

APPLICATION OF A COMBINATION ANALYTICAL HIERARCHY PROCESS WEIGHTING WITH RANKING USING ADDITIVE RATIO ASSESSMENT

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ABSTRACT

Ratio Assessment (ARAS) approach as a decision support system for identifying eligible recipients of the Indonesia Smart Card Scholarship for Higher Education (KIP-K). The AHP method is applied to derive the weight of each criterion using pairwise comparison techniques, whereas the ARAS method is utility to normalize the data, compute optimization function values, determine utility degree scores, and establish the ranking of alternatives. The integration of these two methods is intended to enhance the quality of decision-making based on the administrative data of KIP-K scholarship recipients. This study utilizes secondary data from KIP-K scholarship applicants for the 2025 academic year, obtained from the Academic and Student Affairs Bureau of Tanjungpura University, with an initial total of 1,823 applicants. Following data preprocessing, which included the elimination of duplicate, incomplete, and inconsistent alternatives, a total of 1,491 alternatives were retained for analysis. The evaluation criteria comprised the father's occupation, father's income, mother's occupation, mother's income, and the number of family dependents. The AHP weighting results yielded weights of 0.18, 0.38, 0.11, 0.22, and 0.11, respectively, identifying father's income as the most influential criterion. Subsequently, the ARAS method generated a ranking of all 1,491 scholarship candidates.



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1. Introduction

Education is a fundamental foundation for improving the quality of human resources and strengthening a nation's competitiveness. In Indonesia, the right to education is guaranteed under Article 31 of the 1945 Constitution, ensuring that every citizen has the opportunity to develop their potential through formal education pathways [1]. However, in practice, continuing education to a higher level remains a challenge, especially for prospective students from financially constrained households. This condition causes access to higher education to remain uneven, making interventions necessary to expand study opportunities for groups in need [2], [3], [4].

One widely implemented form of intervention is scholarships, which provide financial assistance to support students' educational continuity. Scholarships not only help meet educational expenses but may also increase motivation and improve the likelihood of academic success among recipients [2], [5]. The main objective of providing scholarships to students in need is essentially to expand access to higher education, encourage academic achievement, and help students complete their studies on time through financial support during their university years [2], [3], [5].

At Tanjungpura University, several scholarship programs are available, one of which is the Kartu Indonesia Pintar Kuliah (KIP-K). KIP-K is a government-funded educational assistance program aimed at increasing access to higher education for economically disadvantaged students [6], [7]. In its implementation, scholarship administration is handled by the relevant unit (e.g., the Academic and Student Affairs Bureau) based on specific criteria. On the other hand, limited recipient quotas require the selection process to be more selective to ensure that assistance is properly targeted. Therefore, a selection process that is objective, consistent, and accountable is needed [6], [8].

Scholarship selection generally involves many criteria (multi-criteria), such as academic, economic, and social aspects, each with different levels of importance. This problem falls within the scope of Multi-Criteria Decision Making (MCDM); therefore, a Decision Support System (DSS) approach is relevant to help decision makers conduct structured assessments, reduce subjectivity, and generate more appropriate scholarship recipient recommendations [6], [8]. A good DSS should be able to accommodate both criterion weighting and alternative ranking based on those criteria [9], [10].

The Analytical Hierarchy Process (AHP) method is widely used for weighting because it can decompose complex problems into a hierarchical structure and provides a consistency test mechanism in pairwise judgments, making the process of determining criterion weights more systematic [11], [12]. After criterion weights are obtained, the next stage is ranking the alternatives. One method that can be used is Additive Ratio Assessment (ARAS), which ranks alternatives based on each alternative's utility degree, making it easier to interpret and efficient for evaluation [13], [14]. The combination of AHP (weighting) and ARAS (ranking) has been applied in various MCDM studies, including selection and evaluation contexts involving multiple criteria [13], [15].

Based on the above, this study aims to develop a DSS for scholarship recipient selection by combining AHP to determine criterion weights and ARAS to rank scholarship candidates. This approach is expected to assist scholarship administrators in determining recipients more objectively, transparently, and accurately according to the established criteria [6], [8], [11], [13].

2. Research Methods

The data used in this study were obtained from the Academic and Student Affairs Bureau (BAK) of Tanjungpura University and represent administrative records, specifically data on applicants for the KIP-K scholarship [7].

2.1 Data Preprocessing

In this study, data preprocessing was carried out as an initial stage to prepare the data before analysis. This stage includes data cleaning by removing variables that cannot be used as criteria. From the available variables, five variables were retained and used as decision criteria. Next, duplicate, incomplete, and inconsistent records were removed because such data issues can affect the accuracy of the analysis; data quality strongly influences the outputs of a multi-criteria decision support system and the resulting decision-making process [6], [8]. After the data-cleaning process, the number of valid KIP-K applicant records used for analysis was 1,491 [7].

2.2 Analytical Hierarchy Process

Criterion weighting using the Analytical Hierarchy Process (AHP) is applied to determine priorities when several criteria must be considered. AHP allows decision makers to structure complex problems into a hierarchy or a series of integrated levels, thereby supporting systematic decision making [11], [12], [9].

1. Constructing the hierarchical structure

Decomposition (hierarchy construction) is performed once the problem has been defined. The problem is broken down into several levels. This decomposition continues until further breakdown is no longer necessary to obtain accurate results [11], [16].

2. Pairwise comparison matrix

The pairwise comparison matrix represents the influence of each element with respect to the goal [11], [12]. Comparisons are conducted based on the decision maker's judgments by assessing the relative importance of one element compared to another. To obtain weights for each element, the Saaty pairwise comparison scale is used in Table 1. Priority judgment data were collected through a questionnaire distributed to an expert who manages KIP-K scholarship data at Tanjungpura University [11], [16].

Table 1. Saaty Scale

Importance Level	Definition	Description
1	Equal importance	Equally important
3	Slightly more importance	Slightly more important than the other
5	More importance	More important than the other
7	Very importance	Much more important than the other
9	Absolutely important	Absolutely more important than the other
2, 4, 6, 8	Intermediate values	Between two adjacent judgments
Reciprocal	$\left(A_{ij} = \frac{1}{a_{ij}}\right)$	If element i has a value when compared to j , then j has the reciprocal value when compared to i

(The Saaty scale and the pairwise comparison concept are widely used in AHP and summarized in modern AHP literature) [11], [12].

3. Computing the geometric mean

After obtaining expert judgments, the geometric mean of each pairwise comparison element is computed as follows [11], [16], [17].

$$a_{ij} = (B_1, B_2, \dots, B_N)^{\frac{1}{N}} \quad (1)$$

where:

a_{ij} : geometric mean value for the comparison of criterion A_i with A_j across N respondents

B_N : comparison value between A_i and A_j for respondent i , $i = 1, 2, \dots, N$

N : number of respondents

4. Computing the normalization matrix

$$c_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (2)$$

where:

P_j : total geometric mean values a_{ij} in column j of the comparison matrix

c_{ij} : normalized value of the geometric mean comparisons

5. Computing the eigenvector (weights)

$$w_i = \frac{\sum_{j=1}^n c_{ij}}{n} \quad (3)$$

where:

w_i : eigenvector (priority weight)

n : number of criteria

6. Computing λ_{maks}

$$\lambda_{maks} = \frac{\sum_{j=1}^n \sum_{i=1}^n a_{ij} \frac{d_i}{w_i}}{n} \quad (4)$$

where:

λ_{maks} : maximum eigenvalue

d_i : row values

n : number of criteria

7. Computing the consistency index (CI)

$$CI = \frac{\lambda_{maks} - n}{n - 1} \quad (5)$$

where:

CI : consistency deviation ratio (consistency index)

8. Computing the consistency ratio (CR)

The Consistency Ratio (CR) is used to determine whether the pairwise comparison matrix is consistent. In general, AHP pairwise judgments should satisfy a consistency threshold so that the derived weights are reliable. A matrix is considered consistent if $CR \leq 0.10$. In this study, stricter thresholds are also noted: $CR \leq 0.05$ for $n = 3$, $CR \leq 0.08$ for $n = 4$, and $CR \leq 0.10$ for $n \geq 5$. If CR exceeds the threshold, the pairwise judgments should be revised [11], [12].

$$CR = \frac{CI}{RI} \quad (6)$$

where:

RI : Random Index

Table 2. Random Index (RI) Values

<i>n</i>	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

2.3 Additive Ratio Assessment

The Additive Ratio Assessment (ARAS) method is one of the Multi-Criteria Decision Making (MCDM) approaches that has been applied across various fields to support decision-making involving multiple criteria [13], [14], [9]. In scholarship selection, ARAS can be used to evaluate and rank prospective recipients based on predetermined criteria, making the selection process more structured and transparent [13], [15]. A common practical issue is the lack of decision support systems that can assess alternatives objectively and efficiently based on multiple criteria [6], [8].

ARAS ranks alternatives based on the utility degree. Conceptually, ARAS can be combined with other methods for determining criterion weights, for example, weights produced by AHP [11], [14]. The ARAS ranking steps are as follows [13], [14]:

1. Constructing the decision matrix

$$X = \begin{bmatrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{i1} & x_{i2} & \cdots & x_{in} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{mj} & \cdots & x_{mn} \end{bmatrix}$$

where:

x_{ij} : value of criterion j for alternative i ($i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$)

x_{0j} : optimal value for criterion j

m : number of alternatives

n : number of criteria

2. Normalizing the decision matrix

Normalization scales criteria so they are comparable [13], [14]. Initial values are normalized under the assumption that larger values are preferred.

For cost criteria:

$$x_{ij}^* = \frac{1}{x_{ij}} \quad (7)$$

$$r_{ij} = \frac{x_{ij}^*}{\sum_{i=0}^m x_{ij}^*} \quad (8)$$

For benefit criteria:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=0}^m x_{ij}} \quad (9)$$

where:

r_{ij} : normalized value for alternative i and criterion j

x_{ij}^* : reciprocal criterion value (for cost criteria)

3. Computing the weighted normalized matrix

$$v_{ij} = r_{ij} \times w_j \quad (10)$$

where:

v_{ij} : weighted normalized value

w_j : criterion weight

4. Computing the optimality function value

The optimality function is obtained by summing the weighted normalized values for each alternative [13], [14].

$$s_i = \sum_{j=1}^n v_{ij} \quad (11)$$

where:

s_i : optimality function value for alternative i

5. Computing the utility degree

The utility degree compares the optimality value of alternative i to the optimal alternative (0) [13], [14].

$$k_i = \frac{s_i}{s_0} \quad (12)$$

where:

k_i : utility degree of alternative i

s_0 : optimality value of alternative 0

6. Confusion Matrix

A confusion matrix is used to evaluate ranking/prediction performance against actual outcomes (e.g., accepted/rejected) and is commonly used in **Table 3** for classification evaluation [18], [19].

Table 3. Confusion Matrix

	Aktual	
	1	0
Predicted	1 True Positive (TP) 0 False Negative (FN)	False Positive (FP) True Negative (TN)

Hint:

Code “1” indicates an applicant is accepted for the KIP-K scholarship, and code “0” indicates rejection. TP is the number of correctly predicted acceptances; TN is the number of correctly predicted rejections; FP is the number of rejected cases incorrectly predicted as accepted; FN is the number of accepted cases incorrectly predicted as rejected [18], [19].

Accuracy is computed as:

$$Accuracy = \frac{TP+TN}{TP+FN+FP+TN} \times 100\% \quad (13)$$

After computing accuracy, overall performance can be interpreted. In addition to accuracy, confusion-matrix-based evaluation is often complemented with other metrics such as MCC to provide a fairer assessment when classes are imbalanced [20], [21]. In this study, the accuracy performance categories are provided in **Table 4** to facilitate interpretation [7], [9], [17].

Table 4. Accuracy Performance

Value	Performance Category
90.01% - 100%	Very good
80.01% - 90%	Good
70.01% - 80%	Fair
60.01% - 70%	Poor
≤ 60%	Fail

3. Results And Discussion

The dataset used in this study comprises KIP-K scholarship applicants at Tanjungpura University for the 2025 cohort and was obtained from the Academic and Student Affairs Bureau (BAK) as administrative application data [8]. There were 1,823 applicants, with 53% accepted and 47% rejected. After preprocessing, 1,491 applicant records remained for analysis. Among these 1,491 applicants, 788 were accepted and 703 were rejected.

3.1. Data preprocessing

Preprocessing in this study involved data cleaning by removing variables that could not be used as criteria; five variables were retained as decision criteria. Next, duplicate, incomplete, and inconsistent records were removed because such issues can affect analysis accuracy. This stage is important because data quality influences ranking results and decisions generated by a multi-criteria decision support system [8], [20].

3.2. Weighting using the Analytical Hierarchy Process

1. Constructing the hierarchical structure

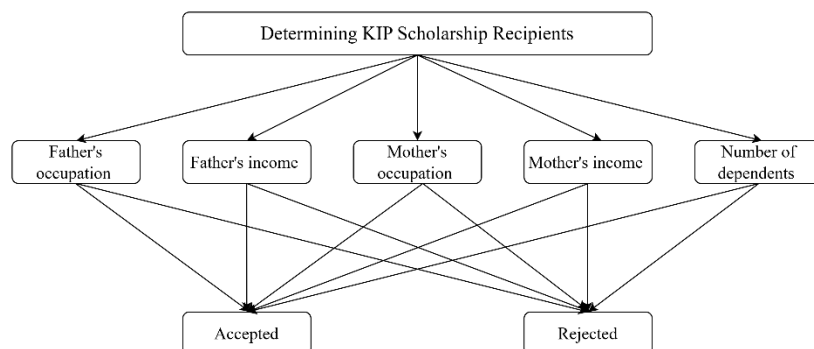


Figure 1. Hierarchical Structure

Figure 1 shows the AHP hierarchical structure used for determining KIP-K scholarship recipients, consisting of three levels. The first level is the main goal: determining KIP-K scholarship recipients. The second level contains the evaluation criteria: father's occupation, mother's occupation, father's income, mother's income, and number of dependents. The third level represents the decision alternatives: accepted or rejected. This hierarchical structure illustrates the systematic relationship between the goal, criteria, and alternatives so that the selection process can be conducted objectively and measurably [10], [11].

2. Pairwise comparison matrix

The pairwise comparison matrix represents the influence of each element with respect to the goal. Comparisons were made based on the decision maker's judgment of relative importance among criteria. Priority judgments were obtained through a questionnaire distributed to an expert who manages KIP-K scholarship data at Tanjungpura University [10], [11].

$$A = \begin{bmatrix} 1 & 1/3 & 2 & 1/2 & 3 \\ 3 & 1 & 4 & 2 & 2 \\ 1/2 & 1/4 & 1 & 1/3 & 2 \\ 2 & 1/2 & 3 & 1 & 2 \\ 1/3 & 1/2 & 1/2 & 1/2 & 1 \end{bmatrix}$$

3. The normalized matrix was computed using Eq. (2):

$$c = \begin{bmatrix} 0.146 & 0.129 & 0.190 & 0.115 & 0.333 \\ 0.439 & 0.387 & 0.381 & 0.462 & 0.222 \\ 0.073 & 0.097 & 0.095 & 0.077 & 0.222 \\ 0.293 & 0.194 & 0.286 & 0.231 & 0.111 \\ 0.049 & 0.194 & 0.048 & 0.115 & 0.111 \end{bmatrix}$$

4. The eigenvector (weights) was computed using Eq. (3):

$$w = \begin{bmatrix} 0.183 \\ 0.378 \\ 0.113 \\ 0.223 \\ 0.103 \end{bmatrix}$$

5. The maximum eigenvalue was computed using Eq. (4):

$$\lambda_{maks} = \frac{26.716}{5} = 5.343$$

6. The Consistency Index (CI) was computed using Eq. (5):

$$CI = \frac{5.343-5}{5-1} = 0.086$$

7. The Consistency Ratio (CR) was computed using Eq. (6):

$$CR = \frac{0.086}{1.12} = 0.077$$

8. A CR value of 0.077 indicates that the pairwise comparison matrix is within an acceptable consistency level (≤ 0.10); therefore, the derived criterion weights are appropriate for use in the subsequent ranking stage.

3.3 Ranking using Additive Ratio Assessment

1. Determining criteria, criterion types, weights, and criterion values

Criterion determination and weighting were conducted using AHP, while alternative ranking was performed using ARAS based on utility degree values [10], [16]. Table 5 ARAS is an MCDM method used to evaluate alternatives based on multiple criteria in a structured manner [12], [16], [13].

Table 5. Description, Criteria, Criterion Types, and Weights

Description	Criteria	Criterion Types	Weights
Father's occupation	C1	Benefit	0.18
Father's income	C2	Benefit	0.38
Mother's occupation	C3	Benefit	0.11
Mother's income	C4	Benefit	0.22
Number of dependents	C5	Benefit	0.11

The criteria codes used are C1–C5. All criteria are treated as benefit criteria, meaning that larger values indicate higher priority for that criterion. The choice of criterion type depends on the research context; in this study, all criteria were defined as benefit to obtain the highest utility degree. The weights were obtained from AHP computations [10], [11]. **Table 6** Combining AHP weighting with ranking methods (such as ARAS) is commonly used in MCDM studies to ensure consistent weighting and clear alternative ranking [12], [16].

Table 6. Criterion Values for Each Criterion

Criteria		
Father's occupation (C1)	Others	7
	Unemployed	6
	Farmers	5
	Fishermen	4
	Entrepreneurs	3
	Private Employees	2
	Indonesian National Armed Forces/Indonesian National Police/Civil Servants	1
Father's income (C2)	IDR. 0 / No Income	7
	≤ Rp. 750.000	6
	IDR. 750.001 – IDR. 1.250.000	5
	IDR. 1.250.001 – IDR. 1.750.000	4
	IDR. 1.750.001 – IDR. 2.250.000	3
	IDR. 2.250.001 – IDR. 3.000.00	2
	≥ IDR. 3.000.001	1
Mother's occupation (C3)	Others	7
	Unemployed	6
	Farmers	5
	Fishermen	4
	Entrepreneurs	3
	Private Employees	2
	Indonesian National Armed Forces/Indonesian National Police/Civil Servants	1
Mother's income (C4)	IDR. 0 / No Income	7
	≤ IDR. 750.000	6
	IDR. 750.001 – IDR. 1.250.000	5
	IDR. 1.250.001 – IDR. 1.750.000	4
	IDR. 1.750.001 – IDR. 2.250.000	3
	IDR. 2.250.001 – IDR. 3.000.00	2
	≥ IDR. 3.000.001	1
Number of dependents (C5)	0-9 Liability	

For example, if an applicant's father is self-employed, the father's income is Rp750,001–Rp1,250,000, the mother is not employed, and the number of dependents is four, then the assigned suitability ratings are 3, 5, 7, 7, and 4. Based on the study data, the suitability ratings are presented in **Table 7**. This rating assignment is necessary so that categorical data can be processed within an MCDM model for ranking [12], [17], [13].

Table 7. Suitability Rating

Alternatives	C1	C2	C3	C4	C5
A1	6	4	7	7	4
A2	5	5	6	6	2
A3	2	4	7	7	2
⋮	⋮	⋮	⋮	⋮	⋮
A1823	6	6	7	7	3

Alternatives correspond to scholarship applicants, while criteria come from scholarship administrative requirements. The maximum value is obtained from the highest criterion value for each criterion as a reference for the optimum value in ARAS [13], [14].

4 Constructing the decision matrix

$$X_{1491,5} = \begin{bmatrix} 7 & 7 & 7 & 7 & 9 \\ 6 & 4 & 7 & 7 & 4 \\ 5 & 5 & 6 & 6 & 2 \\ 2 & 4 & 7 & 7 & 2 \\ 6 & 5 & 7 & 7 & 4 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 6 & 6 & 7 & 7 & 3 \end{bmatrix}$$

The decision matrix serves as the basis for normalization and utility calculations in ARAS.

5 Normalizing the decision matrix

Normalization follows Eq. (9) because all criteria are benefit-type criteria:

$$R_{1491,5} = \begin{bmatrix} 0.00089 & 0.00098 & 0.00073 & 0.00072 & 0.00206 \\ 0.00077 & 0.00056 & 0.00073 & 0.00072 & 0.00091 \\ 0.00064 & 0.0007 & 0.00062 & 0.00062 & 0.00045 \\ 0.00025 & 0.00056 & 0.00073 & 0.00072 & 0.00045 \\ 0.00077 & 0.0007 & 0.00073 & 0.00072 & 0.00091 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0.00077 & 0.00084 & 0.00073 & 0.00072 & 0.00068 \end{bmatrix}$$

6 Computing the weighted normalized matrix

The weighted normalized matrix follows Eq. (10) by multiplying the normalized matrix by criterion weights (from AHP) [10], [16].

$$V_{1491,5} = \begin{bmatrix} 0.00016 & 0.00037 & 0.00008 & 0.00015 & 0.00022 \\ 0.00013 & 0.00021 & 0.00008 & 0.00015 & 0.0001 \\ 0.00115 & 0.00026 & 0.00006 & 0.00013 & 0.00005 \\ 0.00004 & 0.00021 & 0.00008 & 0.00015 & 0.00005 \\ 0.00013 & 0.00026 & 0.00008 & 0.00015 & 0.0001 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0.00013 & 0.00032 & 0.00008 & 0.00015 & 0.00007 \end{bmatrix}$$

7 Computing the optimality function value

The optimality value follows Eq. (11), summing weighted normalized values for each alternative [12], [16]. Example for the first alternative:

$$s_1 = 0.00013 + 0.00021 + 0.00008 + 0.00015 + 0.0001 = 0.00069$$

This step produces an aggregate value for each alternative before computing the utility degree.

8 Computing the Utility Degree

$$k_1 = \frac{0.00069}{0.001} = 0.69114$$

9 Ranking

Table 8. Ranking

No	Alternatif	Utility Degree	Rank
1	A978	0.9497309	1
2	A953	0.9245964	2
3	A1546	0.9155830	3
$\vdots$	$\vdots$	$\vdots$	$\vdots$
1491	A508	0.2657853	1491

Ranking in Table 8 is based on utility degree values, sorted from highest to lowest. This utility-based ranking procedure is a key characteristic of ARAS for establishing alternative priorities in MCDM [12], [16]. In scholarship selection, this approach helps generate a priority order of candidates based on available administrative criteria [9], [7], [17].

Table 9. Confusion Matrix

		Actual	
		Accepted	Rejected
Predicted	Accepted	679	330
	Rejected	109	373

The confusion matrix and accuracy calculation **Table 9** follow **Eq. (13)**. Confusion-matrix-based evaluation is commonly used to assess agreement between predicted outcomes and actual labels [19], [20].

$$Accuracy = \frac{679 + 373}{679 + 330 + 109 + 373} \times 100\% = 70.56\%$$

Based on **Table 9**, the accuracy value is 70.56%, which falls into the “fair” performance category for predicting accepted and rejected scholarship applicants in this study. However, accuracy alone may be less representative when class distributions are imbalanced; therefore, some studies recommend complementing evaluation with other metrics such as the Matthews Correlation Coefficient (MCC) for a fairer assessment on imbalanced data [19], [20].

4. Conclusions

Based on the results of the analysis and discussion, it can be concluded that this study applied the Additive Ratio Assessment (ARAS) method as the ranking approach for selecting KIP-K scholarship recipients at Tanjungpura University for the 2025 cohort. The initial dataset consisted of 1,823 applicants. After preprocessing (data cleaning), 1,491 applicant records were retained for analysis, comprising 788 accepted and 703 rejected cases. Criterion weights were determined using the Analytical Hierarchy Process (AHP), resulting in weights of 0.18, 0.38, 0.11, 0.22, and 0.11 for the five criteria. The weighting results indicate that father’s income (C2) has the largest weight (0.38), making it the most influential criterion in establishing priority. Subsequently, candidate ranking was performed using ARAS, producing a priority order of scholarship candidates considered more eligible based on the administrative criteria used. This approach supports a more structured and objective selection process. However, because AHP weights depend on expert judgments and may vary across selection periods, sensitivity analysis and periodic weight recalibration are recommended to maintain decision consistency.

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Conflict of Interest

The authors declare that he/she has no conflicts of interest to report study.

Declaration of Generative AI and AI-assisted technologies

Generative AI tools were used solely for language refinement (grammar, spelling, and clarity). The scientific content, analysis, interpretation, and conclusions were developed entirely by the authors. The authors reviewed and approved all final text.

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