received academic and social issues warning letter. Lecturers assess the criteria of study motivation, noble character, and organizational activity. Students evaluate the criteria of noble character and organizational activity. These criteria and alternatives can be seen in Table 1 and Table 2.

Table 1. Criteria

No	Criteria	Code
1	GPA	K1
2	No Academic and Social Issues Warning Letter	K2
3	Study Motivation	K3
4	Noble Character	K4
5	Organizational Activity	K5

Table 2. Alternatives

No	Alternatives	Code
1	Alternative 1	AG
2	Alternative 2	AV
3	Alternative 3	IS

No	Alternatives	Code
4	Alternative 4	RD
5	Alternative 5	YM

3.2 Determining Criteria Weights

Criteria weighting is an important step in the analysis process using the PROMETHEE method. Through this weighting, weights are given to each previously determined criterion, which can be found in Table 3. The aim is to facilitate comparative analysis among criteria by providing relative importance levels for each criterion. Using the weights listed in Table 3, the PROMETHEE method can provide more structured results and facilitate interpretation in decision-making.

Table 3. Criteria Weighting

No	Criteria	Indicator	Description	Weight
1	GPA	GPA	3,50 – 4,00	5
			3,00 – 3,49	4
			2,50 – 2,99	3
			1,50 – 2,49	2
			< 1,50	1
2	No Academic and Social Issues Warning Letter	Warning Letter	0 WL	4
			1 WL	3
			2 WL	2
			3 WL	1
3	Study Motivation	Economy	Very Less Capable	5
			Less Capable	4
			Adequately Capable	3
			Capable	2
			Very Capable	1
		Disability	Difabel	2
			Normal	1
		Reason for Studying	Own Desire	3
			Parental Desire	2
			Following Friends	1
		Discipline	Very Disciplined	5
			Disciplined	4
			Adequate	3
			Less Disciplined	2
			Not Disciplined	1
4	Noble Character	Honesty	Very Honest	5
			Honest	4
			Adequately Honest	3
			Dishonest	2
			Very Dishonest	1
		Politeness	Very Polite and Courteous	5
			Polite and Courteous	4
			Adequately Polite and Courteous	3
			Impolite and Discourteous	2
			Very Impolite and Discourteous	1
		Cleanliness	Very Maintains Cleanliness	5
			Always Maintains Cleanliness	4
			Tries to Maintain Cleanliness	3
			Less Maintains Cleanliness	2
			Very Less Maintains Cleanliness	1
		Social Relations	Very Maintains Social Relations	5
			Always Maintains Social Relations	4
			Tries to Maintain Social Relations	3
			Less Maintains Social Relations	2
			Does Not Maintain Social Relations	1
5	Organizational Activity		Very Active	5

No	Criteria	Indicator	Description	Weight
			Active	4
		Organizational	Adequately Active	3
		Activity	Not Active	2
			Very Not Active	1

3.3 Determining Preference Types

Based on the predetermined alternatives and criteria, basic data for each criterion of the alternatives have been obtained for the analysis using the PROMETHEE method. In this method, the preference type used for each criterion is the 'usual' criterion. The reasons for using the “usual”' preference type are as follows: 1) This type aligns with the scholarship acceptance indicators at UNDHARI, which have been scaled by UNDHARI, such as the GPA indicator, where the scale ranges from 1 to 5, which allows for absolute results, 2) This type can provide accurate and precise decisions even with limited available data, 3) This type ensures consistent evaluation across criteria and is not affected by small variations in data, thereby maintaining objectivity and reducing bias in the decision-making process.

Based on the data obtained from the academic department and the questionnaires given to the lecturers and students, the criterion values for each alternative can be seen in Table 4.

Table 4. Criteria Values for Each Alternative

Criteria	Min/Max	AG	AV	IS	RD	YM
f1 (.)	Max	5	4	5	5	4
f2 (.)	Max	4	4	4	4	4
f3 (.)	Max	2.33	2.33	2.67	2.33	3.33
f4 (.)	Max	4.27	4.00	4.53	4.40	4.27
f5 (.)	Max	4.27	3.53	2.20	2.20	2.20

3.4. Calculating Preference Values

Based on the data in Table 4, the next step is to calculate the pairwise preference values (P) between AG and AV, AG and IS, AG and RD, AG and YM, AV and IS, AV and RD, AV and YM, IS and RD, IS and YM, RD and YM. The purpose of this calculation process is to generate values that will be represented in Table 5.

Table 5. Calculation Results of Preference Values

	f1	f2	f3	f4	f5
AG.AV	1	0	0.00	0.27	0.73
AG.IS	0	0	-0.33	-0.27	2.07
AG.RD	0	0	0.00	-0.13	2.07
AG.YM	1	0	-1.00	0.00	2.07
AV.IS	-1	0	-0.33	-0.53	1.33
AV.RD	-1	0	0.00	-0.40	1.33
AV.YM	0	0	-1.00	-0.27	1.33
IS.RD	0	0	0.33	0.13	0.00
IS.YM	1	0	-0.67	0.27	0.00
RD.YM	1	0	-1.00	0.13	0.00

After calculating the pairwise preference values, the next step is to calculate the multicriteria preference index value, which is determined based on the average weight of the preference function Pi. The calculation results can be seen in Table 6.

Table 6. Calculation Results of Multicriteria Preference Index

Alternative	AG	AV	IS	RD	YM	∑
AG	-	0.60	0.20	0.20	0.40	1.4
AV	0.00	-	0.20	0.20	0.20	0.60
IS	0.40	0.60	-	0.40	0.40	1.80
RD	0.20	0.40	0.00	-	0.40	1.00
YM	0.20	0.40	0.20	0.20	-	1.00
∑	0.8	2.00	0.60	1.00	1.40	

3.5. Promethee Ranking

3.5.1 Leaving Flow

Leaving Flow is an essential element in the Promethee method that applies partial order. In the context of assessment to determine the priority order, the results of Leaving Flow are as follows:

AG = 1/(5-1) * 1.4 = 0.35
AV = 1/(5-1) * 0.6 = 0.15
IS = 1/(5-1) * 1.8 = 0.45
RD = 1/(5-1) * 1 = 0.25
YM = 1/(5-1) * 1 = 0.25

3.5.2 Entering Flow

In the Promethee method, Entering Flow is used to determine the priority order when the process uses partial order. The results of the calculation show the priority order as follows:

AG = 1/(5-1) * 0.8 = 0.2
AV = 1/(5-1) * 2 = 0.5
IS = 1/(5-1) * 0.6 = 0.15
RD = 1/(5-1) * 1 = 0.25
YM = 1/(5-1) * 1.4 = 0.35

3.5.3 Net Flow

Net Flow is a crucial phase in the Promethee method that allows the final determination of the priority order in solving the problem. Considering this process, the results of the Net Flow calculation yield a complete priority order for the alternatives of the Academic Achievement Improvement Scholarship recipients at UNDHARI. The results are as follows:

Φ (a) = 0.35 – 0.20 = 0.15
Φ (a) = 0.15 – 0.50 = -0.35
Φ (a) = 0.45 – 0.15 = 0.30
Φ (a) = 0.25 – 0.25 = 0.00
Φ (a) = 0.25 – 0.35 = -0.10

From the calculation results of Leaving Flow, Entering Flow, and Net Flow, the priority order is obtained. The details can be seen in Table 7.

Table 7. Results of Leaving Flow, Entering Flow, and Net Flow Order

Alternatives	Leaving Flow	Entering Flow	Net Flow	Ranking
AG	0.35	0.20	0.15	2
AV	0.15	0.50	-0.35	5
IS	0.45	0.15	0.30	1
RD	0.25	0.25	0.00	3
YM	0.25	0.35	-0.10	4

3.6 Comparison with Other Methods

To demonstrate the advantages of this method, the research results are compared with the conventional scholarship selection methods that rely solely on interviews and academic data without using systematic mathematical methods. Studies show that the PROMETHEE method provides more consistent and objective results compared to the conventional methods, which are often influenced by subjective bias and inconsistencies among evaluators.

In the academic context, other research using the AHP (Analytic Hierarchy Process) method has also demonstrated effectiveness in scholarship selection. However, the PROMETHEE method has advantages in terms of process simplification and clarity of results. Additionally, PROMETHEE allows direct comparisons between alternatives based on complex criteria, providing greater flexibility in decision-making.

Overall, the application of the PROMETHEE method at UNDHARI is expected to enhance transparency, speed, and accuracy in the scholarship selection process, contributing significantly to better decision-making in university management.

4. Conclusion

Based on the ranking results in Table 7, it was found that the highest Net Flow is obtained by Alternative IS, with a value of 0.30. Conversely, the lowest Net Flow is found in Alternative AV, with a value of -0.35. Thus, the ranking order from highest to lowest is IS, AV, RD, YM, and AV.

This indicates that Alternative IS, represented by Irza Silvia, has a very high chance of receiving the academic achievement improvement scholarship based on the highest Net Flow value it obtained. These results can serve as a strong reference in the scholarship recipient determination process, where Alternative IS performs the best compared to other alternatives.

5. Acknowledgments

The successful implementation in this study would not have been possible without the help and support of all related parties. We extend our gratitude to Universitas Adzkia for its contribution in funding the publication for the research team. We also express our gratitude to Universitas Dharmas Indonesia (UNDHARI) for agreeing to be the subject of our research. Our deepest gratitude goes to everyone whose names we cannot mention individually. We hope that what we have accomplished will be beneficial in the future.

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