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A rank aggregating method based on several multi-criteria methodologies “minimum of ranks” (MIRA): a case study for student’s room allocation

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Abstract. Student’s room allocation is a challenging problem. Our aim is to develop a methodology as well as a Decision Support System for allocation students’ rooms considering several criteria and several aggregation methodologies.

For this article we used the multi-criteria decision-making methods like “Analytic Hierarchy Process” (AHP), “Weighted Sum Method” (WSM), “Technique for Order Preference by Similarity to the Ideal Solution” (TOPSIS) and “Combined Compromise Solution” (CoCoSo) to solve the problem of allocation of student accommodation. The contributions of these methods were as follows: AHP to rank criteria weights, WSM, TOPSIS and CoCoSo to rank students. We found that the ranking results of the students from each method are different because each of these methods has its specificity. In relation to this situation, we checked the similarity of the ranks obtained by applying two tests of the rank correlation coefficients, such as Spearman’s coefficient and Kendall’s coefficient. Thus, these tests showed us that ranks tend to be positively correlated for both test scores. As the correlation was proven, we retrieved these ranks and reordered the students to obtain a compromised ranking through the new multi-criteria decision-making method that we called the “Minimum of ranks” (MIRA). To validate this new method, we also checked the similarity of the ranks which has just been obtained compared to those of the WSM, TOPSIS and CoCoSo methods. The test carried out by the coefficients of the ranks of Spearman and Kendall gave us a positive correlation of the ranks. The MIRA process will be presented in this article.

Finally, a decision support system (DSS) based on the AHP, WSM, TOPSIS, CoCoSo and MIRA methods was developed to solve the problem of student’s room allocation.

Keywords: student’s room allocation, DSS, AHP, WSM, TOPSIS, CoCoSo, rank correlation coefficients, MIRA

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1 INTRODUCTION

Multi-criteria decision support methods are used to solve complex problems to choose a better solution. According to Roy, these problems can be classified into three categories, including choice, sorting, ranking [1]. Thus, the choice of a multi-criteria decision-making method to use depends on the type of real encountered problem.

In several areas, authors have used multi-criteria decision-making methods by comparing the results obtained to choose the one that is best suited to the problems dealt with. In 2007, Opricovic and Tzeng compared the extended “Vise Kriterijumska Optimizacija Kompromisno Resenje” (multi-criteria optimization and compromise solution, in Serbian) VIKOR method against the three methods: TOPSIS, PROMETHEE and “Elimination Et Choix Traduisant la Réalité” ELECTRE. The result of these four methods showed that the extended VIKOR method provided maximum collective utility for the majority and minimum individual regret for the adversary [2]. In 2017, Tscheikner-Gratl and his colleagues to be able to make the decision in the planning of the rehabilitation of urban water networks compared the results of the multi-criteria decision support methods including ELECTRE, AHP, WSM, TOPSIS and PROMETHEE. Therefore, they encouraged decision makers to apply multiple methods to check consistency and increase the reliability of results with the end goal of using one of the simplest methods [3]. In 2021, Choudhary and Mishra used the Fuzzy AHP, CoCoSo and Fuzzy AHP-PIV (Proximity Indexed Value) methods for the analysis of Industry 4.0 critical success catalysts. They chose Fuzzy AHP to calculate the desired outcome weights of critical success catalysts. Then, CoCoSo and Fuzzy AHP-PIV were used to find the ranking of identified facilitators. Thus, the obtained results have proven that these hybrid methods are quite similar [4]. So many other authors have also used several multi-criteria decision support methods at the same time. We can cite among others: Jadhav and Sonar used AHP, WSM and Hybrid Knowledge Based system (HKBS) [5]; Jayant and his colleagues used TOPSIS and AHP [6]; Chourabi and his colleagues used AHP, WSM and Weighted Product Method (WPW) [7]; Pangaribuan and Beniyanto used Simple Additive Weighting (SAW), TOPSIS and PROMETHEE [8]; Ulutas and his colleagues used Stepwise Weight Assessment Ratio Analysis (SWARA) and CoCoSo [9].

To compare the results of the TOPSIS, VIKOR, “Complex Proportional Assessment” COPRAS and PROMETHEE II methods, Sařabun and his colleagues [10] carried out a detailed study of the similarity of the final rankings obtained by these methods by calculating the correlation coefficients. Compared to the results they obtained they had mentioned that the choice of a multi-criteria decision-making method has an impact on the decision. Thus, it is necessary to consider not only the chosen method, but above all the normalization method and other parameters. Sařabun and his colleagues pointed out that faced with this difficulty of choosing between multi-criteria decision-making methods, a challenge will be to create a method based on rank comparison that will be able to recommend an appropriate solution.

In our study, we seek to select students to assign them accommodation. This allocation of accommodation is based on the criteria chosen by the universities. To deal with this problem, we used multi-criteria decision-making methods. First, the AHP method to prioritize the weights of the criteria. Then the WSM, TOPSIS and CoCoSo methods to rank the students. As each method has its own characteristic, the ranking results we obtained differ from one method to another. This is why we studied the similarity of the obtained ranks by these three methods using Spearman’s coefficient and Kendall’s coefficient.

Given this situation, our objective is not to criticize a multi-criteria decision-making method but to analyze the obtained results and propose a new method. More precisely, to seek a unique ranking compromise from the obtained ranks by the three methods WSM, TOPSIS and CoCoSo that we used, we propose the "Minimum of Ranks" (MIRA) method to be able to synthesize these different ranks and reclassify the students again. MIRA promotes all existing multi-criteria decision-making methods. It does not seek to compare or improve or even criticize existing methods, but rather the opposite. Knowing the number of authors who carry out studies using several multi-criteria decision-making methods, MIRA seeks to solve or more clearly to encourage the authors to continue their research after having used several multi-criteria decision-making methods by summarizing the ranks obtained. MIRA includes two variants by the additive method (MIRA⁺) and the subtractive method (MIRA⁻). Each of these variants of MIRA is independent one of another and can each solve the problem of summarizing the ranks resulting from the use of several multi-criteria decision-making methods. The user can therefore choose between MIRA⁺ or MIRA⁻ when solving a real problem after using several multi-criteria decision-making methods. The similarities of the ranks obtained by MIRA⁺ and MIRA⁻ compared to the WSM, TOPSIS and CoCoSo methods were analyzed by Spearman's coefficient and Kendall's coefficient. We present the two variants of MIRA in the case of ranking students for the allocation of accommodation.

To facilitate its application, we have developed a Decision Support System (DSS) based on the AHP method to calculate the criteria weights, the WSM, TOPSIS, CoCoSo methods to initially rank the students and the MIRA⁺ and MIRA⁻ methods to synthesize the ranks obtained by WSM, TOPSIS and CoCoSo.

Finally, in this article we successively present the procedure for student's room allocation, the algorithms of the used methods, the structure of the decision support system, the obtained results followed by the discussions, and we end it with the conclusions and perspectives.

2 STUDENT'S ROOM ALLOCATION

University rooms are usually annually allocated to students. To do this, the universities use criteria to select the students because it will be impossible to accommodate all the students in the student university residence if there is not enough housing to distribute. Thus, during our research, we identified a total of thirteen housing allocation criteria used by universities [11–16]. However, the number and chosen criteria, as well as the applied selection procedure, remain different for each university.

Throughout this study, we have chosen a university that uses eleven housing allocation criteria [11] in Madagascar. These criteria are grouped into two categories, including basic criteria and social criteria. We will find in the following table 1 these two groups of criteria as well as the conditions for selecting students according to each criteria.

Table 1. Groups of criteria

Basic criteria	Admission requirements
Age	By level
Year of Baccalaureate	By academic year
Administrative registration	Enrolled
Examination result	Successful
Nationality	According to the case
Professional situation	Not employed
Social criteria	Value
Physical capacity (CP)	Normal = 5 ; Disability = 10
Orphan of parent (OP)	None = 5; Father or Mother = 10; Father and Mother = 15
Parent's place of work (LTP)	University = 10 ; Other = 5
Dependent child of parent (EC)	By number
Distance from home (DD)	By mileage

For the social criteria distance from home (DD), it will be measured from the capital of the region where the student lives to the place where the university is located. The following table 2 gives us this distance for the case of 22 Regions of Madagascar compared to the University of Toamasina.

Table 2. Distance from home to university

Region	Capital	Distance (Km)
Alaotra Mangoro	Ambatondrazaka	399
Amoron'i Mania	Ambositra	609
Analamanga	Antananarivo	350
Analanjirofo	Fenoarivo Atsinanana	102
Androy	Ambovombe	1 349
Anosy	Tolagnaro	1 020
Atsimo Andrefana	Toliara	1 275
Atsimo-Atsinanana	Farafangana	707
Atsinanana	Toamasina	100
Betsiboka	Maevatanàna	667
Boeny	Mahajanga	923
Bongolava	Tsiroamandidy	558
Diana	Antsiranana	1 465
Haute-Matsiatra	Fianarantsoa	757
Ihorombe	Ihosal	951
Itasy	Miarinarivo	441
Melaky	Maintirano	920
Menabe	Morondava	948
Sava	Sambava	1 436
Sofia	Antsohihy	1 040
Vakinakaratra	Antsirabe	515
Vatovavy Fitovinany	Manakara	605

In relation to these two groups of criteria, the assessment procedure proceeds in two stages including the admission test for the basic criteria and the ranking by social criteria.

The basic criteria test is used to check whether the students fulfil them or not. At this stage, students who meet all these criteria move on to the second procedure. On the other hand, those who fail to meet one or more basic criteria cannot pass and their housing applications will be rejected. As for the ranking by the social criteria, the students will be ranked in relation to the sum of the values of these criteria.

This second procedure consists in ranking the students. We propose to use the multicriteria methods at this step. Our aim is to better rank them because the allocation of housing to the students is a complex process. In this way, applying multi-criteria decision-making methods, the process for this university will be summarized in Figure 1 below.

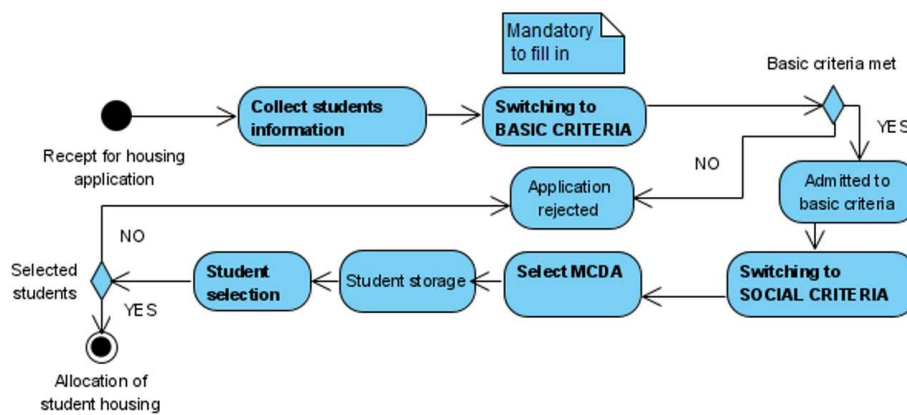


Fig. 1. Process of student’s room allocation

During all these procedures it is good to note that only the decision-maker validates the decisions on the admission of the students to the basic criteria and the selection of the student’s beneficiary of housing. This decision-maker is made up of the members of the housing allocation committee. The housing allocation committee is chaired by the President of the university and composed of the Deans of the faculties or their representatives, the Director/Head of university works, the head of the student housing service and the representatives of the staff of the faculties and /or student representatives from each faculty.

3 METHODOLOGY

Several multi-criteria decision support methods exist, but the choice depends on the category of the problem to be solved. For the case of student’s room allocation, it belongs to the ranking problem, so we chose the AHP method to calculate the weights of social criteria and the WSM, TOPSIS, CoCoSo methods to rank the students and the new MIRA method to summarize the ranks of students resulting from these three methods to obtain the final rank of students. We successively present the principle of these methods.

3.1 Analytic Hierarchy Process (AHP)

According to its founder [17, 18], the method is based on three concepts: hierarchical structure, priority structure and logical consistency. The hierarchical structure should have at least three levels [19]: the overall objective of the problem at the top level, the

criteria at the middle level, and the alternatives at the bottom level as we saw the figure 2 below.

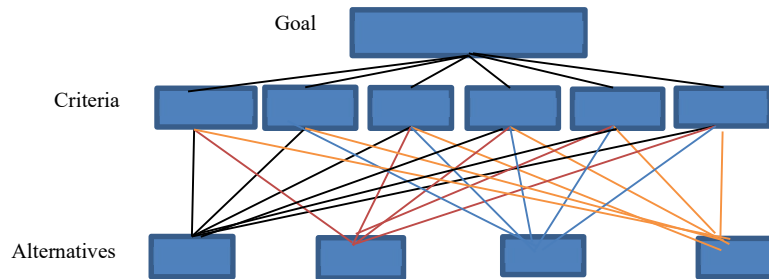


Fig. 2. Hierarchical structure

To prioritize the structure, the Saaty scale presented in the following table 3 will be useful to value the priority of the criteria and the alternatives.

Table 3. Saaty scale [20]

Intensity of importance	Definition of importance	Explanation
1	Same	Neither of the two alternatives is preferable over the other
3	Weak	One alternative is preferred slightly over the other
5	Clear	One alternative is preferred clearly over the other
7	Strong	One alternative is preferred strongly over the other
9	Very strong	One alternative is preferred very strongly over the other
2, 4, 6, 8	Compromise	Can be used for graduation between evaluation

The result of this structure prioritization will get the comparison matrix introduced by Saaty below:

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n} \end{bmatrix} \quad (1)$$

where $\begin{cases} w_1, w_2, \dots, w_n \text{ is the weights obtained by the comparison} \\ \text{and } \frac{w_i}{w_j} = a_{ij} \end{cases}$

Thus, the weight of the criteria will be calculated from this comparison matrix following the process below:

- matrix normalization: $B = \frac{a_{ij}}{\sum_{j=1}^n a_{ij}}$ (2)

$\forall a_{ij} \in A$ and we have $b_{ij} \in matrix B$

- Sum of rows of the normalized matrix: $w_i = \sum_{j=1}^n b_{ij}$ (3)

where w_i is the weight of the criteria i

Now we move on to the logical consistency check. The following calculations must be made:

- medium consistency:
 o matrix A weighting: $C = \sum_{i=1}^n a_{ij} w_i \forall a_{ij} \in A$ (4)

where c_i is total weight of criteria i

o clean vector: $\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{c_i}{w_i}$ (5)

- consistency index: $CI = \frac{\lambda_{max} - n}{n - 1}$ where n is the number of criteria (6)

- consistency ratio: $CR = \frac{CI}{RI}$ (7)

where RI is a random index, whose value will be presented in the table 4 below according to the number of criteria.

Table 4. Random index [21]

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Finally, when comparing pairs, the consistency ratio (CR) must be within 0.1. Otherwise, the results could be inconsistent.

3.2 Weighted Sum Method (WSM)

The weighted sum method combines all criteria into one scalar composite objective function using the weighted sum [22–24]. As a starting point, assume a judgment matrix A composed of m alternatives and n criteria.

$A = (a_{ij}) m \times n$ (8)

Now, the process is as follows.

- matrix normalization: $B = \frac{a_{ij}}{\sum_{j=1}^n a_{ij}}$ (9)

$\forall a_{ij} \in A$ and we have $b_{ij} \in matrix B$

- normalized matrix weighting: $c_i = \sum_{j=1}^n w_j b_{ij}$ (10)

where w_j is the weight of the criteria j

3.3 Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS)

TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the best solution and the longest geometric distance from the worst solution [25]. We always start with a judgment matrix A composed of m alternatives and n criteria.

$$A = (a_{ij}) m \times n \quad (11)$$

To achieve this solution, the following steps must be followed [26].

- matrix normalization: $B = \frac{a_{ij}}{\sqrt{\sum_{i=1}^m (a_{ij})^2}}$ (12)

$\forall a_{ij} \in A$ and we have $b_{ij} \in$ matrix B

- normalized matrix weighting: $X_{ij} = b_{ij} w_i$ (13)

where w_i is the weight of the criteria i

- best alternative: $X_j^b = \max_{i=1}^m X_{ij}$ (14)

- worst alternative: $X_j^w = \min_{i=1}^m X_{ij}$ (15)

- Euclidean Distance compared to the best alternative:

$$d_i^b = \sqrt{\sum_{j=1}^n (X_{ij} - X_j^b)^2} \quad (16)$$

- Euclidean Distance compared to the worst alternative:

$$d_i^w = \sqrt{\sum_{j=1}^n (X_{ij} - X_j^w)^2} \quad (17)$$

- similarity to worst alternative: $S_i = \frac{d_i^w}{d_i^w + d_i^b}$ (18)

3.4 Combined Compromise Solution (CoCoSo)

CoCoSo is based on an integrated simple additive weighting and exponentially weighted product model [27]. After having determined the alternatives and the associated criteria with the judgment matrix A :

$$A = (a_{ij}) m \times n \quad (19)$$

The following steps are to be followed [27].

- matrix normalization:

- o for benefit criteria: $b_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}}$ (20)

- for cost criteria: $b_{ij} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}}$ (21)

- matrix weighting:

- weighted comparability sequence: $S_i = \sum_{j=1}^n b_{ij} w_j$ (22)

where w_i is the weight of the criteria i

- power weight of comparability sequences: $P_i = \sum_{j=1}^n (b_{ij})^{w_j}$ (23)

where w_i is the weight of the criteria i

- assessment scores:

- $k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^m (P_i + S_i)}$ (24)

- $k_{ib} = \frac{P_i}{\min P_i} + \frac{S_i}{\min S_i}$ (25)

- $k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{\lambda \max S_i + (1-\lambda) \max P_i}$ with $0 \leq \lambda \leq 1$ (26)

- final score: $k_i = (k_{ia} + k_{ib} + k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic})$ (27)

3.5 Rank correlation coefficients

The correlation coefficient is the specific measure that quantifies the strength of the linear relationship between two variables in a correlation analysis. The correlation coefficient r is a unitless value between -1 and 1. The closer r is to zero, the weaker the linear relationship. Positive values of r indicate a positive correlation when the values of both variables tend to increase together. Negative values of r indicate a negative correlation when the values of one variable tend to increase and the values of the other variable decrease. The values 1 and -1 each represent “perfect” correlations, positive and negative respectively. To study the similarity of the ranks resulting from the methods WSM, TOPSIS and CoCoSo, we will apply the test of Spearman’s coefficient and Kendall’s coefficient.

Spearman’s rank correlation which denotes by r_s is a non-parametric measure of correlation assesses monotonic relationships. This is the product moment correlation coefficient of u_i, v_i given by the formula below [28]:

$$r_s = 1 - \frac{6 \sum_{i=1}^n (u_i - v_i)^2}{(n^3 - n)} \quad (28)$$

where u_i, v_i are ranks resulting from the respective methods in our case and n is the number of alternatives.

Kendall's rank correlation is used to test similarities in the order of data when ordered by quantities. It uses pairs of observations and determines the strength of the association based on the pattern of agreement and disagreement between the pairs. For our case, consider two random ranks of methods (u, v) observed on a sample of size i with i pairs of observations ($\mathbf{u}_i, \mathbf{v}_i$). An indication of the correlation between u and v can be obtained by ordering the values \mathbf{u}_i in increasing order and by counting the number of corresponding values \mathbf{v}_i not satisfying this order. Kendall's rank correlation is given by the formula below [29]:

$$r_k = \frac{2(N_c - N_d)}{n(n-1)} \quad (29)$$

Where:

N_c : total number of concordant pair

N_d : total number of discordant pair

n : number of alternatives

3.6 Minimum of Ranks (MIRA)

MIRA is a new method which has just been born from the application of multi-criteria decision support methods. It makes it possible to reorder the alternatives from their ranks coming from at least two multi-criteria decision-making methods. Before proceeding with the application of MIRA, it is essential to verify the similarity of the ranks from the multi-criteria decision-making methods to be used. If the rank correlation is justified, the methods are chosen, and it is possible to apply MIRA. Otherwise, one or more multi-criteria decision-making methods must be changed.

To validate the obtained result by MIRA, it is always necessary to check its correlation with the multi-criteria decision-making methods that have been chosen. If the correlation is justified, the MIRA result is acceptable.

Consider the judgment matrix of the correlated ranks coming from the following multi-criteria decision-making methods:

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \dots & r_{2n} \\ \cdot & \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \cdot & \dots & \cdot \\ r_{n1} & r_{n2} & r_{n3} & \dots & r_{nm} \end{bmatrix} \quad (30)$$

where r_{ij} is the rank of alternative i for method j

The algorithm of the MIRA method is presented in the form of which MIRA additive and MIRA subtractive.

3.5.1 MIRA additive (M^+)

It is based on the sum of the ranks obtained by each alternative for all the chosen multi-criteria decision-making methods.

$$M_i^+ = \sum_{j=1}^n r_{ij} \quad (31)$$

This sum of ranks will form the new score allowing to reorder the alternatives. Thus, the best alternative is the one with the minimum score. As we have the score, we can

then rank the alternatives $A = \{a_1, a_2, \dots, a_n\}$ by prioritizing those with minimum scores in lower rank. This prioritization respects the following conditions:

1. $M_1^+ < M_2^+; Rank a_1 < Rank a_2$
2. $M_2^+ < M_1^+; Rank a_2 < Rank a_1$
3. Else $Rank a_2 = Rank a_1$

3.5.2 MIRA subtractive (M^-)

This involves looking for the distance between the ranks of the alternatives for each multi-criteria decision support method chosen in relation to its best rank. To calculate this distance, we use the Euclidean distance.

- Best ranks: $B_i = \min_{j=1}^n r_{ij}$ (32)

- Score: $M_i^- = \sqrt{\sum_{j=1}^n (r_{ij} - B_i)^2}$ (33)

As we have the score, we can then rank the alternatives $A = \{a_1, a_2, \dots, a_n\}$ by prioritizing those with minimum scores in lower rank. This prioritization respects the following conditions:

1. $M_1^- < M_2^-; Rank a_1 < Rank a_2$
2. $M_2^- < M_1^-; Rank a_2 < Rank a_1$
3. Else $Rank a_2 = Rank a_1$

4 PROTOTYPE

4.1 Decision support system (DSS)

Let us recall that a DSS is structured by three main components which are: the model management system, the user interface, and the knowledge base [30]. The DSS will be composed by a Data Base, a Model Base, and a Human/Interface module [31].

The developed DSS consists of allocating housing to students through their applications. We have implemented a relational database management system using six methods AHP, WSM, TOPSIS, CoCoSo, MIRA⁺ and MIRA⁻.

The DSS foresees four types of users who each have their specific tasks. The table 5 below describes each user and their role.

Table 5. User roles

Users	Roles
Administrator	It takes care of the maintenance of the system in the event of a problem. As an administrator, he enters useful generic data for the system. Also, user management belongs to him. If necessary, he can help the housing service team to print the reports.
Decision maker	As a decision maker, he has the right to compare the housing allocation criteria to calculate their weights from the AHP method. He will carry out this task after the decision taken by the central housing commission. In all the needs, it can print reports.

Data Manager	It prepares the data to be able to directly import them into a table, the database, but also to print the reports. In particular, he checks the entered data by the secretaries and makes changes if necessary. He can print all the reports. However, he is the only one who can enter and modify the data concerning the university study and the university residence.
Operator	He enters the useful information appearing on the housing request. He has the possibility to modify and view the information he has just entered. Finally, he can print all the reports.

Below we show some screens of the system. We mention that the DSS screens are in French language because the studied university uses French as the official language throughout their procedure. Thus, the end user of the DSS uses the French language. The figure 3 below shows us the screen for entering accommodation allocation criteria by the Data Manager.

Critère d'attribution de logement

Classification Critère de base

Critère

Code	Description
*	

Echelle

Code	Description	Valeur
*		0

Fig. 3. Entering accommodation allocation criteria

Once the housing allocation criteria have been entered into the database, the decision maker can start comparing these criteria using the AHP method. The screen 4 below shows us the possibility of entering the values during this comparison. To do this, it completes only the upper part of the diagonal because the lower part is automatically calculated.

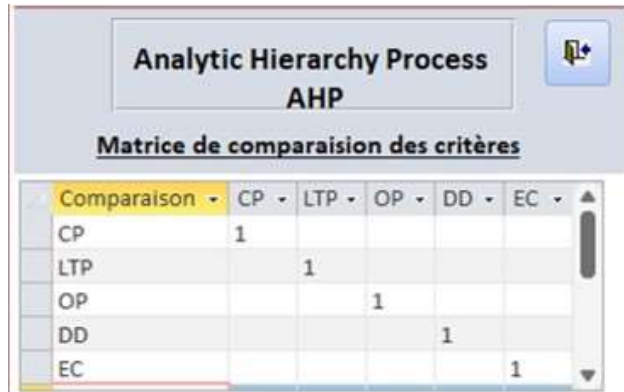


Fig. 4. Comparison of criteria with AHP method

Next, the operator can enter the data on the student housing application form. The screen shown in the figure 5 below.

UA: Université de Toamasina

Etude

Année du Bacc.
 Anné Univ.
 Mention
 Niveau
 Passant
 Inscrit

Sociale

Boursier
 Logement demandé
 Salarié

Familiale

Nombre de frère/soeur
 Orphelin
 Lieu de travail du parent

Contact

Couriel
 Tél.
 Adresse
 Région

Etat civil

Codage
 Civilité
 NOM
 Prénom(s)
 Capacité

Naissance

Date
 Lieu
 Nationalité

Supprimer Nouveau

Fig. 5. Entering student data

When the weights of criteria are calculated and the data concerning the students are also available, we can now process the requests. The screen below gives three possibilities of visualization. First, we can directly see the performance matrix of each department and levels of study in relation to the social situation of the students. Then, we can view the ranking results of the students by each of the methods installed in the DSS, namely WSM, TOPSIS, CoCoSo, MIRA⁺ and MIRA⁻. Also, it allows you to display the selection of student beneficiaries of accommodation according to the availability of accommodation within the university.

Fig. 6. Ranking and student's selection with WSM, TOPSIS, CoCoSo and MIRA

5 RESULTS

5.1 Assessment according to the basic criteria

We present here the case of students from the Mathematics, Computer Science and Applications (MIA: "Mathématiques, Informatique et Applications") department of a university. We processed 97 housing requests. According to the basic criteria test, 80 students have met these criteria and will move on to the second phase. On the other hand, 17 housing requests were rejected. The Figure 7 below shows us these data.

Mention	Niveau	Reçue	Acceptée	Rejetée
Mathématiques, Informatique et Applications	L1	35	27	8
Mathématiques, Informatique et Applications	L2	29	26	3
Mathématiques, Informatique et Applications	L3	12	11	1
Mathématiques, Informatique et Applications	M1	21	16	5
Total		97	80	17

Fig. 7. Summary of student accommodation requests

5.2 Assessment according to social criteria

Let's start with the result of the prioritization of criteria using AHP method. The figure 8 below describes the weights of criteria and verification of logical consistency. Remember that there are five social criteria of which physical capacity (CP), orphan of parent (OP), parent's place of work (LTP), dependent child of parent (EC) and distance from home (DD).

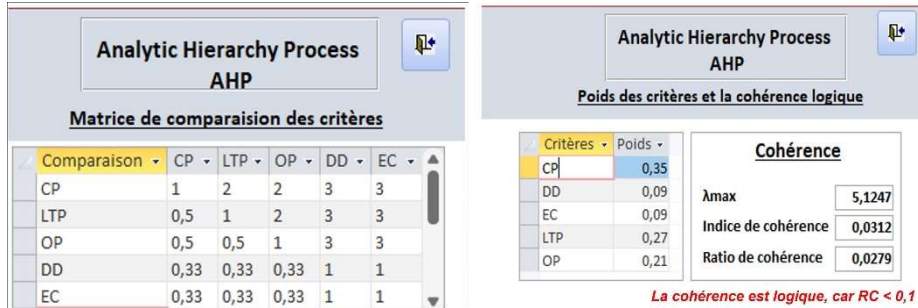


Fig. 8. Prioritization of the criteria by AHP methode

Now we will deal with the 80 selected students using the basic criteria. We show for each of implemented methods in the system, the result for the 27 students of level L1 of the Mathematics, Computer Science and Applications (MIA) department. The figure 9 below presents the performance matrix of these 27 students admitted to the basic criteria in relation to their social situation.

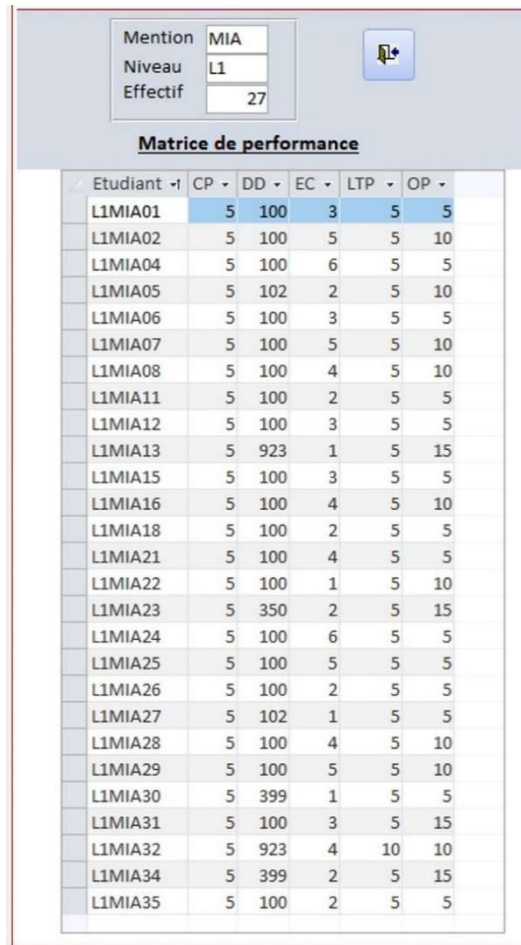


Fig. 9. Performance matrix

We have the criteria weights and the performance matrix, we can move on to the next step which is to rank the students. At first, we present in the table 6 below the results

of student ranks by the methods WSM, TOPSIS and CoCoSo. These student ranks were exported from the DSS.

Table 6. Student ranks by the methods WSM, TOPSIS and CoCoSo

Student	WSM	Student	TOPSIS	Student	CoCoSo
L1MIA32	1	L1MIA32	1	L1MIA32	1
L1MIA13	2	L1MIA13	2	L1MIA01	2
L1MIA34	3	L1MIA34	3	L1MIA13	3
L1MIA23	4	L1MIA23	4	L1MIA34	4
L1MIA01	5	L1MIA31	5	L1MIA23	5
L1MIA31	6	L1MIA30	6	L1MIA31	6
L1MIA02	7	L1MIA02	7	L1MIA02	7
L1MIA07	7	L1MIA07	7	L1MIA07	7
L1MIA29	7	L1MIA29	7	L1MIA29	7
L1MIA08	10	L1MIA08	10	L1MIA08	10
L1MIA16	10	L1MIA16	10	L1MIA16	10
L1MIA28	10	L1MIA28	10	L1MIA28	10
L1MIA05	13	L1MIA05	13	L1MIA05	13
L1MIA04	14	L1MIA22	14	L1MIA22	14
L1MIA24	14	L1MIA01	15	L1MIA04	15
L1MIA30	16	L1MIA04	16	L1MIA24	15
L1MIA22	17	L1MIA24	16	L1MIA25	17
L1MIA25	18	L1MIA25	18	L1MIA21	18
L1MIA21	19	L1MIA21	19	L1MIA06	19
L1MIA06	20	L1MIA06	20	L1MIA12	19
L1MIA12	20	L1MIA12	20	L1MIA15	19
L1MIA15	20	L1MIA15	20	L1MIA30	22
L1MIA11	23	L1MIA11	23	L1MIA11	23
L1MIA18	23	L1MIA18	23	L1MIA18	23
L1MIA26	23	L1MIA26	23	L1MIA26	23
L1MIA35	23	L1MIA35	23	L1MIA35	23
L1MIA27	27	L1MIA27	27	L1MIA27	27

We have seen that these three methods were able to arrange the students according to their algorithms. Now we can compare these results of these three methods in the table 7 below.

Table 7. Comparison of student ranks by the methods WSM, TOPSIS and CoCoSo

Student	WSM	TOPSIS	CoCoSo
L1MIA01	5	15	2
L1MIA02	7	7	7
L1MIA04	14	16	15
L1MIA05	13	13	13
L1MIA06	20	20	19
L1MIA07	7	7	7
L1MIA08	10	10	10
L1MIA11	23	23	23
L1MIA12	20	20	19
L1MIA13	2	2	3
L1MIA15	20	20	19

Student	WSM	TOPSIS	CoCoSo
L1MIA16	10	10	10
L1MIA18	23	23	23
L1MIA21	19	19	18
L1MIA22	17	14	14
L1MIA23	4	4	5
L1MIA24	14	16	15
L1MIA25	18	18	17
L1MIA26	23	23	23
L1MIA27	27	27	27
L1MIA28	10	10	10
L1MIA29	7	7	7
L1MIA30	16	6	22
L1MIA31	6	5	6
L1MIA32	1	1	1
L1MIA34	3	3	4
L1MIA35	23	23	23

Now, we are going to present the rank correlation coefficients given these rankings.

5.3 Rank correlation coefficients

We calculated the correlation coefficient of two respective methods. First, we will start presenting in the following table 8 the Spearman rank correlation coefficient.

Table 8. Spearman's coefficient of WSM, TOPSIS and CoCoSo methods

Spearman	WSM	TOPSIS	CoCoSo
WSM	1	0,93	0,98
TOPSIS		1	0,87
CoCoSo			1

Then the following table presents Kendall rank correlation coefficient for each multi-criteria decision-making method.

Table 9. Kendall's coefficient WSM, TOPSIS and CoCoSo methods

Kendall	WSM	TOPSIS	CoCoSo
WSM	1	0,83	0,89
TOPSIS		1	0,79
CoCoSo			1

As we have noticed, Kendall's correlation coefficients are generally lower than Spearman's.

These two tables showed us the different correlation coefficients between the multi-criteria methods that we used. The result of each coefficient is closer to 1. This shows us that each method has a positive correlation between them. So, we can apply the MIRA method because the similarity of the ranks is proven.

5.4 Application of MIRA method

As we see that the ranks resulting from these three methods are different and they are positively correlated, the MIRA method will take care of these different ranks to rearrange the students. MIRA seeks to find a satisfactory result based on these three results but not return to the initial study based on the performance matrix. Thus, we will propose two solutions. The first consists in the application of **MIRA⁺** which adds the three ranks of each student and reorders them by prioritizing the sum of the minimum ranks. The second is the application of **MIRA⁻** which calculates the difference between the obtained ranks by the three methods with the Euclidean distance and rearranges the students according to priority with respect to the minimum distance. The table 10 below show us the ranks obtained by **MIRA⁺** and **MIRA⁻**. These student ranks were exported from the DSS.

Table 10. Student ranks with MIRA⁺ and MIRA⁻

Student	MIRA ⁺	Student	MIRA ⁻
L1MIA32	1	L1MIA32	1
L1MIA13	2	L1MIA02	2
L1MIA34	3	L1MIA07	3
L1MIA23	4	L1MIA29	4
L1MIA31	5	L1MIA08	5
L1MIA02	6	L1MIA16	6
L1MIA07	7	L1MIA28	7
L1MIA29	8	L1MIA05	8
L1MIA01	9	L1MIA11	9
L1MIA08	10	L1MIA18	10
L1MIA16	11	L1MIA26	11
L1MIA28	12	L1MIA35	12
L1MIA05	13	L1MIA27	13
L1MIA30	14	L1MIA13	14
L1MIA04	15	L1MIA23	15
L1MIA24	16	L1MIA34	16
L1MIA22	17	L1MIA31	17
L1MIA25	18	L1MIA25	18
L1MIA21	19	L1MIA21	19
L1MIA06	20	L1MIA06	20
L1MIA12	21	L1MIA12	21
L1MIA15	22	L1MIA15	22
L1MIA11	23	L1MIA04	23
L1MIA18	24	L1MIA24	24
L1MIA26	25	L1MIA22	25
L1MIA35	26	L1MIA01	26
L1MIA27	27	L1MIA30	27

Now to validate these results, we will check the similarity of the ranks obtained by MIRA⁺ and MIRA⁻ compared to the WSM, TOPSIS and CoCoSo methods using the Spearman and Kendall coefficients.

5.5 Validation of MIRA result

This validation depends on the values of the correlation coefficients of Spearman and Kendall.

First, we present in the following table the result of Spearman’s and Kendall’s correlation coefficient for the MIRA⁺ method compared to the WSM, TOPSIS and CoCoSo methods.

Table 11. Spearman’s and Kendall’s coefficient of MIRA⁺, WSM, TOPSIS and CoCoSo

	WSM	TOPSIS	CoCoSo	
MIRA ⁺	0,98	0,96	0,95	Spearman
	0,92	0,87	0,86	Kendall

Then, Spearman’s and Kendall’s correlation coefficients of the MIRA⁻ method with respect to the WSM, TOPSIS and CoCoSo methods will be presented in the table 12 below.

Table 12. Spearman’s and Kendall’s coefficient of MIRA⁻, WSM, TOPSIS and CoCoSo

	WSM	TOPSIS	CoCoSo	
MIRA ⁻	0,29	0,29	0,29	Spearman
	0,18	0,16	0,19	Kendall

Now, as we have the ranks correlation coefficients of the MIRA⁺ and MIRA⁻ methods compared to the WSM, TOPSIS and CoCoSo methods, we can validate the rank results obtained by this new MIRA method.

Thus, the university decision maker simply chooses either MIRA⁺ ranking or MIRA⁻ ranking according to the correlation coefficient test but is not necessarily both. And the next part of the work of the decision maker is to select the students benefiting from accommodation according to the accommodation quota available for the MIA department of level L1. The DSS that we have developed is able to calculate the housing quota for each department and level of study of a university as well as to make this selection. We do not present them in this article, it will be represented in another manuscript.

5.6 Discussion

Research on the application of multi-criteria decision support methods continues to be developed. There are authors who do their studies by applying a well-chosen method to solve a given problem [23, 32, 33]. There are those who use several methods at the same time to be able to compare the results obtained in order to choose the one that best suits the treated problem [5, 6, 8]. Following the evolution, the tendency of the authors is to develop a decision support system implementing one or more multi-criteria decision support methods to allow users the choice among those who are installed [34–36].

In this article our contribution is divided into three parts. First, we used multi-criteria decision support methods including AHP, WSM, TOPSIS and CoCoSo. AHP to calculate the weight of criteria, WSM, TOPSIS and CoCoSo to rank the students. Our proposal is to process the selection of students when allocating accommodation using multi-criteria decision-making methods in order to fairly rank students according to the criteria for allocating accommodation used by universities.

Second, after analyzing the ranks resulting from the use of these methods, we found that there are some differences. These differences are shown in the figure 10 below.

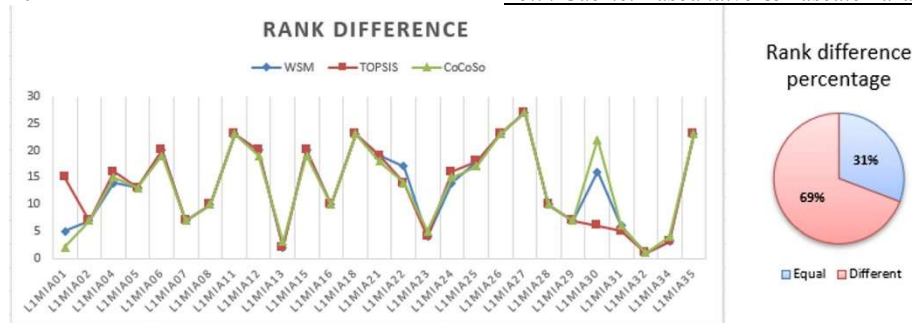


Fig. 10. Rank difference

Thus, this difference reached up to 69% as shown in the figure above. So, it will be difficult for the head of the university to decide which method should be chosen. This is why we have calculated the rank correlation coefficients resulting from the WSM, TOPSIS and CoCoSo methods to know the similarity of the ranks in order to seek a new ranking solution. We applied the Spearman and Kendall correlation coefficients. The coefficients obtained showed us that these three methods are positively correlated whose coefficients are closer to 1. The creation of a method based on the ranks obtained by multi-criteria decision-making methods is a challenge [10], we have proposed the MIRA method with its two variants MIRA⁺ and MIRA⁻ to reorder the students in relation to the ranks obtained by WSM, TOPSIS and CoCoSo. After having succeeded in reordering the students by the variants of MIRA, we also checked the similarity of the ranks of MIRA⁺ and MIRA⁻ from the correlation coefficients of Spearman and Kendall with respect to the WSM, TOPSIS and CoCoSo methods. This test showed us that the ranks held by the MIRA⁺ have a positive correlation closer to 1. The ranks held by the MIRA⁻ have a positive correlation closer to 0. In relation to this obtained correlation coefficient result, we recommend that the decision maker choose the rank obtained by the MIRA⁺ variant.

Above all, MIRA was created in order to avoid the simple comparison of results after using several multi-criteria decision support methods. From now on, it will be possible to continue the work by applying MIRA to rearrange the alternatives.

The objective of the MIRA method is to recover the ranks resulting from the multi-criteria decision-making methods and to stably reorder the alternatives (in this case, the students). In practice, MIRA is divided into two categories including MIRA⁺ and MIRA⁻. By MIRA⁺, the ranks of the alternatives are obtained in a natural way because we just add their ranks coming from these three methods. Therefore, the position of each alternative in the three methods is generally kept. By MIRA⁻, the ranks of the alternatives are obtained by considering the distance of their ranks from their best rank. So, MIRA⁻ has stabilized the different ranks coming from these three methods that we just used. Thus, the final choice of the decision maker depends on the result of the correlation coefficients obtained. This is why we strongly recommend checking the similarity of ranks before and after using MIRA.

With regard to the current technological evolution, our third contribution is that we have developed a decision support system allowing to student's room allocation including the AHP, WSM, TOPSIS, CoCoSo and this new MIRA method. For this first version, the system initially ranks the students according to the developed multi-criteria decision support methods. Then, the decision maker selects the ranked students according to the availability of accommodation within the university.

Thus, in its future version this system will be developed in two stages. First it will be web-oriented so that the housing request will be dematerialized. Then, it will also be possible to manage the assignment of university rooms to students.

6 CONCLUSION AND PERSPECTIVE

We began our research on the field of multi-criteria decision support by applying a PROMETHEE method. Then, an idea was born on the use of several multi-criteria decision-making methods implemented in a decision support system to compare the results obtained using AHP, WSM TOPSIS and CoCoSo methods. Throughout this research we have applied these methods in the management of allocation of accommodation to students in order to fully understand the variation in the ranks of the methods we have chosen. We found that the use of several decision-making methods is interesting because we manage to compare the obtained result and to have an idea of the method to use. Nevertheless, it is even more interesting to look for a new method in order to avoid choosing the method to use after having applied several multi-criteria decision support methods.

After a few years of research, we have come to a conclusion regarding the different obtained ranks by the used methods and to find the solution by birth of the new Minimum of Ranks (MIRA) method. The general principle of this method is to rearrange the alternatives in relation to the ranks they have obtained by prioritizing those with minimum scores.

This method is categorized into two, namely the Minimum of Additive Ranks (MIRA⁺) and the Minimum of Subtractive Ranks (MIRA⁻). The MIRA⁺ method seeks to stabilize the ranks of the alternatives from the multi-criteria decision-making methods chosen by the researchers by combining them. On the other hand, the MIRA⁻ method finds the Euclidean distance of the ranks of the alternatives with respect to their best ranks. We used the sum for MIRA⁺ because when adding the ranks, no values are lost. So, this is the exact value obtained by the MIRA⁺ method. The subtraction is used for MIRA⁻ to get the difference of the values between the ranks. This is why we chose the Euclidean distance. Some metrics like maximum average or geometric mean could not be used for this problem. Also, for the mean and the geometric mean, they consist, as these names indicate, of seeking the mean of the ranks. While the average is not an exact value but rather a value in the middle of the minimum and the maximum. It is not a question of finding an optimum result but a compromise result. In a multi-criteria decision-making problem, we are not talking about maximization or minimization but rather about satisfactory solution.

In this article, we applied this new MIRA method (MIRA⁺ and MIRA⁻) by assigning accommodation to students based on AHP (to prioritize the criteria), WSM, TOPSIS and CoCoSo (to rank the students) methods. Also, we have developed a decision support system implementing these methods. The result showed us that MIRA⁺ and MIRA⁻ are able to rearrange the alternatives in relation to their ranks.

To the decision-making community, this article provides several advantages. First, it informs us that before choosing a decision support method to apply, it is preferable to compare it to other methods to know its reliability. Then, it is possible not to remain at the stage of comparing the results obtained by the multi-criteria decision-making methods, but to continue the study by taking up the ranks in order to apply MIRA. MIRA is useful because, it gives the opportunity to use several multi-criteria decision-making methods at the same time with the aim of analysing the obtained results. From a DSS development perspective, this article is informative to the developer that it is

possible to integrate in the same system several multi-criteria decision-making methods and to compare the obtained ranks using a test of correlation coefficients. Above all, it is also interesting to integrate a new method like MIRA which recovers the obtained ranks by the applied methods and recommended the decision maker for the final method to choose.

Nevertheless, for researchers it will still be possible to create another variant of MIRA in order to improve the MIRA⁺ and MIRA⁻ version by using other arithmetic functions. Another perspective would be to create a new method allowing to rearrange the obtained ranks by the use of several multi-criteria decision-making methods at the same time. .

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