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INNOVATIVE EXTENSION OF THE SMART METHOD FOR GROUP DECISION-MAKING: AN APPROACH BASED ON THE HURWICZ CRITERION

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Abstract. This study falls within the realm of group multi-criteria decision-making (MCDM) and aims to propose an approach that respects the diversity of individual preferences. We introduce SMART-H, a method based on SMART and the Hurwicz criterion, which processes the evaluations of each decision-maker separately before constructing a collective consensus, while explicitly integrating the direction of optimization of the criteria. The experimental results show that SMART-H produces more balanced and consistent rankings than MACASP and Lon-Zo, particularly when the criteria have different optimization directions. While MACASP remains effective only when all criteria share the same direction, SMART-H maintains its robustness in complex and heterogeneous MCDM contexts. This approach opens up prospects for practical applications, the integration of fuzzy data to handle uncertainty, and the formal analysis of its mathematical properties.

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Key words and phrases. MCDM; SMART-H; group multi-criteria decision-making; optimization; MACASP; Lon-Zo; fuzzy data.

1. Introduction

Decision-making within a community plays a very important role in the functioning of human societies and multi-agent systems [10]. Group decision-making represents a complex challenge due to the diversity of individual preferences, divergent interests, and the uncertainties inherent in decision-making environments [8]. In many contexts, decision-makers must not only evaluate multiple criteria but also reach a consensus despite sometimes opposing viewpoints. The Simple Multi-Attribute Rating Technique (SMART) is a decision-aiding technique that considers multiple criteria to evaluate alternatives [5]. It is commonly used for multi-criteria evaluation due to its simplicity and flexibility [6, 13, 17] and is recognized as a relevant approach to multi-criteria decision-making (MCDM) [12, 18].

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However, this method shows certain limitations when it comes to reconciling divergent opinions and managing uncertainty in group decisions.

Faced with these challenges, this article proposes an innovative extension of the SMART method by integrating the Hurwicz criterion [7]. The latter allows for the modulation of decision-making by considering both optimistic and pessimistic scenarios, thereby providing a balanced approach between caution and ambition. The objective is to improve the robustness and consistency of collective decisions, by providing a methodological framework capable of better managing uncertainty and conflicting opinions.

In this study, we begin by establishing the state of the art, exploring in depth the foundations of the SMART method as well as the principles of the Hurwicz criterion. We then present in detail the methodology developed for the extension of SMART, highlighting the mechanisms for integrating the Hurwicz criterion into the decision-making process. This approach is illustrated through practical case studies, notably in the strategic context of supplier selection within enterprises. Finally, we analyze the results obtained, discussing their relevance and implications, before proposing future research directions aimed at enriching and extending the applications of this method.

2. State of the Art

2.1. SMART Method. The Simple Multi Attribute Rating Technique (SMART) method was introduced by Winterfeldt and Edwards in 1986 [3,6,9]. This method is a multi-criteria evaluation technique that aids decision-making by assessing different options across multiple criteria [13,19]. It is based on the principle that each alternative is evaluated based on a set of criteria, each with a value, and each criterion is assigned a weight reflecting its relative importance compared to the others. Here are the general steps of the SMART method:

Step 1: Identification of alternatives and criteria

Step 2: Normalization of criteria weights

The weight of each criterion is normalized using the following relation (1):

$$\widehat{w}_j = \frac{w_j}{\sum\limits_{j=1}^{m} w_j} \tag{1}$$

where w_j is the weight of criterion j and $\sum\limits_{j=1}^{m} w_j$ is the total weight of all criteria.

Step 3: Calculation of the utility value of each alternative

The utility values are calculated based on the nature (beneficial or non-beneficial) of each of these criteria, using the relations (2), (3):

$$u_j(a_i) = \frac{g_{ij} - \min\limits_j \{g_{ij}\}}{\max\limits_j \{g_{ij}\} - \min\limits_j \{g_{ij}\}} \qquad \textbf{beneficial} \tag{2}$$

$$u_j(a_i) = \frac{\max\limits_j \{g_{ij}\} - g_{ij}}{\max\limits_j \{g_{ij}\} - \min\limits_j \{g_{ij}\}} \qquad \textbf{non-beneficial or cost} \tag{3}$$

where:

$u_j(a_i)$ is the utility value of alternative i relative to criterion j;

g_{ij} is the value of alternative i relative to criterion j.

Step 4: Calculation of weighted scores and sum of weighted scores

The sum of weighted scores for each alternative is calculated according to equation (4). This yields an overall score for each alternative, taking into account all evaluations across different criteria.

$$S(a_i) = \sum_{j=1}^{m} \widehat{w}_j u_j(a_i) \qquad \text{with } i = 1, 2, \cdots, n \tag{4}$$

where $S(a_i)$ is the total utility value of alternative i, and n is the number of alternatives.

The best alternative is obtained using relation (5), i.e., the one that achieves the highest score.

$$\max_{\forall i} \sum_{j=1}^{m} \widehat{w}_j u_j(a_i) \qquad \text{where} \qquad \max_{\forall i} \{S(a_i)\} \tag{5}$$

2.2. **Other MCDM Methods.** The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty [14].

It allows for the prioritization of alternatives by considering multiple criteria through a clear hierarchical structure and pairwise comparisons.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a popular method in multi-criteria decision-making that identifies solutions close to the ideal and far from the least desirable alternative [20]. The REGIME method [2], initially introduced by Hinloopen, Nijkamp and Rietveld in 1983, is a multi-attribute method that solves the problem using the REGIME matrix, thereby enabling a final ranking of the alternatives to be established.

The Simple Additive Weighting (SAW) method [1], also known as the weighted linear combination method, is a simple and very frequently used multi-attribute decision-making technique. This method is based on the weighted average. The VIKOR method (VIseKriterijumska Optimizacija I Kompromisno Resenje, in Serbian, meaning "Multi-criteria Optimization and Compromise Solution") is a widely used approach for solving multi-criteria decision problems. Developed by Zoran Z. Vukovic in the 1990s, VIKOR identifies a solution representing an optimal compromise between multiple, often conflicting, decision criteria [11]. The VIKOR method [4] is based on compromise, seeking a solution close to the ideal while considering both collective utility and maximum individual regret.

These methods rely on a compensatory principle, where poor performance on one criterion can be offset by good performance on another. There are many other MCDM methods that may be applicable depending on the context and nature of the decision problem.

2.3. Some Decision Criteria Under Uncertainty.

2.3.1. *Savage Criterion* (*MiniMax Regret*). Calculation of a regret matrix (or loss of earnings) based on the results table. Thus:

$$b_{i,j} = \text{Max}\,(a_{kj}) - a_{ij} \quad ; \quad \forall i \text{ et } j$$

The maximum regret for each alternative is determined (i.e. the worst case scenario)

Rule: The decision that results in the smallest maximum regret is chosen.

2.3.2. *Hurwicz Criterion.* The Hurwicz criterion defines a degree of optimism (α) and a degree of pessimism ($1-\alpha$).

It considers both the best and the worst outcomes of each strategy and weights them in a linear combination.

$$H\,(d_i) = \alpha\,\text{Max}(a_{ij}) + (1-\alpha)\,\text{Min}(a_{ij}), \forall i$$

We compute, for each decision, the Hurwicz criterion H.

Rule : We choose the decision that gives the largest value of H

The Hurwicz criterion balances optimism and pessimism through the optimism coefficient, which makes it suitable for uncertain situations. It provides a unique score for each alternative, facilitating ranking and comparison.

2.4. Overview of the Lon-Zo Method.

Proposed by Z. SAVADOGO et al. [16], this method combines the weighted sum and the harmonic mean: it is a fully compensatory method.

Let G_k be the additive value aggregation function for decision-maker d_k. The collective aggregation function based on the harmonic mean, called the Lon-Zo (Longin-Zoïnabo) method, is defined as follows:

$$U\,(a_i) = \frac{s}{\sum\limits_{k=1}^{s} \frac{1}{G_k(a_i)}} \tag{6}$$

with

$$G_k\,(a_i) = \sum_{j=1}^{m} w_j^k g_j^k\,(a_i)\,; \quad i = 1,\ldots,n; \quad j = 1,\ldots,m \tag{7}$$

where:

$G_k\,(a_i)$ is the overall score of alternative a_i according to decision-maker d_k;

w_j^k is the weight assigned to criterion c_j by decision-maker d_k;

$g_j^k(a_i)$ is the score assigned to alternative a_i on criterion c_j by decision-maker d_k;

$U(a_i)$ is the final numerical value of alternative a_i.

2.5. **Overview of the MACASP Method.** The collective aggregation function based on the arithmetic mean is called MACASP (Collective Aggregation Model using the Weighted Sum). The MACASP method is entirely based on the weighted sum according to [16]; it is a fully compensatory method. The collective aggregation function is denoted by U

$$U\left(a_i\right)=\frac{1}{s}\sum_{k=1}^{s}G_k\left(a_i\right) \tag{8}$$

with

$$G_k\left(a_i\right)=\sum_{j=1}^{m}w_j^k g_j^k\left(a_i\right) \quad i=1,\ldots,n; \quad j=1,\ldots,m$$

Thus

$$U\left(a_i\right)=\frac{1}{s}\sum_{k=1}^{s}\sum_{j=1}^{m}w_j^k g_j^k\left(a_i\right) \tag{9}$$

$$U\left(a_i\right)=\frac{1}{s}\sum_{j=1}^{m}\sum_{k=1}^{s}w_j^k g_j^k\left(a_i\right) \tag{10}$$

This is a fully compensatory aggregation method, which, in its basic algorithm, does not differentiate between beneficial and non-beneficial criteria. This lack of distinction can obscure critical weaknesses in certain criteria.

3. Proposed Methodology

The proposed SMART-Hurwicz (SMART-H) method is an extension of the SMART method based on the Hurwicz criterion.

3.1. **Principle of the SMART-H Method.** The SMART-H approach for group decision-making combines the SMART method and the Hurwicz criterion in order to aggregate individual preferences within a collective framework. The adopted methodology first consists in applying the SMART method to each decision matrix to evaluate the alternatives with respect to the criteria, and then using the Hurwicz criterion to merge the resulting scores.

3.2. **Mathematical Formulation.** To solve a group decision-making problem through the extension of the SMART method, the group members jointly determine, by consensus, the actions and the criteria to be retained. Based on a chosen scale, each decision-maker evaluates the criteria and the considered actions, and then assigns a weight to each criterion according to the importance they attribute to it.

Let:

(a) $D=\{d_1,d_2,\ldots,d_s\}$: Set of the s decision-makers.
(b) $C=\{c_1,c_2,\ldots,c_m\}$: Set of the m criteria.
(c) $A=\{a_1,a_2,\ldots,a_n\}$: Set of the n alternatives.

(d) w_j^k is the weight assigned to criterion c_j by decision-maker d_k, with $j = 1, \ldots, m$ and $k = 1, \ldots, s$.

(e) $f_j^k(a_i)$ is the partial evaluation of action a_i with respect to criterion c_j by decision-maker d_k, with $i = 1, \ldots, n$; $j = 1, \ldots, m$; and $k = 1, \ldots, s$.

Thus, the decision matrix of decision-maker d_k is given in Table [1] below:

	c_1	c_2	$\cdots$	c_m
Weights	w_1^k	w_2^k	$\cdots$	w_m^k
a_1	$f_1^k(a_1)$	$f_2^k(a_1)$	$\cdots$	$f_m^k(a_1)$
a_2	$f_1^k(a_2)$	$f_2^k(a_2)$	$\cdots$	$f_m^k(a_2)$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
a_n	$f_1^k(a_n)$	$f_2^k(a_n)$	$\cdots$	$f_m^k(a_n)$

TABLE 1. Decision matrix of decision-maker d_k

3.3. Description of the SMART-H Method. Step 1: Construction of individual decision matrices

Each decision-maker d_k evaluates the alternatives a_i with respect to the criteria c_j. This yields one decision matrix per decision-maker:

$$M^{(k)} = \begin{bmatrix} w_1^k & w_2^k & \ldots & w_m^k \\ f_1^k(a_1) & f_2^k(a_1) & \ldots & f_m^k(a_1) \\ f_1^k(a_2) & f_2^k(a_2) & \ldots & f_m^k(a_2) \\ \vdots & \vdots & \ddots & \vdots \\ f_1^k(a_n) & f_2^k(a_n) & \ldots & f_m^k(a_n) \end{bmatrix}$$

Step 2: Weight normalization and computation of utility values

In each decision matrix, on the one hand, the normalized weights are computed according to relation (11):

$$\widehat{w}_j^k = \frac{w_j^k}{\sum_{j=1}^{m} w_j^k} \tag{11}$$

and on the other hand, the utility values $u_j^k(a_i)$ are computed according to relations (12) and (13).

$$u_j^k(a_i) = \frac{f_j^k(a_i) - \min_j \left\{ f_j^k(a_i) \right\}}{\max_j \left\{ f_j^k(a_i) \right\} - \min_j \left\{ f_j^k(a_i) \right\}} \tag{12}$$

$$u_j^k(a_i) = \frac{\max_j \left\{ f_j^k(a_i) \right\} - f_j^k(a_i)}{\max_j \left\{ f_j^k(a_i) \right\} - \min_j \left\{ f_j^k(a_i) \right\}} \tag{13}$$

where $u_j^k(a_i)$ is the utility value of alternative a_i with respect to criterion c_j according to decision-maker d_k.

Step 3: Score computation

In each decision matrix, an overall score is computed for each alternative using relation (14).

$$S^k(a_i) = \sum_{j=1}^{k} \widehat{w}_j^k \cdot u_j^k(a_i) \tag{14}$$

where $S^k(a_i)$ is the overall score of alternative a_i according to decision-maker d_k.

This yields a score vector for each decision-maker:

$$S^k = \left[S^k(a_1), S^k(a_2), \ldots, S^k(a_n)\right]$$

Step 4: Aggregation of decision-makers' scores using the Hurwicz criterion

For each alternative a_i, the scores obtained from the decision-makers are aggregated according to the Hurwicz criterion:

$$H\left(a_i\right) = \alpha \cdot \max_k \left(S^k(a_i)\right) + (1-\alpha) \cdot \min_k \left(S^k(a_i)\right) \tag{15}$$

where:

- α reflects the group's level of optimism ($0 =$ very pessimistic, $1 =$ very optimistic).
- $\max_k \left(S^k(a_i)\right)$ and $\min_k \left(S^k(a_i)\right)$ represent, respectively, the best and the worst evaluation of alternative a_i among the decision-makers.

Step 5: Ranking of alternatives

The alternatives are then ranked according to the scores $H(a_i)$. The alternative with the highest score is considered the best.

3.4. **Flow Diagram of the SMART-H Method.** The flowchart presented in Figure [1] illustrates the SMART-H process for multiple decision-makers. The individual matrices are processed using SMART, the scores are grouped into a global matrix, and then the Hurwicz criterion is applied to obtain the final decision. The colors and clusters clearly distinguish the different steps.

3.5. **Algorithmic Pseudo-code of SMART-H.** In order to formalize the proposed methodological framework, Algorithm [1] presents in detail the different steps of the SMART-H method for collective decision-making.

3.6. **Study of Algorithmic Complexity.** Complexity analysis, particularly the analysis of time complexity, is an essential phase in the evaluation of an algorithmic method. It provides crucial insights for assessing scalability, sizing resources, optimizing the process, and conducting comparative analysis. Below, we detail the complexity of each of the 5 steps of SMART-H with s decision-makers, n alternatives, and m criteria.

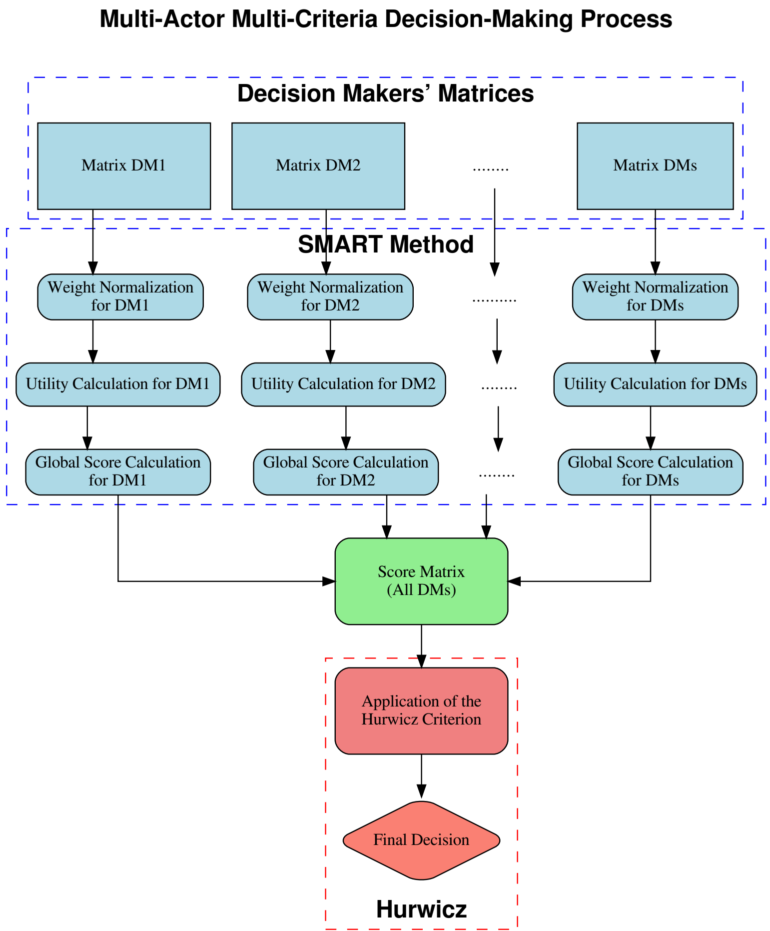

FIGURE 1. SMART-H Decision Flow Diagram

Step 1: Construction of decision matrices

Each decision-maker k constructs a matrix M^k of size $n \times m \longrightarrow O(n \times m)$

The total complexity for s decision-makers is $O(n \times m \times s)$

Step 2: Weight normalization and computation of utility values

- Weight normalization

  For each decision-maker D_k, we:

  - Compute the sum of m weights $\longrightarrow O(m)$
  - Divide each weight by this sum $\longrightarrow O(m)$

  The complexity for each decision-maker is $O(m) + O(m) \longrightarrow O(m)$

  The total complexity for s decision-makers is: $O(m \times s)$

- Computation of utility values

  For one criterion and one decision-maker, we:

  - Compute the minimum and maximum among n alternatives $\longrightarrow O(n)$
  - Compute the utility values for the n alternatives $\longrightarrow O(n)$

Algorithm 1: Pseudo-code of the SMART-H Method

Input: Number of alternatives n, number of criteria m, number of decision-makers s;

Decision matrices $M^{(k)} = [f_j^k(a_i)]$ for $i = 1, \ldots, n$, $j = 1, \ldots, m$, and $k = 1, \ldots, s$;

Criteria weight vectors $w^{(k)} = (w_1^k, \ldots, w_m^k)$;

Optimism parameter $\alpha \in [0, 1]$

Output: Collective ranking of alternatives

for *each decision-maker* D_k, $k = 1, \ldots, s$ **do**

Normalize the weights:

$$\widehat{w}_j^k = \frac{w_j^k}{\sum_{j=1}^{m} w_j^k}, \quad j = 1, \ldots, m$$

for *each criterion* c_j, $j = 1, \ldots, m$ **do**

Compute $\min_i f_j^k(a_i)$ and $\max_i f_j^k(a_i)$, $\quad i = 1, \ldots, n$

for *each alternative* a_i **do**

Compute the utility value $u_j^k(a_i)$

for *each alternative* a_i **do**

Compute the individual SMART score:

$$S^k(a_i) = \sum_{j=1}^{m} \widehat{w}_j^k \, u_j^k(a_i)$$

for *each alternative* a_i **do**

Compute the collective Hurwicz score:

$$H(a_i) = \alpha \max_{k=1,\ldots,s} S^k(a_i) + (1 - \alpha) \min_{k=1,\ldots,s} S^k(a_i)$$

Rank the alternatives in decreasing order of $H(a_i)$

return *Collective ranking of alternatives*

The total complexity for m criteria and s decision-makers is therefore: $O(n \times m \times s)$

The total complexity of this step is: $O(m \times s) + O(n \times m \times s) \longrightarrow O(n \times m \times s)$

Step 3: Score computation

For a decision-maker D_k and an alternative A_i, the weighted sum of m values is calculated $\longrightarrow O(m)$

The total complexity for n alternatives and s decision-makers is: $\longrightarrow O(n \times m \times s)$

Step 4: Aggregation of scores

For an alternative A_i, the minimum and maximum among s decision-makers are calculated $\longrightarrow O(s)$

The total complexity for n alternatives is: $O(n \times s)$

Step 5: Ranking of alternatives

In this final step, the n scores are sorted, yielding a total complexity of: $O(n \cdot \log(n))$

Conclusion: The time complexity study reveals that the proposed method has an algorithmic complexity of order $O(n \times m \times s)$, where n, m, and s denote the number of alternatives, criteria, and decision-makers, respectively. This linear and multiplicative dependence ensures good scalability of the approach.

Table 2. Summary of Overall Complexity

Step	Operation	Complexity
1	Construction of decision matrices	$O(n \times m \times s)$
2	Weight normalization and utility computation	$O(n \times m \times s)$
3	SMART score computation	$O(n \times m \times s)$
4	Score aggregation	$O(n \times s)$
5	Final ranking	$O(n \cdot \log(n))$
Total	Dominant complexity	$O(n \times m \times s)$

4. Applications

4.1. **Optimal Center Selection Problem.** In this section, we present a case study illustrating the progressive application of the SMART-H method. This numerical experiment is taken from [15].

The problem consists in identifying the best center for the management of severe COVID-19 cases in Burkina Faso. To this end, three decision-making committees (a COVID-19 management unit, the Medical Council, and the National Assembly) were assigned the challenging task of evaluating four (04) hospitals in the city of Ouagadougou, Burkina Faso (Yalgado Hospital, Bogodogo District Hospital, Tingandogo Hospital, and Clinique de la Paix), presented in Table[3], based on five (05) criteria (Ventilator equipment, Bed equipment, Staff qualification, Reception quality, and Cost), presented in Table[4]. The hierarchical structure for the selection of healthcare centers is illustrated in Figure[2].

Table 3. Description of the evaluated healthcare centers

Centers	Description
Yalgado (A_1)	Reference public hospital equipped with an advanced technical platform
Bogodogo (A_2)	Modern public hospital with recently developed infrastructure
Tingandogo (A_3)	University hospital center with state-of-the-art equipment and highly qualified staff
Clinique de la Paix (A_4)	Private facility offering a comfortable environment, high-quality reception, and strong responsiveness

TABLE 4. Description of the criteria for evaluating healthcare centers

Criteria	**Description**	**Type**
Ventilator equipment (C_1)	Availability of ventilators for severe cases	Beneficial
Bed equipment (C_2)	Hospital bed capacity	Beneficial
Staff qualification (C_3)	Competency level of medical staff	Beneficial
Reception quality (C_4)	Quality of conditions and patient care	Beneficial
Cost (C_5)	Expenses related to patient management	Cost

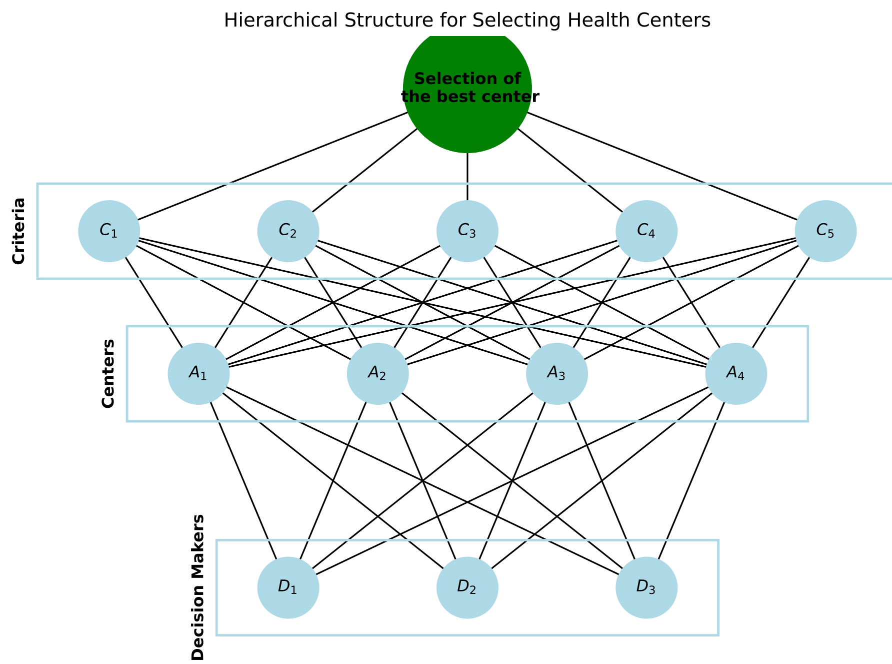

FIGURE 2. Hierarchical Structure for Selecting Health Centers

The judgments of the stakeholders are organized into decision matrices in order to systematically evaluate each healthcare center with respect to the selected criteria. The decision matrices are presented in Tables[5],[6] and [7] below:

TABLE 5. Judgment matrix of the COVID-19 management unit (D_1)

Criteria →	C_1	C_2	C_3	C_4	C_5
Actions ↓ Weight →	6	3	2	4	3
A_1	6	5	2	4	5
A_2	5	6	3	3	4
A_3	7	5	4	6	3
A_4	6	4	5	3	6

TABLE 6. Judgment matrix of the Medical Association (D_2)

Criteria →	C_1	C_2	C_3	C_4	C_5
Actions ↓ Weight →	7	5	3	3	4
A_1	7	6	2	3	3
A_2	6	5	2	5	3
A_3	5	7	3	6	4
A_4	5	4	4	4	3

TABLE 7. Judgment matrix of the National Assembly (D_3)

Criteria →	C_1	C_2	C_3	C_4	C_5
Actions ↓ Weight →	6	4	2	3	3
A_1	6	5	2	4	4
A_2	7	6	3	5	3
A_3	6	5	4	3	5
A_4	5	4	3	6	4

4.1.1. *Resolution Using SMART-H.* **Step 1: Construction of decision matrices**

Based on Tables [5], [6] and [7], the decision matrices of the three decision-makers are as follows. For each matrix, the first row contains the criteria weights, and the subsequent rows correspond to the performance of the centers on each criterion.

$$M^{(1)} = \begin{bmatrix} 6 & 3 & 2 & 4 & 3 \\ 6 & 5 & 2 & 4 & 5 \\ 5 & 6 & 3 & 3 & 4 \\ 7 & 5 & 4 & 6 & 3 \\ 6 & 4 & 5 & 3 & 6 \end{bmatrix} \qquad M^{(2)} = \begin{bmatrix} 7 & 5 & 3 & 3 & 4 \\ 7 & 6 & 2 & 3 & 3 \\ 6 & 5 & 2 & 5 & 3 \\ 5 & 7 & 3 & 6 & 4 \\ 5 & 4 & 4 & 4 & 3 \end{bmatrix} \qquad M^{(3)} = \begin{bmatrix} 6 & 4 & 2 & 3 & 3 \\ 6 & 5 & 2 & 4 & 4 \\ 7 & 6 & 3 & 5 & 3 \\ 6 & 5 & 4 & 3 & 5 \\ 5 & 4 & 3 & 6 & 4 \end{bmatrix}$$

Step 2: Weight normalization and utility value calculation

In each decision matrix, the criterion weights are normalized and the utility values are computed using equations (11), (12), and (13). This yields the following matrices:

$$\widetilde{M}^{(1)} = \begin{bmatrix} 0.333 & 0.167 & 0.111 & 0.222 & 0.167 \\ 0.5 & 0.5 & 0 & 0.333 & 0.333 \\ 0 & 1 & 0.333 & 0 & 0.667 \\ 1 & 0.5 & 0.667 & 1 & 1 \\ 0.5 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$\widetilde{M}^{(2)} = \begin{bmatrix} 0.318 & 0.227 & 0.136 & 0.136 & 0.182 \\ 1 & 0.667 & 0 & 0 & 1 \\ 0.5 & 0.333 & 0 & 0.667 & 1 \\ 0 & 1 & 0.5 & 1 & 0 \\ 0 & 0 & 1 & 0.333 & 1 \end{bmatrix}$$

$$\widetilde{M}^{(3)} = \begin{bmatrix} 0.333 & 0.222 & 0.111 & 0.167 & 0.167 \\ 0.5 & 0.5 & 0 & 0.333 & 0.5 \\ 1 & 1 & 0.5 & 0.667 & 1 \\ 0.5 & 0.5 & 1 & 0 & 0 \\ 0 & 0 & 0.5 & 1 & 0.5 \end{bmatrix}$$

Step 3: Score calculation

In each matrix $\widetilde{M}^{(1)}$, $\widetilde{M}^{(2)}$, and $\widetilde{M}^{(3)}$, the overall score of each healthcare center is computed using equation (14). Thus, for each case, we obtain a vector of global scores, presented below:

$$S^1 = \begin{bmatrix} 0.380 & 0.315 & 0.880 & 0.278 \end{bmatrix}$$

$$S^2 = \begin{bmatrix} 0.652 & 0.508 & 0.432 & 0.364 \end{bmatrix}$$

$$S^3 = \begin{bmatrix} 0.417 & 0.889 & 0.389 & 0.306 \end{bmatrix}$$

Table [8] below summarizes the global scores according to the three decision-making committees.

	D_1	D_2	D_3
A_1	0.380	0.652	0.417
A_2	0.315	0.508	0.889
A_3	0.880	0.432	0.389
A_4	0.278	0.364	0.306

Table 8. Global scores according to the three decision-making committees

Step 4: Aggregation of global scores using the Hurwicz criterion

At this step, the global scores of each center A_i are aggregated using Equation (15). The parameter $\alpha = 0.7$ is adopted in order to reflect a moderately optimistic attitude in the score aggregation process.

$$\begin{aligned} H(A_1) &= 0.7 \times \max(0.380,\ 0.652,\ 0.417) + (1-0.7) \times \min(0.380,\ 0.652,\ 0.417) \\ &= 0.7 \times 0.652 + 0.3 \times 0.380 \\ &= 0.57, \end{aligned}$$

$$H(A_2) = 0.7 \times 0.889 + 0.3 \times 0.315$$
$$= 0.71,$$

$$H(A_3) = 0.7 \times 0.880 + 0.3 \times 0.389$$
$$= 0.73,$$

$$H(A_4) = 0.7 \times 0.364 + 0.3 \times 0.278$$
$$= 0.33.$$

The resulting Hurwicz scores $H(A_i)$ are summarized in Table [9] below.

Table 9. Global Hurwicz scores

	D_1	D_2	D_3	$H(A_i)$
A_1	0.380	0.652	0.417	**0.57**
A_2	0.315	0.508	0.889	**0.71**
A_3	0.880	0.432	0.389	**0.73**
A_4	0.278	0.364	0.306	**0.33**

Step 5: Ranking of healthcare centers

The healthcare centers are ranked according to their scores $H(A_i)$, obtained after aggregating the global scores using the Hurwicz criterion. The center with the highest score is considered the most appropriate. The final ranking of the centers is reported in Table [10] below.

Table 10. Global scores and ranking of healthcare centers

	D_1	D_2	D_3	$H(A_i)$	**Rank**
A_1	0.380	0.652	0.417	**0.57**	**3rd**
A_2	0.315	0.508	0.889	**0.71**	**2nd**
A_3	0.880	0.432	0.389	**0.73**	**1st**
A_4	0.278	0.364	0.306	**0.33**	**4th**

According to Table [10], the following preference order is obtained:

$$A_3 \succ A_2 \succ A_1 \succ A_4, \qquad \text{since} \qquad H(A_3) > H(A_2) > H(A_1) > H(A_4).$$

Consequently, center A_3, namely Tingandogo Hospital, is identified as the most suitable healthcare facility for the management of severe COVID-19 cases in Burkina Faso.

4.1.2. *Resolution using MACASP.* By applying the MACASP method to the problem of selecting the optimal healthcare center, the results reported in Table [11] are obtained.

TABLE 11. Results obtained using the MACASP method

	$\sum_{k=1}^{3} w_1^k g_1^k(A_i)$	$\sum_{k=1}^{3} w_2^k g_2^k(A_i)$	$\sum_{k=1}^{3} w_3^k g_3^k(A_i)$	$\sum_{k=1}^{3} w_4^k g_4^k(A_i)$	$\sum_{k=1}^{3} w_5^k g_5^k(A_i)$	$\frac{1}{3}\sum_{k=1}^{3}\sum_{j=1}^{m} w_j^k g_j^k(A_i)$
A_1	121	65	14	37	39	**92**
A_2	114	67	18	42	33	**91.33**
A_3	113	70	25	51	40	**99.67**
A_4	101	48	28	42	42	**87**

The global scores and corresponding rankings of the healthcare centers are presented in Table [12].

TABLE 12. Global scores and rankings of healthcare centers

	Score	Rank
A_1	92	**2nd**
A_2	91.33	**3rd**
A_3	99.67	**1st**
A_4	87	**4th**

With a global score of **99.67**, healthcare center A_3, namely Tingandogo Hospital, clearly emerges as the best-performing center.

4.1.3. *Resolution using the Lon-Zo method.* By applying the Lon-Zo method to the problem of selecting the optimal healthcare center, the results reported in Table [13] are obtained.

TABLE 13. Results obtained using the Lon-Zo method

	$G_1 = \sum_{j=1}^{m} w_j^1 g_j^1(A_i)$	$G_2 = \sum_{j=1}^{m} w_j^2 g_j^2(A_i)$	$G_3 = \sum_{j=1}^{m} w_j^3 g_j^3(A_i)$	$\frac{3}{\sum_{k=1}^{3}\frac{1}{G_k}}$
A_1	86	106	84	**91**
A_2	78	100	96	**90.26**
A_3	98	113	88	**98.63**
A_4	88	91	82	**86.84**

The global scores and corresponding rankings of the healthcare centers are presented in Table [14].

TABLE 14. Global scores and rankings of healthcare centers

	Score	Rank
A_1	91	**2nd**
A_2	90.26	**3rd**
A_3	98.63	**1st**
A_4	86.84	**4th**

Healthcare center A_3, identified as Tingandogo Hospital, achieves a global score of **98.63**. This performance places it at the top of the ranking, clearly distinguishing it as the best-performing center with respect to all the selected evaluation criteria.

4.2. **Didactic Example: Selection of the Best Supplier.** As part of its supply chain optimization strategy, a company seeks to identify the most suitable supplier among five (05) candidates $(F_1, F_2, F_3, F_4, F_5)$. The evaluation is based on four (04) essential criteria: technical performance of the products, supplier reliability, delivery flexibility, and purchase price, as presented in Table [15].

The decision-making process is conducted by a group of three (03) stakeholders: the Chief Executive Officer (D_1), the Logistics Manager (D_2), and the Quality Manager (D_3), following a hierarchical structure illustrated in Figure (3).

TABLE 15. Description of Supplier Evaluation Criteria

Criterion	**Description**	**Type**
Technical performance (C_1)	Product quality and compliance with specifications	Benefit
Reliability (C_2)	Ability to meet commitments (delivery times, quantities, and quality)	Benefit
Flexibility (C_3)	Responsiveness to demand fluctuations and urgent orders	Benefit
Price (C_4)	Total acquisition cost of the products	Cost

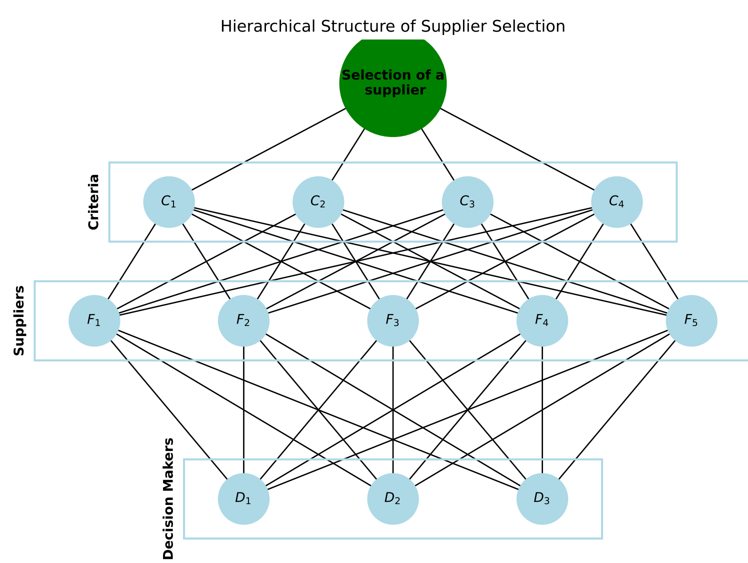

FIGURE 3. Hierarchical Structure of Supplier Selection

The decision matrices are presented in Tables [16], [17], and [18] below:

Table 16. Decision matrix of the General Director(D_1)

Criteria →	C_1	C_2	C_3	C_4
Actions ↓ Weight →	3	4	3	5
F_1	6	8	9	2
F_2	4	5	6	7
F_3	7	6	8	5
F_4	6	8	4	4
F_5	4	4	5	3

Table 17. Decision matrix of the Logistics Manager (D_2)

Criteria →	C_1	C_2	C_3	C_4
Actions ↓ Weight →	4	3	2	5
F_1	8	7	5	6
F_2	4	6	8	4
F_3	6	5	4	4
F_4	5	4	6	4
F_5	2	3	5	2

Table 18. Decision matrix of the Quality Manager (D_3)

Criteria →	C_1	C_2	C_3	C_4
Actions ↓ Weight →	4	5	3	5
F_1	8	7	8	5
F_2	5	6	7	3
F_3	5	8	4	3
F_4	4	7	3	3
F_5	5	6	5	2

4.2.1. *Problem Resolution Using SMART-H.*

Step 1: Construction of the Decision Matrices

Based on Tables [16], [17], and [18], the decision matrices of the three decision-makers, denoted $M^{(1)}$, $M^{(2)}$, and $M^{(3)}$, are constructed as follows:

- The first row specifies the weights assigned to each criterion.

- The following five rows represent the evaluations of the suppliers with respect to the same criteria.

$$M^{(1)} = \begin{bmatrix} 3 & 4 & 3 & 5 \\ 6 & 8 & 9 & 2 \\ 4 & 5 & 6 & 7 \\ 7 & 6 & 8 & 5 \\ 6 & 8 & 4 & 4 \\ 4 & 4 & 5 & 3 \end{bmatrix} \qquad M^{(2)} = \begin{bmatrix} 4 & 3 & 2 & 5 \\ 8 & 7 & 5 & 6 \\ 4 & 6 & 8 & 4 \\ 6 & 5 & 4 & 4 \\ 5 & 4 & 6 & 4 \\ 2 & 3 & 5 & 2 \end{bmatrix} \qquad M^{(3)} = \begin{bmatrix} 4 & 5 & 3 & 5 \\ 8 & 7 & 8 & 5 \\ 5 & 6 & 7 & 3 \\ 5 & 8 & 4 & 3 \\ 4 & 7 & 3 & 3 \\ 5 & 6 & 5 & 2 \end{bmatrix}$$

Step 2: Weight Normalization and Utility Value Calculation

For each decision matrix, the criterion weights are normalized and the utility values are computed using Equations (11), (12), and (13). This leads to the following normalized matrices:

$$\widetilde{M}^{(1)} = \begin{bmatrix} 0.2 & 0.267 & 0.2 & 0.33 \\ 0.667 & 1 & 1 & 1 \\ 0 & 0.25 & 0.4 & 0 \\ 1 & 0.5 & 0.8 & 0.4 \\ 0.667 & 1 & 0 & 0.6 \\ 0 & 0 & 0.2 & 0.8 \end{bmatrix} \qquad \widetilde{M}^{(2)} = \begin{bmatrix} 0.286 & 0.214 & 0.143 & 0.357 \\ 1 & 1 & 0.25 & 0 \\ 0.33 & 0.75 & 1 & 0.5 \\ 0.67 & 0.5 & 0 & 0.5 \\ 0.5 & 0.25 & 0.5 & 0.5 \\ 0 & 0 & 0.25 & 1 \end{bmatrix}$$

$$\widetilde{M}^{(3)} = \begin{bmatrix} 0.235 & 0.294 & 0.176 & 0.294 \\ 1 & 0.5 & 1 & 0 \\ 0.25 & 0 & 0.8 & 0.667 \\ 0.25 & 1 & 0.2 & 0.667 \\ 0 & 0.5 & 0 & 0.667 \\ 0.25 & 0 & 0.4 & 1 \end{bmatrix}$$

Step 3: Score Calculation

In each of the matrices $\widetilde{M}^{(1)}$, $\widetilde{M}^{(2)}$, and $\widetilde{M}^{(3)}$, the overall score for each supplier is calculated using Equation (14). This yields, for each decision-maker, a vector of global scores presented below:

$$S^1 = \begin{bmatrix} 0.933 & 0.147 & 0.627 & 0.6 & 0.307 \end{bmatrix}$$

$$S^2 = \begin{bmatrix} 0.536 & 0.577 & 0.476 & 0.446 & 0.393 \end{bmatrix}$$

$$S^3 = \begin{bmatrix} 0.559 & 0.396 & 0.584 & 0.343 & 0.424 \end{bmatrix}$$

Table [19] below provides a summary of the global scores assigned by the three decision-makers.

TABLE 19. Global Scores by Decision-Maker

	D_1	D_2	D_3
F_1	0.933	0.536	0.559
F_2	0.147	0.577	0.396
F_3	0.627	0.476	0.584
F_4	0.6	0.446	0.343
F_5	0.307	0.393	0.424

Step 4: Aggregation of global scores using the Hurwicz criterion

This step involves aggregating the overall scores of each supplier by applying Equation (15). The parameter $\alpha = 0.7$ was chosen to reflect a moderately optimistic attitude.

As an illustration, the calculation for supplier F_1 is as follows:

$$H(F_1) = 0.7 \times \max(0.933, 0.536, 0.559) + (1 - 0.7) \times \min(0.933, 0.536, 0.559)$$
$$= 0.7 \times 0.933 + 0.3 \times 0.536$$
$$= 0.814$$

The scores for the other suppliers are determined in a similar manner.

The aggregated scores $H(F_i)$ are consolidated in Table [20] below.

TABLE 20. Aggregated Global Scores

	D_1	D_2	D_3	$\mathbf{H}(F_i)$
F_1	0.933	0.536	0.559	**0.814**
F_2	0.147	0.577	0.396	**0.448**
F_3	0.627	0.476	0.584	**0.582**
F_4	0.6	0.446	0.343	**0.523**
F_5	0.307	0.393	0.424	**0.388**

Step 5: Supplier Ranking

The ranking of suppliers is established based on the aggregated scores $H(F_i)$ using the Hurwicz criterion, with the highest score indicating the most suitable supplier. Table [21] presents this final ranking.

Table 21. Aggregated Global Scores and Ranking

	D_1	D_2	D_3	**H**(F_i)	**Rank**
F_1	0.933	0.536	0.559	**0.814**	**1st**
F_2	0.147	0.577	0.396	**0.448**	**4th**
F_3	0.627	0.476	0.584	**0.582**	**2nd**
F_4	0.6	0.446	0.343	**0.523**	**3rd**
F_5	0.307	0.393	0.424	**0.388**	**5th**

From Table [21], the ranking is $F_1 \succ F_3 \succ F_4 \succ F_2 \succ F_5$, which directly follows from the inequalities $H(F_1) > H(F_3) > H(F_4) > H(F_2) > H(F_5)$.
Consequently, supplier F_1 is identified as the best supplier.

4.2.2. *Resolution Using MACASP.* The application of the MACASP method to the problem of identifying the best-performing supplier enabled the establishment of a clear hierarchical ranking of the five candidates. The complete results of this multi-criteria analysis are summarized in Table [22].

Table 22. Results Obtained Using MACASP

	$\sum_{k=1}^{3} w_1^k g_1^k(F_i)$	$\sum_{k=1}^{3} w_2^k g_2^k(F_i)$	$\sum_{k=1}^{3} w_3^k g_3^k(F_i)$	$\sum_{k=1}^{3} w_4^k g_4^k(F_i)$	$\frac{1}{3}\sum_{k=1}^{3}\sum_{j=1}^{m} w_j^k g_j^k(F_i)$
F_1	82	88	61	65	**98.67**
F_2	48	68	55	70	**80.33**
F_3	65	79	44	60	**82.67**
F_4	54	79	33	55	**73.67**
F_5	40	55	40	35	**56.67**

The overall scores and the corresponding ranks assigned to each supplier following the multi-criteria evaluation are presented in Table [23].

Table 23. Overall Scores and Supplier Rankings

	Scores	Ranks
F_1	98.67	**1st**
F_2	80.33	**3rd**
F_3	82.67	**2nd**
F_4	73.67	**4th**
F_5	56.67	**5th**

With a score of **98.67**, supplier F_1 stands out as the highest-performing partner according to the multi-criteria evaluation.

4.2.3. *Resolution using the Lon-Zo method.* Applying the Lon-Zo method to the problem of selecting the optimal supplier allows establishing a hierarchical ranking of the candidates. The results are presented in Table [24].

TABLE 24. Results obtained using the Lon-Zo method

	$G_1 = \sum_{j=1}^{m} w_j^1 g_j^1(F_i)$	$G_2 = \sum_{j=1}^{m} w_j^2 g_j^2(F_i)$	$G_3 = \sum_{j=1}^{m} w_j^3 g_j^3(F_i)$	$\frac{3}{\sum_{k=1}^{3} \frac{1}{G_k}}$
F_1	87	93	116	**97.19**
F_2	85	70	86	**79.62**
F_3	94	67	87	**80.95**
F_4	82	64	75	**72.90**
F_5	58	37	75	**52.08**

The global scores and corresponding rankings of the suppliers are presented in Table [25].

TABLE 25. Global scores and rankings of suppliers

	Score	Rank
F_1	97.19	**1st**
F_2	79.62	**3rd**
F_3	80.95	**2nd**
F_4	72.90	**4th**
F_5	52.08	**5th**

Supplier F_1 achieves a global score of **97.19**. This performance places it at the top of the ranking, distinguishing it as the best-performing partner with respect to all selected evaluation criteria.

5. Comparison and Discussion

In summary, the ranking of healthcare centers and suppliers obtained using the three methods (SMART-H, MACASP, Lon-Zo) is presented in Tables [26] and [27], respectively. This presentation allows for a direct comparison of the results and an assessment of their consistency.

TABLE 26. Ranking of Healthcare Centers Using the Three Methods

Centers	A_1	A_2	A_3	A_4
SMART-H	**3rd**	**2nd**	**1st**	**4th**
MACASP	**2nd**	**3rd**	**1st**	**4th**
Lon-Zo	**2nd**	**3rd**	**1st**	**4th**

TABLE 27. Ranking of Suppliers Using the Three Methods

Suppliers	F_1	F_2	F_3	F_4	F_5
SMART-H	**1st**	**4th**	**2nd**	**3rd**	**5th**
MACASP	**1st**	**3rd**	**2nd**	**4th**	**5th**
Lon-Zo	**1st**	**3rd**	**2nd**	**4th**	**5th**

The best-performing healthcare center is A_3, while the least-performing one is A_4 for all three methods, indicating a clear consensus. The rankings of A_1 and A_2 vary slightly depending on the method, reflecting differences in the aggregation procedures.

All three methods rank F_1 first and F_5 last, demonstrating a clear consensus. Supplier F_3 consistently occupies the second position, while the order of F_2 and F_4 varies according to the method. These differences can be attributed to the specific aggregation mechanisms of each approach, without affecting the overall stability of the ranking.

To facilitate a global assessment, Table [28] summarizes the key advantages and notable limitations of the SMART-H approach, providing a balanced view of its practical utility.

TABLE 28. Advantages and limitations of SMART-H

Advantages	**Limitations**
Effectively aggregates multi-stakeholder preferences;	Sensitive to the optimism parameter α;
Takes into account the optimization direction of criteria;	Slightly more complex calculations;
Incorporates uncertainty through the Hurwicz criterion;	
Provides a global score and robust ranking;	
Flexible and suitable for multi-criteria and multi-stakeholder contexts.	

6. Sensitivity Analysis

This section aims to perform a sensitivity analysis based on the simulation of different scenarios. Its objective is to verify the stability of the ranking of the alternatives.

6.1. **Sensitivity to the optimization parameter α.** This involves determining whether the ranking of suppliers is robust to a variation of the optimism parameter α in the interval $[0, 1]$. The results presented in Table [29] below are obtained.

TABLE 29. Ranking of suppliers according to the optimism parameter α

	$\alpha = 0$	$\alpha = 0.1$	$\alpha = 0.2$	$\alpha = 0.3$	$\alpha = 0.4$	$\alpha = 0.5$	$\alpha = 0.6$	$\alpha = 0.7$	$\alpha = 0.8$	$\alpha = 0.9$	$\alpha = 1$
F_1	1	1	1	1	1	1	1	1	1	1	1
F_2	5	5	5	5	5	5	4	4	4	4	4
F_3	2	2	2	2	2	2	2	2	2	2	2
F_4	3	3	3	3	3	3	3	3	3	3	3
F_5	4	4	4	4	4	4	5	5	5	5	5

Figure [4] below provides an effective visualization of the results.

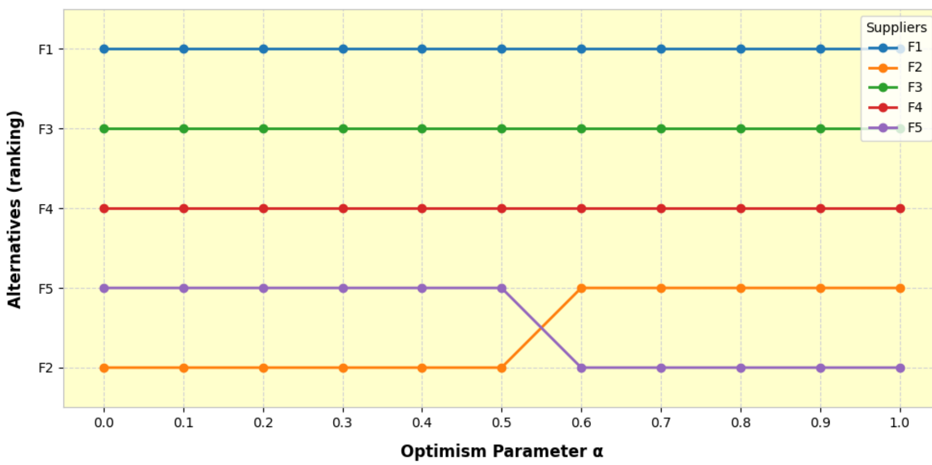

FIGURE 4. Rank of suppliers as a function of α

The results demonstrate a high robustness of the ranking of suppliers with respect to the optimism parameter. The recommendation to select F_1 as the priority supplier is therefore not very sensitive. This stability strengthens the reliability of the proposed decision.

6.2. **Sensitivity to criteria weights.** This analysis aims to determine the robustness of the ranking of suppliers with respect to variations in the relative importance assigned to each criterion. Table [30] below presents the results of the sensitivity analysis conducted on the criteria weights in the SMART-H approach. Each experiment corresponds to a specific weighting scenario, and the selected supplier is indicated for each scenario.

TABLE 30. Experiments for the sensitivity analysis

Experiments	**Description**	**Selected supplier**
E_1	All weights = 0.2	F_1
E_2	All weights = 0.4	F_1
E_3	All weights = 0.6	F_1
E_4	All weights = 0.8	F_1
E_5	All weights = 1	F_1
E_6	Criterion 1 (weight = 1, others = 0.2)	F_1
E_7	Criterion 2 (weight = 1, others = 0.2)	F_1
E_8	Criterion 3 (weight = 1, others = 0.2)	F_1
E_9	Criterion 4 (weight = 1, others = 0.2)	F_1
E_{10}	Criteria 1 & 2 (weight = 1, others = 0.2)	F_1

Figure [5] below provides a clear representation of the results of the sensitivity analysis with respect to the criteria weights.

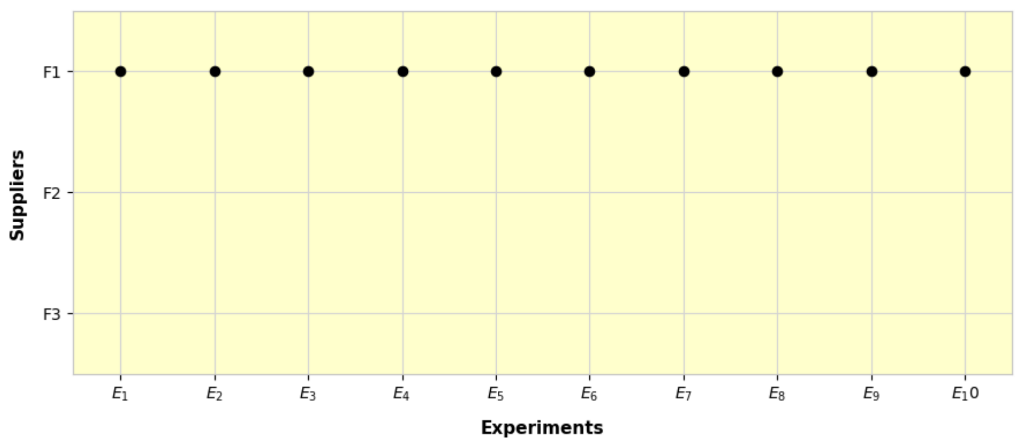

FIGURE 5. Results of the sensitivity analysis with respect to the criteria weights

The 10 weight variation experiments show that F_1 consistently remains the selected supplier, including in extreme cases where a single criterion dominates. The sensitivity analysis confirms that the selection of F_1 as the optimal supplier is extremely robust, which considerably strengthens the reliability and legitimacy of the final decision.

7. CONCLUSION

This study highlighted the effectiveness of the SMART-H method in multi-criteria decision support, in comparison with existing approaches such as MACASP and Lon-Zo. The results show that this method ensures a remarkable stability of the rankings, confirming its ability to produce reliable and consistent decisions in complex and uncertain contexts. SMART-H thus appears particularly suitable for sectors where the legitimacy of decisions is essential, such as healthcare, logistics, industry, or public project management.

This study is mainly based on simulated cases, which limits the extrapolation of the results to real-world contexts. Furthermore, the sensitivity analysis remains limited and could be extended to other sources of uncertainty and to comparisons with more advanced methods.

In future research, the application of SMART-H to real cases would make it possible to confirm its empirical relevance. In addition, the integration of fuzzy data, as well as a more in-depth analysis of the sensitivity and the mathematical properties of the method, would help to strengthen its validity and theoretical robustness.

Ultimately, SMART-H proves to be a reliable and suitable method for group multi-criteria decision-making. Its ability to reconcile methodological rigor with the diversity of viewpoints makes it a particularly relevant tool for structuring complex decision-making processes.

Authors' Contributions. All authors have read and approved the final version of the manuscript. The authors contributed equally to this work.

Conflicts of Interest. The authors declare that there are no conflicts of interest regarding the publication of this paper.

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